ROSALIA Handbooks 5.

Invasive Animal Species in Hungary




Ministry of
Foreign Affairs and Trade
of Hungary

Duna–Ipoly National Park Directorate
Ministry of Foreign Affairs and Trade of Hungary

ROSALIA Handbooks 5.

INVASIVE ANIMAL SPECIES IN HUNGARY

ROSALIA HANDBOOKS

1. Marticsek József (szerk.) (2010): Tájgazdálkodás Pannon gyepeken. Rosalia kézikönyvek 1. – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 244 old. ISBN 978 963 88013 9 5
2. Frank Tamás és Szmorad Ferenc (2014): Védett erdők természetességi állapotának fenntartása és fejlesztése. Rosalia kézikönyvek 2. – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 160 old. ISBN 978 615 5241 12 3
3. Csiszár Ágnes és Korda Márton (szerk.) (2015): Özönnövények visszaszorításának gyakorlati tapasztalatai. Rosalia kézikönyvek 3. – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 239 old. ISBN 978 963 86466 8 2
3. Csiszár Ágnes és Korda Márton (szerk.) (2017): Özönnövények visszaszorításának gyakorlati tapasztalatai. 2. bővített kiadás. Rosalia kézikönyvek 3. – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 247 old. ISBN 978 615 5241 23 9
4. Szmorad Ferenc, Frank Tamás és Korda Márton (szerk.) (2018): Erdőgazdálkodás és erdőkezelés Natura 2000 területeken., Natura 2000 kézikönyv erdőgazdálkodóknak. Rosalia kézikönyvek 4. – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 297 old. ISBN 978 615 5241-28-4

VOLUMES OF ROSALIA

1. Barina Zoltán (2006): A Gerecse hegység flórája. (Flora of the Gerecse Mountains.) – Magyar Természettudományi Múzeum és Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 612 pp. ISBN 963 7093 91 5
2. Nagy József (2007): A Börzsöny hegység edényes flórája. (Vascular flora of the Börzsöny Mountains.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 378 pp. ISBN 978 963 87687 0 4
3. Halpern Bálint (szerk.) (2007): A rákosi vipera védelme. Tanulmány gyűjtemény. (Studies on the conservation of the Hungarian Meadow Viper.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 194 pp. ISBN 978 963 87687 3 5
4. Dobolyi Konstantin és Kézdy Pál (szerk.) (2008): Természetvédelem és kutatás a Szénás-hegycsoporton. Tanulmánygyűjtemény. (Nature conservation and researches on the Szénás Hills.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 431 pp. ISBN 978 963 88013 0 2
5. Pintér Balázs és Tímár Gábor (szerk.) (2010): A Naszály természetrajza. Tanulmánygyűjtemény. (A natural history of Mt Naszály, Hungary.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 817 pp. ISBN 978 963 88013 6 4
6. Verő György (szerk.) (2011): Természetvédelem és kutatás a Duna–Tisza közi homokhátságon. (Nature conservation and researches on the Sandridge of the Danube –Tisza Interfluve.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 521 pp. ISBN 978 615 5241 00 0
7. Vidra Tamás (szerk.) (2012): Természetvédelem és kutatás a Tápió-vidéken. (Nature conservation and research in the Tápió region.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 656 pp. ISBN 978 615 5241 03 1
8. Kézdy Pál és Tóth Zoltán (szerk.) (2012): Természetvédelem és kutatás a budai Sas-hegyen. (Nature conservation and research in Mt Sas-hegy.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 592 pp. ISBN 978 615 5241 04 8
9. Standovár Tibor, Bán Miklós és Kézdy Pál (szerk.) (2017): Erdőállapot-értékelés középhegységi erdeinkben. (Forest state assessment in submontane woodlands.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 616 pp. ISBN 978 615 5241 20 8
10. Korda Márton (szerk.) (2018): Természetvédelem és kutatás a Turjánvidék északi részén. (Nature conservation and research in northern Turján Region.) – Duna–Ipoly Nemzeti Park Igazgatóság, Budapest, 999 pp. ISBN 978 615 5241 25 3

INVASIVE ANIMAL SPECIES IN HUNGARY

Editor:
László Haraszthy

Duna–Ipoly National Park Directorate
Ministry of Foreign Affairs and Trade of Hungary
Budapest, 2022

Rosalia Handbooks Serie Editor: Pál Kézdy

Authors:
Gergely Babocsay, Péter Borza, Béla Csányi György Csóka, Zoltán Fehér, Árpád Ferincz, László Zsolt Garamszegi, Csaba Gáspár, Tibor Hadarics, László Haraszthy, Anikó Hirka, Marcell Kárpáti, Balázs Kiss, Péter Kóbor, Előd Kondorosy, Tibor Kovács, Katalin Kurucz, Ferenc Lakatos, József Lanszki, Gabriella Lanszki-Széles, Veronika Lente, Gábor Majoros, Barna Páll-Gergely, Márton Paulin, Zoltán Soltész, Ádám Staszny, Bettina Szajbert, Levente Szőcs, András Tartally, Tamás Tóth, Edina Török, Katalin Tuba, Ágnes Turóci, Olivér Váczi, András Varga, András Weiperth

Reviewers:
Béla Csányi, György Csóka, Gábor Csorba, László Forró, Tibor Hadarics, Bálint Halpern, Ferenc Hock, Gábor Hegyessy, Sándor Koczor, Ferenc Lakatos, István Matskási, János Sztikler, Attila Torma, Balázs Tóth, András Varga

Translated by: Tibor I. Fuisz (Ph.D.), Sára Márialigeti, Barna Páll-Gergely, Balázs Trócsányi, Anikó Zöllei

Linguistic readers: James J. Busuttil (Ph.D.) Michael Amphlett

References edited by: Tibor Hadarics

Photos:
Márton Árvay, Gergely Babocsay, János Bagyura, Csaba Barkóczi, Bea Bauer, Nóra Békefi, Bence Bődör, Zsolt Brudnyák, Balázs Buzás, David Cappaert, Jean-François Cart, Denis Copilaş-Ciocianu, Dávid Czabán, György Cserép, György Csóka, Tamás Deli, A. Elekes Derzsi, Roland Döbrösi, Balázs A. Farkas, Zoltán Fehér, András Fekete, Árpád Ferincz, Csaba Forrásy, Zsolt Gorli, János Göncöl, Tibor Hadarics, Valéria Halavács, Bálint Halpern, László Haraszthy, Gerald Holmes, Jiri Hulcr, Péter Illés, Zsolt Kalotás, Zita Kemencei, István Kerekes, Szilveszter Kis, Balázs Kiss, Péter Kóbor, Tibor Kovács, György Kriska, Ferenc Lakatos, József Lanszki, Zoltán László, Gábor Leskó, Mactode Publications, Gábor Majoros, Zsolt Málinger, Michal Maňas, Daren Mueller, Krisztina Nemes, János Oláh, Zoltán Orbán, Norbert Papirnyik, Pest and Diseases Image Library, Balázs Pintér, Imre Potyó, Zoltán Sallai, Viktor Schneidler, Zoltán Soltész, Éva Süle, Balázs Szelényi, Ágnes Turóci, Zsolt Újvári, András Varga, András Weiperth

Front cover photos: Turkish Snail (© Zsolt Málinger), Harlequin ladybird (© Tamás Deli), Common Sunfish (© Árpád Ferincz), European Fallow Deer (© Viktor Schneidler)

Back cover photos: Spanish Slug (© András Varga), Signal Crayfish (© András Weiperth), Pond Slider (© Zsolt Újvári), Egyptian Goose (© László Haraszthy)

Recommended citacion:
Haraszthy L. (Ed.), (2022): *Invasive Animal Species in Hungary.* Duna–Ipoly National Park Directorate – Ministry of Foreign Affairs and Trade of Hungary, Budapest. /Rosalia Handbooks 5./

Citation to individual contributions recommended in the following format:
Babocsay G. (2022): Common Snapping Turtle *Chelydra serpentina* (Linnaeus, 1758). In: Haraszthy L. (Ed.), (2022): Invasive Animal Species in Hungary. Duna–Ipoly National Park Directorate – Ministry of Foreign Affairs and Trade of Hungary, Budapest: 298–301.

ISBN: 978-615-5241-40-6

The present publication was financed by the Ministry of Foreign Affairs and Trade of Hungary in accordance with the objectives of the EU Strategy for the Danube Region (Priority Area 6 - Biodiversity and Landscapes, Quality of Air and Soils)

DANUBE REGION strategy
Prosperity through Diversity

Ministry of
Foreign Affairs and Trade
of Hungary

Table of contents

Foreword

The European Union Strategy for the Danube Region (EUSDR) was one of the main achievements of the Hungarian EU presidency in 2011. The Priority Area 6 (PA6 - *Biodiversity and Landscapes, Quality of Air and Soils*) of the EUSDR, co-ordinated jointly by Croatia and Bavaria has, from the start, placed emphasis on invasive species. Experts of the 14 Danube Region countries unanimously concluded that transnational level cooperation is essential for the control and management of invasive species (such as the false indigo, the milkweed, the Chinese mussel or the black bullhead), especially along their main dispersal pathways. This is all the more important, as the Danube and its waterways (as an aquatic corridor connecting the North Sea with the Black Sea) are highly exposed to colonisation by invasive plants and animals.

For the sake of stabilising professional connections, reinforcing cooperation, sharing data and know-how as well as to initiate joint projects, the experts of 10 countries (including Hungary) created the Danube Region Invasive Alien Species Network (DIAS) and worked out its strategy in 2014 in Sofia, Bulgaria.

As part of the EUSDR Action Plan renewed in 2020, the objective of the relevant joint action is the evaluation of the impact of invasive alien species on ecosystems within the Danube Region, creating incentives for mapping out the best practices for their control or eradication in accordance with the DIAS work plan and the IAS Regulation (EU) *1143/2014*, as well as raising public awareness about the threats caused by invasive alien species ().

As the national coordinator of the EUSDR in Hungary, the Ministry of Foreign Affairs and Trade assumes that the publication of the present volume giving an overview of 118 invasive species occurring in Hungary both in English and in Hungarian, shall be a significant contribution to the achievement of the common Danube Region goals set by the Priority Area 6.

We are convinced that this handbook, co-authored by renowned Hungarian experts, shall be interesting and useful both for professionals and for the wider readership. This publication would hopefully motivate readers for further cooperation among public and academic circles, relevant authorities and decision-makers towards the protection of natural ecosystems within the Danube Region.

Budapest, 4th October 2022

Viktor György Oroszi, PhD
EUSDR national coordinator, Hungary

Foreword

Man has always been meddling with nature's order, ever since the beginning of time. The onset of drastic anthropogenic interventions can be dated back to the era of colonialism and since the industrial revolution, anthropogenic effects have become increasingly drastic. As of today, the negative consequences of these interventions are evident. One of these interventions is the transport of plant and animal species within or among continents. The deliberate or inadvertent introduction of exotic species into novel environments is not only in the focus narrow technical and academic circles, but also the topic of public discourse. During the past decades, more and more alien species occurred in Hungary, too, bringing this issue into the limelight. Even though the proportion of alien invasive species to native species is still moderate, the reproductive rate, speed of dispersal and the extent of area invaded by invasive species are worrying at several localities across the country. The most important cause of biodiversity loss is the conversion, deterioration and disappearance of habitats, but a close second is the aggressive spread of invasive alien species. Apart from raising issues for nature conservation, this process may well lead to serious harm both to our health as well as to our economy. As part of the series of technical issues published by the Danube-Ipoly National Park Directorate, we regularly discuss topics concerning invasive alien species. For example, volume III of our so-called Rosalia series is a detailed account of several conservation management programmes, providing the description of the impact of invasive alien plants on the natural environment, the potential ways to control their populations or prevent their spread and the administrative tasks inherent to such processes. As the next volume of the same series, we now present the Esteemed Reader with a new, stopgap handbook on the status of invasive alien animals in Hungary. The publication presents 118 invasive alien animals that are all present in Europe, and many of them have already been recorded in Hungary, too, while the appearance of the rest may soon be expected. To aid identification, the book provides at least one photograph for each species. For those species which there was distribution data available, maps help orientation, too. In the descriptive section, evidence-based, practical advice is provided as to the management or control of the species. Obviously, control is not only a serious challenge but also a relentless battle in case of widespread (and especially, aquatic) animals. In order to be successful in our efforts to control aggressively spreading alien species, technological development and significant resources are essential, both in terms of human and financial means.

I do hope that the comprehensive and practical information bound within this book contribute to a better understanding of this extremely complex issue as well as to the control – and wherever possible – to the prevention of the spread of invasive species. I recommend this volume to professionals, decision-makers, practitioners working in the field and to all those responsible fellow humans who are motivated to contribute to the protection of our natural assets.

Finally, I wish to thank the team of experts and the Editor for their thorough, detail-oriented work. This publication was financed by means of the priority area *'Biodiverstiy, Landscapes and Air&Soil Quality' of the EU Danube Region Strategy (EUSDR)* through a cooperation between the Ministry of Foreign Affairs and Trade and the Danube-Ipoly National Park Directorate (in accordance with our bilateral agreement signed in November 2021).

Budapest, 12th September 2022.

András Füri
director

Introduction

The dramatic increase of human population through the past century along with the exploitation of natural resources – or ever more often, their outright plundering – resulted in the fact that the conservation of biological diversity has become doubtful, to say the least. Alarmingly enough, biodiversity equals life on Earth and therefore its demise is a threat not only to wildlife inhabiting forests or seas and other habitats, but to the existence of life as we know it, in its entirety.

Besides those types of destruction that have been well known for a long time, a novel type of threat also bears down significantly on native wildlife, including local human communities. This threat is imposed by the so-called invasive alien species (IAS) that spread at alarming rates and over increasing areas.

As of today, there is no corner of the planet that would still be spared from this problem. Furthermore, there are some regions, where IAS threatens human existence itself.

But what are these species? As a general rule, we may conclude that IAS have occurred at extreme distances from their original distribution as a result of human activities and can not only survive there, but find ideal circumstances in these novel environments. As every other species, in their native habitats, IAS are part of a natural (self-regulating) system, in which they must co-exist with many other species, competing with rivals, adapting to consumers/predators and parasites that in intricate ways of a complex system, interact to ensure that no species ousts others or becomes the single species present at a site. When invading a novel environment, IAS are free from all these ecological constraints and become not only dominant but may explicitly cause the local extinction of more sensitive (native) species.

We must note that this process is not automatic, and luckily, only a fraction of species can become IAS when introduced to a faraway region.

A part of IAS 'only' causes direct economic damage, but the majority leads first to ecological issues.

This book presents animals that primarily cause ecological issues in their novel environments, but as it shall be evident from the descriptions, there are very few among them that would not have smaller, graver or even catastrophic impact on the economy. Some species we included in this book have not yet reached Hungary, but it is only a question of time and there is no doubt that they shall.

On the other hand, we excluded those invasive animals that are specifically linked to plants also alien to Hungary (imported and grown as crops or ornamental plants). These animals would only damage their one or few host plant species, such as the box tree moth *Cydalima perspectalis,* the western corn rootworm *Diabrotica virgifera,* the Colorado potato beetle *Leptinotarsa decemlineata* and so on. As such species are considered pests and would fill a whole volume themselves, we decided to omit them from here.

It is worth noting what attributes or criteria make IAS a risk to native flora and fauna.

Competitive advantage, enabling IAS to exclude native species. This advantage might arise from higher productivity (e.g. higher number of annual reproductive events or more offspring from one reproductive cycle than those of native competitors). Also, IAS could be better at exploiting food resources, e.g. by feeding on more than one host plant or prey animal, giving them a significant head start.

Hybridization, threatening those native species that are characterized by constrained habitats (tight spatial extent, narrow ecological niche) or have very low abundances. A continuous genetic 'infection' may destroy their 'purebred' populations.

Disturbance, competition or predation within the food network. For species characterized by constrained food resources, the appearance of a novel competitor that not only feeds on the same resource but is also abundant, makes it more difficult to access enough food, consequently dismantling reproductive and subsistence patterns, even if the IAS does not completely deplete the food source in question. The appearance of a novel predator may create pressures that some species cannot tolerate for long.

Habitat conversion. Invasive alien plants come to mind at first, which quickly become dominant if not the single species in a formerly diverse area, thereby excluding many or all other species locally. Unfortunately, some invasive animals also have such potential. Beetle species (Coleoptera), for example, may quickly become so abundant that they make the survival of native species (primarily trees) doubtful, or some slugs that would overgraze just about anything when occurring as a plague.

Introduction of parasites and diseases. IAS from faraway continents may bring along viruses, bacteria and parasites with them. As native species in a freshly invaded area are not adapted to and not protected against these infections, the diseases may cause mass morbidity or even mortality.

Societal impacts. Economic losses linked to IAS can be measured by millions of dollars. Another, less well-known impact is the negative effect on the recreational use of habitats. For example, several coastal bathing sites that had formerly been very popular were closed on account of the extreme increase of the abundance of alien jellyfish (Medusozoa). Also, we must make mention of certain zoonosis (diseases spreading from animals to humans) that may appear in a region with the IAS carrying them. In other cases, IAS only speed up the spread of formerly present diseases.

From this volume, we omitted those exotic species that are characterized by specific habitat requirements, and are thus constrained to sites where they can reproduce but cannot spread and invade nearby habitats. Animals living in warm waters, like some fish (Pisces): the originally Central American rainbow cichlid (*Herotilapia multispinosa*) that has one single reproductive population in the Hévízi Lake and in the upper sections of its two outlets. As field investigation shows, the individuals cannot leave these high-temperature waters, unlike those of the spotted jewelfish (*Hemichromis guttatus*), or the jaguar guapote (*Parachromis managuensis*) and consequently, cannot become invasive.

There are several observations of reptiles, primarily turtles (Testudines), but the establishment and spread of reproductive populations is unlikely for any of the species present in Hungary. Such species are the alligator snapping turtle (*Macrochelys temminckii*), the false map turtle (*Graptemys pseudogeographica*), the Chinese pond turtle (*Mauremys reevesii*), the Chinese stripe-necked turtle (*Ocadia sinensis*), the common musk turtle (*Sternotherus odoratus*), the Cuban slider (*Trachemys decussata*), the Peninsula cooter (*Pseudemys peninsularis*), the river cooter (*P. concinna*) and the subspecies of the painted turtle (*Chrysemys picta* spp.), as well as the king ratsnake (*Elaphe carinata*).

There are also some invertebrates that are already present in Hungary, but luckily, cannot establish viable populations. Such are the following decapods: *Cherax boesemani*, *Ch. pulcher* and *Ch. snowden*, that have been recorded at dispersed locations, but evidently, none of these species could establish long-term populations. Furthermore, various shrimp species were also recorded in Hungary.

Even though our main purpose is to give an overview of the ecological impact of each IAS, we cannot dismiss their economic impact. Within the European Union, the estimated annual losses and costs incurred caused by IAS total at 12 billion EUR, including not only the impact of invasive animals, but also plant species.

Between 1986 and 2020, the invasive populations of the American bullfrog (*Lithobates catesbeianus*) and the brown tree snake (*Boiga irregularis*) caused damages totalling 16 billion USD globally.

Unfortunately, there are no estimates either for annual damages caused by IAS within Hungary or about the magnitude of resources needed for the control of invasive species. As there is no data available on costs, we substitute it with a remarkable and interesting piece of news concerning the problems caused by invasive species that go way beyond ecological and economic issues. On 20th October, 2019, mass had to be cancelled as the church of Nagyhódos (Szabolcs-Szatmár-Bereg County, Hungary) was completely flooded by harlequin ladybirds (*Harmonia axyridis*).

Across the globe, a wide spectrum of methods is applied against IAS, but Hungary is drastically lagging behind, while the costs of delaying the implementation of control programs are on the rise.

Management of IAS has yielded ample knowledge and practical information during the past 20-25 years, most of which is accessible online. As of today, there are several hundred websites available in English with contents on invasive species. The site www.iucngisd.org, i.e. the *Global Invasive Species Database* provides information on thousands of species either classified as an IAS or threatened by one, where contents are searchable by taxonomic, geographic and habitat type categorization.

Presently, online information concerning IAS in Hungary is scarcely available in Hungarian, but www.termesztvedelmikezeles.hu is worth checking for plant data, while www.invaziosfajok.hu contains Hungarian contents about 75 invasive plants and animals present in the European Union.

By the beginning of the 2000s, several volumes of technical literature came to light about the control of invasive plants in Hungary, but not much attention has been paid to invasive animals. Our book is the first of its kind, attempting to give a comprehensive overview of invasive animals in Hungary and the problems inherent to their presence.

Most of the IAS was deliberately introduced to their novel environments. This fact should lend momentum to initiating control programmes against IAS, the extirpation of established populations as well as the strict prohibition of introducing new ones – the latter is all the more important, as each new invasive species potentially brings along new problems.

Hopefully, our book may contribute to putting invasive alien species into the limelight.

This volume was put together by a large team of authors supported by expert readers. We managed to obtain good quality images from Hungarian nature photographers on each species – I wish to thank them here, too.

Besides the authors, readers and nature photographers, several others furthered the preparation of this book. I am especially grateful for Pál Kézdy and Ferenc Hoch for their professional help, for the work of Tibor Hadarics as a reader and editor of the References section, as well as for the fantastic contribution of András Rozs in page setting and other prepress tasks. The Dunatáj Nonprofit Ltd. provided essential support during the preparatory phase, many thanks to them, too.

The publication of this volume was made possible by the Ministry of Foreign Affairs and Trade, and by the Danube-Ipoly National Park Directorate. I thank them on behalf of the team as well as the wider readership.

Budapest, 24th September 2022

László Haraszthy

FLATWORMS
Platyhelminthes

Giant Liver Fluke

Fascioloides magna (Bassi, 1875)

Native range

Pathogens, such as viruses and bacteria, and pests and parasites of animals and plants are usually not considered invasive species, although damaged plantations and severe epidemics clearly demonstrate their invasion potential. This is why this large, North American flatworm (Platyhelminthes), which develops in the livers of deer (Cervidae), is included in this book. Despite its having been first discovered and described from Wapitis (*Cervus elaphus canadensis*) imported from America to the Royal Park near Turin (Bassi 1875), its original area of distribution is limited to the northern regions of America, where it most often occurs in the Mule Deer (*Odocoileus hemionus*) and the White-tailed Deer (*O. virginianus*), both of the group of New World deer (Capreolinae). Apart from these, it may also parasite wapitis, and it can infect every wild ruminant of the deer family (Cervidae). The Giant Liver Fluke is endemic to the southeastern and northwestern coast of the United States of America, to the area of the Great Lakes, to the Canadian ranges of the Rocky Mountains, and to the boundary of Labrador and Quebec, but it occurs sporadically everywhere on the continent where deer are also present (Malcicka 2015).

Introduction to Europe and Hungary

The Giant Liver Fluke was described in Northern Italy, from Wapitis (*Cervus elaphus canadensis*) imported from North America, so it had been introduced to Europe even before scientifically described. At this time, it remained isolated in Northern Italy (Bazsalovicsová *et al.* 2015). American deer (Cervidae) were also introduced to wildlife parks in Moravia, independently of the case in Turin, by the end of the 19th century. Probably these supplied the source population which later dispersed and infected Central European deer in several countries (Erhardová-Kortlá 1971), and is capable of spreading to this day. Despite its presence having already been noticed in Czechia and Saxony in the 1930s (Ullrich 1930, Salomon 1932), it only reached Northeastern Austria in 1983 (Pfeiffer 1983), and Southwestern Slovakia in 1988, after becoming endemic* in several regions of Czechia in the 1960s (Rajský *et al.* 1994). In Hungary, it was first noticed in the Szigetköz area in 1992 (Majoros & Sztojkov 1994), and from then on, it has been spreading rapidly along the Danube, towards the southern part of the country, especially on the Gemenc floodplain. From here, it also reached the counties Baranya and Somogy, and spread north, towards Lake Balaton (Nagy *et al.* 2018). From the Szigetköz, it also spread west, and appeared in the Hanság region. It was also detected in a Red Deer (*Cervus elaphus*) shot by Lake Fertő in 2013 (T. Hadarics *pers. comm.*). As red deer and Roe Deer (*Capreolus capreolus*) droppings, potentially containing fluke eggs, float on the surface for days if they fall in the water, and as the infected intermediate hosts are easily washed away in floods, it is easy for the Giant Liver Fluke to disperse downstream along rivers. It also occurs and causes problems in Serbia and Croatia. From the original infestation centre in Moravia, northward and westward spreading is hardly possible, because the only way for the Giant Liver Fluke to cross mountains is if it is carried by deer. Accordingly, only sporadic occurrences have been reported from Germany and Poland (Demiaszkiewicz *et al.* 2018). On the other hand, its water assisted dispersal caused an intensive invasion in the Danube Basin (Florijančić *et al.* 2010).

*The term endemic is used in parasitology when the occurrence of a parasite is associated with certain areas, whereas other areas are uninfected. So here, this concept does not imply that it only occurs at a certain location, as when used related to animals or plants. The concept has been applied for the liver fluke for a long time, as it is an ancient experience that it is present in some places, and absent in others.

Biology of the species

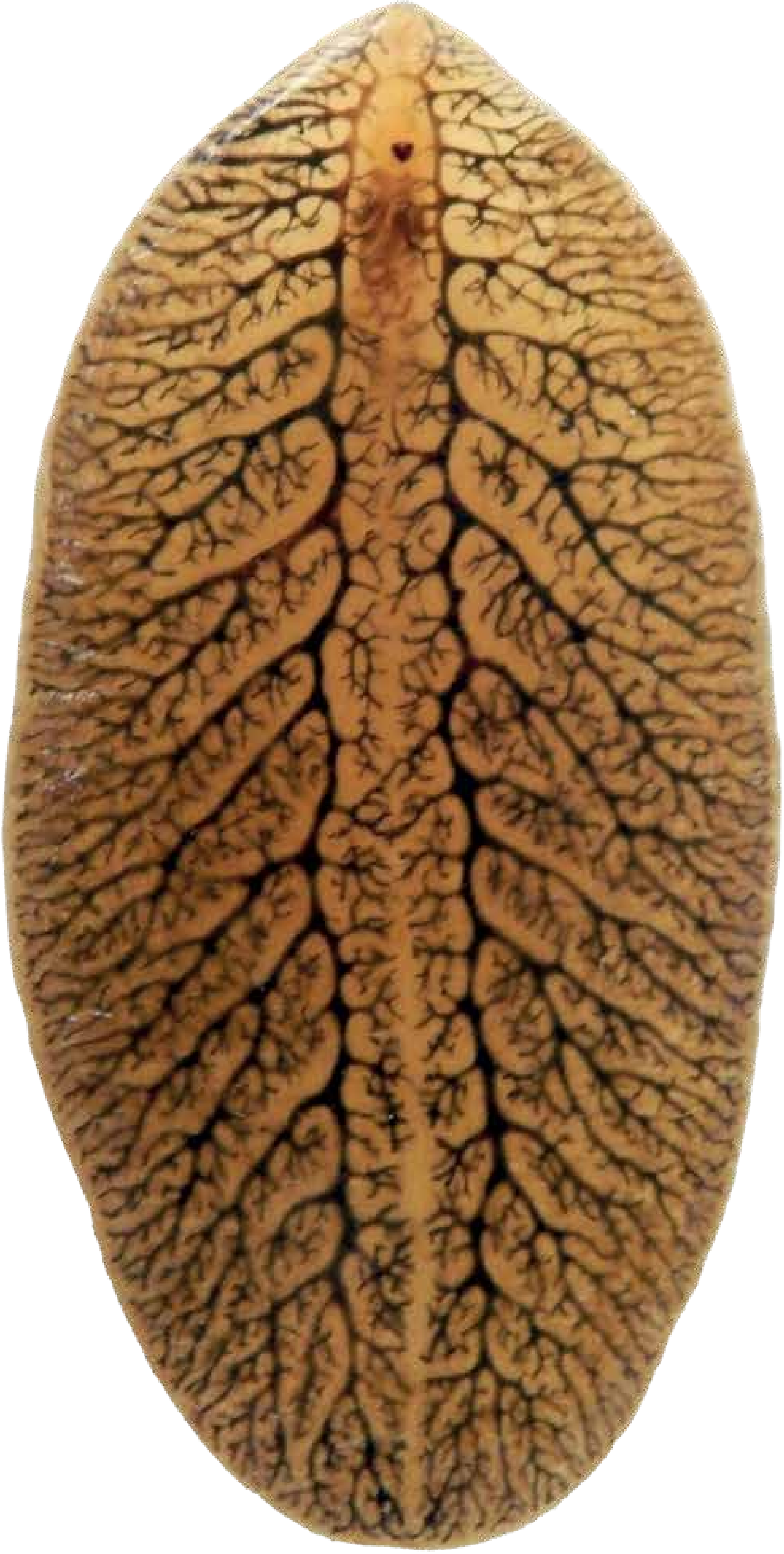
The Giant Liver Fluke is the only species in the genus *Fascioloides*. Its life history is very similar to that of the Common Liver Fluke (*Fasciola hepatica*), the adults of which mainly infect bovids (Bovidae) (Loker & Bruce 2015). Both liver fluke species have adequate and abnormal hosts. They are able to reproduce in the former, and not in the latter. In Hungary, every native and introduced cervid species (Cervidae) is an adequate host. The fluke also starts its development in Cattle (*Bos taurus*), sheep (*Ovis* spp.), and sometimes Wild Boar (*Sus scrofa*), and may even make them severely ill, but it cannot release its eggs, as in cattle, the fibrous capsule in which the fluke lives is enclosed, it does not have duct connections to the bile duct. In cervids, the flat, tongue shaped, up to 10 cm long flukes occur in fibrous capsules in the liver, nearly always in pairs. The capsules, apart from the flukes, also contain their blackish brown faeces consisting of digested blood, and a mass of eggs. Flukes produce eggs by the million, which are released through a small duct connected to the bile duct. Eight to ten such capsules may form in the liver of a single infected deer, so, through the bile ducts and the intestines, it may release hundreds of eggs into the environment every day.

If the deer droppings get into water, ciliated larvae develop in the eggs in the course of a few weeks, which swarm into the water. These larvae, called miracidia, need to find their intermediate hosts, freshwater snails (Pulmonata) the body of which they are able to penetrate, within hours. This is not too difficult, as the gastropods most suitable for the fluke's larval development inhabit exactly the puddles and wallows frequented by deer (Dunkel *et al.* 1996, Rondelaud *et al.* 2005). In Hungary, a tiny snail, *Galba truncatula* is common in shallow ponds and the periphery of marshes, so it is an ideal intermediate host for the larvae of liver flukes. The Giant Liver Fluke also "uses" this snail for the multiplication and the development of its larvae, as it is also its intermediate host in its native range. The miracidia which have penetrated the body of the intermediate host multiply asexually in the course of three distinct developmental stages. When the multiplicative phase is over, more than 20 fluke larvae (cercaria) emerge from the body of *G. truncatula*, which is the size of a wheat grain. From larger intermediate hosts, up to 1000 larvae may emerge (Pybus 2001). The cercaria actively swim in the water by flapping their tails, but only for a few minutes, till they find a solid surface to which they can attach to encyst themselves. If they avoid total desiccation, they can live in the cyst for months. Grazing ruminants swallow the encysted, tailless larvae (metacercaria) attached to the grass. The parasite completes its development inside the body of the definitive host. The metacercaria is practically a juvenile fluke. When it reaches the intestine, it penetrates its wall and migrates into the abdominal cavity. From here, it penetrates the liver, where it develops into an adult fluke. This migrates inside the liver for a while, growing and looking for a mate. In this phase, it damages the liver parenchyma, and causes bleeding, necrosis, and inflammation of the tissues. In spite of this, it rarely causes death, but by damaging the liver, it weakens the deer, which may cause deformities in growing antlers. Deer infected with the Giant Liver Fluke produce reduced quality antlers (Ursprung *et al.* 2005, Slavica *et al.* 2006).

It is an important aspect of the biology of the Giant Liver Fluke that such a huge amount of eggs accumulates in the fibrous capsules in the liver, that even if the flukes are killed by medication or die spontaneously, the hosts may still go on releasing mature, viable eggs. A single healthy looking deer may carry millions of fluke eggs in its liver. If it dies or gets preyed, these eggs will spread on with the faeces of the predators or omnivorous animals devouring its liver, as the shell of the eggs cannot be digested. In nature, wolves (*Canis* spp.) and scavengers may spread the Giant Liver Fluke as well as its definitive hosts.

Ecological conditions in Hungary

Distribution records of the Giant Liver Fluke show that infections are most common in wetlands and habitats with at least intermittent waterbodies, but not necessarily related to plains, as permanent infection centres may also develop in mountains. The snail *Galba truncatula* needs only a little water to survive, and can breed in a pothole on a mud track. It also survives in the permanently humid beds of intermittent watercourses, and wallows deepened by Wild Boar (*Sus scrofa*). For the snails to get infected with fluke larvae, it is necessary for deer (Cervidae) to visit these waters from time to time, either to drink or to wallow. The deer nearly always leave their droppings in places where they spend some time. Fluke eggs remain alive for months, according to some studies, even for a year in droppings fallen into shallow water (Mas-Coma *et al.* 1999). In areas covered in shallow water, *G. truncatula* may produce two or three generations a year, every one of which has a chance of getting infected. In Hungary, *G. truncatula* is common everywhere, from lowland plains to mountain streams, so hypothetically, fascioloidosis of deer may strike anywhere.



© Gábor Majoros

Ecological concern and economic impact

Experience from America and Europe indicates that liver damage caused by the Giant Liver Fluke weakens the afflicted cervids (Cervidae), and causes quality loss in the antlers. In areas strongly affected by liver fluke, Sheep (*Ovis aries*) cannot be kept, as they are susceptible to the infection, which causes their death (Foreyt & Todd 1976). According to some observations, the European Roe Deer (*Capreolus capreolus*) is more susceptible to the fluke than the Red Deer (*Cervus elaphus*), and its populations significantly decrease in highly impacted areas. However, this kind of damage is only rumoured in Hungary, and the public is ignorant of the problem. The reason for this is that hunting companies are interested in overlooking mild diseases, i.e. those that do not cause increased mortality regularly, in order not to scare off hunters, especially foreign guests. They do not really care about diseases or parasitoses as long as they do not require official intervention, and do not have a negative impact on the sport for hunters, as effective control measures would cost much more than the profits gained by organising hunts. It is undeniable that no quality loss of officially judged antlers has been reported in Hungary yet, not even in the most severely impacted regions. It is important to note, however, that the antlers of animals shot in the course of selective harvest do not get examined or judged. The livers of shot deer are not processed, they are usually left at the site of the hunt after field dressing. In some cases, they are destroyed together with the offal, utilised as dog food, or given to the beaters. Venison is sold by processing facilities, so hunters hardly notice changes in the quality and quantity of the meat.

Sheep killed by the Giant Liver Fluke have been only reported sporadically, for example when flocks were grazing illegally in areas reserved for wild game.

These factors combined result the unhindered spreading of the Giant Liver Fluke in Hungary. Hunters can find relevant information about the disease on the website "*Vadászati Információs Portál*" (www.vadasz.info.hu). Here, it is commonly held that the single possible way is to co-exist with this parasite, as, according to expert opinion, its extirpation is impossible.

Selective harvest is commonly considered one of the most important treatments in wildlife management, mainly a task for professional hunters. This is not trusted to nature anywhere, but there are well-defined rules for the shooting of unfit animals. Diseases, including parasitoses like the Giant Liver Fluke also put selection pressure on the wild game population. According to some opinions, the Giant Liver Fluke only attacks "weak" animals, thereby assisting selective efforts. In infected areas, increased utilization of the game stock is suggested (www.vip.gportal.hu), which practically means that the combined effect of the parasite and hunting puts an even stronger pressure on the game population than their separate effects.

The continued dispersal of the Giant Liver Fluke in the entire country may have severe consequences, as yet unforeseen, because it may also affect game stock grazing in poorer habitats than those on the rich floodplains of the Danube. This parasite, apart from causing economic damage by hindering the export of live game or venison, the breeding of game in wildlife parks, or even threatening domestic animals, may also harm European Mouflons (*Ovis aries musimon*), and may also infect species in which its occurrence has not been detected so far. A similar case has already happened in France, where the Common Liver Fluke (*Fasciola hepatica*) infected free-living Nutria (*Myocastor coypus*), which never met this parasite before in the course of their evolution (Ménard *et al.* 2001). As shown by numerous studies, the common liver fluke also infects humans (*Homo sapiens*) (Esteban *et al.* 1998, Mas-Coma *et al.* 1999). This is also a real possibility in the case of the Giant Liver Fluke. We must also reckon with the possibility of the Eurasian Beaver's (*Castor fiber*) becoming a host of this parasite, as this rodent is increasingly widespread in Hungary, and often shares a riparian woodland habitat with both the intermediate host *G. truncatula* and the deer.

Potential control measures

To avoid contamination in venison, no medical treatments are allowed in or directly before the hunting season. In Hungary, population level medication can only be performed on infected Red Deer (*Cervus elaphus*) from spring to midsummer. Such treatments are widely applied in Hungary and other countries as well (Ursprung *et al.* 2005). Unfortunately, deer do not regularly frequent feeders or salt licks at this time of year, therefore the otherwise very effective, orally administered medication is only moderately successful. The application of such medical treatment on free ranging game stock is very costly and has to be conducted with great care, so only well organised, solvent game management companies can afford it (Qureshi *et al.* 1994). Infection rates can be better monitored at wildlife parks, where medical interventions can

© Gábor Majoros

be organised in the winter. This is advantageous, as re-infection from the environment is less likely in the winter (Slavica *et al.* 2006).

It is also expensive to destroy the entrails of the killed deer. It can be achieved by digging, burying in lime pits, or making processed animal protein. Today, these are not common practice, especially in the case of individual still hunting. The responsibility of those conducting the field dressing is great, but they usually perform their task in the night, and the hunter often does not even see the offal. Wild Boar (*Sus scrofa*) and forest predators will clear up the remains of organs hidden under leaf litter or shoved into ditches at the site of the hunt within days, but as they are also able to release liver fluke eggs with their faeces, the entrails and the liver should by no means be left behind.

The third possible control measure is the eradication of the intermediate hosts of the Giant Liver Fluke. This is only worth trying if the locations of the mass occurrence of *Galba truncatula* are precisely known and restricted. This snail is mostly abundant in periodical waterbodies, e.g. potholes or areas flooded by groundwater, not permanent waterbodies. At such sites, the prevalence of the parasite in the snail population can be determined in the laboratory, and the populations of the intermediate hosts can be extirpated if necessary by the desiccation of the habitats or mechanical means. Although such interventions seem difficult to implement, they may become necessary in the future, as medical treatments alone seem ineffective (Haider *et al.* 2012).

References

Bassi 1875, Bazsalovicsová *et al.* 2015, Demiaszkiewicz *et al.* 2018, Dunkel *et al.* 1996, Erhardová-Kotrlá 1971, Esteban *et al.* 1998, Florijančić *et al.* 2010, Foreyt & Todd 1976, Haider *et al.* 2012, *Loker & Bruce 2015,* Majoros & Sztojkov 1994, Malcicka 2015, Mas-Coma *et al.* 1999, Ménard *et al.* 2001, Nagy *et al.* 2018, Pfeiffer 1983, Pybus 2001, Qureshi *et al.* 1994, Rajský *et al.* 1994, Rondelaud *et al.* 2005, Salomon 1932, Slavica *et al.* 2006, Ullrich 1930, Ursprung *et al.* 2005

Gábor Majoros

GASTROPODS

Mollusca

The significance of synanthropic and non-native molluscs in Hungary

In Hungary, too, the highest number of non-native species compared to native ones is found, unlike in any other animal taxa, among molluscs (Mollusca). Besides the approximately 200 naturally occurring species, there are at least 92 gastropods (Gastropoda) and bivalves (Bivalvia) living in our country whose survival and expansion are to some degree assisted by humans (Table 1.). This unfavourable ratio is partly due to the fact that the proportion of molluscs in Hungary's current territory is quite low relative to most of the other animal phyla, and party due to their more unnoticed and easier expansion resulting from their secretive life and small size, compared to more conspicuous animal species. Their colonisation and spreading can happen spontaneously or mediated my humans, some of the species becoming invasive, the most important ones summarised by Csányi & Varga (2017). However, it can never be seen in advance which of the colonising species will later negatively influence the local ecosystem or human activities. It can be suspected, though, that species doing well in human environments will expand much more effectively than those living only in a natural habitat. The rapid expansion of a species, on the other hand, will imply a likelihood of invasion, meaning that it is among synanthropic species where potential invasive species are to be looked for. The following table includes all those gastropod and bivalve species that have spread in Hungary, either outdoors or in captive colonies, in an anthropochorous way, i.e. assisted (mostly) humans. In addition to these species, certainly there are ones that are currently spreading spontaneously in our country but their nativeness is indisputable, and if they become more frequent than their current density and distribution, even if due to human activity, this will not cause any problem in the future. Such are for example garden snails and grove snails (*Cepaea* spp.) (Kovács 1976, 1977) and *Drobacia banatica* (Deli & Farkas 2006).

Original distribution areas

The table shows that molluscs (Mollusca) have spread to or have been introduced to Hungary from all parts of the world – and it is quite sure that this will continue to happen in the future. Relatively few of the introduced species have become invasive, irrespective of whether they arrived from America, Africa or Asia. It appears that it is not the original distribution area that determines the invasive capacity of species, but instead the mutations that make them able to successfully multiply and colonise the new habitats. The importance of knowing the former distribution areas is in that once the invasive nature of a species has been experienced in a foreign county, then it will quite likely retain such a potential in Hungary too. Of course this is not always the case, as for example the giant African Land Snail (*Lissachatina fulica*) has become an aggressive invasive species in some tropical-subtropical countries, but has failed to survive the winters of temperate climate zone. At the same time, the brown garden snail (*Cornu aspersum*), originally living hidden among the sunlit rocks along the Mediterranean coast has completely adapted to the freezing winters of Central Europe (Páll-Gergely *et al.* 2019), thus it may be possible that even species from warmer climates can naturalise themselves in the Carpathian Basin.

The introduction of species into Europe and Hungary

Based on the origin of the species that have settled, it was observed that those from more distant continents did not arrive directly from overseas, but instead they entered the country through European traders and suppliers. It is known that all of these species had been present in one of the countries around Hungary before actually establishing themselves here. Also, species introduced from other European areas or deliberately bred species appeared earlier in neighbouring or nearby countries than in Hungary, all this indicating that molluscs (Mollusca), as expected from slow-moving creatures, *non fecit salta*, i.e. do not spread fast. At least they do not spread with such a speed that their invasion cannot be foreseen once they have proved to be invasive in other countries. Precaution is nevertheless advisable, meaning that at least those species that can be raised in indoor facilities (aquaria and terraria) should not be kept outdoors even if this is technically feasible. Hobbyists will, of course, always import newer and newer exotic snails (Gastropoda) and bivalves (Bivalvia), therefore these species have to be kept an eye on. More and more alien species are expected to show up in Hungary in the future, which need appropriate measures that can prevent them from escaping.

Certain species came on their own, sliding on their foot, to later become invasive species in Hungary. Some do not consider spontaneously settling and naturally expanding species to be invasives, however, the spectacular example of the expansion of Ggolden Jackals (*Canis aureus*) is a quite obvious indication for many people that a potential for invasion is not necessarily associated with anthropochorous introduction. For example, in the case of gastropods (Gastropoda), the Heath Snail (*Xerolenta obvia*) has been present in the Carpathian Basin, although in low numbers, since the Ice Age (Krolopp 1975), yet it must be considered an invasive species for the ability of this snail spreading along roads (*ob via*) to establish itself in almost any weed association and to create very dense populations. As an intermediate host, it transmits parasites in pastures, whereas in sandy areas it is a competitor species to the sub-endemic *Helicopsis striata* whose largest European population is found in the Kiskunság area. In the case of the eastern heath snail, adaptation to anthropogenic environments was the key to its successful expansion.

It must be admitted that the mollusc fauna inevitably changes over time, and the settling of new species is not always a negative phenomenon. Because human presence multiplies the chances of species to spread, it must be expected that species assisted by man will have an advantage compared to spontaneously spreading ones. The particularly synanthropic Spanish Slug (*Arion vulgaris*), for example, invaded entire Hungary during a course of a few years, as opposed to the closely related Chocolate Arion (*A. rufus*) preferring more natural habitats, which, although having started expanding towards the east from the same distribution area, seems to be coming to a halt at the state border (Botka & Varga 1984). Live gastropods and bivalves (Bivalvia) can survive attached to the underside of vehicles and bottom of ships, in shipments of goods, in people's pockets or luggage, sticking to the fur of animals or even in passing through the digestive tract of birds (Wada *et al.* 2011), and can reach Hungary while being transported in such ways.

A strange evidence for molluscs being dispersed by man is the multitude of sea shells and snail shells found sometimes by observant malacologists scanning the ground surface, whose attention is well focused on pointing out such animals in the first place. The pebbly shore of the Danube, for example, is sometimes littered with the shells of smaller marine bivalves (*Donax* spp., *Macoma* spp.) maybe originating from barges, but even more often can one find discarded snail shells or seashells in disposed garbage. Several shell types are used as garden ornaments, and the shells of quite a number of various marine molluscs can find their way into the environment in the form of leftover food, as, for example, shell remains of Asian clams cultured particularly for human consumption are sometimes found in the debris of ditches in the outskirts of Budapest. Because snails and bivalves intended for consumption are shipped live, and most often are also sold live, theoretically it is possible that they get out of human control while still alive. Such animal remains reach their abnormal environment in a passive way, thus clearly proving the role of humans in their dispersion. It is not up to the caution of people that sea creatures swept off or falling off Danubian vessels and then drifting to the shore cannot establish themselves here, but instead it solely depends on the fact that the habitats are unsuitable for them. The high variety of transportation possibilities of freshwater and terrestrial invertebrates can particularly apply for snails, because, due to their lifestyle, they spend long periods in an inactive state, when they are hardly threatened by the effects of the outside world. The states of hibernation and aestivation are both suitable for the animals retreated in their shells to passively change location in a variety of ways.

General features in the biology of mollusc species with expansion potential

Especially in the case of smaller molluscs (Mollusca), the actual living habitats are often restricted to a few square meters, because these species have a strong preference of certain living conditions. In quite a few cases, the population is confined to the place under a single bush, to a rock crevice, a drystone wall, a few taller plants or temporary puddles. However, their dispersion success is improved if their abundance can increase under favourable conditions, because this way there is a greater chance for a few individuals to get outside the boundaries of the limited habitat. It really is a fact that successfully expanding species produce populations with higher density at least every now and then, or produce a huge number of offspring in certain years, under specific weather conditions. The number of individuals in distinguished cohorts can sometimes differ by one or even two orders of magnitude, because snails (Gastropoda) normally produce hundreds and bivalves (Bivalvia) even as many as thousands of offspring. Population booms are almost inevitable for some aquatic and terrestrial species, but such gradation-type population changes are not continuous but instead collapse sooner or later always, and only a few individuals survive to form the successive age group. This strategy is particularly conspicuous in aquatic snails inhabiting periodically drying water bodies and marshes, as well as in the formerly mentioned terrestrial Heath Snail (*Xerolenta obvia*) characterised with rapidly multiplying in an area of only a few square metres, then disappearing totally, to form a dense population a couple of years later in a different location.

The way of reproduction, too, has a great impact on the survival success of different generations. Most of the snail species forming dense populations lay eggs only once or twice, and then die. Such, so-called semelparous organisms seem to risk it all at once, just like annual plants do, this strategy appearing also in many insects (Insecta), because this way the large individuals of the parent generation, characterised with higher metabolic needs, do not have to survive through the winter. Most of the smaller pulmonate aquatic snail and slug species are semelparous, and many terrestrial snails, too, use this type of reproduction strategy. This is how each of the introduced heath snail species reproduce. Semelparous species are more likely to become invasives than the iteroparous molluscs which mate and bear offspring several times. The latter, too, do include invasive species, especially ones that give birth to a great number of live offspring. Tiny snails emerging from the egg upon birth are produced by the New Zealand Mud Snail (*Potamopyrgus antipodarum*), the Malayan Trumpet Snail (*Melanoides tuberculata*), the Quilted Melania (*Tarebia granifera*), while actively swimming larvae are born by the Chinese Pond Mussel (*Sinanodonta woodiana*) and basket clams (*Corbicula* sp.). These molluscs are all invasives characterised with individuals breeding through several years.

Ecological requirements of synanthropic species in Hungary

The special ecological needs of the species in Table 1 can differ greatly depending on their lifestyle, nevertheless it is striking that most species prefer warm water and warmer, non-freezing soils such as the substrate of terrariums and greenhouses, or patches of earth that remain frost-free at the base of stone walls, in rock crevices or under larger stones. There are no cold-loving species (coming from the north) among them. This allows for the assumption that even among species with invasive nature it is mostly the warmth-loving ones that have a potential to become introduced in Hungary.

The majority of species kept in aquaria and terraria – especially those whose occurrence in the wild has not yet been recorded – do not appear to be risky, because, as aquarists often put it, these are so delicate that they will not reproduce under our climatic conditions, even if intensively cared for. This narrow environmental tolerance can widen up, for example when a species preferring brackish water becomes totally freshwater-tolerant, which has been the case with *Caspia* snails from the Black Sea, and with the New Zealand freshwater snails *Potamopyrgus* spp., leading to the dispersal of certain species.

Problems caused by expanding species

Introduced species can have a negative impact on the reproduction success of other species, and can also cause economic damage. An interesting example for the former is the case of Városliget Lake, an artificial but well observable water body in which gradating molluscs (Mollusca) continued to replace one another year after year. Márton Wiesinger, a notable aquarist was still able to collect specimens of the Pond Snail (*Radix ampla)* there (Wiesinger 1975) after the war, which is one of the rarest species nowadays. The possible reason was that the lake had not been drained formerly and nor had its bed been cleaned. *Radix ampla* was competed out in the early 1970s by Common Bithynia (*Bithynia tentaculata*) tolerating the drying out of the bed, which in turn was followed by Pea Clams (*Musculium lacustre*), with the end of this succession of native species signified by a massive population boom of the Valve Snail (*Valvata piscinalis*) just before the end of the 20th century. These were then followed by non-native species, the first of them being the brown Ramshorn Snail (*Planorbella duryi*). The next one was the Malayan Trumpet Snail (*Melanoides tuberculatus*), and most recently the Quilted Melania (*Tarebia granifera*) has become the

Non-native, synanthropic molluscs having entered the current territory of Hungary in the form of living specimens since the appearance of man in the Carpathian Basin, and having spread there in trade or in the wild

Most recent scientific name	Formerly used synonymous name	Most popular or accepted common name	Lifestyle / group	Original distribution centre of the species	Proven or most likely source of introduction	Way of human mediation; introduction media	Time of introduction or start of breeding	Assumed or known places of first introduction	Known place of introduction to outdoor area	Actual damage caused in Hungary so far	Theoretically expectable potential damage	Expected persistence of populations in Hungary
Theodoxus fluviatilis		River nerite	aquatic snail with gills	Europe	Spontaneous expansion	Flowing river water	Middle of last century	Tisza	Tisza; Danube	Not known	Not expected	Extinction not expected
Vittina waigensis	*Neritina waigensis*	Red racer nerite	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Vittina semiconica		Red onion nerite	aquatic snail with gills	Indonesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Neritina auriculata	*Neripteron taitense*	Batman nerite	aquatic snail with gills	Polynesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Neritina pulligera		Dusky nerite	aquatic snail with gills	Indonesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Neritina natalensis		Zebra nerite	aquatic snail with gills	Africa	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Neritina juttingae		King Koopa nerite	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Neripteron violaceum	*Neritina violacea*	Violet nerite	aquatic snail with gills	India	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Neripteron taitense	*Neripteron tahitensis*	Bat snail	aquatic snail with gills	Polynesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible

Most recent scientific name	Formerly used synonymous name	Most popular or accepted common name	Lifestyle / group	Original distribution centre of the species	Proven or most likely source of introduction	Way of human mediation; introduction media	Time of introduction or start of breeding	Assumed or known places of first introduction	Known place of introduction to outdoor area	Actual damage caused in Hungary so far	Theoretically expectable potential damage	Expected persistence of populations in Hungary
Neripteron auriculatum	*Neitina auriculata*	Bat snail	aquatic snail with gills	Polynesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Clithon corona	*Nerita corona*	Horned nerite	aquatic snail with gills	Madagascar	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Septaria porcellana	*Navicella porcellana*	-	aquatic snail with gills	South Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Celetaia persculpta	*Torotaia persculpta*	Blue turbo snail	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Marisa cornuarietis		Colombian ramshorn apple snail	aquatic snail with gills	South and Central America	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Eger stream	Not known	Not expected	New introduction is possible
Asolene spixii	*Ampullaria zonata*	Zebra apple snail	aquatic snail with gills	South America	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Filopaludina martensi	*Paludina cingulata*	-	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Pomacea diffusa	*Pomacea bridgesii*	Pike-topped apple snail	aquatic snail with gills	South America	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Eger stream?	Not known	Not expected	New introduction is possible
Pomacea canaliculata	*Ampullaria canaliculata*	Golden apple snail	aquatic snail with gills	South America	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Pomatias elegans		Round-mouthed snail	terrestrial snail with gills	Southwestern Europe	Food at times of fast?	Deliberate ?	Several hundred years ago	Monasteries, hermit houses	Tihany; Ócsa	Not known	Not expected	Extinction not expected
Pomatias rivularis		Eastern round-mouthed snail	terrestrial snail with gills	Southern Europe	Planting forests	Soil	Early 20th century	Planted Slavonian oakwoods	South-Transdanubia; Bátorliget	Not known	Not expected	Extinction not expected

Most recent scientific name	Formerly used synonymous name	Most popular or accepted common name	Lifestyle / group	Original distribution centre of the species	Proven or most likely source of introduction	Way of human mediation; introduction media	Time of introduction or start of breeding	Assumed or known places of first introduction	Known place of introduction to outdoor area	Actual damage caused in Hungary so far	Theoretically expectable potential damage	Expected persistence of populations in Hungary
Caspia knip-owitschii	*Caspia gmelini*	-	aquatic snail with gills	Sea of Azov area	With ships	Ballast water	A few years ago	Dan-ube-Bend?	Kisoroszi; Budapest	Not known	Not expected	Extinction not expected
Potamopyr-gus antipo-darum	*Potamopyr-gus jenkinsi*	New Zealand mud snail	aquatic snail with gills	New Zealand	With ships	Cracks in water equipment	Decades ago	Danube	Danube; Balaton etc.	Not known	Transmitting parasites	Extinction not expected
Melanoides tuberculatus	*Melanoides tuberculata*	Malayan trumpet snail	aquatic snail with gills	Southeast Asia, Africa	Pet trade	Deliberate	Early 20th century	Pet shops, aquaria	Hévíz; Budapest	Not known	Possible	Extinction not expected
Tarebia granifera	*Thiara gran-ifera*	Quilted melania	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Budapest	Not known	Possible	New introduction is possible
Thiara cancellata	*Melanoides cancellata*	Hairy snail	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Tylomelania perfecta		-	aquatic snail with gills	Indonesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Tylomelania patriarchalis		White-spot rabbit snail	aquatic snail with gills	Indonesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Tylomelania zeamais		Common rabbit snail	aquatic snail with gills	Indonesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Tylomelania spp. hybrids		Rabbit snail	aquatic snail with gills	Indonesia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Faunus ater		Lava snail	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Anentome helena	*Clea helena*	Assassin snail	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Eger-stream?	Not known	Not expected	New introduction is possible
Brotia herculea		Giant tower cap snail	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible

Most recent scientific name	Formerly used synonymous name	Most popular or accepted common name	Lifestyle / group	Original distribution centre of the species	Proven or most likely source of introduction	Way of human mediation; introduction media	Time of introduction or start of breeding	Assumed or known places of first introduction	Known place of introduction to outdoor area	Actual damage caused in Hungary so far	Theoretically expectable potential damage	Expected persistence of populations in Hungary
Brotia pagodula		Horned armour snail	aquatic snail with gills	Southeast Asia	Pet trade	Deliberate	A few years ago	Pet shops, aquaria	Not known	Not known	Not expected	New introduction is possible
Melanopsis parreyssii		-	aquatic snail with gills	Romania	Species recovery programmes	Deliberate	In the last century	Budapest, (Malom-tó, etc.)	Extinct	Not known	Not expected	Extinct
Pseudo-succinea columella	*Lymnaea columella*	American ribbed fluke snail	pulmonate aquatic snail	North America	Aquarium plants	Surface of aquatic plants	Decades ago	Botanical Gardens	Budapest	Not known	Transmitting parasites	New introduction is possible
Orientogalba viridis	*Lymnaea viridis*	Green pond snail	pulmonate aquatic snail	Southeast Asia	Aquarium plants	Surface of aquatic plants	Decades ago	Artificial ponds	Budapest Extinct?	Not known	Transmitting parasites	Extinction expected
Physella acuta	*Physella / Physa heterostropha*	Bladder snail	pulmonate aquatic snail	Central and North America	Aquarium plants	Surface of aquatic plants	Early 20th century	Rivers, canals, pools etc.	In entire Hungary	Damaging biofilm in filters	Blocking pipes	Extinction not expected
Planorbella duryi	*Helisoma duryi*	Brown ram-shorn snail	pulmonate aquatic snail	North America	Aquarium plants	Surface of aquatic plants	Decades ago	Warm water lakes	Hévíz; Budapest	Not known	Not expected	Extinction not expected
Planorbella trivolvis	*Helisoma trivolvis*	Marsh ram-shorn snail	pulmonate aquatic snail	North America	Aquarium plants	Surface of aquatic plants	Decades ago	Pet shops, aquaria	Not known	Not known	Not expected	Possibly extinct
Gyraulus parvus		-	pulmonate aquatic snail	North America	Aquarium plants	Surface of aquatic plants	Decades ago	Pet shops, aquaria	In entire Hungary	Not known	Not expected	Extinction not expected
Gyraulus chinensis		-	pulmonate aquatic snail	Asia	Aquarium plants	Surface of aquatic plants	Decades ago	Pet shops, aquaria	Budapest	Not known	Not expected	New introduction is possible
Ferrissia californica	*Ferrissia wautieri, clessini, stb.*	Fragile ancylid	pulmonate aquatic snail	North America	Aquarium plants	Surface of aquatic plants	Decades ago	Rivers, canals, pools etc.	In entire Hungary	Not known	Not expected	Extinction not expected
Hebetancylus excentricus		Excentric ancylid	pulmonate aquatic snail	North America	Aquarium plants	Surface of aquatic plants	Decades ago	Warm water lakes	Hévíz; Miskolctapolca	Not known	Not expected	New introduction is possible
Alopia monacha	*Alopia straminicollis monacha*	Nun alopia	terrestrial pulmonate snail	Romania	Species recovery programmes	Deliberate	Middle of last century	Bükk: Ablakoskő-valley	Extinct	Not known	Not expected	Extinct

Most recent scientific name	Formerly used synonymous name	Most popular or accepted common name	Lifestyle / group	Original distribution centre of the species	Proven or most likely source of introduction	Way of human mediation; introduction media	Time of introduction or start of breeding	Assumed or known places of first introduction	Known place of introduction to outdoor area	Actual damage caused in Hungary so far	Theoretically expectable potential damage	Expected persistence of populations in Hungary
Alopia livida bipalatalis	*Alopia livida bipalatalis*	Livid alopia	terrestrial pulmonate snail	Romania	Species recovery programmes	Deliberate	Middle of last century	Bükk: Ablakoskő-valley	Extinct	Not known	Not expected	Extinct
Strigillaria rugicollis	*Bulgarica rugicollis*	Mehadian door snail	terrestrial pulmonate snail	Romania	Unknown	Deliberate	Decades ago	Budapest: Gellért Hill	Budapest: Gellért Hill	Not known	Not expected	Extinction expected
Lissachatina fulica	*Achatina fulica*	Giant African land snail	terrestrial pulmonate snail	East Africa	Pet trade	Deliberate	Decades ago	Terraria, Glasshouses	Budapest: Margaret Island	Not known	Not expected	New introduction is possible
Lissachatina immaculata		Pink-lipped agate snail	terrestrial pulmonate snail	East Africa	Pet trade	Deliberate	few years ago	Terraria, Glasshouses	Székesfe-hérvár	Not known	Not expected	New introduction is possible
Allopeas gracile		Graceful awlsnail	terrestrial pulmonate snail	South and Central America	Plant trade	Soil	Decades ago	Botanical Gardens	Budapest	Not known	Not expected	Extinction expected
Allopeas clavulinum	*Lamellaxis mauritianus*	Spike awlsnail	terrestrial pulmonate snail	Southeast Asia	Plant trade	Soil	Decades ago	Glasshouses	Budapest	Not known	Not expected	Extinction expected
Opeas hannense	*Opeas pumilum*	Dwarf awlsnail	terrestrial pulmonate snail	Africa?	Plant trade	Soil	Decades ago	Glasshouses	Budapest	Not known	Not expected	Extinction expected
Cecilioides petitiana		Southern blind snail	terrestrial pulmonate snail	Southern Europe	Plant trade	Soil	Decades ago?	Unknown	In entire Hungary	Damaging plants	Not expected	Extinction not expected
Lucilla singleyana	*Helicodiscus singleyanus*	Smooth coil	terrestrial pulmonate snail	North Amer-ica	Plant trade	Soil	Middle of last century	Unknown	In entire Hungary	Not known	Not expected	Extinction not expected
Hawaiia minuscula		Minute gem snail	terrestrial pulmonate snail	North Amer-ica	Plant trade	Soil	Decades ago	Glasshouses	Budapest; Pécs	Not known	Not expected	Extinction expected
Mediterra-nea hydatina	*Oxychilus hydatinus*	Subterranean glass-snail	terrestrial pulmonate snail	Southern Europe	Spontaneous expansion	Soil	Decades ago	Unknown	South-Hun-gary	Not known	Not expected	Extinction not expected

Most recent scientific name	Formerly used synonymous name	Most popular or accepted common name	Lifestyle / group	Original distribution centre of the species	Proven or most likely source of introduction	Way of human mediation; introduction media	Time of introduction or start of breeding	Assumed or known places of first introduction	Known place of introduction to outdoor area	Actual damage caused in Hungary so far	Theoretically expectable potential damage	Expected persistence of populations in Hungary
Oxychilus translucidus		Caucasian glass-snail	terrestrial pulmonate snail	Turkey	Plant trade	Soil	Decades ago	Glasshouses	Budapest; Vácrátót	Not known	Not expected	Extinction not expected
Gulella io		Greenhouse hunter snail	terrestrial pulmonate snail	Africa	Plant trade	Soil	Decades ago	Glasshouses	Budapest	Not known	Not expected	Extinction expected
Zonitoides arboreus		Quick gloss	terrestrial pulmonate snail	North Amer-ica	Plant trade	Soil	Decades ago	Glasshouses	Budapest	Not known	Not expected	Extinction not expected
Boettgerilla pallens		Worm slug	terrestrial pulmonate snail	Pontic region	Spontaneous expansion	Soil	Decades ago	Unknown	In entire Hungary	Not known	Not expected	Extinction not expected
Tandonia kusceri		Keeled slug	terrestrial pulmonate snail	Southern Europe	Plant trade	Soil	A few years ago	Florists/nurs-eries?	In entire Hungary	Damaging plants	Not expected	Extinction not expected
Tandonia rustica	*Milax rusticus*	Bulb-eating slug	terrestrial pulmonate snail	Western Europe	Plant trade	Soil	Decades ago?	gardens	Győr	Not known	Not expected	Extinction expected
Deroceras panormita-num		Longneck fieldslug	terrestrial pulmonate snail	Western Europe	Forage trading	Forage	A few years ago	Game park	Somogy County	Not known	Not expected	Extinction expected
Deroceras invadens		Tramp slug	terrestrial pulmonate snail	Western Europe	Plant trade	Soil	A few years ago	Florists/nurs-eries?	Horticultures in Budapest	Damaging plants	Damage to plants	Extinction not expected
Ambigo-limax valentianus	*Lehmannia valentiana*	Three-band garden slug	terrestrial pulmonate snail	Eastern Europe	Plant trade	Soil	A few years ago	Florists/nurs-eries?	Horticultures in Budapest	Not known	Damage to plants	Extinction not expected
Krynickillus melano-cephalus		Black-headed slug	terrestrial pulmonate snail	Pontic region	Plant trade	Soil	A few years ago	Florists/nurs-eries?	In entire Hungary	Not known	Damage to plants	Extinction not expected
Limacus flavus	*Limax flavus*	Cellar slug	terrestrial pulmonate snail	Western Europe	Food trading	Food / forage	Decades ago	Inhabited areas	In entire Hungary	Damage to food	Damage to plants	Extinction not expected

Most recent scientific name	Formerly used synonymous name	Most popular or accepted common name	Lifestyle / group	Original distribution centre of the species	Proven or most likely source of introduction	Way of human mediation; introduction media	Time of introduction or start of breeding	Assumed or known places of first introduction	Known place of introduction to outdoor area	Actual damage caused in Hungary so far	Theoretically expectable potential damage	Expected persistence of populations in Hungary
Arion vulgaris	*"Arion lusitanicus"*	Spanish slug	terrestrial pulmonate snail	Western Europe	Food trading	Soil, plant material	Decades ago	Gardens	In entire Hungary	Damaging plants	Transmitting parasites	Extinction not expected
Arion rufus	*Arion empiricorum*	Chocolate Arion	terrestrial pulmonate snail	Western Europe	Spontaneous expansion	Soil	Decades ago	Gardens?	Barcs	Not known	Damage to plants	New introduction is possible
Xerolenta obvia	*Helicella obvia*	Heath snail	terrestrial pulmonate snail	Southern Europe	Attached to vehicles	Surface of vehicles	Since the Pleistocene	Unknown	In entire Hungary	Transmitting sheep parasites	Not expected	Extinction not expected
Xeropicta derbentina		Turkish heath snail	terrestrial pulmonate snail	West Asia	Attached to vehicles	Surface of vehicles	A few years ago	Yards, roadsides	Budapest	Not known	Not expected	Extinction expected
Candidula unifasciata		One-banded heath snail	terrestrial pulmonate snail	Western Europe	Unknown	Surface of vehicles?	Middle of last century	Yards, roadsides	Budapest	Not known	Not expected	Extinction expected
Xeroplexa intersecta	*Candidula intersecta*	Wrinkled snail	terrestrial pulmonate snail	Western Europe	Attached to vehicles	Surface of vehicles	Decades ago	Camping site	Velence	Not known	Not expected	Extinction expected
Cernuella neglecta		Neglected vineyard snail	terrestrial pulmonate snail	Southeastern Europe	Attached to vehicles	Surface of vehicles	Decades ago	Weed-infested areas	Budapest	Not known	Not expected	Extinction expected
Hygromia cinctella		Girdled snail	terrestrial pulmonate snail	Southern Europe	Plant trade	Soil	Decades ago	Gardens	In entire Hungary	damaging ornamental plants	Not expected	Extinction not expected
Chilostoma cingulatum	*Helicigona cingulata*	Alpine banded snail	terrestrial pulmonate snail	Alps	Tourism	Deliberate	A few years ago	Ruin garden	Budapest	Not known	Not expected	Extinction expected
Theba pisana		White garden snail	terrestrial pulmonate snail	Mediterranean	Unknown	Unknown	Unknown	Unknown	Unknown	Not known	Not expected	New introduction is possible
Eobania vermiculata	*Helix vermiculata*	Chocolate-band snail	terrestrial pulmonate snail	Mediterranean	Tourism	Deliberate	Decades ago	Gardens, parks	Lipót; Budapest	Not known	Not expected	New introduction is possible

Most recent scientific name	Formerly used synonymous name	Most popular or accepted common name	Lifestyle / group	Original distribution centre of the species	Proven or most likely source of introduction	Way of human mediation; introduction media	Time of introduction or start of breeding	Assumed or known places of first introduction	Known place of introduction to outdoor area	Actual damage caused in Hungary so far	Theoretically expectable potential damage	Expected persistence of populations in Hungary
Otala lactea		Milk snail	terrestrial pulmonate snail	Southwestern Europe	Escargot business	Mixed among snails	Decades ago	Shipments of Roman snail	Extinct	Not known	Not expected	New introduction is possible
Cornu aspersum	*Helix aspersa*	Garden snail	terrestrial pulmonate snail	Mediterra-nean	Escargot business	Deliberate	Decades ago	Shipments of Roman snail; tourists	In entire Hungary	Not known	Damage to plants	Extinction not expected
Helix lucorum		Turkish snail	terrestrial pulmonate snail	Southern Europe	Escargot business	Deliberate	Decades ago	Shipments of Roman snail	Budapest	Not known	Competing out native species	Extinction not expected
Cantareus apertus		Burrowing snail	terrestrial pulmonate snail	Southern Europe	Plant trade	Soil, plant material	Few years ago	polytunnel	Budapest, Bonyhád	Damaging plants	Damage to plants	Extinction expected
Dreissena rostriformis	*Dreissena bugensis*	Quagga mussel	sedentary bivalve	Black Sea coastal areas	Attached to water vehicles	Surface of vehicles	For a few decades	Boats on the Danube	Danube; Balaton, etc.	Adhering to objects	Filtering out plankton	Extinction not expected
Dreissena polymorpha		Zebra mussel	sedentary bivalve	Black Sea coastal areas	Attached to water vehicles	Surface of vehicles	18-19th centuries	Boats	In entire Hungary	Adhering to objects	Filtering out plankton	Extinction not expected
Corbicula fluminalis		-	bivalve burrowing in sediment	East Asia	With ships	Ballast water	Decades ago	Boats	Danube; Balaton, etc.	Not known	Competing out native species	Extinction not expected
Corbicula fluminea		Asian clam	bivalve burrowing in sediment	East Asia	With ships	Ballast water	Decades ago	Boats	Danube; Balaton, etc.	Not known	Competing out native species	Extinction not expected
Sphaerium solidum		Solid orb mussel	bivalve burrowing in sediment	Western Europe	Spontaneous expansion	Flowing river water	Decades ago	Danube	Danube	Not known	Not expected	Extinction not expected
Pilsbryocon-cha exilis	*Anodonta exilis*	Thai swan mussel	bivalve burrowing in sediment	East Asia	Pet trade	Deliberate	A few years ago	Pet trade	Not known	Not known	Not expected	New introduction is possible
Scabies crispata	*Unio crispata*	Scribbled mussel	bivalve burrowing in sediment	East Asia	Pet trade	Deliberate	A few years ago	Pet trade	Not known	Not known	Not expected	New introduction is possible
Sinanodonta woodiana	*Anodonta woodiana*	Chinese pond mussel	bivalve burrowing in sediment	East Asia	With ship-ments of fish	Skin and gills of fish	Middle of last century	Fishponds	In entire Hungary	Mass exter-mination of bivalves	Killing young fish	Extinction not expected

monodominant species in the lake. Evidenced by collected specimens, these species following each other literally went through a competitive "race", proving that species developing high population densities can become highly effective competitor species for each other. It is a thought-provoking fact that winners in the succession race having taken place in the Városliget Lake so far seem to be non-native species whose expansion has been already experienced worldwide, or which have been deliberately introduced to certain areas.

The economic damage caused by introduced molluscs has been already touched upon in the chapters on the individual important species. Of course, this is not yet known for most potentially invasive species, nevertheless we hereby mention two specific aspects of their potential harm. One is the potential to spread various infections and parasites. It is the terrestrial slugs that can be particularly hazardous by transmitting plant viruses, pathogenic fungi or animal parasites. Viruses and fungal spores are taken from one plant individual to another while the vector gastropod feeds, and are virtually injected into the plant through its exposed epidermis (South 1992). Parasite eggs or larvae can be taken from the faeces of higher animal taxa, from water or from soil. Non-native molluscs, too, can cause a pandemic-like transmission of parasites, as shown by the example in the United States of America where the Common Bithynia (*Bithynia tentaculata*) native to Europe and occurring in Hungary too, became a vector of trematode parasites of American coots (*Fulica americana*) and wild ducks (Anatidae) (Karatayev *et al.* 2012). Among the multitude of various worms that all infect vertebrate animals (Vertebrata) through molluscs acting as intermediate hosts, the nematodes (*Angiostrongylus vasorum*, *Aelurostrongylus* spp., *Crenosoma* spp.) causing pulmonary angiostrongylosis in Dogs (*Canis familiaris*) and Cats (*Felis catus*) seem to be the most hazardous in Hungary, because these parasites can even cause the death of their reservoir host (Benda *et al.* 2017). Unfortunately, the introduced alien Spanish Slug (*Arion vulgaris*) is just one of the most suitable transmitters of these nematodes, but probably other introduced slugs also play a role in spreading them (Morgan & Shaw 2010).

Another specific aspect of the problems caused by small-bodied invasive species is that if their presence is detected in the products we export, the shipment may be rejected. Accordingly, it is important to pay attention that agricultural products never contain Girdled Snails (*Hygromia cinctella*), because this species is included in the blacklist of several countries (Cowie *et al.* 2009).

Ways of control

Knowing the many different ways of alien mollusc introduction, it appears to be an illusion to come up with some general and seemingly effective method for preventing invasives from colonising, and for detecting invasive potential well in time. When invasion has already taken place and damage has been caused, the situation can only be managed with a view to the specific circumstances, for example by extermination, or by the alteration of the environment in a way that can inhibit the further expansion of the particular invasives. The only general type of protection is to detect the early stages of invasion as early as possible, which can be achieved in the case of molluscs (Mollusca) by regular habitat monitoring. In order to detect unintentional introduction as early as possible, it is primarily advisable to carry out occasional inspections of the destinations of live plant and live animal import shipments, and a network of voluntary informants can also be relied on (Páll-Gergely *et al.* 2019).

References

Benda *et al.* 2017, Botka & Varga 1984, Cowie *et al.* 2009, Csányi & Varga 2017, Deli & Farkas 2006, Karatayev *et al.* 2012, Kovács 1976, 1977, Krolopp 1975, Morgan & Shaw 2010, Páll-Gergely *et al.* 2019, South 1992, Wada *et al.* 2011, Wiesinger 1975

Gábor Majoros

Asian Clam

Corbicula fluminea (O. F. Müller, 1774)

Native range

The species was originally described in China, but its distribution range also encompasses Southeast Asia and Japan. It occurs in various types of stagnant and flowing waters, from large rivers and lakes to small canals and fishponds. It prefers freshwater, but it also survives in the areas of estuaries, in low salinity brackish waters (Aldridge *et al.* 2012).

Introduction to Europe and Hungary

As an invasive alien species, it was first recorded on the Pacific Coast of the United States in the 1920s (Burch 1944). In approximately forty years, it spread throughout the country, all the way to the East Coast. It was first reported from South America in the 1970s (Ituarte 1994), and from Europe, in the early 1980s. It was recorded in Portugal, France, and Germany, in the rivers Tejo, Douro, Garonne, Rhine, and Weser, and later, Loire, Rhône, Moselle, and Meuse (Mouthon 1981, Kinzelbach 1991, den Hartog *et al.* 1992). Today it is widespread in Europe.

The exact means of its reaching Hungary is unknown, but it was probably a consequence of pre-existing populations in Europe. The first specimens were observed in the Danube, near the Paks Nuclear Power Plant in 1999 (Csányi 1999).

Biology of the species

Both dioecious and hermaphrodite specimens may occur in a single population of the Asian Clam, in strongly varying ratios. The proportion of hermaphrodites was 39–96% in Hong Kong populations, and the majority of recorded dioecious specimens were females (Morton 1987).

The Asian Clam can reproduce both sexually and asexually (via androgenesis) witin its native range. In androgenesis, the meiosis of sperm cells is not complete, so their chromosome number (2n) is not reduced. Such spermatozoa can be recognised by their two flagella. Maternal DNA is soon expelled from haploid egg cells fertilised by such sperm cells, so the nucleus of the zygote is made entirely from the pronucleus of the sperm. As a consequence, every progeny is a clone of the father animal. Because of the simultaneous occurrence of sexual and androgenetic reproduction, populations with chromosome numbers of 2n, 3n, or 4n all occur in its native range. In its non-native range, it only reproduces via androgenesis. The genetic line(s) that conquered Europe contains two sets of chromosomes (2n) (Pigneur *et al.* 2011). Clonal reproduction is presumably one of the explanations of its high invasion capacity, alongside rapid growth and the early onset of sexual maturity, and the ability to produce a great number of offspring several times a year. It is an ovoviviparous species, zygotes are incubated in the gills, until they become approximately 0.2 mm long pediveligera larvae, when they are released (Pigneur *et al.* 2011). Discharged juvenile specimens may be swept far by the currents, but at the same time, they are able to attach themselves to the solid surface of plants or other substrates with strong byssal threads. Young clams reach sexual maturity at the age of three to eight months. Their maximum lifespan is five years, and they produce offspring twice a year (Sousa *et al.* 2008).

Two morphotypes of *Corbicula* are known in Europe. The more common morph, which has a shorter and wider shell with distinct, far paced pattern, is usually identified as Asian Clam in the strict sense (*Corbicula fluminea*). The other morphotype is easy to distinguish from the above by its swollen umbo, more domed shell, and denser and finer rib pattern. It is often identified as a separate species, *Corbicula fluminalis*. Although morphological similarity is unquestionable, DNA analyses did not prove this morphotype to be actually identical with the species *Corbicula fluminalis* described from the Middle East (Euphrates). In fact, it could not be identified with

© András Varga

any of the *Corbicula* populations living in their native habitats known so far (Pigneur *et al.* 2011, Bódis *et al.* 2011). The two morphs occur syntopically at several locations, e.g. in the Danube near Paks, or in the Rhine, where Pfenninger *et al.* (2002) discovered that the two morphotypes can produce cryptic hybrids. Based on this observation, Pfenninger *et al.* (2002) suggest that these morphotypes should be considered the diverging genetic lines of a currently developing *Corbicula* species complex, rather than distinctly separate species.

The Asian Clam is a filter feeder, it mainly filters microscopic pelagic organisms and suspended organic particles smaller than 20–25 μ. One specimen filters 1–2 l of water a day (den Hartog 1992). According to Hakenkamp & Palmer (1999), it is able to pick up food particles larger than 25 μ directly from the sediment.

© Balázs Szelényi & Zita Kemencei

Ecological conditions in Hungary

The Asian Clam prefers silty, sandy substrates (Paunović *et al.* 2007), but it is also able to form colonies in river sections with fine gravel beds (den Hartog 1992).

In Hungary, it was first found in the Danube, downstream from the warm water outlet of the Paks Nuclear Power Plant (Csányi 1999). Since then, it expanded its area, and now occurs in nearly the entire Hungarian section of the Danube, Lake Balaton (Majoros 2008), the Tisza (Csányi 2002), the Drava (Žganec *et al.* 2020), and other rivers, e.g. Rába, Sajó, Ipoly (Csányi B. *pers. comm.*), Hármas-Körös, Maros (Deli T. *pers. comm.*), and it has also appeared in numerous small watercourses, e.g. Karasica (Pernecker *et al.* 2021).

It may become so abundant that it makes up one third of the macrozoobenthos at a given locality (Paunović *et al.* 2007). It cannot tolerate periodically warming, oxygen poor waters (Sousa *et al.* 2008), so further occurrences may mostly be expected in flowing waters or large stagnant waterbodies.

Ecological concern

Its ecological damage and the ways it affects native communities are not clearly resolved yet. It is presumed that its mass presence may alter habitats, and it may exclude native species (Ferreira-Rodriguez *et al.* 2018). It may have a negative impact on the reproductive success of river mussels (Unionidae) by filtering large amounts of their spermatozoa and floating glochidium larvae from the water (Hakenkamp & Palmer 1999, Strayer 1999). As, related to body mass, its filtering capacity is greater than that of native bivalves, it has competitive advantage when filtering food from the water (McMahon 2002).

Economic impact

Newly released, small larvae may attach with byssal filaments to artificial solid surfaces, such as underwater structures or the insides of industrial filtering equipment. Their mass presence may even cause economic damage.

Potential control measures

There are no reliable means to eradicate the Asian Clam from colonised habitats entirely. In case it causes industrial damage (e.g. by blocking pipes or filters), mechanical or chemical control is applied. Chemical measures, however, may only be applied in highly justified cases and with great care, as these harm the entire ecosystem. The possibility of reducing its populations with flamethrowers in shallow waters and intermittently desiccating habitats has also been tested, but this method has a very limited spatial and temporal applicability, harms the native ecosystem, and reduces populations only temporarily, but cannot achieve complete eradication (Coughlan *et al.* 2019).

References

Aldridge *et al.* 2012, Bódis *et al.* 2011, Burch 1944, Csányi 1999, 2002, Coughlan *et al.* 2019, Darrigran 2002, Ferreira-Rodríguez *et al.* 2018, Hakenkamp & Palmer 1999, den Hartog *et al.* 1992, Ituarte 1994, Kinzelbach 1991, Majoros 2009, McMahon 2002, Morton 1987, Mouthon 1981, Paunović *et al.* 2007, Pernecker *et al.* 2021, Pfenninger *et al.* 2002, Pigneur *et al.* 2011, Sousa *et al.* 2008, Strayer 1999, Žganec *et al.* 2020

Zoltán Fehér

Quagga Mussel

Dreissena rostriformis bugensis Andrusov, 1897

Native range

The Quagga Mussel is native to the indented estuary of the Southern Bug and Dnieper Bug liman in Ukraine. The low salinity, slow flowing limans were created when sea levels rose after the ice age, and the water of the Black Sea poured into the Southern Bug and the lower reaches of the Dnieper. The Quagga Mussel is also native to the broad Dnieper Delta, the source of its dispersal into the Dnieper basin (Son 2007). The species did not expand its range until the first half of the last century, it used to be known only from these rivers of the then Soviet Union (Zhadin 1952). The construction of canals connecting rivers, and the development of artificial river banks gave it an opportunity for dispersal (Orlova *et al.* 2005).

Introduction to Hungary

Inadvertently introduced species are usually only noticed when their abundance reaches a perceptible level, not when they first arrive. So for example, the presence of many alien molluscs (Mollusca) was only recorded when they had outbreaks in suitable habitats in Hungary.

The first Hungarian record of the Quagga Mussel, then called *Dreissena bugensis*, is from the Danube (Szekeres *et al.* 2008). The authors surveyed the Danube at numerous sites from Rajka to Hercegszántó, and found the Quagga Mussel at six locations between Komárom and Dunaújváros. A year later, Majoros (2009) recorded the occurrence of the species in Lake Balaton. By then, it was abundant in the eastern basin of the lake. Majoros (2009) also mentions that the Quagga Mussel was found in sediment collected near Tihany in 2007 (a year earlier then its first officially documented occurrence). The reason for the delay of the detection of the species is the lack of regular research activity. By the time its presence was noticed, the Quagga Mussel had already become abundant both in the Danube and Lake Balaton.

The expansion of international trade, the construction of new waterways, increasing water traffic, and the transport of recreational water vessels between waterbodies all contributed to the dispersal of this species. The Quagga Mussel has been expanding its range since 1930, first to the Ponto–Azov Basin (Moldavia, Ukraine) and the Volga (Russia), and later to the rivers of Eastern Europe. It reached the Romanian section of the Danube in 2004, the Rhine and its tributaries in 2006, the Main in 2007, the Main–Danube Canal in 2008, and the Moselle in 2010. It was observed in Lake Erie in the United States in 1989, and started spreading rapidly. It has been found in every one of the Great Lakes, the Finger Lakes, and the rivers St. Lawrence, Ohio and Mississippi as well (Marescaux *et al.* 2012).

The Quagga Mussel got its English name from American scientists because the clearly banded *Dreissena polymorpha* had been previously named Zebra Mussel. The similar species with paler, faded stripes reminded scientists of the now extinct South African zebra species, the quagga.

Biology of the species

According to recent genetic analyses, the taxon originally described by Andrusov in 1897 as *Dreissena bugensis* can be regarded a subspecies (Therriault *et al.* 2004) of *Dreissena rostriformis* (Deashayes, 1838). Its shell is black, with zig-zagged, cream or whitish bands, which may be pale or absent. The shell is 3–4 cm long, evenly domed, as the sharp ridges typical of the Zebra Mussel (*Dreissena polymorpha*) are absent. The flat parts of the valves divided by the ventral gape form the ventral surface. This is where byssus is secreted, which attaches the mussels to the substrate. The ventral surface of the Quagga Mussel is not flat but rounded, similarly to the dorsal side.

© Tamás Deli

Due to this, quagga and Zebra Mussels are easy to distinguish in the field by placing them ventral sides down on a flat surface. The Quagga Mussel topples over, while the Zebra Mussel does not (Welter-Schultes 2012).

The life history of the Quagga Mussel is similar to that of the Zebra Mussel, the two species often share a habitat. The Quagga Mussel is dioecious. The eggs are rich in yolk, and externally fertilised in the water. Females produce up to 960 000 eggs per year (Keller *et al.* 2007). A further factor enhancing fecundity is that it is able to reproduce at low temperatures, unlike the Zebra Mussel. Gonadal activity and spawning was observed in the Quagga Mussel at 4,8°C, while in the Zebra Mussel, only above 12°C (Roe & MacIsaac 1997). Pelagic, ciliated trochophora larvae emerge from fertilised eggs. The next developmental stage is a shelled veligera larva. The body with shells, foot, and byssus gland develops within days. From this time on, larvae are able to attach to solid substrates. They reach sexual maturity by the end of their first year, when their shells are usually 6–10 mm long. Specimens are fully grown by the age of two years. The average lifespan is five years.

Ecological conditions in Hungary

While the Zebra Mussel (*Dreissena polymorpha*) occurs mainly near the surface (epilimnic), the Quagga Mussel lives both in littoral and deep (hypolimnic) waters. The two species, permanently attached to the substrate with byssal threads, form common colonies at wave exposed sites. The Quagga Mussel is also able to inhabit extensive, connecting surfaces on soft substrates in deep waters, which are unaffected by waves (Roe & MacIsaac 1997).

Hungarian experience shows that in a single habitat, the shells of Quagga Mussels are much thinner than those of the previously introduced Zebra Mussels of the same size. Quagga Mussels are easily crashed between two fingers, while Zebra Mussels can only be cracked with difficulty or not at all. Thin shelled mussels grow faster than thick shelled ones. This can be observed in large pond mussels (e.g. *Anodonta cygnea*) and river mussels (*Unio* spp.) as well (Gittenberger & Janssen 1998). As a consequence, the nutrient utilisation of Quagga Mussels is more effective, so they survive in more types of habitats and colonise them quicker than Zebra Mussels.

© Tamás Deli

Zebra Mussel in a Quagga Mussel colony

Ecological concern and economic impact

The ecological impact of the species is similar to that of the Zebra Mussel (*Dreissena polymorpha*). Quagga Mussels have a powerful filtering ability, so they remove a significant amount of suspended particles and phytoplankton from the water. Although this improves water clarity, it also reduces the food supply of planktonic and higher aquatic organisms, e.g. the Sabre Carp (*Pelecus cultratus*) or the Bighead Carps (*Hypophthalmichthys* spp.), resulting in the transformation of energy flow in the ecosystem. Another important factor is the large amount of faeces produced by abundant mussel colonies, which may also have negative effects on the environment (Welter-Schultes 2012). According to research conducted in North American lakes, Quagga Mussels and Zebra Mussels destroy surfaces where fish could attach their eggs (Gillis & Mackie 1994). The likeliness of this eventuality is even higher in the case of the Quagga Mussel, as it can form colonies in deep waters as well. Research clearly indicates the negative effects of biofouling of these mussel species (*Dreissena* spp.) on habitats. Continuing proliferation of Zebra Mussels and Quagga Mussels may pose an immense threat to native species, especially the increasingly rare swan mussel (*Anodonta cygnea*) (Bódis 2015).

The impacts of Zebra Mussels and Quagga Mussels have been thoroughly studied in the United States of America, where they cause enormous ecological and economic damage. Although no direct evidence has been found, these mussels presumably act as an important reservoir of the bacterium *Clostridium botulinum*, the toxins of which cause common paralysis and death among water birds (avian botulism). These bacteria are abundant and prolific in anaerobic environments, for example in carcasses decaying in the heat. During a hot spell in summer, they become extremely abundant in oxygen poor waters, at the sites of mass mussel die-offs. In the region of Lake Balaton, the mass die-off of ducks caused by botulism occurred regularly previously as well, but their consuming decaying mussels from shallow waters may have made this problem worse. In this respect, the abundant Quagga Mussel colonies, which are easy to consume because of their thin shells, pose a great threat to birds feeding in the lake or the connected canals. The reduction of their populations is by all means desirable.

Apart from the ecological problems, Quagga Mussels may also affect the recreational activities of humans. The sharp shells often cause cuts and other injuries to bathers, which easily become infected. Because of its high abundance, the species causes serious damage by attaching in masses to every solid surface, such as the hulls of ships or inlets of pipes. In case of heavy draughts, masses of decaying mussels are exposed, and their penetrant smell is repelling to holiday makers.

Potential control measures

The natural enemies of the various developmental stages of the Quagga Mussel are much the same as those of the Zebra Mussel (*Dreissena polymorpha*), but their effect on mussel populations is hardly perceptible. Sponges (Porifera), moss animals (Bryozoa), and algae are ineffective competitors of these mussels. Common Breams (*Abramis brama*) in Lake Balaton regularly prey on Quagga Mussels attached to stones, but they cannot significantly reduce their populations as they are only able to eat young specimens.

There are no developed procedures for the effective eradication of Quagga Mussel populations inside waterbodies. It is impossible to stop the pelagic larvae from getting anywhere with the currents. Older, shelled Quagga Mussels often call attention to themselves by forming thick biofouling layers on artificial objects, e.g. ships or coolant pipes. In such cases, physical and mechanical treatments may be effective, i.e. the scraping, scouring, high pressure hosing, or hot water treatment of the affected objects, to name just a few. Quagga Mussels are unable to attach to objects covered in certain types of paint or on copper-nickel alloys, but these materials are not only expensive, but also toxic to the rest of the aquatic community as well. The possibility of biological control seems promising, as successful experiments have been conducted with various strains of bacteria, but the results are not yet patented.

Inspired by the high fecundity of the Quagga Mussel, some scientist suggest the deliberate breeding of the species in order to produce a cheap protein source for fish feed (Balogh 2008). This idea was picked up by the media as well. As artificial breeding of invasive mussels and the practicalities thereof have already been discussed in Hungary earlier (Kiss 1990), this suggestion is also worth mentioning, although it is neither ecologically nor economically approvable. It is still possible to hope for the collapse of spontaneously breeding populations of alien species in the future, but their purposeful breeding promotes the development of genetic variations which are better adapted to their new environments than the original invader. When looking for a way to utilise bivalves (Bivalvia) economically, the breeding of indigeneous species should be attempted. We do hope that neither the Quagga Mussel nor any other invasive bivalve will ever be industrially bred.

Comprehensive understanding and consideration of the interactions of invasive species in their aquatic communities are essential for the elaboration of effective control strategies and the determination of priorities. To achieve this, targeted basic research is of critical importance (Bódis 2015).

References

Balogh 2008, Bódis 2015, Gillis & Mackie 1994, Gittenberger & Janssen 1998, Keller *et al.* 2007, Kiss 1990, Majoros 2009, Marescaux *et al.* 2012, Orlova *et al.* 2005, Roe & MacIsaac 1997, Son 2007, Szekeres *et al.* 2008, Therriault *et al.* 2004, Welter-Schultes 2012, Zhadin 1952

András Varga & Gábor Majoros

Zebra Mussel

Dreissena polymorpha (Pallas, 1771)

Native range

The Zebra Mussel is native to the catchment areas of the Black Sea, the Caspian Sea, the Sea of Azov, and the Aral Sea. Apart from the Zebra Mussel, at least five or six similar, closely related species occur in the fresh and brackish waters of this area, indicating that the native range of the *Dreissena* genus may be located in the region of the Caucasus (Zhadin 1952). Their closest relatives are marine bivalves (Bivalvia) of the littoral zone, some of which switched to a freshwater life. Among these relatives is the genus *Congeria*, which comprised numerous species in the geochronological past, most of them extinct today. Their fossils are known as the "Goat Nails" (*Congeria ungulacaprae*) of Lake Balaton in Hungary. These mussels also adapted to freshwater environments when the salinity of the Pannonian Sea was reduced. The Zebra Mussel was described from the Caspian Sea and the Ural river by German zoologist Peter Simon Pallas (Pallas 1771). It originally occurs in the mixed waters of the estuaries of the large Russian rivers, but Pallas also found it in the sea. Bivalves with such wide ecological tolerance ranges are especially apt to expand invasively. The appearance of similar species is also to be expected in the future. For example, a relative of the Zebra Mussel, Conrad's False Mussel (*Mytilopsis leucophaeata*), which is native to the Gulf of Mexico and the East Coast of the United States of America, has already reached the Mediterranean, the Black Sea, and the Caspian Sea by hitch-hiking in the ballast water of ships. Despite its being native to brackish waters, it is not impossible that it will also colonise the rivers of Europe (Gittenberger & Janssen 1998).

Introduction to Europe and Hungary

The date of the appearance of the Zebra Mussel in uncertain. Csiki (1906) pointed out its old, forgotten record by Grossinger (1794), who detected the species in 1790 in the Holt-Zsitva and the Büdös brook, between Kurtakeszi (Krátke Kesy) and Izsa (Iža), both in today's Slovakia. This disproves the general assumption that the Zebra Mussel appeared in the Danube in 1824 (Meisenheimer 1901). It was first recorded in Hungary at isolated locations in or near the Danube. It was especially common near Budapest (Entz 1898, Hazay 1881). It probably reached the Hungarian section of the Danube attached to the hulls of ships coming from the Black Sea, as the Danube became navigable. Papp (1908) found it in the Zagyva river, approximately 8 km from its confluence with the Tisza. It had not yet been recorded in the Tisza and its tributaries at this time, but based on its occurrence in the Zagyva, it presumably occurred in the Tisza as well, as ships regularly sailed to Szolnok, and could easily have carried the Zebra Mussel on their hulls. During spring flood waves, the Tisza causes flow reversals in the Zagyva several kilometres long, so larvae could have been swept into the tributary. The introduction of the species to Lake Balaton was noticed in the 1930s (Entz 1934, Sebestyén 1934, 1935). It could have got there through the Dabune–Sió canal. Today, it occurs in every suitable habitat in Hungary, in fishponds, canals, and streams as well.

Balogh (2008) gives a detailed description of the most important stages of the Zebra Mussel's European expansion. It first appeared in England in 1824, in the London Docks. Today it occurs in every river in the country. It appeared in Prussia (1825), Germany (1830), Belgium (1833), France (1838), Denmark (1840), Central and Southwestern Europe (1920s), Ireland (1997), and Spain (2001) as well.

It has also been introduced to North America. The first specimen was found in Lake St. Clair, near Detroit, in 1986. In the following years, it spread rapidly on the continent. In 1988, it already occurred in every one of the Great Lakes (Hebert *et al.* 1989), and later it reached the Mississippi and its canal system as well (Bobeldyk *et al.* 2005).

Biology of the species

Zebra Mussels are sessile, and usually occur in colonies, attached to solid substrates with threads resembling horse hair (byssal threads). These enduring threads, in some bivalves called sea silk, are secreted by the byssal gland in the foot, and consist of a chitin-like material. The liquid secretion of the glands solidifies in the water, ensuring that mussels become permanently anchored to solid substrates, enabling them to cover large distances on the hulls of ships (Gittenberger & Janssen 1998). Byssus filaments are so strong and durable that in times past, the sea silk of large sea bivalves was woven into fine fabrics, which kept their elasticity for thousands of years (Maeder 2008). This is why the shells of Zebra Mussels fixed on each other remain in place even when the animals are long dead.

The shell of an adult Zebra Mussel is 2–4 cm long, triangular, reminiscent of the hoof of a goat. It is yellowish or greenish oily brown, with dark, wavy stripes. The characteristic pattern gave it its name.

The sex ratio in Zebra Mussel populations is usually 1:1. Animals of 8-10 mm length are capable of reproduction, but their shells may still grow, and become up to 5 cm long in two years (Welter-Schultes 2012). The males fertilise eggs produced by the females externally. This may happen from spring to late summer, depending on water temperature, from 12–15°C, with an optimum of 18–20°C. A single female produces over 40 000 eggs in one reproductive cycle, and the number of eggs produced in a year may reach 960 000 (Keller *et al.* 2007). In three to five days, so-called veligera larvae emerge from the eggs, which can already swim actively. These go on swimming about in the water for up to a month. Swept by currents, they are widely dispersed. At the end of this stage, they settle to the bottom, and look for a solid surface to permanently attach themselves to with byssal filaments. The density of Zebra Mussel colonies may be extreme, up to 220 000 specimens/m^2 (Balogh *et al.* 2008). One mussel filters ca. 1 l water a day, while filter feeding on algae and microscopic particles (Starobogatov 1994, Olenin *et al.* 1999). However, its role in keeping waters clean is ambiguous, as its faeces and the ammonia it produces mean nearly as heavy

© Tamás Deli

an environmental load as its uptake. Its so-called pseudofaeces, a mess consisting of the remains of digested material and non digestible particles caught in the mucus accumulates on lake bottoms, and forms rotting silt (Schloesser *et al.* 1996).

Ecological conditions in Hungary

The Zebra Mussel's ability to adapt to various temperatures is proven by its large distribution area, from Scandinavia to the Balkan Peninsula. It typically inhabits littoral zones of rivers, lakes, and oxbows, especially where it can find suitable solid surfaces to cling to (in muddy fishponds, e.g. in the Hortobágy, even a rusty can will do). It survives prolonged starvation, and also temporary desiccation of its habitat. It can also tolerate fluctuating oxygen content in the water and some degree of pollution, but it is absent from heavily polluted waters.

As the Zebra Mussel filter feeds in flowing water, and it is unable to change its location, its colonies settle in habitats with ample microorganism availability, where the current is strong enough to supply them with oxygen and food. Swift flowing, epilimnic waters in nutrient rich, eutrophic habitats are ideal for their breeding, so they often settle on rocks near the shores, washed by seething water, or the submersed parts of artificial objects floating on the surface. They may also attach to the valves of larger mussels protruding from the silt, as this mobile substrate provides even better conditions than a motionless piece of rock, which cannot change its location when water levels are low or the water freezes. This is why Zebra Mussels attached to swan mussels (*Anodonta cygnea*) in Lake Balaton grow bigger than specimens attached to structures near the shore or shore protection ripraps. Many onlookers think that the Zebra Mussels carried by swan mussels are their "babies", which injure the feet of bathers.

It is also quite certain that as our waters get warmer because of the changing climate, Zebra Mussels will become increasingly abundant, as they prefer tepid waters. They may become so abundant in the cooling systems of power plants that they cause serious mechanical problems. These cases typically remain hidden from the public, and are not scientifically examined either. They are a warning sign that human disturbance in ecosystems may assist the invasion of alien mussel species, and their mass proliferation may have unforeseeable consequences. Zebra Mussels are especially abundant near thermally polluted discharges of power plants in rivers or reservoirs, so these sites may be considered as reservoirs for this invasive species.

Ecological concern

Hungarian surveys indicate that the mass proliferation of Zebra Mussels may threaten the populations of large native mussel species, such as the unionids (*Unio* spp.), the Swan Mussel (*Anodonta cygnea*), and the depressed River Mussel (*Pseudanodonta complanata*). These species react differently to the mass appearance of Zebra Mussels. Zebra Mussels clinging to the shells of big bivalves protruding from the sediment may modify the filtering ability and mobility of the host. In case of mass colonisation, they may even cause its suffocation. Although it is not documented, Zebra Mussels grouped about the syphons probably also filter the sperm or egg cells of the hosts ejected through the syphons, and consequently decrease their reproductive success. Along similar lines, Zebra Mussels clinging near the inhalant syphon presumably filter at least a part of the nutrients from the water inhaled by the host, so there is less left for the larger bivalve.

These threatening factors may somewhat vary, depending on the host species. Besides the above considerations, the complexity of the interactions is further enhanced by the timing of these effects. The negative effects are most pronounced in late summer and early autumn (Bódis *et al.* 2014, Schloesser *et al.* 1996, Majoros 2009).

The Zebra Mussel is the most aggressive freshwater invader, its appearance and mass proliferation may irreversibly alter native ecosystems. The biomass of its populations may exceed that of all of the other invertebrate species many times over. Targeted research, providing nature conservationist and economists with relevant information is the only means by which we can learn about the dangers of this species, and get a chance to control them. It is worth mentioning that a teacher, J.S. Krenner found the Zebra Mussel in Budapest in 1878, in the plumbing of a house, where it caused a blockage (Entz 1898).

Damage caused by Zebra Mussels may appear when least expected. Its manifestations are also manifold, e.g. their mass die-off, the disappearance of pelagic plankton, or the drifting and death of the eggs of certain fish species.

Potential control measures

According to published data (Molloy *et al.* 1997), the Zebra Mussel has nearly 200 predator and parasite species. Many fish species eat it in Hungary, e.g. Roach (*Rutilus rutilus*), White Bream (*Blicca bjoerkna*), and Carp (*Cyprinus carpio*), and also numerous birds, e.g. Common Pochard (*Aythya ferina*), Common Goldeneye (*Bucephala clangula*), Tufted Pochard (*A.*


© Gábor Majoros

Comparison of Zebra Mussel shells (left) and Quagga Mussel shells (right)

fuligula), Mallard (*Anas platyrhynchos*), and Eurasian Coot (*Fulica atra*) (Balogh *et al.* 2008). Evidently, these predators are mainly able to crack the valves of small mussels with thin shells, so full grown Zebra Mussels with thick shells have practically no predators. Even the Muskrat (*Ondatra zibethicus*), which usually likes to eat large mussels (Bivalvia), avoids Zebra Mussels, possibly because of their relatively low nutritional value. Zebra Mussel larvae are preyed on by crustaceans (Crustacea) and aquatic insects (Insecta). However, the changes caused in Zebra Mussel populations by these predators are hardly be noticeable. The same applies to organisms competing with mussels for solid surfaces, such as sponges (Porifera), moss animals (Bryozoa), or related sessile bivalves.

Mechanical control (scraping, scouring, high pressure water jets, freezing, drying etc.) may be effective when thick layers of biofouling need to be removed from structures or floating artefacts, but these are only suitable for removing the shells. Very vigorous scraping is required to get rid of the byssal threads attached to surfaces, for example to ships. Biological control possibilities are also being explored. Some strains of bacteria, for example, may produce effective toxins. More drastic treatments are also possible, by using various chemicals (chlorination is the most frequently applied method), but these cannot be applied regularly, as they severely affect the entire ecosystem. For example, niclosamide treatments are used against molluscs (Mollusca) which transfer tropical parasites in Africa and America, but as this chemical kills every gastropod and bivalve, its application in natural waters is prohibited in Hungary (Coelho & Caldeira 2016).

As Zebra Mussels mostly spreads from one waterbody to another attached to watercraft and fishing or angling gears, it is advisable to dry these instruments for at least five days before using them in different waterbodies. Those familiar with waters know only too well how thick layers of biofouling Zebra Mussels form on ropes, buoys, and every other submersed object, especially where the bottom is muddy. Therefore, it is extremely harmful when durable waste, such as tyres, rocks, or large spare parts are thrown into the water, as these serve as breeding sites for the Zebra Mussels.

References

Balogh 2008, Balogh *et al.* 2008, Bobeldyk *et al.* 2005, Bódis *et al.* 2014, Coelho & Caldeira 2016, Csiki 1906, Entz 1898, 1934, Gittenberger & Janssen 1998, Grossinger 1794, Hazay 1881, Hebert *et al.* 1989, Keller *et al.* 2007, Maeder 2008, Majoros 2009, Meisenheimer 1901, Molloy *et al.* 1997, Olenin *et al.* 1999, Pallas 1771, Papp 1908, Schloesser *et al.* 1996, Sebestyén 1934, 1935, Starobogatov 1994, Welter-Schultes 2012, Zhadin 1952

Gábor Majoros & András Varga

Chinese Pond Mussel

Sinanodonta woodiana (Lea, 1834)

Original area of the species

The area of the species, first described from the Canton Province of China, is located between the Amur and Yangtze Rivers. As this mussel predominantly spreads via Cyprinid fishes as vectors, and carps were cultivated in China before the start of written history, we can safely assume that this species spread not only spontaneously, but its area expansion in the Far-Eastern region of Asia was aided by human introductions long before the species was discovered and scientifically described. Therefore we can consider the area occupied prior to its expansion as the original area of this mussel. This area could be placed from East Siberia to Southern China. A Russian scientist, Schrenck, reported the species from the Amur River as early as 1867, and noted that the species originates from China (Schrenck 1867). Later Zsadin, in a fauna review based on his own data collected in 1938, mentioned the occurrence of this mussel in Eastern Siberia as well as Japan, China, Taiwan, Cambodia and Thailand (Zsadin 1952). Similarly to all related mussel species, the Chinese Pond Mussel was found in rivers, water reservoirs and lakes, so it inhabited non-drying out deep-water bodies.

The introduction of the species to Europe and Hungary

Kiss Árpád hypothesized that the Chinese Pond Mussel was first introduced to Hungary in 1962, when large quantities of Grass Carp (*Ctenopharyngodon idella*), Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix)* imported from the Soviet Union were stocked in Hungarian fisheries (Kiss 1990). It is confirmed that one of the important hosts of this mussel, the Stone Moroko (*Pseudorasbora parva*), was surely introduced to Hungary then. The fish species was present in high numbers Romania in 1961, and the first specimen was found by Kálmán Molnár in 1963 in a fishery at Paks (Pintér 1989). Twenty years later, the Chinese Pond Mussel itself was discovered by Ede Petró in the pond of the Fortress of Gyula (Petró 1984). At this time the mussel had already been reported from Romania in 1983 (Sárkány-Kiss 1986). Later Kiss (1990) reported this species from 16 locations in Hungary, but it was discovered in Lake Balaton only in 2006 (Majoros 2006). As the larval stage of the Chinese Pond Mussel can parasitize several fish species, there is no doubt that the species was spread by fishes all over Europe, from Sweden through France to Italy (Welther-Schultes 2012). Numerous scientific papers deal with its occurrence in Eurasia and the Americas as well (Urbańska & Andrzejewski 2019, Watters 1997).

Life history of the species

The Chinese Pond Mussel belongs to a well-defined taxonomical unit of large fresh water mussels; it is placed into the river mussels (Unionidae) family. All the species belonging to this family are characterised by the nacraceus layer lining the shells' inner surface, and their larval stage development on fishes. Originally every river system had a unique set of Unionidae mussels, and oftentimes these had quite limited geographical ranges. Besides the large endemic Unionidae species inhabiting both rivers and lakes that either became extinct or are threatened by extinction, there are some superabundant species that are capable of colonising or invading new habitats. These latter species has been utilised at industrial scale for producing pearl, shirt buttons, and even burnt lime in various locations. No wonder that these species, capable of fast growth and reproduction, were introduced intentionally to new areas by mankind, and hence were forced to adapt to their new habitats. Possibly it led to the ability of the Chinese Pond Mussel's larvae to develop on many fish species, a quite unique trait among freshwater mussels.

The larval stage of Chinese Pond Mussel lives as a parasite on the skin of various freshwater fish species,


© Gábor Majoros

predominantly on their fins. The sexes are usually separate in bivalves - or very rarely hermaphroditism also occurs (Dudgeon & Morton 1983). The eggs are released into a chamber over the outer gills, and the fertilised eggs go through cleavage and hatch into a glochidium larva. This larval stage possesses embryonic shells, and locomotion is achieved by crawling and floating in the water. The larva extends a mucous thread from its body. On the edge of each embryonic shell there is a barbed spike. When the mother exhales through its syphon the ripe glochidium larvae, they attach themselves with these spikes to fish swimming nearby. The glochidium larvae induce inflammation as they attach to the skin of the fish, and trigger a tissue response in the epithelium that forms a small cyst around each larva. The epithelial cells of the fish overgrow the encysted mussel within some hours, and the mussel develops inside the cyst into a young mussel. Its metamorphosis leads to the formation of organs characteristic of adult mussels, and also the final valves will form. At this stage the epithelium layer loosens around the mussel, and the parasite falls to the bottom. Thereafter it lives independently on the bottom surface of the water in the mud layer. The Chinese Pond Mussel can reproduce from spring to autumn, depending on the geographic region. The majority of Unionidae species has a similar life cycle.

The length of the parasitic larval stage is strongly correlated with water temperature: at 15 Celsius: 15–18 days, at 25 Celsius only 7–8 days (Dudgeon & Morton 1984). According to laboratory experiments, several fish species might act as hosts in Asia: such as the Western Mosquitofish (*Gambusia affinis*) introduced from America, Gold Barb (*Puntius semifasciolatus*), (*Rhodeus sinensis*), while in Europe its main host is the Eurasian Carp (*Cyprinus carpio*), but the Prussian Carp (*Carassius gibelio*), Stone Moroko (*Pseudorasbora parva*), Tench (*Tinca tinca*) Common Roach (*Rutilus rutilus*), Grass Carp (*Ctenopharyngodon idella*), Silver Carp (*Hypophthalmichthys molitrix*), Bighead Carp (*H. nobilis*) and some other Cyprinid fish species may also act as hosts. Based on observations from natural water bodies and laboratory experiments, we can assume that the larvae of the Chinese Pond Mussel can develop in all Old World and New World carps, and even in the unrelated killifishes (Cyprinodontiformes). The length of mature specimens can reach 30 centimetres, and the free-living developmental stage can be as long as 10 to 15 years. Some researchers believe they can live for 25 years. The life cycle of the Chinese Pond Mussel is studied in Hungary in order to support its commercial breeding (Kiss & Pekli 1988).

The ecological requirements of the species in Hungary

The Chinese Pond Mussel is characterised by high ecological tolerance. It is capable of producing larvae even in the winter among its gills, although they are not released into the water in that season. It proves that in can reproduce all year around. It can live in the deep water sections of the fish nursery ponds at Hortobágy, and also in the shallow river bed sections of the Szigetköz, even at low water level. It lives in masses around the water outlet of the Paks Nuclear Power Plant, in the always mildly warmed up Danube, but it is also present in the cold waters of the water reservoirs of the Őrség region. The subtropical origin of this species is proven by the fact that it develops especially well in thermal waters, the cooling ponds of power plants and the lakes forming around thermal springs (Kraszewski & Zdanowski 2001). It occurs in the canals of the Great Hungarian Plain, and infiltrates into the isolated fishing lakes also. Nowadays in Hungary it is probably present in all larger water bodies.

It can spread into new areas with the fish stocks of different carp species (Cyprinidae) released from nurseries into fishing lakes, or with the stocks of Western Mosquitofish (*Gambusia affinis*) released in the warm-water lakes (as an example, it can occur in the concrete-bottomed Városligeti Lake in Budapest, where the Western Mosquito fish occurs in high numbers).

Ecological problems

As it can infect fish fry, it can certainly spread with very small-sized fish also. Its spread is facilitated by the severe decrease of the native related Unionidae mussel species where the Chinese Pond Mussel proliferates. This shows that it competes for habitats with them, namely with the Swan Mussel (*Anodonta cygnea*) and Depressed River Mussel (*Pseudanodonta complanata*). It is confirmed by the observation that there are Danube river sections (for example at Dunaremete, Ercsi, Paks), where almost exclusively only the shells of the Chinese Pond Mussel can be found. Furthermore in certain stagnant water bodies (for example, the Hortobágy Fish ponds, the Danube's oxbow lakes at Gemenc) only this species occurs. In Lake Balaton it might co-occur with certain other Unionidae mussels, but even at these locations (e.g. the Bay of Keszthely) the Chinese Pond Mussel is dominant over other mussel species. Some studies suggest that the presence of the Chinese Pond Mussel is negatively correlated with the reproduction of other large mussel species (Benkő-Kiss *et al.* 2013). The larvae of the protected Depressed River Mussel develop in the skin of the same species as those of the Chinese Pond Mussel.

Economic effects

In recent years, the Chinese Pond Mussel has made it to the headlines when they were devastated in large masses in the second half of the summer (Benkő-Kiss 2012). Their demise was most evident at places that are frequented by tourists, and the visitors or anglers were disturbed by the floating masses of dead mussels (for example, Lake Tisza, or the Körös oxbow lake at Szarvas.) Although the mass devastation of the mussels was more prominent in the media than in scientific talks, several institutes tried to investigate the cause of the phenomenon. The devastation of Danube stocks was explained by extra low water levels, as it was detected in many mussel species (Bódis *et al.* 2014). But it is almost certain that the mass devastation of the Chinese Pond Mussel was always a species-specific event, as at every location only a single species of Unionid mussel species was devastated. If it had not been caused by a mussel specific agent, but instead a more general water chemical or physical attribute had been the culprit, it would negatively affect a wide spectrum of species, and not only the highly tolerant Chinese Pond Mussel. In the 1990s, researchers of the Ichtiopathological Laboratory of the Hungarian Animal Health and Welfare Institute showed that *Unionicola aculeata* water mites developing in the mantle of mussels induces scars in the epithelial layer when they exit their host, where putrefactive bacteria can invade (Majoros 2006). This complex developmental cycle could not be reproduced in the laboratory, but it was proven that tissue material taken from infected mussels could induce the development of illness in healthy mussels, so the devastating agent was an infective organism and not a toxic effect. The reoccurring mussel devastations are most wide-spread in the Chinese Pond Mussel populations. Hence their monitoring might be necessary to predict the occurrence of these mass devastation events (Benkő-Kiss 2012).

Methods of control

As no harmful chemical substances threatening living organisms can be applied for biological control to natural water bodies, chemical control of the larval stages living on fishes or developed mussels inhabiting the bottom of the water is impossible. Locally, mechanical singling can be carried out; for example, in fisheries after the fish had been harvested the mussels could be collected from the bottom of the lakes. In the shallow fish nursery ponds the mechanical crushing of mussels could be carried out from boats. Removal of the sediment from the bottom can also help control the mussel populations. But it should be taken into account that Chinese Pond Mussels also inhabit deep water reservoirs such as the Hasznosi reservoir in the Mátra Mountains, Szálkai and Zsibriki reservoirs in Tolna county, and furthermore they are present in our deep lakes such as the Lake Tata, and these populations will always form a reserve to replenish the Hungarian water bodies.

There is a single natural enemy of the Chinese Pond Mussel in Hungary: the Muskrat (*Ondatra zibethicus*), which is also an introduced mammal in our fauna. This aquatic rodent is capable of opening even the largest mussels. When the mussels are in very shallow water, or are trapped in desiccating shore areas, for example after the fast withdrawal following a flash flood, storks and herons can also consume them. These birds puncture the shells at their most arched part, while the Muskrat chews the anterior surface of the shells. But all these predation acts only affect the individuals that failed to dig deep into the mud, and hence do not really control or reduce the mussel populations.

References

Benkő-Kiss 2012, Benkő-Kiss *et al.* 2013, Bódis *et al.* 2014, Dudgeon & Morton 1983, 1984, Kiss 1990, Kiss & Pekli 1988, Kraszewski & Zdanowski 2001, Lea 1834, Majoros 2006, Petro 1984, Pintér 1989, Sárkány-Kiss 1986, Schrenck 1859–1867, Urbańska & Andrzejewski 2019, Watters 1997, Welter-Schultes 2012, Zsadin 1938, 1952

Gábor Majoros

River Nerite

Theodoxus fluviatilis (Linnaeus, 1758)

Native range

The River Nerite is the most widespread species of the *Theodoxus* genus. Distributed in Europe and West Asia, its range spreads from Ireland and Portugal to the Baltic, the western part of Russia, Crete, and the region of the Black Sea and the Sea of Marmara. In North Africa, it occurs in Algeria and Morocco (Kebapçi & Van Damme 2012). To the east, it has been recorded sporadically in Turkey and Georgia (Sands *et al.* 2020), and, according to Glöer & Pešić (2015), even in Iran. It conquered Northern and Northwestern Europe in the Holocene. The study of Bunje (2005) indicates that the northern part of its current native range was colonised by a genetic lineage originating probably from the Southern Alps. However, until recently, it did not occur in

© Tamás Deli

© Zoltán Fehér

River Nerite shells with different patterns

the Danube basin, i.e. it was absent from the entire catchment of the Danube, apart from the coast of the Black Sea. Inside its native range, it inhabits fresh and brackish waters: coastal habitats with brackish water, estuaries, rivers of various size, springs, and lakes (Kebapçi & Van Damme 2012). As it lives attached to solid surfaces, it needs gravelly or rocky substrates, or artefacts with solid surfaces.

Introduction to Hungary

The River Nerite is not native to the Carpathian Basin. Its was first recorded in Hungary in the River Tisza, near Szeged (Horváth 1955). It was found in 1981 in the Danube at Budapest, and since then, it has spread along the entire Hungarian section of the river (Fehér *et al.* 2006). It was first found in the Hármas-Körös in 1997 (Békésszentandrás) (Lennert 1997), and in Lake Balaton in 2013 (Tihany) (Takács *et al.* 2019).

It was first recorded in Slovakia in 2002 (Čejka & Horsák 2002). It was found a year earlier in the Austrian section of the Danube (Tulln) (Steger & Bisenberger 2011). By the early 2010s, it became common in the entire Bavarian section of the Danube (Hirschfelder *et al.* 2011). This genetic lineage, spreading upstream along the Danube, crossed the Danube-Main-Rhine Canal soon afterwards and recolonised the Rhine, from where its original populations died out by the turn of the millennium (Gergs *et al.* 2015).

Biology of the species

The shell of the River Nerite is a slightly elongated hemisphere. Those of adult specimens consist of three to three and a half whorls, reach 4.5–6.5 mm heightand 6–9 mm (in some cases, up to 13 mm) width. The colour of the shell varies, partly determined genetically, but also influenced by environmental factors, e.g. the ion concentration of the water, the chemical composition of the substrate, or food type. Zettler *et al.* (2004) showed that in the area of the Baltic, outer coastal waters are dominated by nearly entirely black specimens, while populations in the inner parts are mostly yellowish green. Glöer & Pešič (2015) observed darker coloured populations on darker rocks. Shell pattern is also highly variable. Northern European populations have patterns resembling elongated light drops on a dark background. The first Hungarian specimens, discovered in the Tisza and the Danube, were also like this. There are numerous morphotypes with different patterns in the area from Southern Europe to the region of the Black Sea (Glöer & Pešič 2015, Sands *et al.* 2020). Recently a morph with thin, zigzagged lines also appeared in the waters of Hungary (the one that recolonised the Rhine in the 2010s), confused by many with the Danube Nerite (*Theodoxus danubialis*).

River nerites feed on algae growing on rocky surfaces and on detritus. Their highest population densities may exceed 2000 specimens per m^2 (Kirkegaard 2006).

The average lifespan is 2.5–3.5 years. They reach sexual maturity at 1.5 years. They lay their eggs on various solid surfaces, including the shells of their conspecifics, in hemispherical capsules of ca. 1 mm diameter. A single specimen may lay up to 150 eggs (Marković *et al.* 2014).

© Michal Maňas

Ecological concern

Simultaneously to the River Nerite's spreading in Hungary, two native riverine *Theodoxus* species have been observed to decrease, the Striped Nerite (*Theodoxus transversalis*), protected and a Natura 2000 species of community interest, and the protected Danube Nerite (*T. danubialis*). It is however uncertain whether there is a causal link between the expansion of the River Nerite and the decline of the other two, or whether the River Nerite is more tolerant of the deteriorating conditions that are causing the disappearance of the indigenous *Theodoxus* species. In fact, the River Nerite is able to co-exist with either of the two native nerite species without excluding them entirely. It is also a fact that in the habitats of the most stable Hungarian populations of the striped nerite, the River Nerite has not yet appeared, and it would be desirable if it did not appear.

Kirkegaard (2006), studying a population in Denmark, observed maximal growth rate and lowest mortality between May and August. On the other hand, in winter there was no or little growth, while mortality was highest. Oviposition took place from late May to the middle of November. Most capsules bearing eggs appeared on the surfaces of rocks in May–June and August–September. Eggs laid in the spring hatched in August or September, while those laid in late summer or early autumn hatched next year in the spring.

The species is euryhaline, i.e. it can tolerate changes of water salinity in a given range. Kangas & Skoog (1978) examined the effects of changing salt concentrations experimentally, with specimens collected from brackish and freshwater habitats. Their results indicate that survival in both high or low salinity environments was basically determined by the type of water the snails originated from. They also observed that both freshwater and brackish water specimens were able to tolerate water with medium salinity (1.5–10.0‰).

Ecological conditions in Hungary

It has established populations at numerous locations in the major Hungarian rivers, and its appearance in Lake Balaton shows that it has potential for further dispersal. At the same time, some of its formerly thriving populations have weakened or disappeared in the last decades, because of degrading environmental conditions (beyond a certain level even this species cannot tolerate excessive accumulation of sediment on solid surfaces).

Economic impact

The River Nerite does not cause detectable or measurable economic damage, or at least we do not know about it.

Potential control measures

There is neither precedent nor effective method for its eradication, and it does not seem feasible either. It would be essential to know more about its impact on the native species (*Theodoxus danubialis* and *T. transversalis*), and to research the conditions that could guarantee their survival in the presence of the River Nerite. In order to protect the native species, it is also critical to do our best to conserve their habitats in the natural state.

References

Bunje 2005, Čejka & Horsák 2002, Gergs *et al.* 2015, Glöer & Pešić 2015, Fehér *et al.* 2006, Hirschfelder *et al.* 2011, Horváth 1955, Kangas & Skoog 1978, Kebapçi & Van Damme 2012, Kirkegaard 2006, Lennert 1997, Marković *et al.* 2014, Sands *et al.* 2020, Steger & Bisenberger 2011, Takács *et al.* 2019, Zettler *et al.* 2004

Zoltán Fehér

Red-rimmed Melania

Melanoides tuberculata (O. F. Müller, 1774)

Native range

The original range of this species, as well as the genus *Melanoides*, is situated in Central Africa, as several other *Melanoides* species also occur in the large African lakes. However, its present range is much larger, expanding from North Australia via Southeast Asia and India to Syria and Africa (Brown 1980). It has probably been present in Malta since before recorded history (Zhadin 1952, Giusti *et al.* 1995), as, despite its being a freshwater snail, it is native to several distant islands, such as Sri Lanka, Madagascar, Taiwan, and Java. It presumably had a much wider range before the arrival of humans, as it also occurred in mainland Europe. It has also been found in Hungary in Pleistocene sediment (Krolopp 1983). As members of barely distinct related families (Thiaridae, Melanopsidae) occurred in Europe in the Oligocene (34–23 million years ago) and the Pliocene (5.3–1.8 million years ago) (Bartha 1971, Báldi 1973), and this species was also found in Quaternary sediment from the western slopes of the Pamir Mountains (Zhadin 1952), it is quite plausible that it had inhabited our continent in earlier epochs, and only became extinct during the ice age.

Introduction to Europe and Hungary

As the Red-rimmed Melania has been recorded in America since 1930 (Clench 1969), it probably reached Europe, too, early in the last century. The species, originally described from India, has been long known to occur to the north, till Turkmenistan and Uzbekistan (Zhadin 1952), but its further dispersal was almost certainly assisted by the activity of aquarists. It was already mentioned as a common aquarium snail in 1979 in East Germany (Sterba 1979). In Hungary, Márton Wiesinger found it first, when stocking ornamental fish from Munich into pools in the zoo at Budapest (Wiesinger 1975). The exact date of the arrival of this transport is unknown, but Hungarian aquarists certainly had not known the species before the 1970s, as it is not mentioned in any previously written books for aquarists (Lányi & Wiesinger 1955, Lányi 1961). Lajos Soós, who investigated aquarium snails (Soós 1933), did not mention this species in any of his works, although, for example, he discussed the history of the invasion of the Zebra Mussel (*Dreissena polymorpha*) in great detail (Soós 1955). It is also to be noted that renowned hydrobiologist Géza Entz, when writing the parts pertaining to Hungary in a translation of a German language educational publication, did not even mention the Red-rimmed Melania at the beginning of the twentieth century, although he paid special attention to the species *Melanopsis parreyssii*, a thermophilous relative of the species, which occurred in Püspökfürdő in Nagyvárad, then part of the Austro-Hungarian Empire (Lampert 1904).

In the Hungarian malacological records, it is first mentioned by Pintér *et al.* (1977) as a snail *"introduced to Budapest, Lake Malom and Margaret Island"*. On the other hand, it occurred by the million in 1995 in the warm water outlet of a now defunct eel farming pond in Hévíz, and in had a similarly abundant population in Lake Városliget in Budapest in 2011. It has been abundant both in Hévíz and the Városliget ever since (G. Majoros). Publications on the European distribution of the species report that it occurs in "botanical gardens and aquariums" (Welter-Schultes 2012, Glöer 2019), just like in Hungary. Alongside ca. 20 more aquarium gastropods, it appears in the pools of hothouses, aquariums, and hot water springs all over the country (Horváth 2010).

Biology of the species

Countless, readily accessible publications discuss the biology of this species, regarded today widespread throughout the tropics, so we only mention here that an important reason for its high dispersal ability is that most of its populations reproduce via parthenogenesis, i.e. a single specimen is enough to establish a new population. Viviparity also adds to its success. Little snails with 1–4 mm shells are released from its brood pouch. It is able to produce an offspring a day. Young specimens reach maturity at the age of 3–7 months (Keller *et al.* 2007). It feeds on detritus and microscopic algae, it does not eat higher plants. During the day, it usually rests in the mud (Fofonoff *et al.* 2003, Miranda & Perissinotto 2012).

When discussing the potential invasion ability of this species, it is important to see that in its native range in Africa, although abundant in its habitats, its populations remain isolated (Brown 1980). It tolerates the salinity of water to some degree, but it cannot survive in desiccating waterbodies (Lévêque 1972). In the expanded range, its overabundant populations collapse from time to time and then start growing again (Work & Mills 2013), as could also be observed in the outlet canal of Lake Hévíz, and the thermal water side of Lake Városliget for years.

© Tamás Deli

Ecological conditions in Hungary

© Tamás Deli

The Red-rimmed Melania only breeds in warm water, there are no records from cold waters which freeze in winter. In this respect, the ELTE Botanical Gardens provide the perfect demonstration, as the species is abundant in every indoor pool, but no live specimens have been found in any of the outdoor ponds, at any time of the year. The species has been present in the warm waters below the waterfall of the Zsigmondy Well on Margaret Island for years, but it is absent from the colder water of the pond at the end of its outlet. Near this site, empty shells from the outlet of the spring are sometimes washed to the bank of the Danube, but live specimens cannot be found in the river. It is abundant in the outflow canal of Lake Hévíz, but live specimens have not been found in the Zala river or Lake Balaton, although both are connected to this canal.

Ecological concern

Data on the Red-rimmed Melania's impact on other snail species is controversial. According to some publications, it can co-exist in a single spring with native species (Karatayev *et al.* 2009, Ladd & Rogowski 2012, Cilia *et al.* 2013), but on the other hand, it has been deliberately introduced to several habitats to exclude native species which spread blood flukes (Schistosomatidae) (Pointier *et al.* 1989, Pointier 2001, Guimarães *et al.* 2001). No Hungarian data are available on its competing for habitats, as it only occurs in waters which either did not have a natural fauna, or had secondary faunas of European freshwater species.

The Red-rimmed Melania can be the intermediate host of at least forty types of flukes (Trematoda) and nematodes (Nematoda). The fluke species *Centrocestus formosanus* has also been detected in Hungary in imported fish (Majoros 2000). In Asia, the Red-rimmed Melania is the intermediate host of several parasites attacking humans, including the Chinese River Fluke (*Clonorchis sinensis*), the Oriental Lung Fluke (*Paragonimus westermani*), and the Rat Lungworm (*Angiostrongylus cantonensis*), which causes encephalitis in humans (Vaz *et al.* 1986, Derraik 2008). These dangerous parasites infect people who eat raw food. Although they have not been recorded in Europe yet, but as all their hosts already occur on the continent, their future appearance is possible.

Potential control measures

The Red-rimmed Melania cannot be totally eradicated in the country, as abundant source populations are being continuously bred by aquarists. Local control can be attempted by the desiccation of pools or canals, but this is not everywhere possible. Populations can also be reduced by a drop in water temperature, as all specimens die within 12 days at temperatures below 13°C (Mitchell & Brandt 2005). In theory, they can be killed with molluscicides (chemicals killing molluscs) as well (Mitchell *et al.* 2007), but as these treatments are not selective, they are by no means justified or advisable in Hungary.

References

Báldi 1973, Bartha 1971, Brown 1980, Cilia *et al.* 2013, Clench 1969, Derraik 2008, Fofonoff *et al.* 2003, Giusti *et al.* 1995, Glöer 2019, Guimarães *et al.* 2001, Horváth 2010, Karatayev *et al.* 2009, Keller *et al.* 2007, Krolopp 1983, Ladd & Rogowski 2012, Lampert 1904, Lányi 1961, Lányi & Wiesinger 1955, Lévêque 1972, Majoros 2000, Miranda & Perissinotto 2012, Mitchell & Brandt 2005, Mitchell *et al.* 2007, Pintér *et al.* 1977, Pointier 2001, Pointier *et al.* 1989, Soós 1933, 1955, Sterba 1979, Vaz *et al.* 1986, Welter-Schultes 2012, Wiesinger 1975, Work & Mills 2013, Zhadin 1952

Gábor Majoros

Pontic Reticulate Snail*

Clathrocaspia knipowitschii (MAKAROV, 1938)

Native range

Clathrocaspia knipowitschii is an endemic, Ponto-Caspian species with a small native range. The classification of the remarkably rich Ponto-Caspian fauna is in many cases difficult and not yet resolved (KANTOR *et al.* 2010, NEUBAUER *et al.* 2018, WESSELINGH *et al.* 2019). According to ANISTRATENKO (2013), *C. knipowitschii* can be best distinguished from closely related species based on the fine structure of the embryonic shell (protoconch), and the structure of the radula. The species was described by Makarov in 1938. It occurs on the northern periphery of the Black Sea, together with three other species of this genus (*C. makarovi*, *C. gmelini aluschtensis*, *C. stanislavi*). According to expert opinion (WESSELINGH *et al.* 2019), the latter are all identical with *C. knipowitschii*, but in order to reliably disentangle their taxonomy, numerous live specimens have to be collected for the necessary molecular analyses. The holotypes of *Caspia knipowtschii*, as named by Makarov in 1938, were destroyed in the second world war with the rest of Makarov's collection. ANISTRATENKO *et al.* (2021) described a neotype, which was collected in the estuary of the Dnieper, near Kherson (the site mentioned in Makarov's original description). Individuals of this species were detected 1–3 m deep in the water, on silty sand substrate, among the colonies of zebra mussels (*Dreissena* sp.).

Introduction to Hungary

The first specimens of the species were found in the Danube in the course of the Joint Danube Survey 3 in 2013, outside of the Carpathian Basin, below the Kazan gorge. During deep water sampling in cross sections of the Danube conducted on 10 September 2013, many individuals of this species were recorded at four sampling sites out of five near Vrbica in Serbia and Șimian in Romania, from depths between 3.6–12 m. Samples were determined under stereomicroscopes. This is how specimens smaller than 2 mm could be noticed and identified as members of the *Caspia* genus by malacologist András Varga. Four days later, on 14 September, one specimen was found in the sample taken below Kozloduy, near the right bank of the river as well.

In the same year, on 28 August, Bulgarian hydrobiologist Mila Ihtimanska found some very little snails strongly resembling these, near Vardim Island (542–546 rkm) in Bulgaria. German and Bulgarian researchers described these (BOETERS *et al.* 2015) as a new species, *Caspia milae*. According to current knowledge, these specimens also belong to the species *Clathrocaspia knipowitschii* (SZEKERES *et al.* 2022).

In June 2018, three more specimens of *C. knipowitschii* were found in the area of Kladovo, in shallow water, at low water level. Their DNA analysis revealed an unknown sequence. Interestingly, during dredging conducted at the same time in deeper parts of the river, no specimens of the species were found. On 25 September, during a repeated sampling in Kladovo, more specimens were collected from the same shallow water environment, in the gravelly littoral zone. The snails were gliding on the lower sides of large pebbles, protected from the currents.

C. knipowitschii was first found in the Hungarian section of the Danube on 28 April 2019, during the dredging of aquatic macroinvertebrates in the branch between Zebegény Island and the left river bank. Numerous specimens were found in samples from 4–5 m depth. Its second record consists of a few adult individuals found near Gönyű on the Slovakian side of the Danube, in the course of the dredging conducted by the Joint Danube Survey 4.

* Translated from the Hungarian common name

Surprisingly, environmental DNA analyses conducted by Slovakian researchers indicated its presence also in the river section near Medveďov, where it had not been found earlier.

In January 2020, many specimens were collected in the littoral zone of the Danube near Zebegény, and later, in March 2020, it was detected at numerous locations and dates in the section between Felsőgöd and Alsógöd. The site of the southernmost Hungarian record to date is located on Szentendre Island, where it was found in April 2021, near the car ferry connecting Horány and Dunakeszi. Meanwhile, in April and August 2021, a significant population was found by Gönyű, near the right bank of the Danube, with an abundance of young specimens, indicating that this gravelly habitat is favourable to the species.

It is interesting to consider how this small Ponto-Caspian snail, which originally inhabited rivers to the north of the Black Sea, reached the area of the Danube. It has been recorded in the sediment of the Danube Delta and large brackish lakes to the south of it (e.g. Lake Razim). Its dispersal could have been assisted by human activity; river navigation may have promoted its upstream spreading.

Biology of the species

C. knipowitschii is a very small snail, the shell of the adults is little over 2 mm high. The shell has a typical, reticulate sculpture, but its shape varies. It may be either thick or elongated even within the same population. Its life cycle is little known. As the shells of young animals approach or even exceed 0.5 mm by the end of summer, they presumably hatch in the spring.

C. knipowitschii occurs in slow flowing sections of large, lowland rivers which flow into the Black Sea from the north. Near their estuaries, fine sediment substrates are dominant. It has been recorded in its native range, for example in the lower section of the Dnieper, on silty sand substrates, where the only available solid surface is provided by colonies of the Zebra Mussel (*Dreissena* sp.) or their accumulated, empty shells (Anistratenko *et al.* 2021). In Hungary, however, it has only been found so far in the middle section of the Danube, on solid gravel substrates, and it seems to be absent from silty beds. It feeds on biofilm, moves relatively quickly, and only occurs on large pebbles. These are suitable for this snail as they are not easily relocated even by strong currents at large discharge, therefore they offer a relatively stable habitat for the tiny specimens of this species. The species occurs in similar habitats in the Serbian and Bulgarian sections of the Lower Danube. According to our observations, it explicitly avoids silty limans in the Middle and Lower Danube.

Ecological conditions in Hungary

C. knipowitschii is difficult to detect, partly because it is very small, and partly because its habitats are continuously flooded with water, and are only accessed without difficulty at low water levels. At medium or high water levels, the species can only be detected by special sampling methods (e.g. dredging, air-lift) in its habitats in the deep, hardly accessible zones of the river, and even then, it is important to take care not to damage its shell when removing bed material. Accordingly, in the few cases when it was collected by dredging, bed material could have been in a stable state for a longer period of time. At low water levels, however, thorough searching will bear fruit.

At sites where it was found at all, its populations are significant. This is demonstrated in the Danube by Göd and Gönyű, where at low water level, great numbers were collected from the littoral zone by individual sampling with nets. The thorough stirring of the gravel of the river bed is necessary for an effective sampling. Floating bed material can be collected by sweeping movements, which will also catch the small snails, provided its population is abundant enough.

Ecological concern

As *C. knipowitschii* is really small, it seems justified to doubt that its presence has any negative effects on the native communities of its habitats. No information is available on its causing any damage, no ecological problems induced by this species have been reported so far. As it presumably occurs in the Danube between Medveďov and Budapest (although it has not yet been detected everywhere), it is probably able to co-exists with a species of community interest in the Natura 2000 network, the thick shelled River Mussel (*Unio crassus*), which is now very rare and its populations are small.

Economic impact

We have no information about any economic damage caused by this snail.

Potential control measures

It is not necessary – and probably not possible – to control the expansion of the aquatic snail *C. knipowitschii*.

References

Anistratenko 2013, Anistratenko *et al.* 2021, Boeters *et al.* 2015, Szekeres *et al.* 2022, Kantor *et al.* 2010, Neubauer *et al.* 2018, Wesselingh *et al.* 2019

Béla Csányi

New Zealand Mud Snail

Potamopyrgus antipodarum (J. E. Gray, 1843)

Native range

The species is widespread in New Zealand, its native land, from sea level up to 800 m altitudes. It inhabits freshwater ecosystems. In New Zealand, it becomes abundant in degraded habitats, therefore it is regarded an indicator species (Towns 1981).

Introduction to Hungary

It was first recorded in Hungary near Szántód, in Lake Balaton. In 1977, a student from Gyöngyös (Gábor Nagy) collected a litre of them (approximately 70 000 specimens), and brought the sample to the Matra Museum in Gyöngyös. Then, it was identified as *Potamopyrgus jenkinsi* (Pintér 1978). In the same year, it was found in Balatonszárszó as well. No-one noticed its presence before, although by the end of the decade, it was abundant in Lake Balaton. Afterwards, it spread explosively. Besides the Danube and Lake Balaton, it also became a common snail in watercourses of various sizes (Dráva, Marcal, Tarna, Bene stream etc.), where its mass proliferation can be observed from time to time. The spreading of alien species can only be precisely traced if long-term historical data are available. For such purposes, archived museum collections are of critical importance.

In Europe, it was first detected in England in 1859. The first specimens were collected and described as *Hydrobia jenkinsi* from the brackish waters of the Thames Estuary (Smith 1889). The species spread rapidly, Boycott (1936) already mentioned it as a common member of the English freshwater fauna. It was found in 56 districts of England and Wales, nine Scottish counties, and Ireland. Its rapid dispersal was probably promoted by the development of the canal system connecting waterways in England. By 1887, it had spread to mainland Europe as well (Loo *et al.* 2007). Today, it occurs in most European countries.

The New Zealand Mud Snail is also widespread in the freshwaters of Australia and North America, and it has been introduced to Chile (Collado 2014), Iraq, Turkey, and Japan as well. Alonso (2013) provides a comprehensive study of its dispersal.

Biology of the species

Ponder (1988) recognised that the invasive species spreading rapidly in Europe, described by Smith (1889) as *Hydrobia jenkinsi* from the Thames, is identical to the species *Potamopyrgus antipodarum*, previously described by J. E. Gray in 1843 on New Zealand, which was also spreading rapidly in Australia. The species occurs in any type of stagnant and flowing water, with salinity between 0.0–1.7%. It is often abundant, its density may reach 100 000 specimens per m^2 (Welter-Schultes 2012).

It is a small aquatic snail with gills and operculum. Its shell is cone shaped, it may be smooth or variously sculpted, with a slight keel and spines. The reasons for this morphological diversity have been widely studied. Research of its breeding showed that the sculpture of the shell is mainly determined genetically, while shell size is strongly influenced by environmental factors (type of current, food availability). Chemical composition and organic matter content of the water have no effect on the formation of the sculpture. Algal metabolites in the water may induce the development of the keel (Warwick 1952). The function of the spines is unclear, but they may protect from small predatory fish (Pisces) (Holomuzki & Biggs 1999). Evolutionary and ecological conditions may decidedly differ in the native and the expanded ranges of a species. The wide ecological tolerance range of the New Zealand Mud Snail played an important role in its conquering the world, as it was able to adapt to a wide variety of habitats (Verhaegen *et al.* 2018). A single female specimen is enough to start a population in a new ecosystem. In its native

© Tamás Deli

range, sexual and asexual reproduction occur simultaneously (Winterbourn 1973). In its non-native range, the sex ratio of populations is different. Males are extremely rare, the most common form of reproduction is parthenogenesis, i.e. mating with males is not necessary for the fertilisation of eggs (Jokela *et al.* 1997). Females are ovoviviparous. The embryos develop in a kind of "uterus", and the mothers "give birth" to tiny snails. Young specimens become sexually mature when they are 3.0–3.5 mm long. Their are extremely fecund. An adult specimen produces up to 50 offspring at a time. The species has one to six generations per year, so a single specimen produces ca. 230 offspring a year (Richards 2002). Countless reports have been published about their mass proliferation in the newly invaded areas. Some examples from the United States: Owens River 10 000 – 20 000 specimens/m^2, Middle Snake River 10 000 – 500 000 specimens/m^2 (Bowler 1991). Its highest recorded density so far is 800 000 specimens/m^2, observed in a slow flowing, small stream in Belgium, on the substrate and the aquatic vegetation (Lucas 1959).

Ecological conditions in Hungary

New Zealand Mud Snails occur in lakes, ditches, rivers, streams, and other aquatic habitats, on submersed vegetation, wood, rocks, sand, and silt as well. It is an aggressively spreading species. Its thick shell can be closed with an operculum, which enables the snail to survive extreme environmental conditions, even the temporary drying of its habitat. In case of permanent desiccation, it burrows into the sediment. It has been shown that it is able to pass through the digestive system of the Australian eel unscathed (Ryan 1982), indicating that fish (Pisces) may assist its rapid dispersal. If a single specimen is carried to a new habitat, large populations may be established via parthenogenesis. Due to its wide ecological tolerance, it may potentially colonise any of the Hungarian aquatic habitats. Anglers and fisheries effectively assist its dispersal (Loo *et al.* 2007).

Ecological concern

The occurrence of the New Zealand Mud Snail in Hungarian ecosystems is damaging and irreversible. Its invasion may change habitat properties, reduce biological diversity, and induce homogenisation. Its wide tolerance range, high reproduction rate, and great ability for both active and passive dispersal explain its rapid expansion (Alonso & Castro-Díez 2008). It produces a large amount of biomass, and has a very varied diet, comprising organic matter, live plants, and microorganisms. Fisheries probably find it useful as a source of fish food. However, its ability to pass through the digestive system of the eel alive (Ryan 1982) is thought provoking. This phenomenon has not yet been studied in Hungary, but if this can happen with other fish species (Pisces) as well, then these also assist the spreading of the New Zealand mud snail. Its role in the invaded ecosystems is intensively studied both in America and many European countries. In Hungary, research of this kind is lacking, but would be necessary in order to detect unforeseen consequences of the expansion of this species. This could be the only way to contain the continuing dispersal of this new invasive snail species.

Potential control measures

In the absence of research conducted in Hungary, control is practically impossible. Chemical or physical eradication is not possible in rivers, streams, or lakes, as the treatments would damage the entire community. In fisheries, the species can be completely eradicated by the desiccation and chemical treatment of ponds.

References

Alonso 2013, Alonso & Castro-Díez 2008, Bowler 1991, Boycott 1936, Collado 2014, Holomuzki & Biggs 1999, Jokela *et al.* 1997, Loo *et al.* 2007, Lucas 1959, Pintér 1978, Ponder 1988, Richards 2002, Ryan 1982, Smith 1889, Towns 1981, Verhaegen *et al.* 2018, Warwick 1952, Welter-Schultes 2012, Winterbourn 1973

András Varga

Acute Bladder Snail

Physella acuta (Draparnaud, 1805)

Native range

This snail was originally called "western bladder snail" in Hungary, as everything pointed at its Western European origin. It had been described in France (Draparnaud 1805), but later it was discovered that it had been introduced from America. It has many relatives in Central and North America (Taylor 2003), and after taxonomic consideration, the species, which was originally a member of the *Physa* genus, was moved first to the *Physella* genus, and later to the *Haitia* genus, based on its relations with the American species. However, now it is again included in the genus *Physella*. As the appearance of the Acute Bladder Snail is highly various, many morphs were formerly described as distinct species (e.g. the name "*heterostropha*" was also used in Hungary). Because of the repeated changes of its name and its confused taxonomy, the species is still designated by several names in scientific publications. The original population is probably from the Northeastern United States, most likely from the area surrounding New York, or the eastern coast of Canada (Taylor 2003), also the source of numerous other alien species in Europe. According to Soviet authors, the Acute Bladder Snail has reached Asia by 1952, starting from Western Russia (Zhadin 1952). Under these circumstances, even the American origin of the introduced populations becomes uncertain. It is possible that the species spread from one location to the next within area of the Old World.

Introduction to Europe and Hungary

It is almost certain that it was present in Europe well before its discovery. Its occurrence was mostly noticed by aquarists, as it was a popular aquarium snail. According to the records of Lajos Soós, the species was first found in Hungary in the Botanical Gardens of Budapest (Füvészkert, today ELTE Botanical Gardens) in 1926, and next, in Lake Malom, behind the Lukács Bath (Soós 1943). Later, it colonised wastewater clarifiers as well (Vajon 1959). Its occurrence is also mentioned in warm water outlets, also recommended for collecting aquatic plants (e.g. Aranyárok stream near Aquincum, Budapest) (Wiesinger 1975). This is by no means a coincidence, as the species spreads successfully with aquarium plants, and accordingly, it is currently present in every one of our botanical gardens and parks with some kind of ornamental pond. It is also common in pet stores and display tanks, and it even occurs in the seal pool of the Budapest Zoo. It has probably been introduced repeatedly, and even today, this extremely widespread species may be spreading back and forth. Analyses of mitochondrial DNA markers showed that many unrelated introduction events happened for example in Africa, and as the haplotypes of the African populations are not different from the European ones, the introduction events are also here ongoing and unrelated (Lawton *et al.* 2018). This should raise awareness, both in the case of this species and in general, that the fact of an introduction should not be regarded a single and exceptional event. It is more likely that if a species can adapt to relocation and has an invasion potential, it remains potentially invasive for ever.

Biology of the species

The Acute Bladder Snail is a sinistral snail, i.e. the direction of its coil is left-handed, unlike most snail species. Its aperture is on the left if viewed frontwise. Opposed to the native Common Bladder Snail (*Physa fontinalis*), which has a very shiny, thin shell with a blunt apex, the shell of the Acute Bladder Snail is sharply pointed, and the peristome, i.e. the margin of the aperture is swollen like a lip on fully grown specimens. The body is black with light patches, and shows through the thin, brownish yellow shell. The name "bladder snail" refers to its ability to float straight up to the surface from the bottom of the water, like a rising bubble. Other freshwaters snails also do this occasionally, but it is quite common among the quick moving bladder snails. This behaviour facilitates the rapid intake of air, and probably also helps the snail to escape its predators. The Acute Bladder Snail breathes atmospheric oxygen, but it can also utilise dissolved oxygen in the water as, besides its lungs, the projections on its mantle margin enlarge its surface, for the exchange of dissolved gases (Taylor 2003).

The Acute Bladder Snail is hermaphroditic and capable of self-fertilisation. Offspring created by self-fertilisation are somewhat less viable than those produced by two parents, but both types of reproduction are present in every population. Population density does not affect the way of reproduction (Jarne *et al.* 2000). Compared to other freshwater snails, the Acute Bladder Snail can accumulate more heavy metals in its body, so it can be used as an indicator species of pollution (Spyra *et al.* 2019). This trait is due to an effective detoxification mechanism, which enables it to colonise polluted waters as well.

It prefers tepid or warming waterbodies with stagnant or slow flowing water, for example canals or ornamental ponds. It also survives in the coolant water or wastewater outlets of industrial plants. It feeds on algae and bacteria attached to the surface of rocks, concrete, or aquatic plants. As it is capable of self-fertilisation, a single specimen is enough to start a colony. Aquarists often experience this, because if they leave a single egg in the tank after cleaning, the Acute Bladder Snail will start a new population again. It attaches its eggs to the substrate in elongated, gelatinous capsules which are transparent and ca. 1 cm long. One snail can lay several such clusters, resulting in hundreds of offspring. Small snails hatch in two or three weeks at room temperature. They are entirely identical to the adults, but they are not much longer than 0.5 mm. The growth rate of young specimens is highly varied, i.e. some specimens remain smaller, and relatively few become fully grown. However, some young specimens can reproduce without being fully grown, resulting in overlapping snail sizes in different generations. As synchronous growth is lacking, small and big specimens are present in every population with equal probability.

Ecological conditions in Hungary

Looking at the distribution data of the Acute Bladder Snail, it is clear at a glance that the species can colonise practically any type of water, at least temporarily. It feels at home in the pools of the clearest


© Tamás Deli

karst springs, for example in Kácsfürdő in the Bükk Mountains, in the fast flowing stream, alongside specimens of the protected *Theodoxus prevostianus*. At the same time, it is able to breed on the biofilm of the trickling filters used for the biological treatment of sewage. It may form populations of several millions in a tower. It does not establish populations in cold mountain streams, but if the stream has any type of warm water discharge, shells or live specimens of the Acute Bladder Snail are sure to be present in its sediment. This is how snails get into the Eger stream from the outlets of the Eger bath (Varga 1977), or into the Hejő stream from the Csónakázó pond in Miskolctapolca (Soós 1943, Varga 2009). It is doubtless that in Hungary, surface waters that do not freeze in winter form reservoirs of this species. These are either warm (e.g. Lake Hévíz, or the cooling ponds of the Tatabánya power plant and other power plants, or Lake Cseke and the Fényes Bath in Tata), too fast flowing or deep to freeze, or their surface cannot thoroughly freeze as a consequence of continuous human activity (e.g. fishponds of Pilisvörösvár, Szarvas, and the Hortobágy, Szilas stream in Budapest, or Lake Naplás). Perhaps the reason for the success of this species, besides its high invasion capacity, is that it fills an important ecological niche that no other snail species used before.

By the Danube, it has spread from the Szigetköz to Gemenc, and in the Tisza, it occurs sporadically between Szeged and the southern border of the country (Varga & Csányi 1997). In some places, it becomes abundant as in a gradation. Specimens swept away from the dense populations may be the sources of recorded colonies consisting of only a few specimens. Such isolated populations may occur in temporary poodles or roadside ditches (Horváth 1950), and even in artificial ponds with plastic lining in the sand of the Kiskunság. These occurrences, far from natural waters, are attributed to the assistance of animals, especially birds, as the eggs of the snails may attach to their feathers (Boag 1986). The Acute Bladder Snail may also disperse in mud stuck to vehicles (Banha *et al.* 2014).

Ecological concern

Despite its worldwide distribution, reports on damage caused by the Acute Bladder Snail are few. It spreads some parasites of animals (e.g. species of the Strigeidae and Echinostomidae families), which potentially endanger humans as well (Faltynková & Haas 2006). When it becomes too abundant in aquariums, it may be a nuisance to aquarists, but it is also deliberately introduced to clear off the algae.

It does not seem to compete with other snails in natural habitats, as it may co-exists with any kind of freshwater snail in a great variety of habitats (Horváth 1950). In aquariums, it can be kept with various fish species and other snails. Fortunately, it does not even clash with the native European Common Bladder Snail (*Physa fontinalis*) with a similar life history, as the native species only occurs in cool, shaded waters, while the introduced Acute Bladder Snail prefers tepid, sunny habitats. Microhabitat separation also makes it possible for the two species to co-exist, for example in the marshes of Ócsa. The common bladder snail inhabits dark, stagnant waters rich in humic acids in alder groves, while the Acute Bladder Snail occurs in the flowing, sunny waters of the canals with ample algal growth. Because of its thermophilous nature, the Acute Bladder Snail often rests on the bottom in the shallow water, while the Common Bladder Snail mostly floats on its back on the surface.

Economic impact

Specific damage of this species was reported in Hungary from a now defunct warm water fishery, when it became so abundant that it blocked the inlets of the spawning ponds. In wastewater clarifiers, it damaged the biofilm layer used for biological detoxification, and as it was difficult to get rid of, a change of technology became necessary. Similar cases may have occurred more frequently, but as problems of this kind are rare and not covered by protocol, they are solved individually in every facility, and usually do not merit public documentation.

Potential control measures

The species is so common that the complete eradication of its populations is not a real possibility. As toxic chemicals cannot be discharged into waters, the oils of certain plants are recommended to control the species (Bedini *et al.* 2016). In practice, however, mechanical control seems the most effective way, which is also the least damaging to the environment. Any kinds of control measures can only be applied locally and in highly justified cases, as the species in general cannot be considered damaging.

References

Banha *et al.* 2014, Bedini *et al.* 2016, Boag 1986, Draparnaud 1805, Faltýnková & Haas 2006, Horváth 1950, Jarne *et al.* 2000, Lawton *et al.* 2018, Soós 1943, Spyra *et al.* 2019, Taylor 2003, Vajon 1959, Varga 1977, 2009, Varga & Csányi 1997, Wiesinger 1975, Zhadin 1952

Gábor Majoros

Ash Gyro

Gyraulus parvus (Say, 1817)

Native range

According to current scientific consensus, the Ash Gyro is yet another American species, as most researchers agree that the European specimens are identical to the species described from River Delaware (Meier-Brook 1983, Glöer 2019, Welter-Schultes 2012). Its dispersal route is also clear. As it is able to survive in ornamental ponds, it invaded Europe, and probably other continents as well, assisted by humans. It is to be noted, however, that the source population of the European expansion need not have been in North America. As the Ash Gyro was already used for parasitology research in aquariums in the first half of the past century (Krull 1931), and it occurs in European aquariums and gardens as well, it is more likely that the genetic variations which enabled the species to become widespread in Europe were created in an artificial environment. Today the Ash Gyro occurs in the central parts of Europe, from France to Hungary, and from Denmark to Northern Italy (Welter-Schultes 2012). It is widespread in its place of origin, North America (Burch 1989).

Introduction to Hungary

The shells of even fully grown Ash Gyros are only 3–4 mm wide. Due to the yellowish white colour, they are even less conspicuous, therefore their spreading probably started unnoticed, with the introduction of aquarium plants. Many common plant species, several of them with remarkable invasion potential have been introduced to Europe from America from aquariums or warm water environments, e.g. mosquito fern (*Azolla* sp.), fanwort (*Cabomba* sp.), water hyssop (*Bacopa* sp.), water hyacinth (*Eichhornia* sp.), water cabbage (*Pistia* sp.), waterweed (*Elodea* sp.), primrose-willow (*Ludwigia* sp.), burhead (*Echinodorus* sp.), and arrowhead (*Sagittaria* sp.) (Wiesinger 1975). No wonder aquatic snails hitch-hiked on some of them. The Ash Gyro has probably been present in aquariums for a long time, but as malacologists usually do not investigate aquarium snails, its introduction was only noticed later. This is all the more likely as this species hardly differs from some native European *Gyraulus* species, of which there are almost 40 (Glöer 2019), so it is not readily recognised by the shell. Its occurrence was first noticed in Germany in a lake by a motorway in 1973 (Meier-Brook 1983). By the turn of the millennium, it has spread throughout Switzerland, and it also appeared in several other European countries (Beran & Horsák 2002, Boschi 2011). At the time of research conducted for a graduate thesis in Hungary (Horváth 2010), it was quite frequently found both in aquariums and outdoor waterbodies, despite there being no trace of it in the catalogue compiled on the basis of its occurrence data available in the Mollusca collection of the Hungarian Natural History Museum in 1979 (Pintér & S. Szigethy 1979). The Hungarian records of the species are still somewhat uncertain as it looks very similar to the native White Ramshorn (*Gyraulus albus*), and also to *Gyraulus chinensis*, probably another alien. Precise anatomic or genetic examinations are usually necessary for their exact identification (Meier-Brook 1983).

Biology of the species

The Ash Gyro is a red-blooded freshwater snail of the ramshorn family (Planorbidae). Ramshorn snails are freshwater pulmonate gastropods, distributed worldwide. Numerous species are intermediate hosts of dangerous parasites (Malek 1985). Based on studies conducted on other species, members of the *Gyraulus* species usually live for a year, and produce eggs repeatedly during this time, i.e they are iteroparous (Krull 1931, Glöer & Meier-Brook 1998, Horváth 2010). The Ash Gyro lays clusters of 1–4 eggs (Meier-Brook 1979). In the course of chromosomal analyses

conducted on another North American ramshorn species, *Gyraulus circumstriatus*, which, according to some scientists, is a variant of the Ash Gyro, it has been shown that *Gyraulus* species are tetraploid, therefore less sensitive to mutations (Burch 1960). All *Gyraulus* species are capable of mass proliferation. The Ash Gyro feeds on algae, characteristic in nature in stagnant or slow flowing aquatic habitats. It is not a coincidence that Ash Gyros frequently occur in the clear water of aquariums, even if owners do not always notice them, or mistake them for young specimens of the larger Seminole Rams-horn (*Planorbella duryi*). At first glance, Ash Gyros are indeed similar to Seminole rams-horns, because inside the transparent shell, they also have a red body, and the shape of their shell is also similar. The Ash Gyro has become abundant in Hungary as well as other European countries in artificial pools and ponds. The only significant ecological difference between this species and the Seminole rams-horn is that unlike its larger relative, the Ash Gyro is able to colonise habitats in Europe outside warm water environments.

Ecological conditions in Hungary

The ecological demands of the Ash Gyro have not been studied, due to its seeming insignificance. Based on its habitat preference, it presumably likes large, permanent waterbodies, and creates scattered populations. From on our own research, we know that it occurs in Lake Balaton and the Danube as well (Horváth 2010), although identification is very difficult because its shell is nearly identical to that of a native species, *Gyraulus laevis*, making data collection based on empty shells uncertain. Live specimens are hard to find in nature, as it breeds in undisturbed, hidden waters, which are usually barely accessible to humans because of the dense vegetation or some other reason (Meier-Brook 1983). It is important to emphasise that other Hungarian *Gyraulus* species also usually appear incidentally in the course of collecting trips, and we usually only notice the large amount of shells following the collapse of their populations after a gradation, usually in beds desiccated before autumn. Therefore, intensive and widespread research would be necessary to gain a comprehensive understanding of the situation of Ash Gyro populations in Hungary. To further complicate matters, an Asian species, *Gyraulus chinensis*, which is kept expressly as an aquarium snail, is probably also present in Hungary, and distinguishing it from the other two smooth shelled *Gyraulus* species is also only possible by examining live specimens. Knowing how frequently aquarium plants are introduced into natural thermal waters in Hungary (e.g. Hévíz, Tata, Tapolca, Miskolctapolca), it is by no means impossible that *Gyraulus chinensis* also escaped from the aquariums in Hungary, as it has been documented to do in several European countries (Beran & Glöer 2006, Glöer 2019). It is possible that these alien species co-exist in suitable habitats with warm water.

Ecological concern

The Ash Gyro continues to invade Europe unobserved. The extent to which its expansion can be traced is probably only a matter of money spent on research, and the commitment of scientists. It does not call attention to itself by any prominent impact on its environment. The reason it is still discussed in detail in this volume is a special concern, which, however, may emerge related to different species as well, namely, that it is able to form hybrids with a related European species, thereby excluding it from its original habitats (Pointier *et al.* 2005). Hybridisation of native and alien species can occur anywhere, but usually only cases which pose some kind of actual threat gain public attention, like snakes (Serpentes) introduced to Florida (Orzechowski *et al.* 2019). Although the fact that there are many native European *Gyraulus* species indicates that hypothetically, several related species are able to co-exist in the same area, so few typical *Gyraulus laevis* specimens have been found in Hungary lately, that the occurrence of this native species is recently doubtful. This raises the possibility that the Ash Gyro is replacing its native relative, or is gradually changing it by hybridisation. This is quite possible, as these two small ramshorn snails probably share a common ancestor (from the times when Europe and America were still connected) (Meier-Brook 1983). Some authors do not even distinguish these species, but regard them as the local forms of a single species with a Holarctic range (Zhadin 1953). It is also conceivable that this “swapping of species” is due to the gradual warming of our waters, and the Ash Gyro only occupies habitats vacated by the more cold demanding native species. According to experience, the environmental requirements of the Ash Gyro and *G. laevis* are somewhat different, they do not occur in the same habitats (Meier-Brook 1983). *G. laevis* may have been more common in the ice age, as it regularly occurs in sediment layers from the Pleistocene (Krolopp 1983), and most of its range is located north of Hungary (Glöer 2019). On the other hand, the Ash Gyro occurs in Alaska, too (Burch 1989), indicating that it tolerates cold climate. Whatever the reason for the different current frequency of the two species, the future progress of the invasive Ash Gyro will probably indicate some kind of change worthy of our attention.

Potential control measures

Because of its potential to colonise lakes and rivers, there is no hope whatsoever to eradicate this species, but it is not necessary either. Its dispersal should be monitored alongside other aquatic species.

References

Beran & Glöer 2006, Beran & Horsák 2002, Boschi 2011, Burch 1960, 1989, Glöer 2019, Glöer & Meier-Brook 1998, Horváth 2010, Krolopp 1983, Krull 1931, Malek 1985, Meier-Brook 1979, 1983, Orzechowski *et al.* 2019, Pintér & S. Szigethy 1979, Pointier *et al.* 2005, Welter-Schultes 2012, Wiesinger 1975, Zhadin 1952

Gábor Majoros

Seminole Rams-horn

Planorbella duryi (Wetherby, 1879)

Native range

The Seminole Rams-horn was described from the Everglades wetlands in Florida. It is native to the eastern and southeastern parts of the United States and Canada.

Introduction to Europe and Hungary

The Seminole Rams-horn is an aquarium snail which is popular and widely bred all over the world. As its blood is red, it has a pretty colour, and adds a bright spot to every aquarium community. It is unknown when its breeding started, but it became a common alien species in Europe quite recently. Hungarian aquarists did not yet know this species in the 1960s and 1970s (Wiesinger 1975). It is considered certain that it has not been introduced from its native range, but from populations bred in aquariums. Its first occurrence outside of an aquarium was observed in Germany in 1994 (Glöer 2019). Its presence has been detected about this time in other parts of Europe as well. It has only colonised pools and warm thermal waters tended by humans in Europe so far (Welter-Schultes 2012), but the problems it is likely to generate because of its origin, establishment, and mass proliferation may be considered a model for the case of several other deliberately bred molluscs (Mollusca).

It is doubtless that in 1977, there was not a sign of free living, alien specimens of this snail occurring in Hungary, as it is not mentioned in the catalogue of the distribution of Hungarian molluscs, compiled by many authors and published that year (Pintér *et al.* 1977), although it may already have been known and bred by some aquarists. Its first occurrence in natural waters was recorded by Gyula Kovács in the ornamental pond of the park in Miskolctapolca in 1979. Back then, in Hungary, the species found in the dense vegetation of coontail (*Ceratophyllum* sp.) was little known, even in aquariums. No wonder that even the specimens examined by museum scientists were identified as *Planorbella trivolvis* (Kovács 1979). As anatomical examinations are necessary to distinguish this closely related species from the Seminole Rams-horn (Malek 1985), the identification of the collected specimens was very uncertain at first, especially as only full grown, sexually mature specimens can be exactly identified. After the first documentation, it spread quite rapidly in Hungary. By 1980, it was already common in the thermal pool near the drinking tap of Széchenyi Bath in Budapest, and it also occurred in Lake Hévíz, and the thermal pools of the public bath of Eger. In 2007, it was abundant in Lake Városliget in Budapest, alongside another alien, thermophilous freshwater gastropod, the Acute Bladder Snail (*Physella heterostropha*). It is to be noted that the occurrences recorded in Miskolc, Hévíz, and Budapest are all associated with sites where aquarists had deliberately introduced aquarium plants. Snails or their eggs may be carried in the plants, as they are able to survive drying for a while.

Biology of the species

The Seminole Rams-horn belongs to the ramshorn snail (Planorbidae) family. The most typical characteristic of these freshwater pulmonate gastropods is their hemolymph containing dissolved hemoglobin, which means that their blood is red. This oxygen-transport protein did not evolve in these organisms to make oxygen transport more efficient, but in order to bind superfluous oxygen that could damage the tissues when the snail is exposed to air on dry land for a longer period of time. As a result, these snails are able to survive for months without water, for example at times of draught in desiccated lake bottoms. They have neither a permanent operculum nor can create an epiphragm, a calcareous disc secreted by the foot, which would temporarily seal the aperture of their shell, yet they survive freezing cold or hot and dry spells without water, deeply withdrawn into their shells, hidden in the mud or among decomposing plant material. Species originating from areas with a hot climate, and also the Seminole Rams-horn, are naturally equipped to withstand the heat of summer.

Information about the biology of the Seminole Rams-horn is scarce, but its close relative, *Planorbella trivolvis* is much better known, as it was used as a model organism in laboratories (Fried *et al.* 1996, Norton *et al.* 2018). The possibilities of eradicating naturalised populations have also been studied in this species (Mitchell 2002). The reason for this interest is that the larvae of African and American species of tropical blood flukes (*Schistosoma* spp.) develop in relatives of these snails, in species of the genera *Biomphalaria* and *Bulinus*. These flukes are very dangerous. As they can infect via skin contact, they disease several million people every year. It is vital to find out which of some closely related snail species are suitable as intermediate hosts of these parasites and why, while others of the same group are not. From related research, it is understood that *Planorbella* and *Helisoma* species only breed at water temperatures over 20°C, and they are not suitable intermediate hosts for the blood flukes causing human illness. This is why it seemed handy to use these species to replace snails which are able to carry parasitic larvae (Ayad *et al.* 1970, Rasmussen 1975). However, there is a twist in the story: *Planorbella* species themselves are intermediate hosts of blood flukes of birds. These can burrow into human skin and cause inflammation, the original reason for experimenting with their eradication. The Seminole Rams-horn, which is easy to breed, has been introduced to numerous habitats of *Biomphalaria* or *Bulinus* species, for example into the Nile and some reservoirs in Tanzania. According to reports, the introduced snails successfully excluded the related species, which are intermediate hosts of dangerous blood flukes, from several habitats (Rhousdy & El-Emam 1981, Madsen 1983, Yousif *et al.* 1993). As these alien snails remained free from parasitic larvae in their new environments, they gained a good reputation. No wonder aquarists wanted to introduce the species into aquariums, and selectively bred various colour morphs of it.

The Seminole Rams-horn is a hermaphrodite species, i.e. any two specimens can mate, and attach small, gelatinous clusters of eggs on plants or other solid surfaces. Self fertilisation is not possible in this species, but they can store sperm cells received from their partner for five months. Consequently, a single individual may establish an entire colony. It lives at least for a year depending on temperature. Although its fecundity decreases in dense populations, scattered specimens are all the more prolific (Madsen *et al.* 1983). They are also popular among aquarists as they mainly feed on algal and bacterial biofilms

© Tamás Deli

clinging to the surface of plants and rocks, i.e. periphyton and perilython, and they are also able to clean glass surfaces with their radulas. This is why most aquarists consider this snail both spectacular and useful, and do not in the least mind if they can easily replace dead specimens with snails (or fish) from hothouse pools, garden ponds, or warm water canals. This is clearly demonstrated by children scraping about with little nets in Lake Városliget, in Budapest.

It is also noteworthy that as *Biomphalaria* species, intermediate hosts of the blood fluke, are just as pretty and easy to breed as *Planorbella* species, aquarium suppliers sometimes also sell the former. They probably presume that these snails cannot survive in the wild under temperate climate conditions, and they have no chance of becoming infected with blood fluke larvae anyway. For example, the websites www.acuaryus.com or www.aquaportail.com provide every necessary information about keeping these snails in aquariums. Species of the *Biomphalaria* genus, however, are able to establish free living populations in Europe, if conditions are favourable (Majoros *et al.* 2008), and their occurrence may be difficult to detect with the very similar Seminole Rams-horn already present. As the biology of these two genera of snails is nearly identical, it is very interesting to see which one would outcompete the other in case of an invasion in the temperate zone.

Ecological conditions in Hungary

According to current information, the Seminole Rams-horn only breeds in pools of thermal water and hot springs in Hungary. Single specimens, mostly only empty shells are sporadically found in other habitats as well. For example, shells washed down from Lake Hévíz have been found on the eastern side of the Tihany Peninsula and in the Danube. The latter could have originated from the Által rivulet in Tata, the ornamental pond of the Zsigmondy Spring on Margaret Island, or the pond by Lukács Bath. In Hungarian pools with aquarium plants, the Seminole Rams-horn is probably either already present, or could be introduced any time. The largest reservoir of the Hungarian population, however, is held by the large number of aquariums in public institutions, stores, and homes all over the country.

Ecological concern

We have no information about the Seminole Ramshorn's escaping confined habitats and significantly transforming its environment, either in the past or the present, apart from replacing its tropical relatives. At the same time, it is entirely conceivable that a mutation may adapt to life in the cold waters of Europe in the future and become abundant. The species does not spread any diseases or parasites in its newly invaded habitats, but in its native range in America, it does act as an intermediate host of some species of animal flukes, and the prevalence of one of these parasites grows as climate gets warmer (Paull & Johnson 2011). Theoretically, it may acquire parasites in its expanded range as well, but only from the species pool already carried by its local relatives, the native ramshorn snails. These are, for example, intermediate hosts of flukes parasitising the rumen of ruminants (*Paramphistomum* spp.). As several ramshorn snail species are native to Hungary (Pintér *et al.* 1977), the possibility of the Seminole Rams-horn getting infected by the larvae of European flukes is real, but its spreading blood fluke larvae which cause the inflammation of human skin (swimmers' itch) is negligible, due to the presence of other abundant snails which have the same effect.

Potential control measures

Populations inhabiting artificial ponds could be reduced by desiccation, as in fact happens sometimes during maintenance works. On the other hand, there is not the slightest chance of eradicating the huge reservoir of this species living in aquariums, and such ambitions would not be justified either. In America, eradication of free living populations of a close relative, *Planorbella trivolvis* was attempted with copper sulphate treatments, but it meant such heavy pollution to the environment in general that today this procedure is prohibited (Mitchell 2002). A preparation called *Bayluscid*, containing the active ingredient niclosamide decomposes quite quickly in nature, and kills aquatic snails effectively. It was widely applied against *Biomphalaria* species spreading blood fluke (Harrison 1966). However, as it is also highly toxic to every fish species (Pisces), its application may only be justified in cases where humans are highly threatened by dangerous parasites. Saponines are also effective against aquatic snails, but these also harm fish and other aquatic organisms as well.

References

Ayad *et al.* 1970, Frandsen & Madsen 1979, Fried *et al.* 1996, Glöer 2019, Harrison 1966, Kovács 1979, Madsen 1983, Madsen *et al.* 1983, Majoros *et al.* 2008, Malek 1985, Mitchell 2002, Norton *et al.* 2018, Paull & Johnson 2011, Pintér *et al.* 1977, Rasmussen 1975, Rhousdy & el-Emam 1981, Welter-Schultes 2012, Wiesinger 1975, Yousif *et al.* 1993

Gábor Majoros

Keeled Slug

Tandonia kusceri (H. Wagner, 1931)

Native range

The Keeled Slug is native to the Balkan Peninsula, but it occurs at several locations from Bulgaria to the eastern coast of the Black Sea (Wiktor 1996, Dedov & Mitev 2011, Welter-Schultes 2012). Around the Black Sea, it has been reported from Ukraine (Odesa), Romania (Dobrudja), and European Turkey, and it has also been recorded in Northern Greece. It is widespread in the Mediterranean climate, in inhabits screes on limestone mountains, but it also occurs in shrublands and forests (Wiktor 1987, 1996).

Introduction to Hungary

In the last decade, it reached the Crimea (Leonov 2007), Russia (Sysoev & Schileyko 2009), Moldavia (Balashov *et al.* 2013), Slovakia (Korábek *et al.* 2016), Samothrace Island (Greece) (Georgiev 2017), and it was also detected in Montenegro (Telebak *et al.* 2013). It was first reported from North America in 2014 (Illinois) (Gerber (2014). It was first observed in the Carpathian Basin (Transcarpathia) in 2019 (Gural-Sverlova *et al.* 2019).

The first specimen was found in Hungary in April 2019, in the Farkasréti cemetery in Budapest. Soon after, it was found at several locations in the Transdanubia region and in Bács-Kiskun County, but most of its occurrences were recorded in Budapest and its neighbourhood, where it is even abundant at some sites (Turóci *et al.* 2020a). The time of its introduction is uncertain, as slugs have not been intensively studied in the last decades in Hungary.

Several factors may contribute to its spreading, but anthropogenic effects are probably the most prominent. The expansion of trade facilitates the spreading of slug species, as they are easily carried to long distances, even across continents with the transportation of horticultural products. Slugs or their eggs survive long journeys in a pot of wet soil. The species has been detected in several garden centres in Budapest and in other parts of Hungary as well.

Biology of the species

The Keeled Slug occurs in screes or other rocky habitats, usually on limestone formations. It is a synanthropic species with a wide ecological tolerance range. It occurs in urbanised areas and mixed broadleaf forests as well. It has been detected up to 2000 m height above sea level in Bulgaria (Wiktor 1987, Welter-Schultes 2012).

The extended length of live specimens may exceed 10 cm, the mantle covers about one quarter of the body (Wiktor 1987). The appearance of the species is very diverse, the colour varies from light pink to pinkish grey. In the latter form, pigments accumulate in the grooves of the skin, and provide a somewhat reticulate pattern. The keel, characteristic of the Milacidae family, extends from the mantle to the tip of the tail. The foot is light and the mucus is transparent, but it becomes thick and opalescent when the animal is disturbed (Wiktor 1987).

Similarly to most slugs, the Keeled Slug feeds on live plants. It is a characteristic of the species of the *Tandonia* genus that they are able to burrow into the ground, so it may also chew roots.

Information about its life cycle is scarce. It lays eggs in April, and the offspring hatch after 16–20 days (under laboratory conditions). In nature, several sizes (maturity phases) of Keeled Slugs occur together, so several generations presumably overlap (Welter-Schultes 2012).

Ecological conditions in Hungary

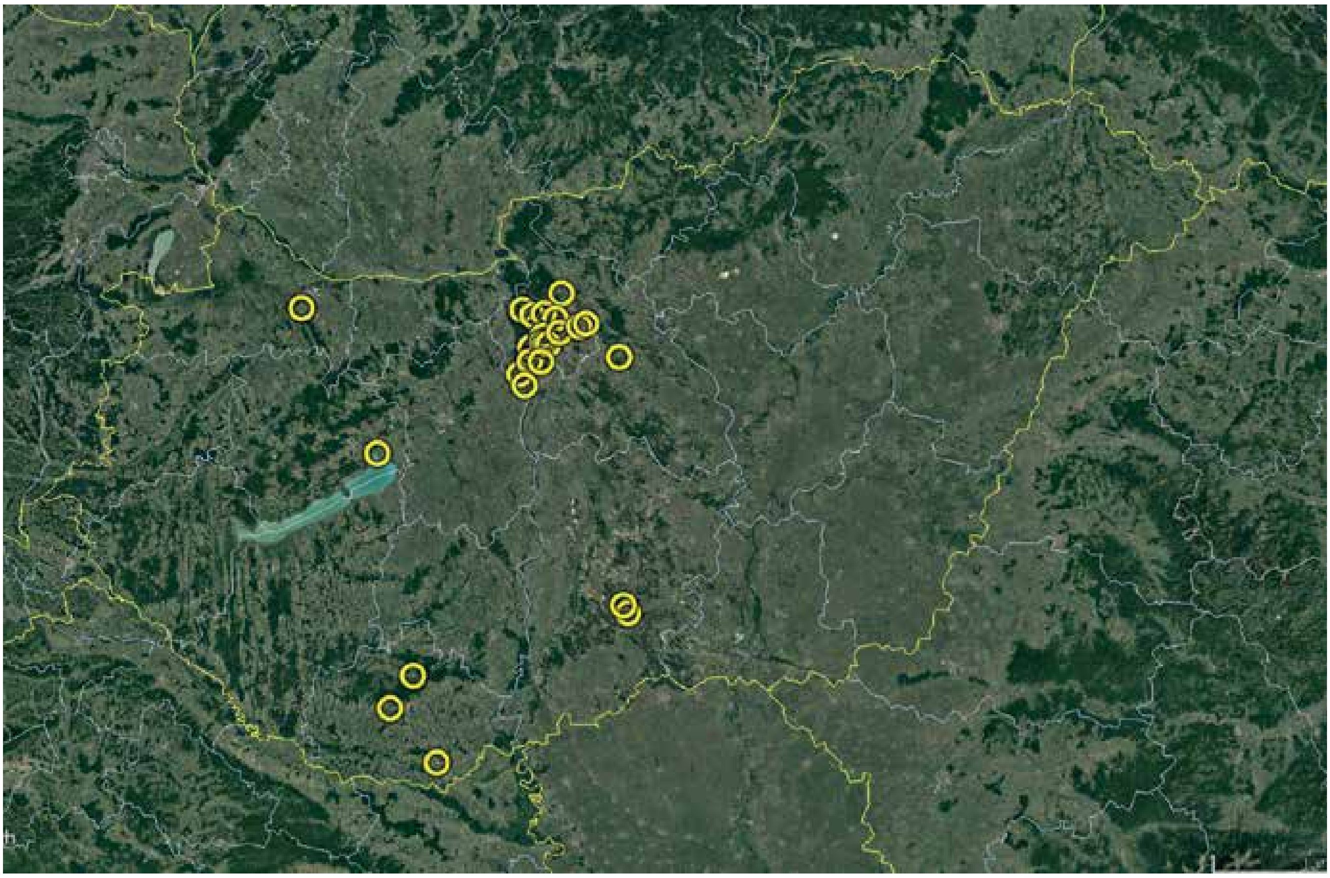
The Keeled Slug mainly occurs in urbanised environments in Hungary. When the weather is rainy, masses of it may appear on the streets after dark, as the only species present. It may also be spotted on warm,

© Ágnes Turóci

dry days in gardens, often even outside shelters typically used by slugs to protect them from desiccation. Such an occurrence was reported from Tárnok (Ágnes Turóci).

For the estimation of its Hungarian populations, besides collecting trips all over the country, citizen science is also applicable. We provide a summary of how this method works and how useful it may be. The increasingly popular citizen science projects make it possible for interested laypeople to take part in some stages of scientific research, by supplying useful information to scientists. The public can usually contribute to data collection (Bonney *et al.* 2009, Mc Kinley *et al.* 2017). It is a great advantage of these methods that huge amounts of data can be collected in a relatively short time (Kosmala *et al.* 2016), and researchers even take a peep at sites they could never visit personally (e.g. privately owned gardens). The method, however, has its limitations, as only characteristic, easily recognisable, fairly large species can be studied this way. Slugs are suitable objects for such projects. It is also important that people have an economic interest in supporting their research, as their data contribute to the reduction of damage in their own gardens. Social media was employed to explore the Hungarian population: in a Facebook post, the species was introduced with photos, and an appeal was made to the public to report occurrences (Páll-Gergely *et al.* 2019, Turóci *et al.* 2020a). The post got ca. 50 shares in a week, resulting in approximately 20 records of its occurrence in a short time. Data collection has not stopped, information keeps trickling in about the Hungarian distribution of the species.

The Keeled Slug is widespread in Hungary. Owing to the Facebook post, its occurrence has been reported



Distribution of the Keeled Slug in Hungary

from 45 sites all over the country till November 2021. It is to be noted that data obtained this way may distort, and the actual distribution of a species may only partially overlap with the acquired records. It is uncertain whether the species is actually absent from sites it has not been reported from, or only the people living there did not see the Facebook post, or are not really interested in such assessments.

Ecological concern

The Keeled Slug is hard to notice. As it is mainly active in the night, we have scarce information about the characteristics of its habitats, but so far it has mainly been detected in inhabited areas. Abundant populations do not occur in near natural habitats.

Economic impact

Some slug species cause significant damage in vegetable gardens, but reviewing Hungarian publications, we find that many of these cases are anecdotal and difficult to verify (Turóci *et al.* 2020b). As slugs mainly feed during the night, but their traces are typically discovered in the morning, the exact species causing the damage is often only guessed at.

We have no information about the Keeled Slug causing any damage so far. We are in touch with several garden owners on whose property the species occurs, and despite frequent observations, none of them has yet succeeded in catching the Keeled Slug "red-handed". However, several species of the Milacidae family and the *Tandonia* genus are economic pests (Wiktor 1987), so the keel slug may also cause some degree of damage if it becomes abundant.

Potential control measures

As there have been no reports about its damage, garden owners are probably not concerned about this species. Most of the treatments suggested against the Spanish Slug (*Arion vulgaris*) are applicable against other slugs as well.

References

Bonney *et al.* 2009, Balashov *et al.* 2013, Dedov & Mitev 2011, Georgiev 2017, Gerber 2014, Gural-Sverlova *et al.* 2019, Korábek *et al.* 2016, Kosmala *et al.* 2016, Leonov 2007, McKinley *et al.* 2017, Sysoev & Schileyko 2009, Telebak *et al.* 2013, Páll-Gergely *et al.* 2019, Turóci *et al.* 2020a, 2020b, Welter-Schultes 2012, Wiktor 1987, 1996

Ágnes Turóci & Barna Páll-Gergely

Worm Slug

Boettgerilla pallens Simroth, 1912

Native range

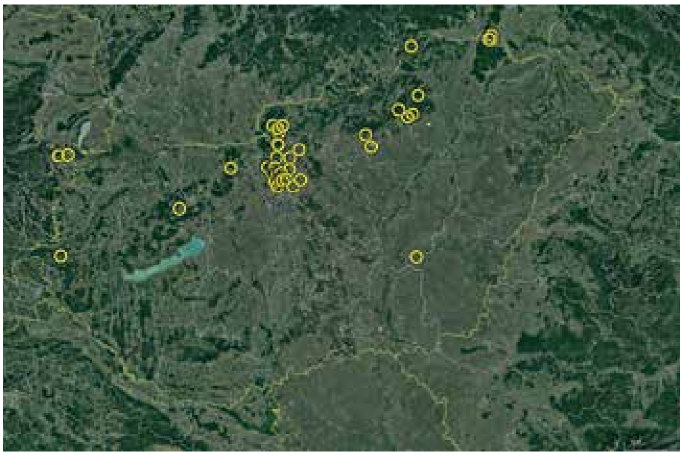
The Worm Slug is native to the Caucasus, Abkhazia, and Western Georgia, and probably also to the Crimea (Rowson *et al.* 2014, Welter-Schultes 2012).

Introduction to Europe and Hungary

In 1959, Andrzej Wiktor reported the discovery of a new slug species from Poland. He named it *Boettgerilla vermiformis*, but it was later confirmed to be identical with the species *Boettgerilla pallens*, as described by Simroth in 1912 from the Caucasus. This was the first published evidence of the Worm Slug's occurrence in Europe. The expansion of its range began in the mid-twentieth century, and by now, it has entirely conquered the temperate regions of Europe. According to museum specimens, it was already collected from the western part of Germany in 1949, although it was not identified (Rowson *et al.* 2014). It had probably been there earlier as well, but it went unnoticed due to its hidden life history. A combination of spontaneous and anthropogenic (long distance transportation of gardening products) factors facilitated its successful spreading.

The first specimen in Hungary was collected by László Pintér in 1971 in Hűvösvölgy, Budapest. It

© Ágnes Turóci



Distribution of the Worm Slug in Hungary

was first identified as *Boettgerilla vermiformis* by Hungarian malacologists, but in the catalogue of the Hungarian species (Pintér 1974), it is already mentioned as *Boettgerilla pallens*. It was recorded in the southern part of the Börzsöny Mountains in 1978 (Erőss 1980), in Solymár and Vácrátót in 1979, and in various parts of the Mátra Mountains in 1979 and 1980 (Varga 1980, Bába & Varga 1980). The map catalogue of Hungarian molluscs (Pintér & Suara 2004) lists 33 occurrences. Its presence in the Baradla-cave, in water, is especially interesting (Dányi *et al.* 2015). It probably drifted into the cave, and started breeding successfully.

Biology of the species

The Worm Slug is a burrowing species. Its unusual, slender, worm-like body makes it possible for it to move in tunnels of earthworms (Lumbricidae) and similar burrows, usually 2–20 cm (up to 60 cm) underground. It is found in gardens as well as near natural forests (for example beech forests of the Börzsöny and Bükk Mts.). Its mating season lasts from late summer till autumn. It lays its eggs in clumps of one to six, 9–27 cm deep below the surface. Adults die shortly after laying the eggs. The young hatch after 20–22 days. Newly hatched specimens are white, but by the end of spring (May–June) next year, their colour changes to grey (Welter-Schultes 2012).

Ecological conditions in Hungary

Due to its hidden, underground life, it may occur practically anywhere, as, below the surface, it is protected from extreme weather conditions. It may be common in gardens, forests, valleys of streams, in heaped-up driftwood of rivers, even in worm burrows in wet decaying wood. Due to its hidden life history, it is difficult to estimate its population size. Its mass appearance has never been observed.

Ecological concern

This species may cause ecological damage by eating earthworms (Lumbricidae) and other gastropods (Gastropoda), as well as their eggs. As is may be common in some gardens and forests, it may also have a negative effect on the native fauna. However, quantitative research on these relations have not yet been conducted either in Hungary or in other European countries.

Economic impact

The Worm Slug is omnivorous. It consumes decaying fungi and plants, faeces of earthworms, and also dead animals, namely earthworms (Lumbricidae) and slugs. Besides these, it also chews the roots and shoots of living plants, but it seems unable to penetrate the skin of the Carrot (*Daucus carota* subsp. *sativus*) (Gunn 1992). It may also eat the eggs of other slug species (Barker & Efford 2004). Hitherto it has not caused considerable economic damage anywhere, but minor cases – damaging greenhouse ornamental plants – have been reported (Godan 1983).

A parallel story of a rare snail species may illustrate the possible surprises a little gastropod may cause. A considerable part of the Lettuce (*Lactuca sativa*) plantation was seriously damaged in the greenhouse of the agricultural co-operative in Bázakerettye in 1972. Tiny snails bore holes and chewed the stems empty (Pintér 1975). The unexpected damage was caused by one of the rarest snails in Hungary, the subterranean *Cecilioides petitiana* (which some researchers suspect of being introduced). We have no reports about similar damage caused by the Worm Slug, but the above example is thought provoking and may evoke cautiousness in the case of other gastropod species as well. In this case, a very rare, lurking species was able to have a local outbreak with severe consequences.

Potential control measures

According to our present knowledge, this species causes no harm, so it is not necessary to take any measures against it, and it would be nearly impossible anyway, due to its hidden, subterranean life history.

References

Bába & Varga 1980, Barker & Efford 2004, Dányi *et al.* 2015, Erőss 1980, Godan 1983, Gunn 1992, Pintér I. 1975, Pintér L. 1974, Pintér & Suara 2004, Rowson *et al.* 2014, Varga 1980, Welter-Schultes 2012

András Varga, Ágnes Turóci &
Barna Páll-Gergely

Yellow Cellar Slug

Limacus flavus (Linnaeus, 1758)

Native range

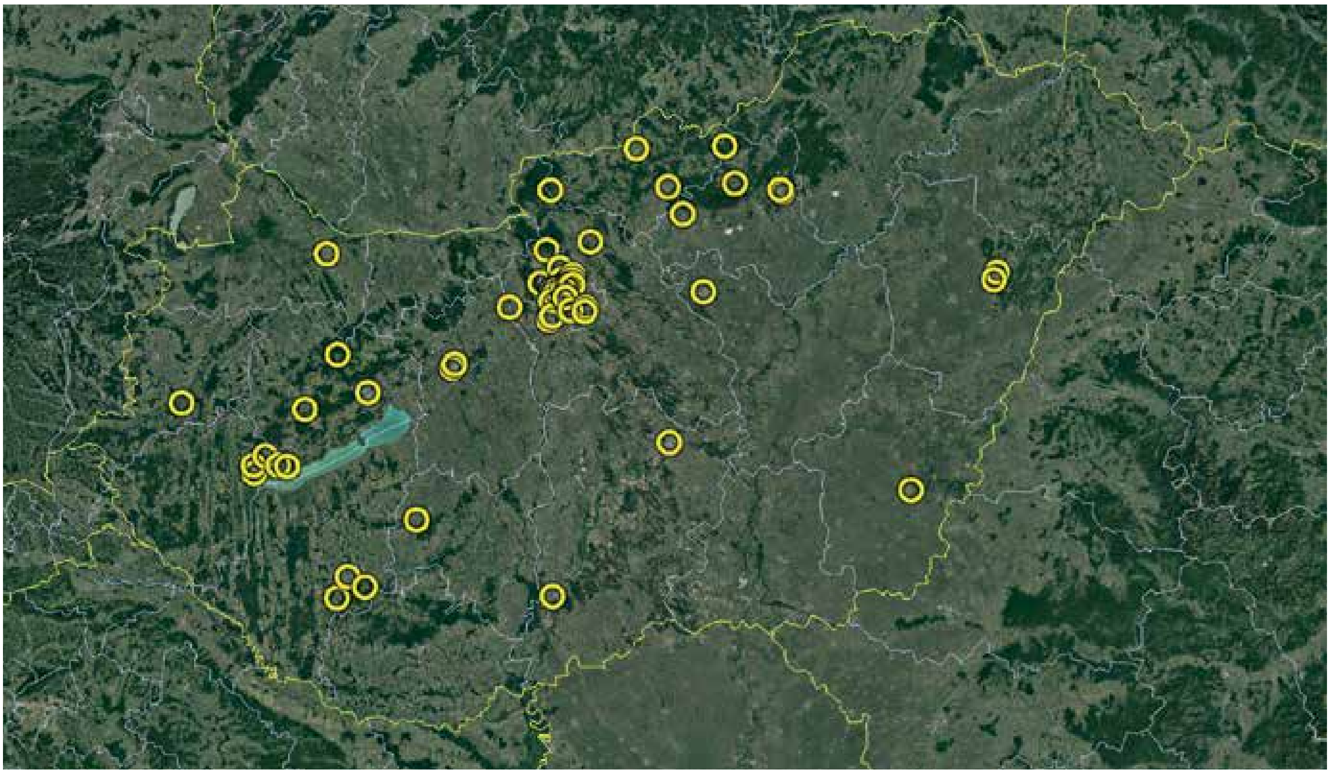
The native distribution area of the Yellow Cellar Slug is uncertain, but it probably originates from the Mediterranean (Southeastern Europe, Asia Minor). It may have originally inhabited lowland forest habitats (Wiktor 1996, Wiktor *et al.* 2000), but it has also been found at higher altitudes in mountain ranges (1500–1800 m) of the Caucasus, and in Bulgaria, Macedonia, and Italy (Welter-Schultes 2012).

Expansion in Europe and introduction to Hungary

The Yellow Cellar Slug started expanding its range from the Mediterranean, and today it is widespread throughout mainland Europe (Kerney *et al.* 1979, Welter-Schultes 2012). It occurs in Great Britain and Ireland (Rowson *et al.* 2014), in North and South America, Africa, China, New Zealand, and on some islands of the Pacific as well (Wiktor 1996, Wiktor *et al.* 2000).

© Ágnes Turóci

External morphology of the yellow cellar slug



Distribution of the Yellow Cellar Slug in Hungary

It has been registered in the Hungarian fauna for a long time, but its first record is uncertain. Mihály Rotarides already mentioned it in his studies in 1927 and 1928 (Rotarides 1927, 1928), reporting its occurrence in Szeged. According to the work of János Wagner, one of its earliest collected specimens dates from 1924 (Wagner 1936). In 1931 and 1934, studies have been published on its anatomy (Rotarides 1931, Szabó & Szabó 1934). All of these early works describe the Yellow Cellar Slug as a synanthropous species which spreads passively, and is a fixed resident of cellars and warehouses. It is also mentioned in every later revision and catalogue of molluscs (Soós 1943, Pintér 1973, 1974, 1984, Wiktor & Szigethy 1983, Pintér *et al.* 1979, Pintér & Suara 2004). Today it is spread throughout the country except for the north-eastern regions and the central parts of the Great Plain.

Biology of the species

The Yellow Cellar Slug is a large slug species (Limacidae), its extended length is 8–12 cm. It is adorned with alternating greyish green and light cream coloured patches. Its sides are predominantly light, the darker (olive or greyish green) parts do not extend to the sole. The keel is only present on the tail, the tentacles are grey. The sole is light and undivided. The mucus is yellowish, or may be darker, lending an orange hue to the animal (Wiktor 1996, Wiktor *et al.* 2000).

Little is known about its ecological requirements in its native range.

It has a multiannual life cycle, the average life span is three to four years. Oviposition takes place in the summer and the autumn (from July to December). They lay altogether 40–60 eggs at a time, divided in a few clusters, in humid, sheltered spots. The eggs are pointed at both ends like a lemon, which is unusual among slugs, therefore the species can be identified even by its eggs. Small Yellow Cellar Slugs hatch after 40–60 days, their colour is light. They reach sexual maturity in 9–11 months, but this is not necessarily reflected in their size, as smaller specimens are occasionally also capable of reproduction. Interestingly, the life cycle of specimens in human environments, e.g. in cellars or vegetable storerooms is somewhat quicker. They may lay eggs at any time of the year, the young hatch within 25–30 days, and the average lifespan is 2,5–3 years (Welter-Schultes 2012).

Ecological conditions in Hungary

The species is typically synanthropic in most of its range, also in Hungary. This means that it usually occurs near humans or their stored goods (e.g. in the plots of garden stores, greenhouses, yards of dairies, parks, cemeteries, private gardens, cellars, other storage spaces for vegetables and fruits) (Wiktor 1996, Wiktor *et al.* 2000). As in the case of most invasive molluscs (Mollusca), human assistance is a major

© Valéria Halavács

factor in its successful dispersal. It can cover long distances with horticultural transports, and under favourable conditions, it may establish stable populations (Turóci *et al.* 2020a).

As of November 2021, 53 occurrence sites have been documented in Hungary, compiled of our own samplings, reports received on Facebook, and the sites listed in the map catalogue of Hungarian molluscs (Pintér & Suara 2004, based on data collected till the mid-nineties). Most occurrences have been reported from Budapest and its neighbourhood, but there are several records from the Transdanubia region and the North Hungarian Mountains, and sporadic observations from some lowland settlements.

Ecological concern

As most slugs, the Yellow Cellar Slug is active during the night. Owing to this and its hidden life history, the ecological effects of its presence are difficult to detect. As it primarily inhabits urbanised areas in Hungary, and only occurs sporadically and with low abundance in near natural sites, it is not likely to impact native species or cause other ecological problems.

Economic impact

The Yellow Cellar Slug lives hidden and is active in the night, so any damage caused by it is difficult to identify. As reflected in its English name, it usually hides in cellars or other storage spaces near humans, where it occasionally chews stored vegetables and fruits (so-called storage pest). It prefers bulbous and root vegetables, e.g. Beets (*Beta vulgaris*), Carrots (*Daucus carota* subsp. *sativus*), Potatoes (*Solanum tuberosum*) to green leaves. This preference has been documented in Hungary for a long time (Bachó 1952, Beczner *et al.* 1970, Bognár & Huzián 1974). It is one of the six most common slug pests (Turóci & Páll-Gergely 2020). As its mass proliferation is not common, it is not likely to cause large scale agricultural damage, but it may still grieve garden owners. By chewing vegetables and fruits kept in cellars and storerooms, it facilitates infection, and chewed fruits may soon start to rot.

Potential control measures

The treatments suggested against the Spanish Slug (*Arion vulgaris*) are applicable against most other slugs, including the Yellow Cellar Slug as well (Turóci *et al.* 2020b).

References

Bachó 1952, Beczner *et al.* 1970, Bognár & Huzián 1974, Kerney *et al.* 1979, Pintér 1973, 1974, 1984, Pintér & Suara 2004, Pintér *et al.* 1979, Rotarides 1927, 1928, 1931, Soós 1943, Szabó & Szabó 1934, Rowson *et al.* 2014, Turóci & Páll-Gergely 2020, Turóci *et al.* 2020a, Turóci *et al.* 2020b, Wagner 1936, Welter-Schultes 2012, Wiktor 1996, Wiktor & Szigethy 1983, Wiktor *et al.* 2000

Ágnes Turóci & Barna Páll-Gergely

Black-headed Slug

Krynickillus melanocephalus Kaleniczenko, 1851

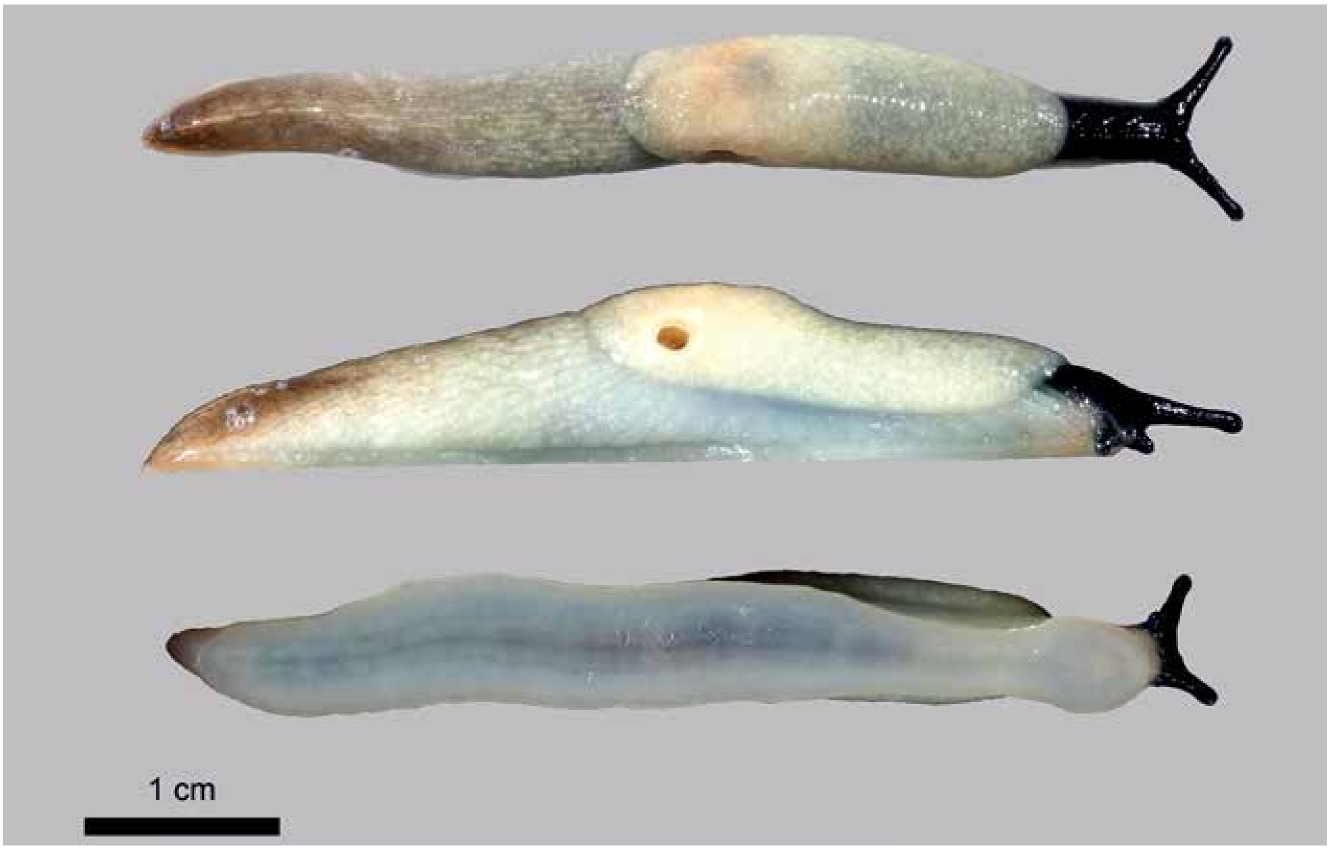
Native range

The Black-headed Slug is native to the Crimea, Anatolia, and the Caucasus (Northeastern Turkey, Northern Iran). It inhabits lowland and subalpine mixed forests, and often occurs near springs. It usually hides under bark or leaves (Wiktor 2000, Welter-Schultes 2012).

Introduction to Europe and Hungary

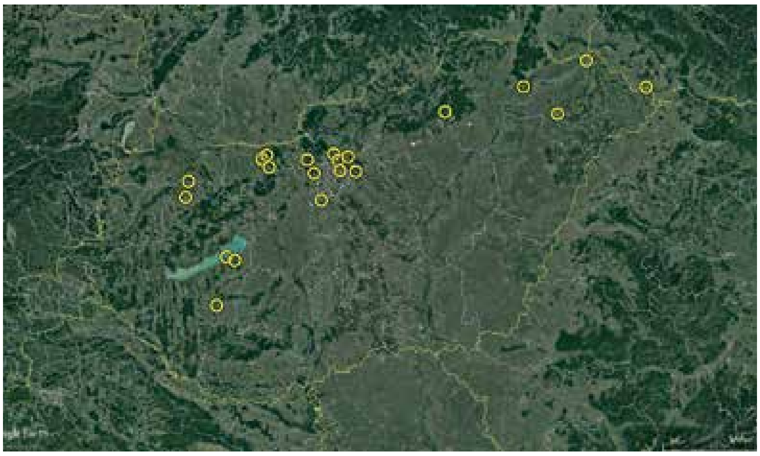
In the last decades, it appeared in Belarus (Ostrovskiy 2017), Germany (Bößneck & Feldmann 2003), Latvia (Dreijers *et al.* 2017), Lithuania (Stalažs *et al.* 2017), Russia (Likharev & Viktor 1980, Sysoev & Schileyko 2009), Sweden (Proschwitz 2020), and Ukraine (Korol & Kornyushin 2002, Sverlova & Son 2006).

Its first specimen was observed in Hungary in October 2019 in Tata, near Lake Öreg (Turóci *et al.* 2020a). After this, we used social media to collect more data, similarly to the instance of the Keeled Slug (*Tandonia kusceri*). We briefly presented the Black-headed Slug with photos in a Facebook post, and made an appeal to the public to report its occurrences (Turóci *et al.* 2020a). As a result, ca. 20 sites



© Ágnes Turóci

External morphology of the black-headed slug



Distribution of the Black-headed Slug in Hungary

were reported until November 2021 (different streets of the same settlement were considered the same site), mainly from the north and the Transdanubia region, and from the area of Budapest. It is interesting that the Facebook post concerning the keeled slug was shared about fifty times within a week, while the post of the Black-headed Slug had about 560 shares. We do not know the reason for this difference, perhaps it is because the Black-headed Slug is such a pretty creature. Despite the difference in shares, we received approximately the same amount of data about both species. This indicates that the Black-headed Slug is probably less common.

The exact time of its introduction to Hungary is uncertain, similarly to other recently introduced slug species. This is due to the lack of research on slugs in Hungary. By taking a look at its European distribution, the sporadic quality of its occurrence sites is conspicuous, indicating that the species spreads to isolated spots on the continent. Human assistance is probably the most important factor in its dispersal, both at its first introduction and also its later expansion. The species can survive long journeys in the earth balls of plants, and is inadvertently introduced to an increasing number of locations.

Biology of the species

Extended live specimens of the Black-headed Slug are usually 4–4.5 cm long (Wiktor 2000), but may reach 6 cm as well (Turóci *et al.* 2020a). Its appearance is typical, its dirty white or bluish grey body combined with a jet-black head and nape make it easy to recognise. The mantle is shorter than one third of the body. Its sole is light, often semitransparent, with the internal organs showing through. Its mucus is transparent and watery.

Like most slugs, it feeds on live and decaying plants. Information about its life cycle is scarce. Mature, adult specimens appear in autumn. Most records of the species were made in October and November, and if the weather is mild, it is active till the end of November.

Ecological conditions in Hungary

It inhabits lowland and subalpine forests and shrublands. Although it is not common in towns or strongly urbanised areas, it is mostly recorded in cultivated forests with disturbed vegetation (e.g. Lake Öreg in Tata, Budakeszi Wildlife Park, disturbed beech forest in Felsőtárkány), and in gardens (von Proschwitz 2020, Turóci *et al.* 2020a).

Ecological concern

We have no information about any outbreaks so far, but experience shows that where one specimen was found, there are probably others as well. The most abundant population so far was observed in the Budakeszi Wildlife Park, where more than 50 specimens were found under leaf litter in a relatively small, definitely marked area (under an oak).

We do not know about the ecological damage it may cause. It may exclude native slug species if it becomes locally abundant.

Economic impact

Although some slug species are significant pests, the majority do not damage vegetable gardens or crops. Some reports are, however, available on damage caused by the Black-headed Slug. It was observed in Latvia that it likes to feed on the fruits of cucurbits (Cucurbitaceae) (Dreijers *et al.* 2017). No damage has been reported from Hungary yet.

Potential control measures

As there are no reports of its damage, the Black-headed Slug probably does not cause problems to garden owners. The treatments suggested against the Spanish Slug (*Arion vulgaris*) are applicable against most other slugs as well (Turóci *et al.* 2020b).

References

Bößneck & Feldmann 2003, Dreijers *et al.* 2017, Likharev & Viktor 1980, Korol & Kornyushin 2002, Ostrovskiy 2017, Proschwitz 2020, Stalažs 2017, Sverlova & Son 2006, Sysoev & Schileyko 2009, Turóci *et al.* 2002a, 2020b, Welter-Schultes 2012, Wiktor 2000

Ágnes Turóci & Barna Páll-Gergely

Spanish Slug

Arion vulgaris Moquin-Tandon, 1855

Native range

Moquin-Tandon (1855) did not give the exact collecting site in the original description of the species, only generalities: it occurs in France, especially in the northern and central regions. On the basis of certain molecular analyses, it had been suggested that the species is native to Central Europe (Pfenninger *et al.* 2014), but this was later disproven (Zemanova *et al.* 2016). According to current scientific consensus, the Spanish Slug originates from Southwestern France. It expanded its range and reached Central and Eastern Europe, and is still spreading aggressively through Europe (Welter-Schultes 2012, Zemanova *et al.* 2016, Zając *et al.* 2019).

© Ágnes Turóci

External morphology of the Spanish slug

Expansion in Europe and introduction to Hungary

According to literary data, the expansion of the Spanish Slug was really spectacular in Europe in the last 50 years. Its dispersal can be traced in detail, as we have records, among others, from Spain (Chevallier 1972), Germany (Schmid 1970), the Netherlands (de Winter 1989), Poland (Kozlowski 2007), Italy (van Regteren Altena 1971), Denmark, Norway and Sweden (von Proschwitz 1992, von Proschwitz & Winge 1994), Slovakia (Čejka *et al.* 2006), Czechia (Juřičková 1995, Dvořák & Horsák 2003), Bulgaria (Kerney *et al.* 1979), Austria (Fischer & Reischütz 1998), and Romania (Păpureanu *et al.* 2014).

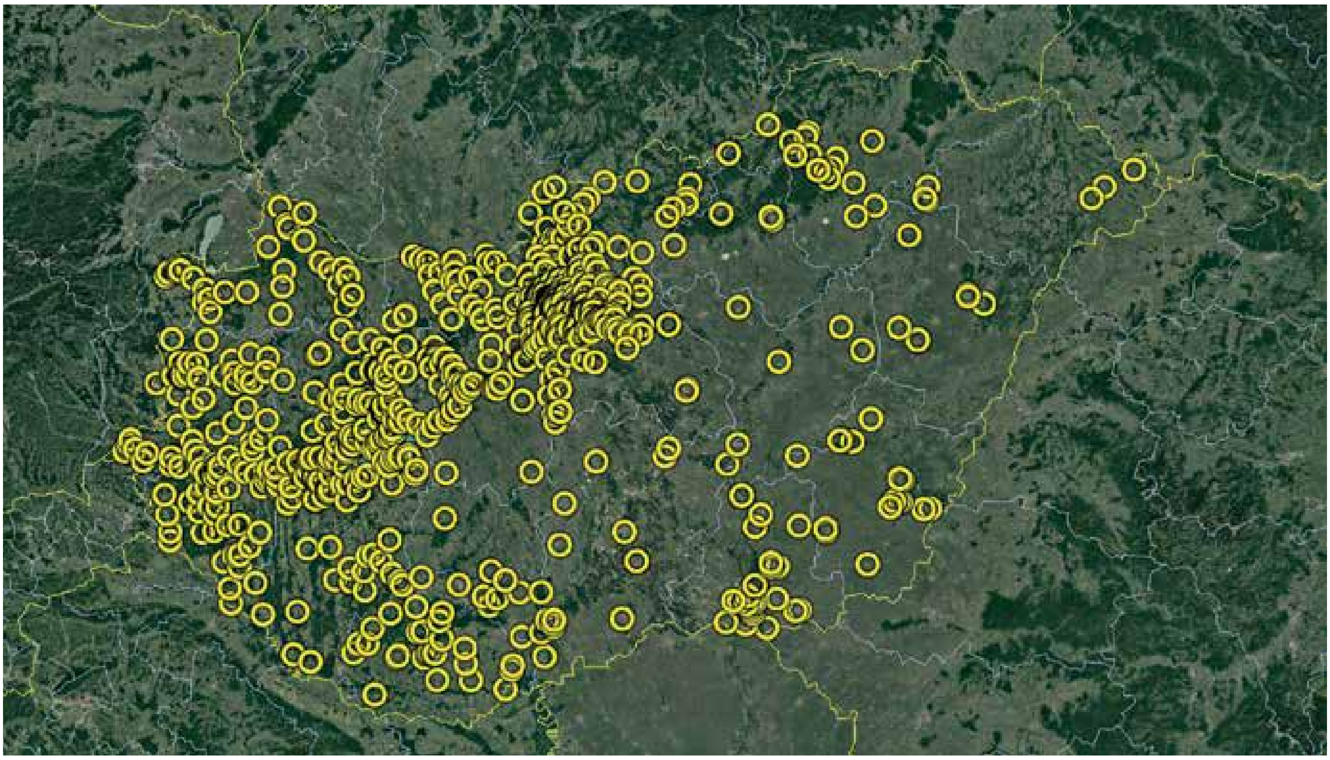
It was first recorded in Hungary in the northwestern region of the country. The first specimen was collected on the bank of the Ikva stream on 29 June 1985. Later, András Varga identified it by dissection as the Spanish Slug – *Arion lusitanicus*, according to the nomenclature of the time (Varga 1986). The species was presumably already present in the country earlier, but it was not noticed. In autumn 1987, enormous masses of it invaded the city of Szombathely. An outbreak such as this, however, can only happen after years of latency. From its first appearance, it has been spreading continuously, and in rainy years, it may become highly abundant in the Transdanubia region. Today, it occurs practically everywhere in the country.

The determination of the precise area of origin of the Spanish Slug was complicated by its having been misidentified for a long time, referred to as *Arion lusitanicus* in scientific publications (van Regteren Altena *et al.* 1955). At the end of the 1990s, it became clear that *Arion lusitanicus* (Portuguese slug) is an endemic species which only occurs in a small area in Portugal, and the species spreading aggressively in Central Europe is *Arion vulgaris*. The "Spanish" species specifier in its English and Hungarian names originates from the incorrect translation of the name *Arion lusitanicus*, which was used for decades. "Spanish Slug" became so fixed in both academic and public circles in Hungary that despite the precise identification of the species, and the "changing" of its scientific name (to *Arion vulgaris*), it remained "Spanish Slug" in Hungary, too.

Biology of the species

The Spanish Slug is one of the large *Arion* species, the length of the body is 8–14 cm when extended. Its colour varies from bright orange to chocolate brown, so it is not enough to reliably identify the species. The sole is light or grey, the mucus light or yellowish.

Similarly to most slugs, the Spanish Slug also feeds on live or decaying plants. It is not choosy, various plants of vegetable and flower gardens form a part of its diet. According to the accounts of garden owners, it can chew all the cultivated plants in an area



Distribution of the Spanish Slug in Hungary when it becomes abundant (Turóci *et al.* 2020). It even eats dog mess, dead conspecifics, and earthworms (Lumbricidae) it finds aboveground.

It has an annual life cycle, but some large specimens may overwinter (Zając *et al.* 2017). They mate in July, but the mating season, under favourable weather conditions, may last till November. The actual mating season of populations varies by region, and even within a region, it may be different every year, depending on the weather (Kozłowski & Kozłowski 2000). Oviposition peaks in August and September. A specimen lays up to 400–500 eggs at a time, and small slugs hatch usually after 3–5 weeks.

© András Varga

© András Varga

Ecological conditions in Hungary

The Spanish Slug, similarly to related species, occurs in humid environments, mainly in grassy areas and broadleaf forests. Originally, it was probably a forest dwelling species (Wiktor 1996). In its non-native range, it appears in parks and gardens (Kozłowski *et al.* 2008), but also in cemeteries, cultivated landscapes, and other habitats strongly affected by human activity (Wiktor 1996). It has a wide ecological tolerance, and frequently becomes highly abundant.

Human assisted dispersal is probably the most important factor of its expansion. It covers long distances in horticultural transports (Dreijers *et al.* 2013, Zając *et al.* 2017).

Its populations in Hungary were surveyed in 2005, 2010, and 2018. In the first two cases, data collection was conducted mainly via mailing lists, e-mails, appeals, and personal requests. The survey of 2018 was conducted by way of an online form. The purpose of the data collection was to find out how many Spanish Slugs the respondents have seen and where, and from those who own gardens, also to obtain information about whether the species caused them any damage, and what control measures they have taken, if any (Turóci *et al.* 2020). According to the results of the survey, the Spanish Slug occurs throughout Hungary, although it is less common on the Great Plain. The amount of records grows with the passing of time. The species was altogether recorded 758 times in 2005 and 2010, while it had 853 records in 2018. Data collection has not stopped, the distribution map of the species is continuously updated according to our own observations, and information collected on social media. There are some interesting descriptions among the reports received in 2005 and 2010 worth mentioning here. These reports indicate what this species is capable of, even in a short time. A garden owner in Mezőszilas who kept statistics from the middle of May till September 2008 collected over 10 000 specimens. Great masses of the species had to be killed off in Letenye in 2006, the highest number of specimens killed in a day was over 1800, but over 1000 a day were killed on several occasions. There was a major invasion in Szenta in 2010, where public workers had to be ordered to kill them. There was also some positive feedback, but only from anglers, according to whom it is a good bait for Carp (*Cyprinus carpio*), Tench (*Tinca tinca*), and Chub (*Squalius cephalus*).

Ecological concern

Although most of our data are from garden owners, according to our own collecting trips, and the observations of nature conservationists and hikers, the Spanish Slug has not only invaded urbanised habitats highly degraded by humans, but also successfully colonised near natural areas (e.g. national parks, forests less influenced by human activity). It reached the centre of the protected Kis-Balaton with the flotsam of the River Zala (A. Varga).

Due to its wide ecological tolerance range, annual life cycle (every generation reproduces within a year from hatching), its success in colonising habitats, and its mass proliferation in certain (mainly rainy) periods, it could potentially exclude native slug species (Zemanova *et al.* 2016). During our earlier surveys, we received accounts about native slugs becoming rarer in gardens since the appearance of the Spanish Slug.

Economic impact

Slugs usually live a hidden life and avoid human contact, so most of them do not cause severe economic problems. However, there are several invasive species among them, and most of these are considered agricultural and horticultural pests (Wiktor 1987, 1996, 2000, Douglas & Tooker 2012, Kozłowski 2012, Rowson *et al.* 2014, Zając *et al.* 2017, 2019). Of these, the Spanish Slug is one of the worst, earning a place on the list of the 100 worst invasive species in Europe (Rabitsch 2009).

From those filling in the form for the 2018 survey, 86% experienced some kind of damage caused by the Spanish slug, on a great variety of vegetable garden plants, e.g. Pea (*Pisum sativum*), French Bean (*Phaseolus vulgaris*), Strawberry (*Fragaria × ananassa*), Cabbage (*Brassica oleracea*), Lettuce (*Lactuca sativa*), Tomato (*Lycopersicon esculentum*), the fruits of cucurbits (Cucurbitaceae), and on various ornamental plants (Turóci *et al.* 2020). According to the data of the Hungarian Central Statistical Office, some kind of agricultural activity is conducted in nearly 1.1 million Hungarian households. In a half of these, so in approximately half a million households, vegetables or ornamental plants suitable for the Spanish Slug were probably planted. Assuming that every such garden experienced some degree of damage, and calculating with only 2000 HUF damage per garden, the sum would add up to 1 billion HUF of damage (Turóci *et al.* 2020).

Potential control measures

There are numerous ways to control this species. The most frequently used are physical eradication, desiccants (ash, lime etc.), slug pellets, and beer traps (Turóci *et al.* 2020). Physical eradication methods are very effective and cheap, and scalding is the quickest solution of all. However, these methods require intensive contact with the slugs, therefore many people are reluctant to apply them. Some chemical treatments damage the environment (e.g. salting), and also cause unnecessary suffering to the animals. Slug pellets containing metaldehyde kill slugs efficiently, but they are not advisable to those with small children or dogs. Because of a change of the law, their application is further restricted: from August 2021, only those with a qualification in plant protection are allowed to buy chemicals containing metaldehyde. It is also important to keep in mind that the granules may kill other, possibly protected slug species as well.

As a form of biological control, the Indian Runner Duck (*Anas platyrhynchos* f. *domestica*) is very effective. It is able to regulate the slug population permanently. The only problem is that its keeping takes infrastructure, time, and energy. A Parasitic Nematode (*Phasmarhabditis hermaphrodita*) has also long been known, which kills attacked slugs specifically (Rae *et al.* 2007, Kozłowski *et al.* 2014), and there are also experiments examining the possibility of applying predatory ground beetles (Carabidae) (Symondson 1994, Pianezzola *et al.* 2013).

References

Čejka *et al.* 2006, Chevallier 1972, Douglas & Tooker 2012, Dreijers *et al.* 2013, Dvořák & Horsák 2003, Fischer & Reischütz 1998, Juřičková 1995, Kerney *et al.* 1979, Kozłowski 2007, 2012, Kozłowski & Kozłowski 2000, Kozłowski *et al.* 2008, 2014, Moquin-Tandon 1855, Păpureanu *et al.* 2014, Pfenninger *et al.* 2014, Pianezzola *et al.* 2013, von Proschwitz 1992, von Proschwitz & Winge 1994, Rabitsch 2009, Rae *et al.* 2007, van Regteren Altena 1971, van Regteren Altena *et al.* 1955, Rowson *et al.* 2014, Schmid 1970, Symondson 1994, Turóci *et al.* 2020, Varga 1986, Welter-Schultes 2012, Wiktor 1987, 1996, 2000, de Winter 1989, Zając *et al.* 2017, 2019, Zemanova *et al.* 2016

Ágnes Turóci & András Varga

Girdled Snail

Hygromia cinctella (Draparnaud, 1801)

Native range

The Girdled Snail is a typical Mediterranean species. Its native range encompasses the Mediterranean, from Dalmatia to Southeastern France. Its recent expansion in Europe probably started in the first decades of the twentieth century, when it was accidentally introduced to many countries with transports of various cultivated plants, so the boundaries of its original range are difficult to reconstruct today.

Introduction to Hungary

The first Hungarian occurrences of this species were reported by Wagner (1938, 1939) and Visnya & Wagner (1938). János Wagner discovered isolated populations in Zugliget, part of Budapest, in 1936, and in Hűvösvölgy, also part of Budapest, in 1937. The first specimens may have been introduced inadvertently by a garden owner who brought some plants from somewhere around Fiume (today Rijeka). Wagner conducted a thorough anatomical examination of the snail, and found its genitals perfectly identical with those of samples brought directly from the Istria (Wagner 1940). Petró (1984) and Perjési (1985) explored the exact distribution of the species in the capital and its neighbourhood. For a long time it seemed that the species only colonised this region. Petró (1984) also recorded it in Kaposvár (in cemeteries and parks), and supported Wagner's observation, i.e. that the Girdled Snail is introduced with plants and becomes abundant rapidly. Over the last decades, the species appeared at

© Tamás Deli

an increasing number of locations, and today it is probably spread throughout the country. It is common in Budapest. Live specimens or empty shells can be collected practically anywhere on the Buda side. The map catalogue of Hungarian molluscs (Pintér & Suara 2004) already listed numerous occurrence sites, even though data collection for this volume was finished in the early 1990s. The leaves of bushes are literally teeming with it in the garden of the Felsőtárkány Visitor Centre of the Bükk National Park, where members of the Malacological Society regularly gather. Its photos have been posted to a group about animal identification on Facebook from the following locations: Balatonalmádi, Káptalanfüred, by the Szinva creek, Kecskemét, Ferenc Liszt International Airport. This clearly demonstrates that it is abundant enough to attract public attention.

The revitalisation of the park of the Mátra Museum in Gyöngyös was completed in 2007. Before this, the Girdled Snail had not been recorded at this location, but it found its way here clinging to some of the innumerable shrubs and herbs planted in the gardens, supplied by various garden stores. In the course of a few years, it became so abundant that after rain its masses cover the pathways, causing a slipping risk to visitors.

The European expansion of the Girdled Snail started in the 1930s and is still in progress today. It is widespread in Northern France and Great Britain, and has been known from Germany and the Netherlands since the 1990s. It presumably occurs in suitable habitats (cemeteries, gardens, lush parks, stream valleys by settlements etc.) all over Europe. As these sites are scarcely studied by malacologists, only incidental observations increase the number of its known habitats (Welter-Schultes 2012).

Biology of the species

In the vegetation period, in feeds exclusively on plants (herbivorous, polyphagous species). It may also be active in the winter, under leaf litter in sites with southern exposure. In this period, it eats decaying plant material. In Budapest, in February 1981, crawling specimens with active metabolism were observed at −8°C, under a 5 cm thick layer of leaf litter (Petró 1984). The species has a wide ecological tolerance range and high plasticity. These ensure its survival and rapid proliferation in alien environments. Its eggs are very resistant, contributing to the success of its dispersal assisted by horticultural activity.

Ecological conditions in Hungary

It typically occurs in cemeteries, disturbed habitats of inhabited areas, and low shrublands. It shows a definite preference for densely woven creeping ornamental plants. When the weather is cool, it is active during the day, and can be readily observed on leaves. It can become abundant on the ground, under dense vegetation, in wet litter, or among small rocks. It does not leave the shelter of dense vegetation on dry, sunny days.

It is mostly active during the night, when air humidity is at its highest. In a fine grizzle, gliding specimens can be also observed everywhere during the day, from paved sidewalks to the walls of houses. When the weather gets warmer, they attach to flat surfaces (walls, fences), become inactive, and only move when it is raining again, or after dark. The species is extraordinarily mobile, it can cover several meters in a night.

It frequently reaches natural habitats, spreading from settlements along densely vegetated valleys of watercourses. In sudden floods after downpours, live specimens may be washed away with the driftwood, but their occurrence in natural forests, apart from the dense vegetation near watercourses, has not been observed in Hungary yet. A single gravid specimen is enough to establish a new population, which may become abundant in a few years.

Ecological concern

As this species prefers disturbed habitats and exotic plants, it is not likely to pose a severe threat to native species, either directly or as a competitor. It is difficult to predict whether its expansion will have negative effects, but it seems likely that this species does not cause particular damage in its new environments (Walton 2017).

Economic impact

The introduction of non-native species is always a potential threat both to native species and agriculture. In the case of the Girdled Snail, chances of a severe impact are relatively slight.

Potential control measures

As far as we know, the species does not cause any damage, so the application of control measures is not necessary.

References

Perjési 1985, Petró 1984, Pintér & Suara 2004, Visnya & Wagner 1938, Wagner 1938, 1939, 1940, Walton 2017, Welter-Schulte 2012

András Varga & Barna Páll-Gergely

Garden Snail

Cornu aspersum (O. F. Müller, 1774)

Native range

The Garden Snail is native to the Mediterranean. Based on molecular analyses, its genetic diversity is greatest in North Africa (Morocco and Tunisia), so this may be the source of its expansion towards Europe (the Iberian and the Apennine Peninsulas) in the Quaternary period. It probably dispersed in Southern Europe in the Holocene, at least partly due to human activities, as it was consumed and introduced to new habitats since ancient times (Yildirim *et al.* 2004, Welter-Schultes 2012, Scherpa *et al.* 2018).

Introduction to Hungary

Its occurrence was already detected in Vecsés and Tihany in the 1970s (Pintér *et al.* 1979). In the map catalogue of Hungarian molluscs (Pintér & Suara 2004), only four occurrences are mentioned (Érdliget, Pestszentlőrinc, Tihany, Vecsés) (note that although this volume was published in 2004, it is based on data collected until the early 1990s).

It seems that the Garden Snail started spreading rapidly after the democratic change, i.e. 1989-1990. László Drimmer conducted comprehensive surveys in Budapest in 1991 and 1992, mainly on the Buda side, and did not find a single specimen. A possible explanation is that in the turbulent years after the change, many people imported various helicid land snails from Southern Europe for the purpose of snail farming, but as the trade was not really working, many "breeding snails" were simply released (Páll-Gergely *et al.* 2019). We have learned from conversations with garden owners that no matter how much damage snails cause by chewing crops, no-one likes to kill large snails resembling the Roman Snail (*Helix pomatia*). They rather collect them, take them to nearby bushy areas, and set them free. This behaviour probably promoted the spreading of the species.

Currently, the species has been detected in about a dozen settlements, apart from Budapest and Pest County (Badacsonytördemic, Bakonyszombathely, Békéscsaba, Dad, Dunaföldvár, Eger, Gyöngyös, Hajdúsámson, Keszthely, Kőröshegy, Martonvásár, Mosonmagyaróvár, Nyíregyháza, Tihany), but it is most widespread and abundant in the capital and its neighbourhood, where it has been found at 150 locations so far. In Budapest, it occurs nearly everywhere, although it is more common in Pest than in Buda. The situation is reversed in the case of the Turkish Snail (*Helix lucorum*) (Páll-Gergely *et al.* 2019).

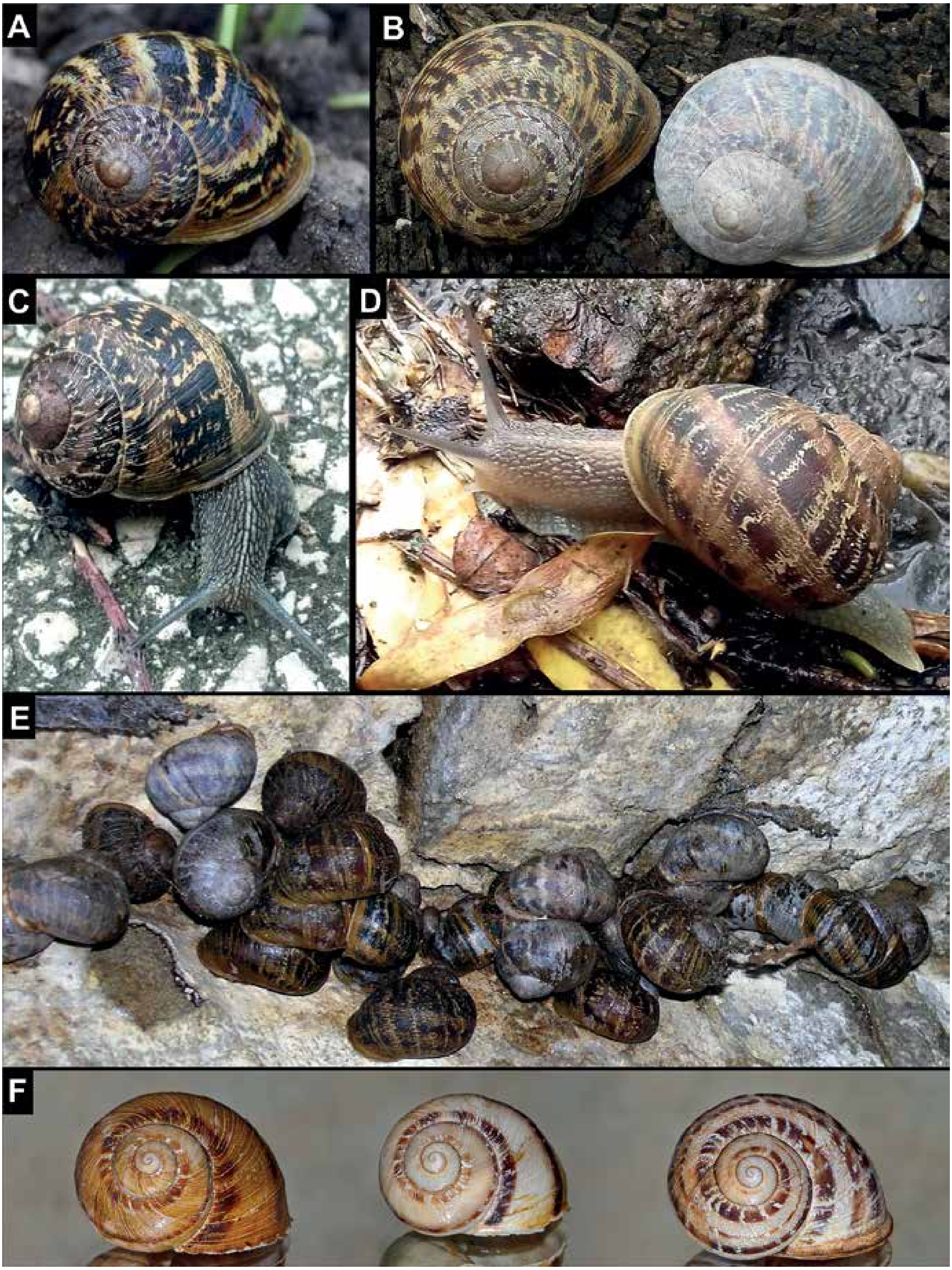
Biology of the species

The appearance of the species is extremely diverse, but it is easy to distinguish from similar native species of the genus *Helix*, as its shell is usually smaller and thinner, and carries the characteristic reticulated pattern. Its shape is also different: the last whorl is broader compared to the others than in native *Helix* species.

The Garden Snail has a wide ecological tolerance range. It occurs and may become abundant in shaded shrublands, open and closed forest, and also in gardens. It feeds on plants, and is regarded a vegetable garden pest in several countries. In spite of its Mediterranean origin, it is tolerant to freezing, it can bear temporary ice formation in 60% of its body (Ansart *et al.* 2001). In the long run, however, it needs a frost free spot to burrow, e.g. crevices in rocks, meter pits, or deep soil.

It lays 50–190 round eggs five to eight days after the mating, and small snails emerge in 15–30 days. Its breeding season lasts from May to October in Central Europe. Its average lifespan is about four years (Welter-Schultes 2012).

Its natural enemies are the same as those preying on similar native species, e.g. the northern white-breasted Hedgehog (*Erinaceus roumanicus*), thrushes (Turdidae), large ground beetles (Carabidae) etc.



Garden Snail. A: district XXII, street XXIII, Budapest (© Éva Süle); Budapest: Balatoni road – Baross street (© Nóra Békefi);
C: 12 Emília street (© Zsolt Gorli); D: 25 Kaszáló street (©Zoltán László); E: 30 Szélmalom street (meter pit) (©János Göncöl);
E: bank of the Szilas stream (©Bea Bauer)

Distribution of the Garden Snail in Hungary

Distribution of the Garden Snail in Budapest and its neighbourhood

Ecological conditions in Hungary

In Hungary, the Garden Snail mainly occurs in settlements, gardens, parks, hedgerows, so basically anywhere it can find a place for hiding and wintering. It is very common, at some locations even abundant in Budapest. It is less widespread in Buda than the Turkish Snail (*Helix lucorum*), but this probably has historical rather than climatic or habitat preference reasons, i.e. the Turkish snail probably started spreading earlier in Buda, while the Garden Snail in Pest, and their ranges are only beginning to overlap. So far, it seems that both species are able to tolerate the environmental conditions of Hungary, so their expansion seems unstoppable.

Another similar invasive snail, the Turkish Snail (*Helix lucorum*) has been observed to practically exclude the native Roman Snail (*H. pomatia*) from its habitats in the course of twelve years in Czechia (Doležal 2021). Based on this, it is reasonable to suspect that the Garden Snail is a competitor of the native, protected Roman snail, but it is difficult to draw conclusions with any certainty. This is partly due to the lack of reliable information on the abundance of the Roman snail before the arrival of the Garden Snail, and partly to the difficulty of defining the basis of their competition, as both species are generalists feeders. Surveying the quantitative relations of these species is in progress in several habitats in Budapest. This may shed some light on their competitive relations.

Ecological concern

The species mainly occurs in inhabited areas, its damage has not been reported from natural habitats yet. Theoretically, it may cause ecological damage by locally outcompeting the Roman Snail (*Helix pomatia*), and perhaps other protected snail species, e.g. the White-lipped Snail (*Cepaea hortensis*) or the Grove Snail (*C. nemoralis*) as well, but the significance of this effect is negligible and it is also likely to remain so, as the native species are widespread and abundant.

Economic impact

We consider the Garden Snail a vegetable garden pest, based on reports from many countries (Basinger 1931, Barker & Watts 2002). It is unknown, however, if damage caused by its chewing is greater than that of the indigenous species, e.g. the Roman Snail (*Helix pomatia*), White-lipped Snail (*Cepaea hortensis*), and Grove Snail (*C. nemoralis*). We collected the following "data" on its damage and abundance from garden owners in Budapest: *"it finished my plantain lilies in a night"*, *"they totally graze the vegetable beds during the night"*, or *"tomatoes, cucumbers, spinach, chard, everything. You cannot walk in the garden after rain, because they creep out of their burrows and crack under your feet"*.

Potential control measures

The quickest and most humane control method is to collect the snails and pour hot water on them, which kills them instantly. However, after consultation with several garden owners, it became evident that people simply pity snails, they do not want to kill them, so it is unrealistic to expect them to eradicate the species. Garden owners rather collect them and remove them to bushy sites, which effectively contributes to their dispersal.

Snail or slug pellets containing metaldehyde, usually applied against slugs (Limacidae, Arionidae, Agriolimacidae) kill every gastropod, but the dead, slimy carcasses of the snails are "disgusting", so many people avoid such chemicals. Those with pets or small children also refrain from using these substances.

References

Ansart *et el.* 2001, Barker & Watts 2002, Basinger 1931, Doležal 2021, Páll-Gergely *et al.* 2019, Pintér *et al,* 1979, Pintér & Suara 2004, Sherpa *et al.* 2018, Welter-Schultes 2012, Yildirim *et al.* 2004

Barna Páll-Gergely

Turkish Snail

Helix lucorum Linnaeus, 1758

Native range

The original distribution area of the Turkish Snail encompasses Asia Minor, the area of the Caucasus till Northwestern Iran, and probably also the southern and western regions of the Balkan Peninsula (Neubert 2014, Korábek *et al.* 2018). The populations in France and Italy were presumably introduced by the Romans for gastronomical purposes (Yildirim *et al.* 2004, Neubert 2014). Populations in Turkey show the highest degree of morphological diversity, ranging from specimens nearly as large as a human fist to much smaller ones with flat shells. Genetic variation is also highest in Turkey (Korábek *et al.* 2018). Besides its English name, the French common name (*escargot turc*) also refers to Turkey.

Introduction to Europe and Hungary

The species was introduced to Austria, Czechia, Spain, Russia (Moscow), Slovakia, and Ukraine (Fischer *et al.* 2008, Quiñonero Salgado *et al.* 2010, Peltanová *et al.* 2012, Balashov *et al.* 2013, Čejka & Čačaný 2014, Egorov 2017). The existence of the Moscow population clearly demonstrates that the species, contrary to prior notions, can survive harsh winters.

Its first Hungarian record was documented by Varga (1995), by surveying the introduction and establishment of a Turkish Snail from Bulgaria for ten years in a garden in Kaposvár. Varga (2010) later summarised its Hungarian occurrences, from Budapest (Jókai Garden), Fót, Kecskemét, Gyöngyöshalász, and Vecsés. In the course of a survey started in 2019 and conducted with the "citizen science" method, i.e. the active participation of the public, we also received occurrence data from Lajosmizse, Hetényegyháza, Balatonvilágos, and Ajka-Podragkút (Páll-Gergely *et al.* 2019). Nearly 70 records were provided from Budapest (mainly the Buda side) and the agglomeration until November 2021.

Similarly to the Garden Snail (*Cornu aspersum*), the rapid expansion of the Turkish Snail also started after the democratic change in Hungary (1989–1990). László Drimmer did not detect the species during his survey conducted in Budapest in 1991 and 1992, even though his sampling was most intensive in Buda, where the species is today widespread. Information on the means of its introduction is scarce, but it presumably has something to do with the special interest in snails after the democratic change (for details see Garden snail) (Varga 1995, Páll-Gergely *et al.* 2019).

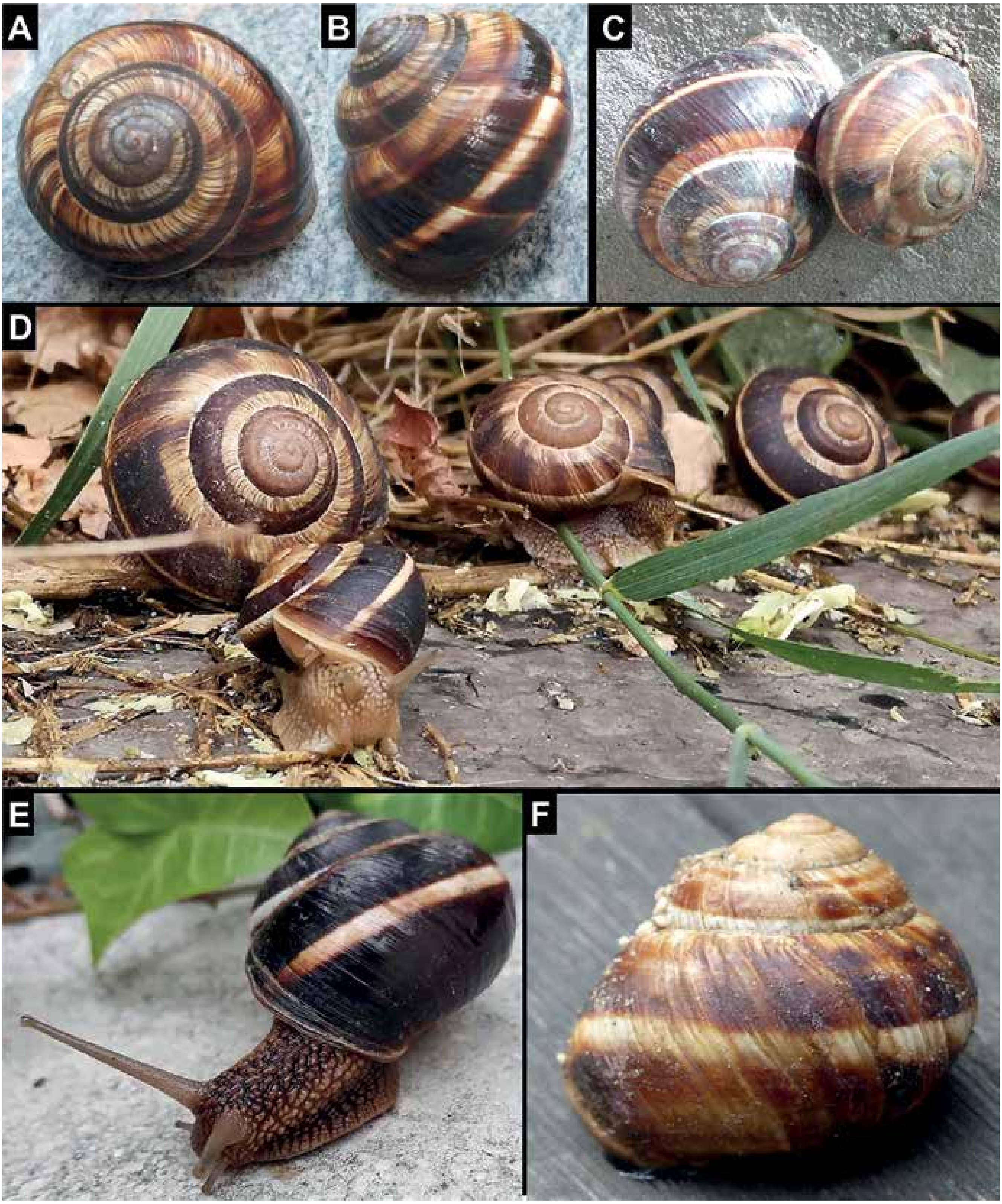
Biology of the species

The Turkish Snail is the size of the Roman Snail (*Helix pomatia*), but its shell is typically more flattened. The shell is basically darker than that of the Roman snail, it is usually chocolate brown. The white spiral stripe along the middle of the whorl, most conspicuous on the last whorl, forms a stronger contrast with the background than in the case of the Roman snail. The body of live specimens is darker, a deeper brown.

It is a species with a wide tolerance range. In its native range, it prefers not exceedingly dry shrublands, open steppe-like habitats, the base of cliffs, open woodlands, and gardens (Welter-Schultes 2012). In Turkey and in Hungary, it can often be observed on the walls of houses and cliffs, several metres high, which is not characteristic to either the Roman snail or the Garden Snail (*Cornu aspersum*). In Hungary, it mainly occurs in gardens and dense hedgerows along roads.

It is a herbivorous species, which may be considered a vegetable garden pest, just like other large helicids.

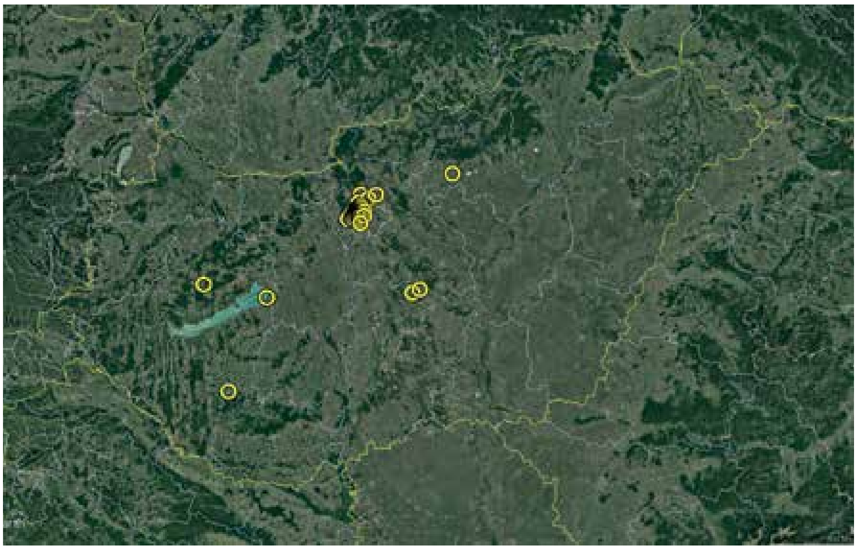
Little specific information is available on its natural enemies, but they are probably the same as those preying on the native Roman Snail: northern white-breasted hedgehog (*Erinaceus roumanicus*), thrushes (Turdidae), large ground beetles (Carabidae) etc.



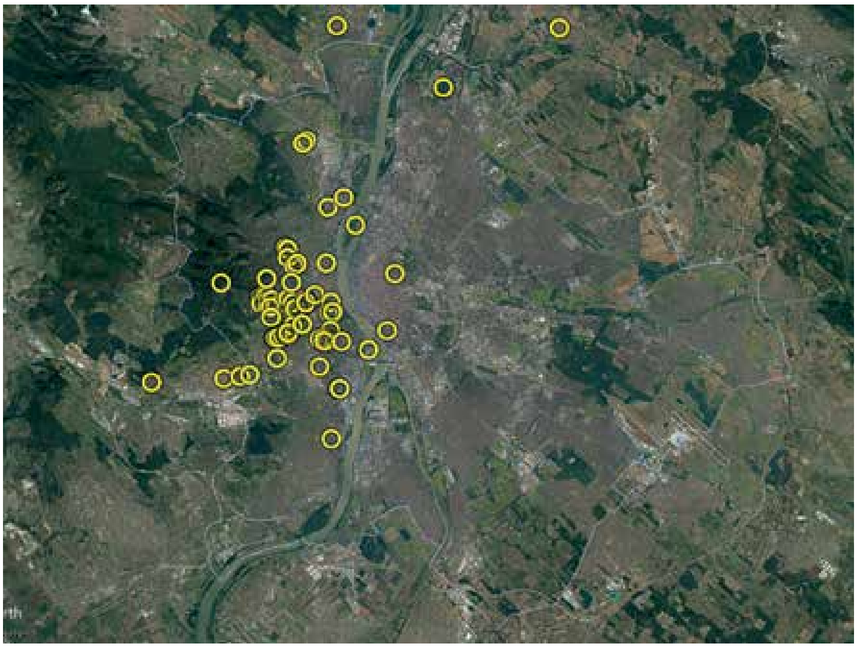
Turkish Snail. A–B: Ajka-Padragkút, south-southeastern border of the village; C: crossing of Csorna street and Mártonlak street, Budapest (© Balázs Attila Farkas); D: crossing of Fehérvári road and Andor street, Budapest (© Krisztina Nemes); E: Mechwart grove, Budapest (© Zsolt Málinger); F: Apor Vilmos square, Budapest (© Andor Derzsi Elekes)

Ecological conditions in Hungary

The Turkish Snail occurs in Hungary only sporadically apart from the capital, where it is common, at some localities even abundant on the Buda side. It mainly occurs in shrublands and gardens, and glides over 3 m high on the walls of houses.



Distribution of the Turkish Snail in Hungary



Distribution of the Turkish Snail in Budapest and its neighbourhood

According to research, the Turkish Snail practically excluded the native Roman Snail (*Helix pomatia*) from a habitat in Czechia in 12 years (Doležal 2021). It is also obvious that in numerous habitats in Buda, only the Turkish Snail occurs, while the Roman snail is either absent or its populations are small. Unfortunately, no exact data are available on the abundance of the Roman snail in these areas before the invasion of the Turkish Snail, but the invasive species presumably did replace the native one in some of its habitats.

Currently, it seems that although both invasive helicid species, i.e. the Garden Snail (*Cornu aspersum*) and the Turkish Snail were introduced to Budapest at about the same time, the garden snail is much more widespread and successful. It will be interesting to observe the quantitative changes in the populations of the native Roman snail and the two alien species in the coming decades.

Ecological concern

As the Turkish Snail mainly occurs in settlements, it cannot be considered an invasive species threatening near-natural habitats. Although it may replace the native Roman snail (*Helix pomatia*) at some localities, but as the export of snails for culinary purposes diminished, the latter is no longer endangered. Its entire Hungarian population is not threatened by the presence of either of these two invasive snail species.

Economic impact

The Turkish Snail can be regarded a vegetable garden pest, as it is also herbivorous, like other snail species of similar size. It seems that it will remain less abundant than the garden snail (*Cornu aspersum*), so theoretically, it should cause less damage by its feeding. It is also less studied than the garden snail. We received the following accounts from garden owners in Budapest: *"they crawl all over the road when it is rainy, I collect 30–40 of them in my garden every time, they eat the painted nettle and the signet marigold"*; *"they destroyed the hollyhock in my garden"*.

Potential control measures

Treatments suggested against the garden snail (*Cornu aspersum*) are applicable. It is pointless to discuss its eradication, as most people will not kill large snails.

References

Balashov *et al.* 2013, Čejka & Čačaný 2014, Doležal 2021, Egorov 2017, Fischer *et al.* 2008, Korábek *et al.* 2018, Neubert 2014, Páll-Gergely *et al.* 2019, Peltanová *et al.* 2012, Quiñonero Salgado *et al.* 2010, Yildirim *et al.* 2004, Varga 1995, Welter-Schultes 2012

Barna Páll-Gergely

Hiding aliens – 32 land snail species

Populations of some non-indigenous species almost explode, and keep colonizing new areas with an incredible speed. These are the rapidly spreading, invasive species. Besides them, several other land snail species are known, which arrive to Hungary, and instead of spreading, establish one or only a few localized populations without showing signs of becoming invasive. Sometimes they remain silent (i.e. do not spread further), and sometimes, from one day to another, can be found in remote places. We know altogether 32 such species. These are the ‚hiding aliens', some of which can become invasive conquering large geographic areas. Due to the lack of focussed research, we do not know whether they can cause irreversible processes in the ecosystems in which they arrive. Here we aimed to present a complete list. Therefore, following a systematic order, we list all those land snail species.

Round-mouthed Snail

Pomatias elegans (O. F. Müller, 1774)

Eastern Round-mouthed Snail

Pomatias rivularis (Eichwald, 1829)

Both species are protected by the law in Hungary due to the small number of their known localities. In face of this, both species occur in degraded, synanthropic habitats, which suggests that they have been spreading via human transportation.

Similarly to all terrestrial operculate species, these two species as well show no signs of becoming invasive, even if the population size and density is large at some of their populations (vicinity of Bérbaltavár, Zákány, Tihany, Nagymányok and Szekszárd, see Majoros 1987, Uherkovich 2009, Páll-Gergely & Szentes 2010).

Besides those localities, empty shells of *Pomatias elegans* are found in the Danube-Tisza Interfluve and around the Lake Balaton, while *P. rivularis* is known in the soil of the Bátorliget Nature Reserve. Furthermore, the former species is known from a few Pleistocene sites (Krolopp 1983, Krolopp & Varga 1991).

These snails exclusively inhabit the upper layer of the soil, and it is probably that from their putative native area (in the north-western Balkans) they have been introduced with forest plantations at the beginning of the 20th century (Great Hungarian Plain, Szekszárd Hills). It is also possible, that monks have carried them as a food source to be consumed at fast, because there have been monasteries at several of the known localities of *Pomatias* species (Ócsa, Tihany), and it is known that monks have kept land snails as food source in monastery gardens. Analysis of mitochondrial genes by Fehér *et al.* (2009) revealed a rapid expansion of *P. rivularis* towards northwest, although the reasons of spreading were not investigated.

Nun Alopia

Alopia monacha (M. Kimakowicz, 1894)

Livid Alopia

Alopia livida bipalatalis (M. Kimakowicz, 1883)

Endemic taxa to the Southern Carpathians. Miklós Szekeres introduced the two subspecies from the Bucegi Mountains (Southern Carpathians) to the Bükk Mountains in Hungary in 1970. Investigations revealed that they are hybridizing with each other (Szekeres 1976). According to Kiss & Pintér (1983, 1985), the populations in the Bükk Mountains have gone extinct, and they have not been re-collected since their introduction. We have not found any specimens (not even empty shells) in June, 2019 (R. Farkas, B. Páll-Gergely & M. Szekeres). We note that *Alopia monacha* has been introduced in the Harz Mountains in Germany, and that population is doing well (Walther & Neiber 2012).

Mehadian Door Snail

Strigillaria rugicollis (Rossmässler, 1836)

Originally distributed in Romania in Mehadia in the vicinity of Băile Herculane, and it has possibly been introduced to Hungary with plants. The first specimens were found by Imre Fürjes in 1980 in a few gardens of Mt. Gellért in Budapest (Pintér & Varga 1981). Due to the lack of research it has been thought to be extinct, while in 2019 Dávid Murányi and Barna Páll-Gergely found this species in a neighbouring garden.

Giant African Land Snail

Lissachatina fulica (Bowdich, 1822)

Pink-lipped Agate Snail

Lissachatina immaculata (Lamarck, 1822)

Achatina and *Lissachatina* species are native to tropical areas of Africa. They are often kept as a pets in Hungary. These species are occasionally found in the nature, after their owners got bored of them and released them. A specimen of *Lissachatina fulica* was found in the castle of Eger (Varga *et al.* 2010), and Gábor Majoros has a live-collected specimen from the Margaret Island of Budapest. Páll-Gergely and Hanti (2019) reported *L. immaculata* from Székesfehérvár. *Lissachatina fulica* is a real disaster in the tropics. However, there is not information about its (and of its relatives') overwintering in the temperate region.

Graceful Awlsnail

Allopeas gracile (T. Hutton, 1834)

Tropical snail species, which lives in the botanical garden of the Eötvös Loránd University (‚Füvészkert') (Gábor Majoros).

Spike Awlsnail

Allopeas clavulinum (Potiez & Michaud, 1838)

This species is indigenous in islands of the Pacific Ocean. It was reported in the palm house and the horticultural centre of the Budapest Zoo (Pintér & Suara 2004, Fehér & Gubányi 2001). According to collection data, it is abundant there. The first specimens were identified by the well-known Africa-expert malacologist Bernard Verdcourt under the name *Lamellaxis mauritianus* (see Pintér 1984).

Dwarf Awlsnail

Opeas hannense (Rang, 1831)

Indigenous in the tropical and subtropical parts of Amerika, and has been introduced to several European countries including Hungary. It can reach large quantities in greenhouses. The map catalogues of Hungarian molluscs (Pintér *et al.* 1979, Pintér & Suara 2004, Fehér & Gubányi 2001) reported this species in the Arboretum of Vácrátót, in Galyatető in the Mátra Mountains, in Budapest (greenhouse in Sasad, Palm garden of the Zoo, and the Botanical Garden of the Eötvös Loránd University), and in Sződliget.

Southern Blind Snail

Cecilioides petitiana (Benoit, 1862)

The taxonomy of the genus *Cecilioides* is very problematic, because first, the snail shells contain few useful characters (one can mostly rely on the ratio of the aperture and the shell height), and second, it is very challenging to find living specimens for molecular study.

Two *Cecilioides* species have been reported from Hungary so far. Namely, *Cecilioides acicula*, which is widespread, and can often be found in soil samples around human settlements, and the much rarer *C. petitiana*. Welter-Schultes (2012) suggested that the latter species may be a synonym of *Cecilioides tumulorum* (and if true, *tumulorum* will be the accepted name since it was described earlier). *Cecilioides petitiana* is also synanthropic, and is mostly known from the Mediterranean. Therefore, it is likely (although not certainly) non-indigenous.

Smooth Coil

Lucilla singleyana (Pilsbry, 1889)

It is debated whether *Lucilla singleyana* is introduced or indigenous. Some authors claim it to be native, while other argue for the contrary. Domokos and Majoros (2008) presented a literature overview, although the question is still a matter of debates.

In Hungary it is known from several sites, e.g. Budapest, Kaposvár, Gyöngyös, and it is often found in river deposits, which can be transported by rivers from several hundred kilometres.

Minute Gem Snail

Hawaiia minuscula (A. Binney, 1841)

A North American species. In Europe it has been reported in greenhouses, for example, it lives in the garden of the University of Pécs (southern Hungary) and in the Füvészkert (botanical garden of the Eötvös Loránd University) (observations of Gábor Majoros). As a result of exchanging the soil in the greenhouses, shells of this species can be found outside of greenhouses, although it is not known whether it can overwinter. Domokos and Majoros (2008) gave an overview about the morphological differences of this species and *Lucilla singleyana*.

Subterranean Glass-snail

Mediterranea hydatina (Rossmässler, 1838)

Similarly to *Cecilioides petitiana*, this species also has a Mediterranean distribution type (Welter-Schultes 2012). It is mostly synanthropic, and maybe non-indigenous.

Caucasian Glass-snail

Oxychilus translucidus (Mortillet, 1853)

This species originates from eastern Turkey and norther Iran, its type locality being Trabzon in northeastern Turkey. Pintér and Podani (1979) reported from the greenhouse of the Vácrátót Botanical Garden, where it lives in large populations, according to collection data. The origin of Hungarian populations is unknown, although possible they arrived with plants. The map catalogues of Hungarian molluscs report this species from the Füvészkert (botanical garden of the Eötvös Loránd University) and the Botanical Garden of Vácrátót.

Greenhouse Hunter Snail

Gulella io Verdcourt, 1974

This species is most probably native to tropical Africa, although its original distribution is unknown. Its original description (Verdcourt, 1974) reports it from greenhouses in Bratislava and Great Britain, but it has also been reported from further European countries since (Welter-Schultes 2012). It also lives in the greenhouses of the Budapest Zoo and the Füvészkert (botanical garden of the Eötvös Loránd University) (observations of Gábor Majoros).

Quick Gloss

Zonitoides arboreus (Say, 1817)

Its first Hungarian occurrence was reported in the 1970's from the Arboretum of Vácrátót (Pintér 1974), to which it has probably been introduced by plants. This species originates from North America. The map catalogues of Hungarian molluscs (Pintér *et al.* 1979, Pintér & Suara 2004, Fehér & Gubányi 2001) report it from the Arboretum of Vácrátót, the botanical garden of the University of Pécs, Budapest (Sasad, palm garden of the Budapest Zoo, the Füvészkert, the greenhouse at Tengerszem street) Dunakeszi (greenhouse of the mechanical laboratory), and the Arboretum of Szarvas.

Bulb-Eating Slug

Tandonia rustica (Millet, 1843)

Indigenous in southern part of Central Europe, although it is probably also native in Southeastern England and southern Ireland (Welter-Schultes 2012; Rowson *et al.* 2014). Today it occurs from South- and Central-France to the southern Netherlands, in Germany at higher elevations, in the Appenines in Italy, and in Czechia. Isolated populations are also known in Romania and Poland (Western Sudetes) (Welter-Schultes 2012).

Only three localities are known in Hungary: Sanatorium of Esztergom, Kőszeg (Pintér & Suara 2004), and Győr (Szabadhegy, garden) (Fehér & Gubányi 2001). The paper of Fehér and Gubányi (2001) contains all lots deposited in the Natural History Museum. The specimens from Győr, which was collected by Lajos Ottó in 1984, was also examined by us, and the species identity was confirmed. The current owners of that very garden did not find that slug species recently. A local biology teacher, however, found another non-indigenous species, *Tandonia kusceri* in the close vicinity of the original site of *T. rustica*.

The sanatorium in Esztergom is closed for a few years, and it was not possible to enter to its garden. However, on the outer side of its fence also *T. kusceri* was found. Consequently, we have not found *T. rustica* in Hungary during the last years.

Longneck Fieldslug

Deroceras panormitanum (Lessona & Pollonera, 1882)

Gábor Majoros found a single specimen he identified as at *Deroceras panormitanum* in the deer farm in Bőszénfa. Pintér (1974) reports this species as *Deroceras caruanae*, which is a junior synonym of *D. panormitanum*).

Tramp Slug

Deroceras invadens Reise, Hutchinson, Schunack & Schlitt, 2011

Deroceras invadens was not distinguished from *Deroceras panormitanum* before the recognition and description of the latter species (Reise *et al.* 2011). Based on molecular genetic analysis and mating behaviour it turned out that *Deroceras panormitanum* is endemic to Malta and Sicily, the species spreading all across the world is *D. invadens*.

The native range of *D. invadens* is unknown, but it supposed to be somewhere in Southern Italy (Reise *et al.* 2011), which was confirmed by molecular genetic investigations (Hutchinson *et al.* 2020). This species is rapidly spreading in the entire world, and its main trigger is human transportation by means of horticultures and botanical gardens.

This species is already widespread in Western- and Central-Europe (from Great Britain to

Hungary), the USA, Australia, and probably also in New Zealand (Horsák *et al.* 2013, Hutchinson *et al.* 2014, Čejka *et al.* 2020). It was further reported in Argentina (Gutiérrez Gregoric *et al.* 2013). We have found it in several horticultures (where ornamental plants are grown and sold) in Budapest and the Füvészkert (botanical garden of the Eötvös Loránd University).

Reise *et al.* (2011) clarified that the closely related *Deroceras* species can only be distinguished from each other by careful anatomical examination. Therefore, it is very probably that the former records of *Deroceras panormitanum* and *D. caruanae* actually refer to *D. invadens*. Consequently, it is possible that *D. invadens* has been introduced to Hungary earlier than thought (Ágnes Turóci).

Three-band Garden Slug

Ambigolimax valentianus (A. Férussac, 1821)

This species is native to the Iberian Peninsula, and presumably to some parts of north-western Africa, such as Algeria, Tunisia and Morocco (Wiktor *et al.* 2000). It was reported from several countries in Western and Central Europe, Asia, and North and South America as well. However, Hutchinson *et al.* (2022) showed that distinguishing from related species is problematic based on outer morphology, and moreover, still difficult using traits of the inner (mostly genital) anatomy. Therefore, preceding literature data on the occurrence of this species are unreliable. First mention of this species from the Füvészkert (botanical garden of the Eötvös Loránd University) appeared under the name *Limax valentianus* by Flasarová & Flasar (1965). However, since this was a record without published illustrations and no voucher specimen was collected, this species disappeared from later Hungarian checklist. As a result of the collection activities of the last few years, this species was found in the Füvészkert and in several horticultures in Budapest.

Chocolate Arion

Arion rufus (Linnaeus, 1758)

Native to Western- and Central Europe and Northern Italy (Welter-Schultes 2012). It was reported from a single Hungarian size: Barcs, garden of Primary School no. 1. (Botka & Varga 1984, Pintér & Suara 2004). This species, although without exact locality, was also mentioned by the catalogue of Fehér & Gubányi (2001). Based on outer morphology it is impossible to distinguish it from related species, and it is still problematic by examining the genitalia. Its taxonomic status is also complex. It belongs to the *Arion ater* species group, in which all species can hybridize with the each other (Reise *et al.* 2020). The Spanish slug, *A. vulgaris* also belong to the same species complex. Hybrids of *A. vulgaris* and *A. rufus* show intermediate character states of their genitalia, and their hybrid origin can be proved by means of molecular methods (Reise *et al.* 2020). *Arion rufus* prefers less-disturbed forests, and where *A. vulgaris* appears, it usually outnumbers *A. rufus* (B. Rowson pers. comm.).

Heath Snail

Xerolenta obvia (Menke, 1828)

This species are present in Hungary since the Quaternary (Füköh 1995). However, human activity played a major role in the spreading of this species, and making it one of the most widespread and commonest species in Hungary (Pintér & Suara 2004). Namely, the formerly humid habitats have been dried up due to constructions of roads and railways.

Turkish Heath Snail

Xeropicta derbentina (Krynicki, 1836)

This species is known from the Caucasus Mountains to Southern France, although its area is not continuous. It is one of the most common land snail in Turkey (Welter-Schultes 2012). It lives in very dense populations near the National Institute for the Blind (Budapest, Hermina út 21.), and the overpass at Hungaria körút (Gábor Majoros).

One-banded Heath Snail

Candidula unifasciata (Poiret, 1801)

This species is native to the southwestern part of Europe. Its intentional or unintentional introduction to Hungary may have happened at the beginning of the 1930's. János Wagner (1933) described the specimens collected at the beginning of the 1930's in Hűvösvölgy (Budapest) as a species new to science (*Helicella soosiana*), which are considered as a valid subspecies by others as *Candidula unifasciata soosiana*. The map catalogues of Hungarian molluscs (Pintér *et al.* 1979, Pintér & Suara 2004, Fehér & Gubányi 2001) report this species from the following sites: Adyliget (Budenz street), Fekete-fej, Hűvösvölgy (Nagyhíd, Szépilona, Versec sor 1.), Dunaegyháza.

Wrinkled Snail

Xeroplexa intersecta (Poiret, 1801)

This western European species may have been unintentionally introduced to Hungary around the 2000's. It was collected at the campsite of Velence by Gábor Majoros (Varga 2006, Fehér & Gubányi 2001, Pintér & Suara 2004).

Neglected Vineyard Snail

Cernuella neglecta (Draparnaud, 1805)

This species is indigenous to Southwestern Europe, which has presumably been introduced to Hungary unintentionally. Pintér and Suara (2004) reports from the following Hungarian sites: Budapest (Újmátyásföld, Szilas-stream), Vezseny (bank of River Tisza), Dunakiliti (Helena, bank of River Duna). Based on observations made in 2021, it has a viable population along the Szilas Stream in Budapest (B. Bauer pers. comm.).

Alpine Banded Snail

Chilostoma cingulatum (Studer, 1820)

A viable population of this species was first reported from the ruins of the Buda Castle's church (Páll-Gergely *et al.* 2020b). We suspect that the Hungarian populations are most similar to one of the subspecies, *Ch. cingulatum baldense*, which is thought to be native to Monte Baldo, near the Lake Garda in northern Italy. This species has a narrow ecological tolerance, occurring exclusively on limestone-rich rock walls. Therefore, it is highly unlikely that it will become an invasive species.

White Garden Snail

Theba pisana (O. F. Müller, 1774)

This species has been listed by Domokos and Pelbárt (2011), which is a list of Hungarian names of all molluscs living in Hungary. Besides that list, we have no knowledge of the occurrence of that species in Hungary. *Theba pisana* is certainly a widespread species, which has been introduced to multiple countries. For example, it is an important pest species in Australia (Clarke *et al.* 2000, Bailey 2007).

Chocolate-band Snail

Eobania vermiculata (O. F. Müller, 1774)

An introduced Mediterranean species, which was first reported by Lajos Ottó from the thermal bath of Lipót in north-western Hungary (Ottó, 1980). The species has presumably gone extinct since. Páll-Gergely *et al.* (2020a) reported from Budapest, but the only living specimen was collected. It is possible, that similarly to other Mediterranean species, *E. vermiculata* can also survive in Hungary.

Milk Snail

Otala lactea (O. F. Müller, 1774)

A species with western Mediterranean distribution (Welter-Schultes 2012). It has been introduced to Hungary together with other large-bodied edible snails: Gábor Majoros found living specimens of *O. lactea* in the garden of a snail meat processing factory in Hajdúszoboszló. We cannot exclude the possibility, that similarly to other Mediterranean snails (e.g. *Cornu aspersum* and *Helix lucorum*), it can also survive under the Hungarian climate.

Green Garden Snail, Burrowing Snail

Cantareus apertus (Born, 1778)

Widely distributed Mediterranean species (Welter-Schultes 2012), which may become a horticultural pest within and outside of (USA, Australia, Germany) its native range. However, it is considered as a less important pest as *Cornu aspersum* (Cowie *et al.* 2009). In Hungary it was found in a supermarket in Bonyhád and in Budapest. The specimen from Bonyhád was found inside of a lettuce, which, according to the information of the supermarket, was produced in Hungary (Páll-Gergely *et al.* 2021). If this was true, than this species may already have a Hungarian greenhouse population.

References

Bailey 2007, Botka & Varga 1984, Čejka *et al.* 2020, Clarke *et al.* 2000, Cowie *et al.* 2009, Domokos & Majoros 2009, Domokos & Pelbárt 2011, Fehér & Gubányi 2001, Fehér *et al.* 2009, Flasarová & Flasar 1965, Gutiérrez Gregoric *et al.* 2013, Horsák *et al.* 2013, Hutchinson *et al.* 2014, 2020, 2022, Kiss & Pintér 1983, 1985, Krolopp 1983, Füköh 1995, Krolopp & Varga 1991, Majoros 1987, Ottó 1980, Páll-Gergely & Hanti 2019, Páll-Gergely & Szentes 2010, Páll-Gergely *et al.* 2020a, 2020b, 2021, Pintér 1974, 1984, Pintér & Podani 1979, Pintér & Suara 2004, Pintér & Varga 1981, Pintér *et al.* 1979, Reise *et al.* 2011, 2020, Rowson *et al.* 2014, Szekeres 1976, Uherkovich 2009, Varga 2006, Varga *et al.* 2010, Verdcourt 1974, Wagner 1933, Walther & Neiber 2012, Welter-Schultes 2012, Wiktor *et al.* 2000.

Barna Páll-Gergely, Gábor Majoros
Ágnes Turóci & András Varga

NEMATODES

Nematoda

Pine Wilt Nematode

Bursaphelenchus xylophilus (Steiner & Buhrer, 1934)

Native range

According to common consent, the species originates from North America, from the United States and Canada (Ryss *et al.* 2005, Sutherland 2008). It first caused severe damage in Japan as an introduced species in 1905. Since then, it has been detected in several other Asian countries, for instance in China (Zhao *et al.* 2008), South Korea (Shin 2008), and Taiwan (Nakamura-Matori 2008).

Introduction to Europe

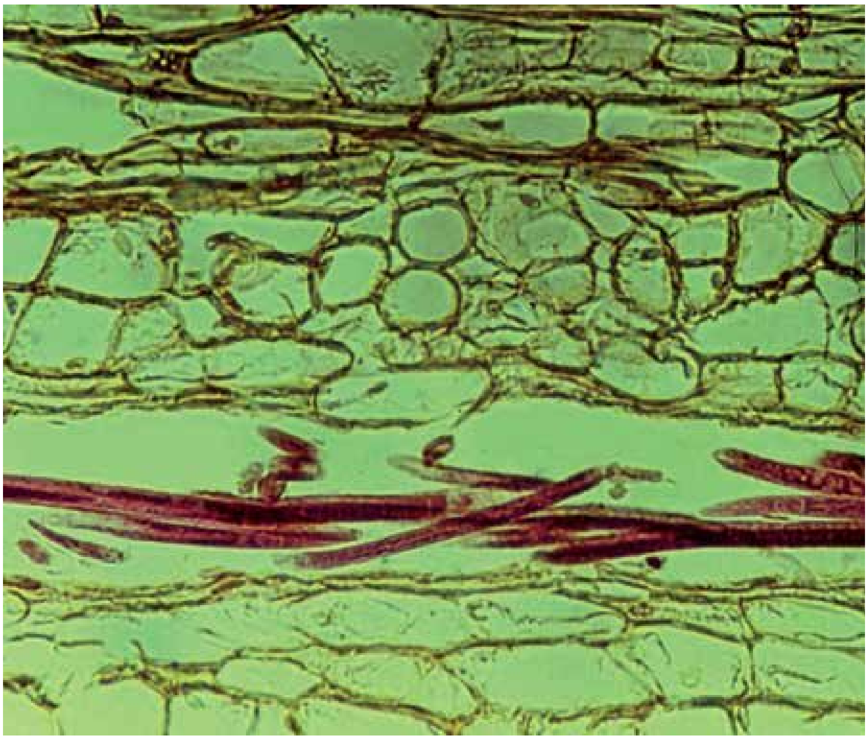
It was first identified in Europe in Portugal, in 1999 (Mota *et al.* 1999, Sousa *et al.* 2001). It has been repeatedly found at isolated locations in Spain since 2008 (EPPO Reporting Service 2010a, 2010b). It appeared in Madeira in 2009 (EPPO Reporting Service 2011).

It is a priority pest. Its introduction and assistance of spreading is prohibited in Hungary, according to Decree No. 7 of 2001 (I.17.) FVM of the Minister of Agriculture and Rural Development on the rules of the implementation of phytosanitary measures. Accordingly, it is featured on the A2 List of quarantine pests of the European and Mediterranean Plant Protection Organization (EPPO) as well.

Biology of the species

It is a slender nematode (Nematoda), its body length is 0.5–1.3 mm (Roques *et al.* 2009). As several morphologically very similar nematode species may occur on pine trees (Pinaceae), genetic analyses are necessary for its reliable identification.

In Europe, pine sawyers (*Monochamus* spp.) are important vectors of the Pine Wilt Nematode. Perhaps the habitat, host plants, and development of these beetles fit the demands of the Pine Wilt Nematode best. In Portugal, the Black Pine Sawyer Beetle (*Monochamus galloprovincialis*), and in Japan and Korea, Sakhalin Pine Sawyer (*M. saltuarius*) are its most significant vector organisms, but there are other significant vectors as well: the Japanese Pine Sawyer (*M. alternatus*) in Japan and Korea, and the Carolina Sawyer (*M. carolinensis*) and Southern Pine Sawyer (*M. titillator*) in North America (Sousa *et al.* 2001, Schröder *et al.* 2009). In its current distribution area, the Pine Wilt Nematode has been detected in the bodies of several other longhorn beetle species (Cerambycidae) as well, for example



© Mactode Publications (bugwood.org)

Pine wilt nematode, 75x magnification

© Ferenc Lakatos

Black pine sawyer beetle (*Monochamus galloprovincialis*)

Acanthocinus spp., *Arhopalus* spp., *Asemum* spp., *Rhagium* spp., *Spondylis* spp., and some *Xylotrechus* spp. (EPPO/CABI 1996). These genera also occur in Europe. Apart from longhorn beetles, some metallic wood-boring beetles (*Chrysobothris* spp.), bark beetles (Scolytidae), *Pissodes* spp., and *Hylobius* spp. have also been observed as vectors of this pest in Europe (Braasch 2001).

The Pine Wilt Nematode breeds in the resin ducts of conifers and obstructs them. As a consequence, resin flow gets slowed or stemmed, natural protection of the tree is impaired, so the tree will be less resistant against the infestation of bark beetles or longhorn beetles. Bark beetles plant fungi (*Ceratocystis* spp., *Ophiostoma* spp.) into their galleries, which form a part of the nematode's diet. The Pine Wilt Nematode becomes sexually mature after four juvenile stages. Individuals in the third juvenile stage search for the pupal chambers of pine sawyers. In this stage, the larva does not feed. It is more resistant and more adaptable than the other juvenile stages, therefore its role in spreading the infection is more pronounced. In the pupal chamber, stage three juveniles moult and become resistant dispersal larvae (dauer larvae). These enter the spiracles of pine sawyer pupae. A single pine sawyer may carry 15 000 – 230 000 nematode larvae. In the course of primary infection, newly hatched adult pine sawyers look for new, healthy trees to feed on, so they can become sexually mature and find a mate. Simultaneously, they transfer the infection. In such cases, Pine Wilt Nematodes first start breeding in the resin ducts (phytophagous phase), and wait for the bark beetle to supply them with fungi. Secondary infection happens when the pine sawyer visits a diseased, decaying tree trunk or felled timber to lay its eggs on, and meanwhile transfers the nematode. In these trees, fungi for the nematode to feed on are already present (mycophagous phase) (Wingfild 1987, Tóth

2011). However, the recent intensive expansion of the Pine Wilt Nematode is not primarily associated with its vectors, but human activities, i.e. global timber trade (Yusheng *et al.* 2002).

Pine Wilt Nematode infection causes needle discolouration beginning from the top. The trees wilt and die rapidly. The reason for this is partly the obstruction of resin ducts, and partly the toxins produced by the nematode (Oku *et al.* 1979, Shaheen *et al.* 1984). These factors combined hinder water transport and resin production in the tree (Mamiya & Tamura 1977). Together with the nematode infection, damage by bark beetles and the galleries of longhorn beetles are also present in the wood.

Optimal average temperature in the summer for Pine Wilt Nematode development is 20 °C. Development is prolonged at other temperatures (Rutherford & Webster 1987). Its daily optimum temperature is about 25 °C, at which a new generation may develop within four days (Ishibashi & Kondo 1977, Mamiya 1984).

Ecological conditions in Hungary

The Pine Wilt Nematode is a thermophilous species. Draughts in the height of summer assist its spreading both directly and indirectly. On the one hand, as it prefers dry wood (Halik & Bergdahl 1990), and on the other, as in such periods the natural defence of trees is weaker.

Accordingly, climatic conditions in Hungary are suitable for the Pine Wilt Nematode and its vectors, but the relatively small area of pine forests in Hungary may be a limiting factor. Apart from these, infection rates in Hungary may be influenced by the degree of colonisation from warmer countries, and the character and degree of climate change. Some forest management practices (e.g. the absence of forest edges, overfelling, and anything else resulting in warmer stands) may indirectly increase the risk of infection.

Ecological concern

The Pine Wilt Nematode infects members of the pine family (Pinaceae). It diseases mainly pine species (*Pinus* spp.), but also firs (*Abies* spp.), cedars (*Cedrus* spp.), larches (*Larix* spp.), spruces (*Picea* spp.), and Douglas firs (*Pseudotsuga* spp.). The vectors of this nematode, the pine sawyers (*Monochamus* spp.) also feed and oviposit on junipers (*Juniperus* spp.), false cypresses (*Chamaecyparis* spp.), hemlocks (*Tsuga* spp.), and Japanese cedar (*Cryptomeria japonica*), so the Pine Wilt Nematode could also occur on these (Evans *et al.* 1996). Arborvitae (*Thuja* spp.) and yews (*Taxus* spp.) are considered secure, as pine sawyers avoid them. Based on this, severe Pine Wilt Nematode damage can be expected in Hungry on Scots Pine (*Pinus sylvestris*) and possibly Common Juniper (*Juniperus communis*). In case of an outbreak, it may induce a significant transformation of native, prevalent saproxylophagous communities.

Symptomatic trees mostly die within one to three months. In case of a latent infection, latency may last up to 14 years (Tóth 2011). After the death of a tree, the nematode can still be detected in its wood for up to three years, depending on climate conditions and the drying rate of the wood (Malek & Appleby 1984).

Economic impact

Damage caused by the Pine Wilt Nematode in forests and the cost of management programmes between 1999 and 2009 reached 80 million euros in the European Union (Costa *et al.* 2011). The additional costs of reforestation and monitoring are also to be reckoned with.

Potential control measures

The first line of defence is prevention. Following infection, control is no longer possible. The only way to stop the dispersal of the Pine Wilt Nematode is by introducing and strictly observing quarantine measures, and by continuously and consistently monitoring host plants and vector organisms. Currently, it mainly spreads in wood packing materials and woods for other uses, its spontaneous spreading via its vectors, the pine sawyers (*Monochamus* spp.) is secondary. Therefore, obligatory heat treatment of wood packing materials – both the nematode and its vector die within 30 minutes at 56 °C (Dwinell 1990, 1997) –, the felling and burning of infected trees, or the felling of susceptible trees in the infected area are necessary.

References

Braasch 2001, Costa *et al.* 2011, Dwinell 1990, 1997, EPPO/CABI 1996, EPPO Reporting Service 2010a, 2010b, 2011, Evans *et al.* 1996, Halik & Bergdahl 1990, Ishibashi & Kondo 1977, Malek & Appleby 1984, Mamiya 1984, Mamiya & Tamura 1977, Mota *et al.* 1999, Nakamura-Matori 2008, Oku *et al.* 1979, Roques 2009, Rutherford & Webster 1987, Ryss *et al.* 2005, Shaheen *et al.* 1984, Schröder *et al.* 2009, Shin 2008, Sousa *et al.* 2001, Sutherland 2008, Tóth 2011, Yusheng *et al.* 2002, Wingfield 1987, Zhao *et al.* 2008

Katalin Tuba & Ferenc Lakatos

DECAPODS

Decapoda

Red Cherry Shrimp

Neocaridina denticulata (De Haan, 1844)

Native range

The species *Neocaridina denticulata* has had many synonymous names, and has several subspecies. Its taxonomy is not entirely clear yet, and accordingly, its precise distribution range is also debated. According to current knowledge, however, the species kept by aquarists is native to Taiwan, where it inhabits small streams and lakes.

Introduction to Europe and Hungary

The first specimens of the Red Cherry Shrimp reached Europe, including Hungary, in the late 1990s. Because of its small size, it repeatedly got here hidden among fish and other crustaceans. It has been observed to disperse from garden ponds in the tropics. In Europe, free-living populations have so far been described from Germany and Poland (Klotz *et al.* 2013, Jabłońska *et al.* 2018). In Hungary, and in the entire Carpathian Basin, it was first observed in nature in a thermal spring near Miskolctapolca (Békás pond) and in Csónakázó pond, in their outflows, and several kilometres downstream in the Hejő stream in November 2017 (Maciaszek *et al.* 2021, Weiperth *et al.* 2019a). It has established populations in both these thermal water habitats and the natural section of the stream.

© András Weiperth

Biology of the species

The Red Cherry Shrimp is a small species. Its length rarely reaches 4 cm, even old specimens are usually only 2-3 cm long. Males and females are easy to distinguish, as females are larger, have a slightly bulging abdomen, and their colour is darker and denser, both in wild and selectively bred colour morphs. The males are smaller and not so bright coloured. The species has many selectively bred colour morphs, but the wild variant is green and brown. The naturalised populations in Europe, including the thermal pond of Miskolctapolca and the Hejő stream consist almost exclusively of wild coloured specimens. Feeding affects their colour considerably. A saddle-shaped thickening can be found on the shells of females behind their head, which indicates the fertility of the eggs. The "saddle" and the eggs are yellow or green. The Red Cherry Shrimp does not live long, its average adult lifespan is one to two years. It becomes sexually mature at the age of four to six months, but development and reproductive cycles are significantly influenced by water temperature. Females lay 20–30 eggs, and carry them on their pleopods for two or three weeks. Newly hatched shrimplets are smaller than 1 mm. This species does not have a pelagic larva. The young do not climb onto their mothers, but start their lives hidden among plants, rocks, or pebbles.

Although it is commonly considered thermophilous (Tropea *et al.* 2015, Weiperth *et al.* 2019b), based on its European occurrences, it is also able to adapt to periodically warming and cooling natural waters (Weiperth *et al.* 2019a, 2020d). In Asia, numerous symbiotic taxa, e.g. rotifers (Rotatoria) have been described from this species, which it may spread when attached to its shell (Patoka *et al.* 2016).

Ecological conditions in Hungary

Since its detection, its permanent presence has been repeatedly proven in its only Hungarian natural habitat. In spite of this, however, new populations could only form in natural thermal waters or habitats polluted by used thermal water or industrial warm water discharge (Weiperth *et al.* 2019a, 2019b). From these thermally polluted habitats, it could presumably successfully colonise surrounding natural and urbanised habitats. The remarkable adaptability of the only known Hungarian population demonstrates the plausibility of this prediction.

Ecological concern

No information is available on damage caused by the Red Cherry Shrimp, either in Hungary or elsewhere. So far, its role as a vector of pathogens is scarcely known in Europe. According to some studies, it is resistant to the Crayfish Plague (*Aphanomyces astaci*), and may act as a vector of its pathogen (Mrugała *et al.* 2019, Svoboda *et al.* 2014).

Economic impact

The Red Cherry Shrimp is a very important species on the global pet market. Currently, it is one of the shrimp species most abundantly bred and kept in aquariums (Faulkes 2015). It is usually kept in so-called nano-tanks together with small fish, but large specimens can be kept with medium-sized, peaceful fish species as well. Because of its great adaptability and non-aggressive behaviour, it is among the most popular aquarium pets. The survey of the Hungarian population showed that several fish species, e.g. the Native Roach (*Rutilus rutilus*), Common Chub (*Squalius cephalus*), and gudgeon (*Gobio gobio* complex), and also the alien Pumpkinseed (*Lepomis gibbosus*) and topmouth Gudgeon (*Pseudorasbora parva*) prey on this shrimp regularly in the Hejő stream.

Potential control measures

The species is commercially available, and it is legal to keep in Hungary as well as the rest of Europe. To stop further illegal releases in Hungary, it is essential to educate aquarists. The results of surveying the already existing populations indicate that informative, awareness-raising campaigns are needed on the dangers of releasing any non-native species, also decapod species kept in aquariums, into natural waters or ornamental ponds in gardens and public spaces (Botta-Dukát 2016, Faulkes 2015, Patoka *et al.* 2014, Weiperth *et al.* 2020d). It is possible to reduce its populations in artificial habitats by stopping thermal pollution, i.e. warm water supply in autumn and winter. The introduction of large omnivorous fish species, e.g. the Eurasian Carp (*Cyprinus carpio*), or smaller predatory fish species, e.g. the European perch (*Perca fluviatilis*) may also be effective for containing its populations.

References

Botta-Dukát 2016, Faulkes 2015, Klotz *et al.* 2013, Jabłońska *et al.* 2018, Maciaszek *et al.* 2021, Mrugała *et al.* 2019, Patoka *et al.* 2014, 2015, 2016, Svoboda *et al.* 2014, Tropea *et al.* 2015, Weber & Traunspurger 2016, Weiperth *et al.* 2019a, 2019b, 2020d

András Weiperth

Chinese Mitten Crab

Eriocheir sinensis H. Milne-Edwards, 1853

Native range

The Chinese Mitten Crab originates from the Far East. In accord with its name, it is native to the lower reaches and the estuaries of the great rivers of China, and to coastal areas from Hong Kong to the southern part of the Korean peninsula. The most important part of this comprises the lower section and the estuary area of River Yangtze. It is of economic significance in its original distribution area, but its populations are diminishing because of water pollution, overfishing, and dam construction. It is the intermediate host of an Asian Lung Fluke species (*Paragonimus westermani*), which also infects humans (Jin *et al.* 2001, www.cabi.org, www.iucngisd.org).

Introduction to Europe and Hungary

Simultaneously with the reduction of the area of its native habitats, the Chinese Mitten Crab was introduced to Europe, North America, and the Middle East (Iran, Iraq), in the ballast water tanks of ships (Robbins *et al.,* 2006, www.cabi.org, www.iucngisd.org). In Europe, it was first detected in Germany in 1912 (Panning 1939). Since then, it has invaded a considerable part of the coasts, estuaries, and lower river sections in Europe, and it keeps spreading upstream. It is able to spread by 380–562 km a year (Herborg *et al.* 2003). In Europe, it currently occurs in the coastal waters of the Atlantic Ocean, the Baltic, North, Mediterranean, Black, and Caspian Seas, and

© Balázs Szelényi

in rivers flowing into them as well (Robbins *et al.* 2006, www.cabi.org, www.iucngisd.org). Fisherman in Hungary reported catching animals similar to the European crab in the Danube in the mid-1990s, but the first officially recorded specimen was collected in November 2003 downstream from Budapest, and another one was caught near Kölked in 2004 (Puky *et al.* 2005, Puky & Schád 2006). Its appearance in Hungary was expected, as its presence had formerly been reported from the River Danube in Austria and Serbia (Paunovic *et al.* 2004, Rabitch & Schiemer 2003). Up to this point, a total of 15 live specimens and numerous shell remains have been found in Hungary. Altogether nine individuals were caught in the main and side arms of the River Danube, three adults were found in ponds in Budapest, and three more were caught on land (Bódis *et al.* 2012, Puky 2012, Seprős *et al.* 2018a, Weiperth *et al.* 2020d). Since its first documented occurrence, a specimen is caught nearly every year in the capital, or the River Danube downstream from it. Adult Chinese Mitten Crabs are imported to many countries for farming purposes. The ones caught are mostly escapees of such transactions, as directly proven by individuals collected in Budapest (Puky 2012, Weiperth *et al.* 2020d).

Biology of the species

The Chinese Mitten Crab is one of the most readily discernible alien decapods in Europe. It is a crab (Brachyura), therefore its structure is totally different from other freshwater decapods native or introduced to Europe, which makes identification easy. The carapace is 3–10 cm wide, and usually brown, sometimes with black spots. The fingers of the claws are white, sometimes greyish. The species got its name from the dense coat of setae covering its claws, which can grow quite large on males. The cephalothorax is 7 cm long on average, with a doubly serrated frontal edge, and four times serrated anterolateral teeth (ISSG 2016). As regards environmental needs, the Chinese Mitten Crab is moderately sensitive to polluted water, its body is able to accumulate pollutants (e.g. heavy metals, microplastic, remains of chemicals), and it has a wide tolerance range of water salinity and temperature (Veilleux & de Lafontaine 2007). Severe pollution and significant transformation of its natural habitats restricted its native range, but simultaneously, it is expanding its alien range with great success. It is an omnivorous species, active in the night. Walking on the substrate, it preys on worms, snails, mussels, and the eggs and young of fish, but it also eats carcasses and plant debris. It is relatively short-lived, adults rarely live longer than three to five years. Potential lifespan is highly influenced by water temperature. It is a catadromous species, i.e. sexually mature specimens migrate from their freshwater habitats to the sea to spawn. For the early stages of its development, it needs brackish or sea environments. It is highly fecund, females produce 250 000 – 1 000 000 eggs depending on their size (Veilleux & de Lafontaine 2007). In its first a larval stage, it is attached to seaweeds, the substrate, or some other solid surface. The second stage is a more developed pelagic larva (Sewell 2016). The transparent, free-floating larva (*megalopa*) is able to disperse. It has been known since the detection of the first European population of the species (Germany) that these larvae are able to cover great distances in the ballast water tanks of ships (www.cabi.org). The species excavates extensive burrow systems on seashores and river banks, to hide at times of low tide and draught. The Chinese Mitten Crab, apart from the above mentioned zoonotic lung fluke (*Paragonimus westermani*), may also carry pathogens of several other diseases, including the crayfish plague (*Aphanomyces astaci*) (Svoboda *et al.* 2017).

Ecological conditions in Hungary

It is has wide ecological tolerance range, but because of its special breeding cycle, self-sustaining populations cannot form in Hungary. Hungarian occurrences are the result of spontaneous dispersal from both the lower and the upper sections of the Danube, or of specimens escaping or being released after legal or illegal trading. As the species is also used for culinary purposes, the escapees probably come from crab farms or kitchens.

Ecological concern

The worldwide expansion of the Chinese Mitten Crab is the consequence of its excellent adaptability and its dispersal ability, which is outstanding among decapods. If abundant, it may cause significant economic and nature conservation damage by putting predatory pressure on native communities, and by mechanically altering habitats. It consumes considerable amounts of organic matter (detritus), as well as plants and animals, and it is able to accumulate pollutants. It is resistant to the crayfish plague, but as a host, it can transfer its pathogen on native and other alien decapod species (Decapoda).

Economic impact

Its burrowing, by eroding embankments along rivers or on the seashore, causes several million euros

© Balázs Szelényi

of damage every year in Europe (www.cabi.org, www.iucngisd.org). Specimens carrying human pathogens have not been recorded in Europe so far. During the dissection of a specimen collected in 2011 in Budapest, the larva of the zoonotic Asian lung fluke (*Paragonimus westermani*) was not found (Majoros & Puky 2012). Its yearly commercial worth is 3–6 million euros, as it is exported to Asia from several European countries. It is featured on the list of the 100 worst invasive species of the world (www.cabi.org, www.iucngisd.org).

Potential control measures

The species is banned in Hungary as well as the rest of Europe, but the specimens collected in the capital are proof that it is being traded illegally. The release of further live specimens could be prevented by modifying the law and also enforcing it more effectively. As Hungary is located far from the estuaries of both the River Rhine and the Danube, the establishment of stable populations is not to be expected, but single specimens may appear in the middle section of the River Danube in the future as well (Botta-Dukát 2016, Weiperth *et al.* 2020d).

Also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

Botta-Dukát 2016, Bódis *et al.* 2012, Herborg *et al.* 2013, ISSG 2016, Jin *et al.* 2016, Majoros & Puky 2012, Panning 1939, Paunovic *et al.* 2004, Puky 2004, 2012, Puky & Schád 2006, Puky *et al.* 2005, Rabitch & Schiemer 2003, Robbins *et al.* 2006, Seprős *et al.* 2018a, Sewell 2016, Svoboda *et al.* 2017, Veilleux & de Lafontaine 2007, Weiperth *et al.* 2022d

András Weiperth

Australian Redclaw Crayfish

Cherax quadricarinatus (von Martens, 1868)

Native range

As the name suggests, the Australian Redclaw Crayfish is native to Queensland in Northern and Northeastern Australia, and Southeastern Papua New Guinea (Lawrence & Jones 2000).

Introduction to Europe and Hungary

The first specimens were introduced to Italy from Australia in 1985, for crayfish farming purposes (D'Agarao *et al.* 1985). Later, in the early 1990s, several specimens were taken to England (Holdich *et al.* 1999) and Ireland (Holdich & Sibley 2009, Faulkes 2015) to aquariums. It is one of the most widely bred and imported decapods (Dacapoda) in Europe. It is currently kept as a pet or farmed in 17 countries, and its presence in natural or near natural habitats has been reported from eight of these (Kouba *et al.* 2014, Haubrock *et al.* 2021a, 2021b, www.cabi.org).

In Hungary, the first specimens were imported to aquarium supplier stores in the late 1990s, and its aquarium breeding also started at this time. It was first observed in a natural habitat, a side branch of the Danube in Budapest (Kopaszi Dam, 1649 river km), in September 2016. In November of the same year, a male and a female were found in the Fényes Spring near Tata, and an adult female in the Melegvíz canal south of Harkány (Weiperth *et al.* 2019b). During surveys conducted all over the country, it was found in many natural and artificial thermal water environments. Old, sexually mature adults were found in the River Danube, at sites where industrial or natural thermal water discharge flows into the river (Szendőfi *et al.* 2018, Mozsár *et al.* 2021, Weiperth *et al.* 2020b, 2020d). Its breeding in the wild in Hungary has not yet been proven, but young specimens are sometimes collected from the Városliget pond in Budapest. It is not yet clear whether their presence is a result of natural reproduction or illegal release (Weiperth *et al.* 2020d).

Biology of the species

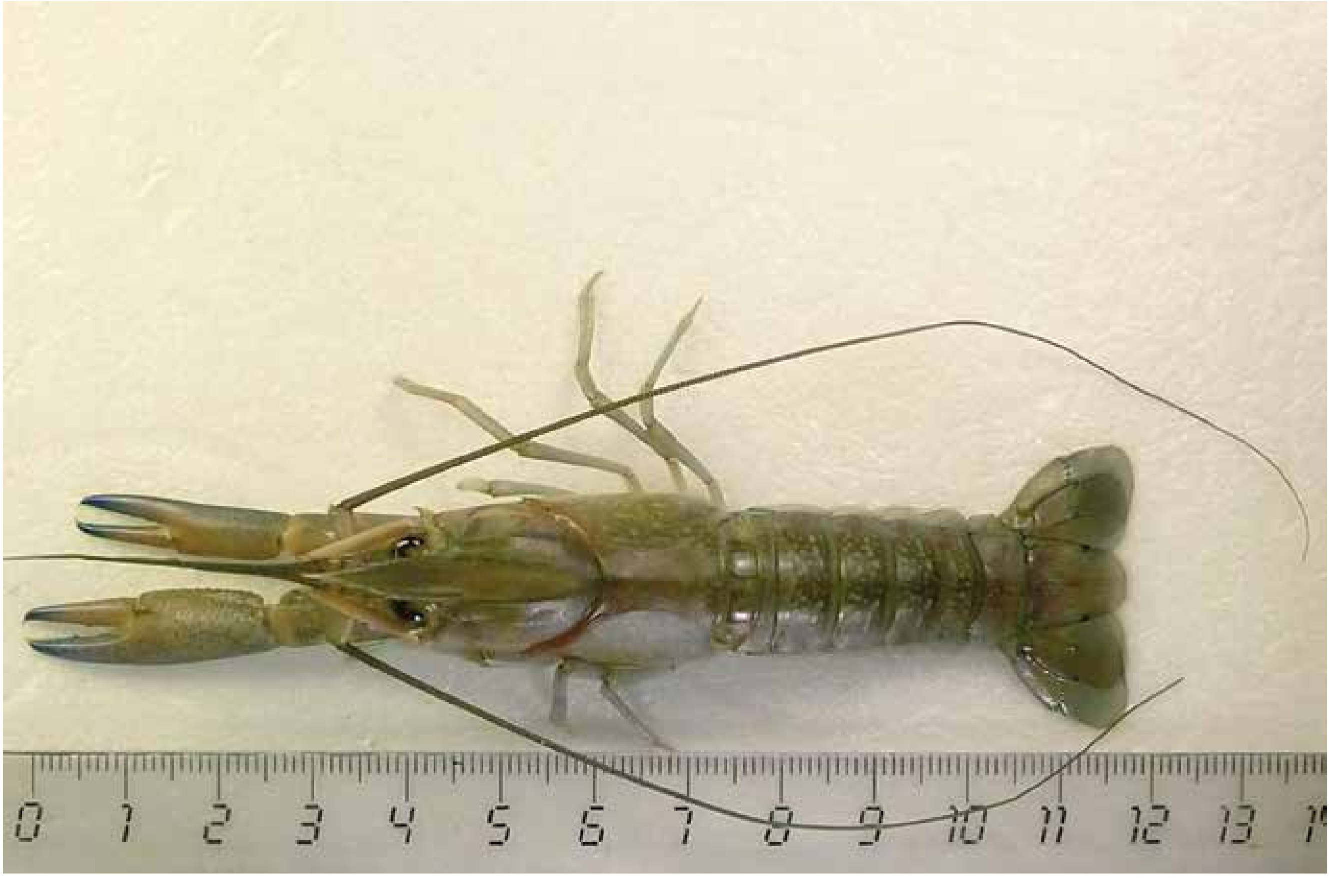
The head of the Australian Redclaw Crayfish is elongated and slightly flattened. One large and several smaller spines line the edge of the carapace, behind the cervical groove. The rostrum is serrated on both sides, and from the dents nearest to each eye, a pair of ridges adorns nearly the entire length of the head. There are two shorter ridges parallel to these on both sides. The species has many colour variations, but it is usually blue or bluish green, with light, green, or greenish yellow patches on both sides of the body. The edges of the abdominal segments are light green or yellowish of specimens of the wild colour morph. Young individuals are lighter and have a uniform colour, the specific pattern usually develops about the time of sexual maturation. One of its common colour morphs is blue ("tropical blue crayfish"). The claws are elongated, and smaller relative to the body than those of native Hungarian species. The inside of the carpus joint bears two spurs, one large and one small. The insides of the fixed (*propodus*) and moveable fingers (*dactylus*) are serrated, with a dark spot near the tip, and a red tip. The edges or the joints of the fingers, and sometimes the entire claws become bright red after sexual maturation. Adults grow up to 25-30 cm long, and may weigh more than 600 g (Souty-Grosset *et al.* 2006, Kozák *et al.* 2015). It is a thermophilous species, its potential for establishment and the rapidity of its dispersal are restricted by its heat demand. In countries of the temperate zone, including Hungary, it can only establish self-sustaining populations in natural thermal waters or habitats loaded with heated industrial discharge. In its native range, the species occurs in still and flowing waters, lagoons of the sea, and brackish waters. According to studies, it tolerates permanently warm (>30°C) and polluted waters well. It prefers solid substrates, and avoids muddy habitats (Kozák *et al.* 2015). In

© András Weiperth

Hungary, it was only found so far in thermal waters and in habitats loaded with the outflows from spas, on various substrate composition (Szendőfi *et al.* 2018, Weiperth *et al.* 2019b, 2020b, 2020d). It is omnivorous, but plants form a considerable part of its diet, both in the newly colonised and the original habitats (Kozák *et al.* 2015, Haubrock *et al.* 2021b). It is susceptible to crayfish plague caused by the Water Mould (*Aphanomyces astaci*). Cases of infection and death have been reported from crayfish farms, but in natural habitats, no infected specimens have been recorded so far. On the other hand, the Australian Redclaw Crayfish is a vector of several other pathogens which pose a threat to other, native and alien decapods (Decapoda), for example the white spot syndrome virus (WSSV), which has been detected in samples from aquarium specimens (Mrugała *et al.* 2015). It may carry other viruses as well, e.g. the decapod iridescent virus 1 (DIV1) (Xu *et al.* 2016). As a vector, it can transfer diseases to native and alien species susceptible to them. Its life cycle is quick, but it is not aggressive, and does not burrow (Souty-Grosset *et al.* 2006, Kozák *et al.* 2015). At temperatures above 23°C, it reaches sexual maturity at the age of six to nine months, which is an important factor of its successful establishment. It is able to survive and even establish self-sustaining populations in habitats continuously exposed to disturbances, e.g. thermal pollution. Its co-existence with native and alien species has been documented in Hungary (Mozsár *et al.* 2021, Weiperth *et al.* 2020b, 2020d). Under favourable conditions, it can reproduce twice a year. It produces 200–1000 eggs at a time, depending on size and maturity of the abdomen. Its average lifespan is four to five years.

Ecological conditions in Hungary

Although it is a species with a wide tolerance range, it can only form established populations in Hungary in natural thermal waters, or habitats loaded with heated discharge from thermal baths or industrial plants. There are no abundant populations in Hungary yet, but since its first detection, specimens have been recorded in various waterbodies every year (Weiperth *et al.* 2020b, 2020d). As it inhabits warm waters, it is active throughout the year.



© András Weiperth

Ecological concern

The damage of the Australian Redclaw Crayfish has mainly been documented in tropical, subtropical, and Mediterranean countries. We cannot give an account of any actual damage in Hungary. The diseases it can transfer, however, raise concerns. If a specimen carrying a pathogen enters a natural habitat, it may infect other decapods, even more rapidly spreading, alien species, such as the Spiny-cheek Crayfish (*Faxonius limosus*). In suitable habitats, it can establish abundant populations rapidly, which has a severe negative effect on aquatic vegetation (Haubrock *et al.* 2021a, 2021b).

Economic impact

Direct and indirect economic effects have been reported from warmer countries, where it is regarded an ecosystem engineer, with a negative impact on the native communities of colonised habitats. It endangers indigenous dacapods by predation and the transfer of pathogens (Kozák *et al.* 2015, Haubrock *et al.* 2021a, 2021b). We have no information about damage on an economic scale in Hungary.

Potential control measures

The species is commercially available everywhere in Europe, including Hungary. To stop further illegal releases in Hungary, it is essential to educate aquarists. The fact that specimens are found repeatedly every year calls our attention to the need of informative, awareness-raising campaigns about the dangers of releasing the Australian Redclaw Crayfish, or any other non-native decapod species kept in aquariums, into natural waters or garden ponds (Botta-Dukát 2016, Faulkes 2015, Weiperth *et al.* 2020b, 2020d. It is possible to reduce established populations in artificial habitats by draining the pools, or by stopping thermal pollution, i.e. hot water discharge in the cold periods of autumn and winter, as mortality is nearly 100% at temperatures permanently below 10°C. In isolated waterbodies, their density can be decreased by the application of biocides, or the introduction of heat tolerant native predatory fish species, for example the European Catfish (*Silurus glanis*).

References

Botta-Dukát 2016, D'Agaro *et al.* 1999, Haubrock *et al.* 2020a, 2021b, Holdich 1999, 2009, Holdich & Sibley 2009, Kouba *et al.* 2014, Kozák *et al.* 2015, Lawrence & Jones 2002, Mozsár *et al.* 2021, Oficialdegui *et al.* 2021, Mrugała *et al.* 2015, Souty-Grosset *et al.* 2006, Szendőfi *et al.* 2018, Weiperth *et al.* 2019b, 2020b, 2020d, Xu *et al.* 2016

András Weiperth

Signal Crayfish

Pacifastacus leniusculus (Dana, 1852)

Native range

The Signal Crayfish is native to North America, to the Western United States along the Rocky Mountains (Washington, Oregon, Idaho), and to the Province of British Columbia, Canada. In its original distribution area, it is common in main and side arms of large rivers, and in fast-flowing sections of tributaries, but it also inhabits clean standing waters. It also tolerates eutrophic habitats with periodically low oxygen concentration. It survives desiccation in self-made deep burrows (Souty-Grosset *et al.* 2006, Kouba *et al.* 2014, Kozák *et al.* 2015, Taylor *et al.* 2007).

Introduction to Europe and Hungary

The Signal Crayfish was first introduced to Sweden in 1959, and to Finland in 1967–1968, to replace locally extinct populations of the noble crayfish (*Astacus astacus*). It was also introduced illegally to Austria in the 1970s for economic reasons (Holdich *et al.* 2009). Due to the excellent adaptability of individuals escaping crayfish farms, it is currently the most common alien decapod species in Austria. Its dispersal in Europe is unstoppable, its occurrence has already been reported from 29 countries (Kouba *et al.* 2014, Kozák *et al.* 2015). The exact date of its appearance in Hungary is uncertain, but according to published and personal communications, it may have been present in some watercourses in Western Hungary as early as the mid-1990s. Its first scientifically recorded specimens were collected in the Gyöngyös stream in Kőszeg, in 1998 (Kovács *et al.* 2005). It now occurs in many watercourses entering the country from Austria. In some of them, it is abundant, and continues spreading east (Liziczai *et al.* 2020). Currently, it is present in the entire Hungarian section of the Rivers Drava, Leitha, Mura, Rába, and Rabnitz, in many of their tributaries, in some deep, clean standing waters, and also in the Moson Danube side arm system and the main arm of the River Danube downstream from Gönyű (1785 river km) (Weiperth *et al.* 2020). The cases of Hungary, Slovenia, and Croatia demonstrate the spontaneous dispersal ability of the Signal Crayfish, which, since its first introduction to Europe, has been described from an increasing number of countries. It is spreading rapidly, typically along river catchment areas (Botta-Dukát 2016).

Biology of the species

The Signal Crayfish is one of the largest alien decapod (Decapoda) species in Hungary. Adult specimens are usually longer than 12 cm. The males are bigger than the females, they are up to 16-18 cm long, and weigh up to 200-250 g. Old individuals are reddish brown, sometimes with a bluish tinge. The cervical groove dividing the two parts of the carapace is smooth, and the carapace lacks postorbital ridges. The fixed finger of the claw (*propodus*) and the joint of the movable finger (*dactylus*) bear a white or greyish blue spot. This spot gave the species its name as, if in danger, it spreads its claws to show off the light spot and warn off the attacker. Young specimens are similar to adults, but the spots on the claws may be paler and smaller. Due to its high adaptability, e.g. tolerance of salinity and heat, the Signal Crayfish is able to survive in brackish waters, and also thermally or otherwise polluted habitats. However, it is more abundant in deep, clean lakes and watercourses. The Signal Crayfish can rapidly adapt to the environmental conditions of newly colonised habitats. It inhabits waterbodies affected by urbanisation, also in its native range. It can spread both up- and downstream spontaneously. This is demonstrated by its rapid dispersal form catchments in Austria to the waters of Slovenia, Croatia, and Hungary. In Austria, it appeared spontaneously in mountain lakes and watercourses above 1500 m, and excluded populations of the Noble Crayfish (*Astacus astacus*) and the Stone Crayfish (*Austropotamobius torrentium*). It appeared simultaneously in the River Danube as well, downstream from Vienna. When its habitat dries up, it burrows up to 1-1.5 m deep. The Signal Crayfish is pronouncedly omnivorous. Where it appears, it usually becomes monodominant, with high population densities (Kozubiková *et al.* 2010). It eats organic matter of plant or animal origin, algae, aquatic macrophytes, but microscopic aquatic invertebrates and small fish as well (Souty-Grosset *et al.*, 2006). The populations of some native species preferring strong currents, e.g. Common Chub (*Squalius cephalus*), Common Barb (*Barbus barbus*), and Brown Trout (*Salmo trutta*), are decreased by its predation in England (Copp *et al.* 2017). Because of its extensive burrowing and wide food spectrum, it is regarded an ecosystem engineer. Unlike other non-native decapods in Hungary, the Signal Crayfish is long-lived, adults may live up to 20 years. It usually reaches sexual maturity at the age of three. The female carries 100–400 eggs at a time, but 500 eggs have also been observed on large specimens (Savolainen *et al.* 1996). The incubation period of the eggs is strongly influenced by water temperature, and is usually between 166–280 days. The juvenile hatch fully developed, between March and June. They remain on or near their mother for several weeks (Kozák *et al.* 2015). The young separate from their mother when 9–11 mm long, and moult several times during the first year. By the end of the year, their body length is 30–40 mm. The juvenile compete for vacated habitats, but most of them migrate, which serves as a partial explanation of the remarkably rapid expansion of the species (Wutz & Geist 2013).

Ecological conditions in Hungary

According to foreign studies, the Signal Crayfish is able to become a dominant fauna element in colonised habitats in a short time. Its rapidly growing populations put intense predatory pressure on the communities of natural habitats. Unfortunately, research of the Signal Crayfish in Hungary is scarce. We have no precise data on either the size or the expansion rate of the Hungarian populations, or their impact on natural habitats. Its rapid expansion and its spreading the pathogen of the Crayfish Plague (*Aphanomyces astaci*) may be responsible for the disappearance or decrease of populations of the Noble (*Astacus astacus*) and Stone Crayfish (*Austropotamobius torrentium*) in several habitats in Western Hungary.

Ecological concern

In suitable habitats, the Signal Crayfish grows rapidly, has high fecundity rates, behaves aggressively, and transfers the pathogen of the Crayfish Plague (*Aphanomyces astaci*) to susceptible native species. In standing waters, it grazes submersed macrophytes, thereby contributing to the increase of the amount of pelagic algae, causing the deterioration of

© András Weiperth

water quality. By damaging the aquatic macrophyte vegetation of watercourses, it remobilises bed material. Its predation has considerable effects on fish communities.

Economic impact

The Signal Crayfish digs extensive burrows for its winter hibernation. It also burrows into steep banks to survive periods of draught or low water level. This may cause the erosion of banks both in natural and urbanised habitats (Weiperth *et al.* 2020).

Potential control measures

The Signal Crayfish reached Hungary via spontaneous expansion, it was not imported as either a pet or to breed on farms. Today, stopping its spontaneous dispersal along watercourses is not feasible. The species is sensitive to water pH. It cannot survives in acidic environments (pH<6), so its spreading can be hindered by planting riparian alder forests. It has been observed along several small watercourses in Austria and in the Őrség National Park that it can only cross banks lined by alders with difficulty or not at all. Therefore, alder groves along watercourses may form a natural barrier between the native populations of the Noble (*Astacus astacus*) and the Stone Crayfish (*Austropotamobius torrentium*), and the non-native populations of the Signal Crayfish. It is presumably in part due to alder groves along the streams that a population of the Signal Crayfish remained isolated in the Kőszeg Mountains, in streams (Hármas stream) and springs (Hétforrás, Ciklámen spring) near the location called Stájerházak. Mechanical removal from standing waters (by trapping, or the application of electric fishing machines) does not eradicate its populations entirely, and the required effort is too great for it to be worth the trouble. If the treatment is not repeated at suitable intervals, the population returns to its original size. Chemical control, i.e. the application of biocides may be effective, even final in isolated water systems, or at the early stages of invasion. Apart from these, an increasing amount of evidence from Hungary suggests that native predatory fish species, e.g. European Catfish (*Silurus glanis*), Asp (*Leuciscus aspius*), Northern Pike (*Esox lucius*), European Perch (*Perca fluviatilis*), and Pikeperch (*Sander lucioperca*) prey on non-native decapod species, including the Signal Crayfish (Seprős *et al.* 2018a, Weiperth *et al.* 2020).

Also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

Botta-Dukát 2016, Copp *et al.* 2017, Holdich *et al.* 2009, Kouba *et al.* 2014, Kozák *et al.* 2015, Kozubíková *et al.* 2010, Liziczai *et al.* 2020, Savolainen *et al.* 1996, Seprős *et al.* 2018a, Souty-Grosset *et al.* 2006, Taylor *et al.* 2007, Weiperth *et al.* 2020, Wutz & Geist 2013

András Weiperth

Mexican Dwarf Crayfish

Cambarellus patzcuarensis Villalobos, 1943

Native range

The Mexican Dwarf Crayfish is native to Central America. It has a limited range, it only occurs in Lake Pátzcuaro and some of its tributaries, and in small springs near Chapultepec, Opopeo, and Tzurumutaro (Hobbs 1974a, www.fws.gov). Because of illegal collecting, water pollution, and the transformation of its habitats, it has become endangered in its native range (Pedraza-Lara *et al.* 2012)

Introduction to Europe and Hungary

The species first arrived in Europe and presumably also Hungary in the 2000s, via international pet trade (Faulkes *et al.* 2015). Its breeding also started at this time in Hungary and the surrounding countries (Patoka *et al.* 2015). Today, it is a popular pet, not just in Europe, as it is small and easy to keep in nano-tanks.

It was first detected in a natural habitat outside of its original range in Hungary, in May 2017. It was found in a thermal pond in Budapest, its outflow, and also the main arm of the River Danube (Weiperth *et al.* 2017). Since its first detection, a few individuals have been found repeatedly in the pond, and in the River Danube, downstream from the confluence of the pond's outlet (Weiperth *et al.* 2020d). In autumn 2020, six mature specimens were found in Városliget, in the ornamental pond of the thermal spring near Széchenyi Bath.

© András Weiperth

Biology of the species

The Mexican Dwarf Crayfish is a very small decapod (Decapoda). Sexually mature females are 4–5 cm long, the males are somewhat smaller. Old individuals may reach a body length of 6–7 cm. Specimens caught in the wild are brown, blue, or grey, without specific patterns. As a result of selective breeding, it has many colour morphs, with orange as the most common (*Cambarellus patzcuarensis* sp. *orange* – 'CPO'). The head is slightly elongated. The rostrum is somewhat raised, with three small spines. Its edges form two longitudinal ridges, leading to the middle of the head. Two smaller ridges run parallel to these, from behind the eyes, to the middle of the head. Its eyes are large, but the elongated claws are small relative to the body, each with a small dark spot at the tip. This spot is present in every colour morph. The abdomen is wide and thick, with a dark, wavy pattern on the dorsal side.

Its life is relatively short, it rarely lives more than two years. It reaches sexual maturity at four or five months of age. The female can carry up to 50-60 eggs at a time. The juvenile hatch fully developed, and remain on or near the mother for weeks (Papavlasopoulou *et al.* 2014). The Mexican Dwarf Crayfish is a thermophilous, omnivorous species, feeding mainly on animal-source food. According to published research, it may carry the pathogen of the Crayfish Plague (*Aphanomyces astaci*) (Mrugała *et al.* 2015).

© András Weiperth

Ecological conditions in Hungary

Although it has a wider ecological tolerance range than most non-native species, in Hungary, it can only establish stable populations in natural thermal waters, or habitats polluted with used thermal water or industrial warm water discharge, where medium-sized and large fish and other decapods are absent (Weiperth *et al.* 2017, 2019b). Its only population detected so far is a proof of its adaptability.

Ecological concern

There are no available data either from Hungary or internationally on damage caused by the Mexican Dwarf Crayfish.

Economic impact

We have no information about either direct or indirect damage or other economic impact of the Mexican Dwarf Crayfish.

Potential control measures

It is commercially available and legally kept everywhere in Europe. The key to preventing repeated illegal introductions in Hungary is the education of aquarists. Results of surveying its established population and the collection of other free-living specimens imply the need for awareness-raising informative campaigns on the dangers of releasing any kind of alien species, including decapod species kept in aquariums into natural waters or garden ponds (Botta-Dukát *et al.* 2016, Faulkes 2015, Patoka *et al.* 2014, Weiperth *et al.* 2020d). It is possible to reduce its populations in artificial habitats by stopping thermal pollution, i.e. warm water supply in autumn and winter. The introduction of large omnivorous fish species, e.g. the Eurasian Carp (*Cyprinus carpio*), may also be effective for containing its populations.

References

Botta-Dukát 2016, Faulkes 2015, Hobbs 1974a, Loureiro *et al.* 2015, Mrugała *et al.* 2015, Papavlasopoulou *et al.* 2014, Patoka *et al.* 2014, 2015, Pedraza-Lara *et al.* 2012, Weiperth *et al.* 2017, 2019b, 2020d

András Weiperth

Red Swamp Crayfish

Procambarus clarkii (Girard, 1852)

Native range

The Red Swamp Crayfish is native to North America, its range encompasses the Southern United States and Northern Mexico. In its original distribution area, it inhabits side branches and floodplains of large rivers, and eutrophic standing waters (Kozák *et al.* 2015, Loureiro *et al.* 2015, www.cabi.org).

Introduction to Europe and Hungary

In Europe, it was first introduced to Spain in 1973, for farming purposes. It soon escaped to rice fields and marshy habitats, resembling its native habitats (Holdich *et. al.* 2009). In the last five decades, it gained commercial importance on the Iberian Peninsula, but it also causes considerable economic and nature conservation damage. It reached Portugal, Italy, and France in the 1970s and 1980s, presumably illegally. It is spreading rapidly with human assistance throughout Europe. Currently, it is abundant in some regions of several European countries (Huner 2002, Souty-Grosset *et al.* 2006, Holdich *et al.* 2009, Chucholl 2011a, Kouba *et al.* 2014, Kozák *et al.* 2015). It also appeared in countries (e.g. Sweden) with basically unfavourable climate conditions (Chucholl 2011b). An explanation for its rapid expansion is its being a popular pet. It is also often released into garden ponds and pools, from where it easily escapes. Irresponsible introductions and releases are the only plausible explanation for its patchy appearance in distant catchment areas (Faulkes 2015). The invasion of the Red Swamp Crayfish has also been noticed in numerous African, Asian, and North, Central and South American countries. The exact date of its appearance is not everywhere known (Loureiro *et al.* 2015).

In Hungary, the first individual was found in the thermal pond of Városliget in Budapest, in 2015 (Weiperth *et al.* 2015). Since 2016, it was recorded in many thermal lakes across the country, in thermally polluted small watercourses, and also in the River Danube and several of its side arms and tributaries (Gál *et al.* 2018, Szendőfi *et al.* 2018). In the River Tisza catchment, it has been found in two thermal water habitats (Egerszalók, Gyula). According to a survey of the main arm of the River Danube, it already occurs in an approximately 120 km section (Seprős *et al.* 2018a). It is spreading very rapidly along the Middle Danube, while its populations in the River Tisza catchment area remain isolated for the moment (Weiperth *et al.* 2020a).

Biology of the species

Adult specimens of the Red Swamp Crayfish are deep red, with elongated claws and head. The rostrum tapers anteriorly, and lacks the median carina. There are either very few or no spines on the cephalothorax. A caudally tapering line runs along the centre of the cephalothorax, between the two carapace plates. There are several rows of bright red tubercles centrally and laterally on the chelipeds, and on the surface of the claws. Juvenile specimens are differently coloured, the typical red colour only develops later. Therefore, the young are difficult to distinguish from other *Procambarus* species. The length of fully-grown adults rarely exceeds 15 cm.

Its life is relatively short, rarely more than five years. It usually reaches sexual maturity at the age of one year. Females carry up to 500 eggs at a time. Juveniles hatch fully developed, and remain on or near the mother for several weeks. If habitat conditions are favourable, females carrying eggs make a special burrow for hatching, and emerge with the next generation. Unlike other decapods (Decapoda), the Red Swamp Crayfish is known to show social behaviour. Old males and females guard their territories, and the juvenile compete for vacant habitats, but many of them migrate, which explains the rapid expansion of the species (Loureiro *et al.* 2015).

© András Weiperth

The Red Swamp Crayfish is remarkably adaptable. It can survive in brackish water, thermal water, seasonally flooded habitats, e.g. marshes or rice fields, and even in deep lakes in Scandinavia. It quickly adapts to the environmental conditions of the colonised sites. In its native range, it has adapted to seasonally desiccated floodplains and brackish habitats as well. It survives periods of draught by burrowing deeply, but among damp vegetation, when the sky is overcast or in the night, it can cover several kilometres on foot as well (Souty-Grosset *et al.* 2006, Kouba *et al.* 2014, Kozák *et al.* 2015, Loureiro *et al.* 2015). This also accounts for its rapid expansion. Its appearance in mountain lakes located above 1200 m in Spain demonstrates its adaptability and dispersal ability (Souty-Grosset *et al.* 2006, Kozák *et al.* 2015, Loureiro *et al.* 2015). It can survive hot summers, but also cold winters, even if its habitat freezes permanently. In such periods, it burrows up to 1-1.5 m deep. Its improved breathing also assists its dispersal overland (Souty-Grosset *et al.* 2006).

The Red Swamp Crayfish is omnivorous. Besides decomposing organic matter of plant or animal origin, it consumes everything from algae to higher plants, and from microscopic aquatic invertebrates to the larvae and juvenile of large fish (Loureiro *et al.* 2015). In some Mediterranean countries and in Hungary it has been observed to graze grass and search for land invertebrates in grassy patches on embankments or lakeshores in the night (Weiperth *et al.* 2020a). In areas with abundant populations, it is regarded an ecosystem engineer because of its extensive burrowing and wide food spectrum. The burrows are deep with many ramifications, with roomy terminal chambers. As a single specimen makes several burrows a year, abundant populations may significantly transform the dynamics of deposition in watercourses, and the structure of their banks.

Ecological conditions in Hungary

The adaptability of the Red Swamp Crayfish is remarkable. It can colonise practically any type of waterbodies, and become a dominant element in the community. Its rapidly growing populations put a strong predatory pressure on native communities, which they also significantly transform. According to Hungarian studies, it finds favourable conditions in small, near-natural or urbanised watercourses, public and garden ponds, thermal or thermally polluted lakes, and the main and side arms of the River Danube (Gál *et al.* 2018, Weiperth *et al.* 2019b, 2020d).

Ecological concern

The Red Swamp Crayfish reproduces quickly in suitable habitats, and establishes abundant populations in a short time. It has a high reproduction rate and behaves aggressively. It spreads the pathogen of the Crayfish


© András Weiperth

Plague (*Aphanomyces astaci*), which is dangerous to native crustaceans. Individuals migrating from infected waterbodies may carry the disease as vector organisms. It consumes the eggs and young of fish, and also eggs and larvae of amphibians (Loureiro *et al.* 2015), thereby also causing considerable damage to natural habitats.

Economic impact

Its extensive burrowing causes bank erosion in both urbanised and natural habitats. In urban environments, erosion of the sides of public utilities (surface and subsurface waterpipe networks), roads, and canals has been documented. In some settlements, it appeared in some garden ponds far from watercourses. Damaging the fish fauna and aquatic plants has been reported in every such case (Gál *et al.* 2018, Weiperth *et al.* 2020d).

Potential control measures

Trading the Red Swamp Crayfish was banned in Hungary in 2016, but aquarists keep breeding it to this day (Weiperth *et al.* 2019b). It is critical to prevent the offspring produced in aquariums from being released into natural waters by every possible means. First, awareness-raising, informative campaigns aimed at pet keepers, breeders, and traders are needed. Information should concern not only the Red Swamp Crayfish, but every other alien decapod species (Decapoda) as well, and attention should primarily be called to the dangers of releasing them in natural waters or garden ponds (Botta-Dukát 2016, Faulkes 2015, Weiperth *et al.* 2020d).

It is usually difficult to contain invasive decapods (Decapoda). Published results of long-term surveys show that the population growth of the Red Swamp Crayfish cannot be stopped by artificially disturbing the concerned waterbodies (e.g. by vegetation thinning, population regulating interventions, or water management). In fact, the species may even be the first to recolonise new, vacant habitats after some interventions, for example artificial desiccation (Loureiro *et al.* 2015, Patoka *et al.* 2014). In some isolated waterbodies, the introduction of large predatory fish, for example Northern Pike (*Esox lucius*), European Catfish (*Silurus glanis*), European Perch (*Perca fluviatilis*), or Pikeperch (*Sander lucioperca*) may locally reduce populations, but as the red marsh crayfish is able to disperse overland, the problems caused by its migration and colonisation of new habitats remain unsolved.

Also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

Botta-Dukát 2016, Chucholl 2011a, 2011b, Faulkes 2015, Gál *et al.* 2018, Holdich *et al.* 2009, Huner 2002, Kouba *et al.* 2014, Kozák *et al.* 2015, Loureiro *et al.* 2015, Patoka *et al.* 2014, Seprős *et al.* 2018a, Souty-Grosset *et al.* 2006, Szendőfi *et al.* 2018, Weiperth *et al.* 2015, 2019b, 2020d

András Weiperth

Florida Crayfish

Procambarus alleni (Faxon, 1884)

Native range

The Florida Crayfish, or alternatively Everglades crayfish or blue crayfish is native to Central and Southern Florida, in North America. Its largest population lives in the Everglades, which forms the southern border of its range (Hobbs 1984, www.nas.er.usgs.gov).

Introduction to Europe and Hungary

The Florida Crayfish reached Europe and presumably also Hungary in the 2000s, by way of the international pet trade (Faulkes *et al.* 2015, Patoka *et al.* 2015). Single specimens have been found in natural habitats in France (Souty-Grosset *et al.* 2006), and a large male was caught in the River Rhine, in Germany (Gross *et al.* 2008). Its third occurrence in Europe was recorded in Hungary, and this is the only case in which the establishment of a free-living population has been proven by a thorough survey. In August 2018, one male and one female were observed in the Gombás brook near Vác. In the course of the following survey, 38 more specimens were found (Weiperth *et al.* 2020d).

Biology of the species

In natural populations, wild coloured specimens of the Florida Crayfish are blue, brown, or reddish. In pet trade, however, almost exclusively the selectively bred entirely blue colour morph ('electric blue', 'brilliant blue') is available. Every specimen found in natural habitats in Hungary so far was also blue. The head of the Florida Crayfish is elongated, the rostrum tapers into a triangular, sharp spine, without lateral spines. The edges of the rostrum form laterally curved ridges on the head, which end at the centre of the head, behind the eyes. A ridge runs on each side of the head, from behind the eyes, slightly curving towards the centre of the head. The carapace bears either only a few spines or no spines at all. There are tiny tubercles arranged in a single row along the cervical groove. There are several lines of tubercles on the claws, centrally, marginally, and on its surface. The inside of the carpus joint bears one large and several small spurs. Young specimens are paler, the dark, dense colour develops in the course of the moulting.

The Florida Crayfish is of medium size, its body length rarely exceeds 10 cm. It is highly adaptable. As it can tolerate salinity, it occurs in brackish waters, but it also survives in thermal waters or temporarily desiccating habitats, e.g. in swamps or riparian habitats, roadside ditches, or desiccation pools. In periods of low water level or entire desiccation, it burrows into the bank or the bed (Hendrix *et al.* 1998, Dorn & Volin 2009). Like other *Procambarus* species occurring in Hungary, it is omnivorous. Based on its extensive burrowing and wide food spectrum, it may be regarded an ecosystem engineer. It has a relatively short life, adult specimens mostly live for three or four years. It becomes sexually mature at the age of one year. In its natural range, reproduction starts at the beginning of the dry season. Females excavate burrows in steep, loose banks or fine sediment, and lay their eggs (Hendrix *et al.* 1998). At the time of floods, the females come out of the burrows with newly hatched young attached to their pleopods. The young remain on or near the mother for weeks. The dynamics of inundation and draught strongly influences the reproductive cycle of the species.

Ecological conditions in Hungary

The species is known as thermophilous, but detection in early spring and late autumn demonstrate its adaptability (Weiperth *et al.* 2019b, 2020b). The Hungarian population inhabits a nearly 300 m long stretch of the Gombás brook near Vác. Cleaned communal wastewater from Vác and its neighbourhood, and untreated rainwater from the drainage system are both discharged into the stream. Because of this discharge, both the stream and its

© András Weiperth

estuary on the Danube floodplain have a fine particle sediment substrate, rich in organic matter (Weiperth *et al.* 2020b).

Ecological concern

No information on damage caused by the Florida Crayfish outside its native range is available, either from Hungary or elsewhere. However, it is a burrowing species, which behaves aggressively, and can transfer the pathogen of the Crayfish Plague (*Aphanomyces astaci*), which diseases native species (Dorn & Trexler 2007, Svoboda *et al.* 2017).

Economic impact

We have no information about either direct or indirect damage of the Florida Crayfish, due to its small population size and low abundance.

Potential control measures

The Florida Crayfish is commercially available and legally kept in Europe, including Hungary. The key to preventing repeated illegal introductions in Hungary is the education of aquarists. Results of surveying its established population point out the need for awareness-raising informative campaigns on the dangers of releasing any kind of alien species, including decapod species kept in aquariums, into natural waters or garden ponds (Botta-Dukát 2016, Faulkes 2015, Patoka *et al.* 2014, Weiperth *et al.* 2020b, 2020d). The population established in the Gombás brook could be reduced via the collection of the specimens during a continuous monitoring programme. It is also important to emphasise that, due to its recent detection only a few years ago, our knowledge on how it will behave in its Hungarian habitat is rather limited. Continuous monitoring of the population is by all means necessary, and if it adapts to our climatic conditions and begins expanding, immediate and firm measures need to be taken.

Should new populations be established, in isolated waterbodies, biocides or desiccation may be applied. The introduction of native predatory fish species, e.g. Pike (*Esox lucius*), European Catfish (*Silurus glanis*), European Perch (*Perca fluviatilis*), or Pikeperch (*Sander lucioperca*), or omnivorous fish species, for example the Eurasian Carp (*Cyrinus carpio*) could also reduce its populations and prevent its further dispersal.

References

Botta-Dukát 2016, Dorn & Trexler 2007, Dorn & Volin 2009, Faulkes 2015, Gross *et al.* 2008, Hendrix *et al.* 1998, Hobbs 1984, Patoka *et al.* 2014, 2015, Souty-Grosset *et al.* 2006, Svoboda *et al.* 2017, Weiperth *et al.* 2019b, 2020b, 2020d

András Weiperth

Marbled Crayfish

Procambarus virginalis Lyko, 2017

Native range

As far as we currently know, the Marbled Crayfish developed in the course of aquaristic breeding in Germany. It was first mentioned in 1995 (Lukhaup 2001, Huner 2002). According to published data, it has no natural occurrences (Peer *et al.* 2010, Scholtz *et al.* 2003). Its closest relative is the Slough Crayfish (*Procambarus fallax*), native to North America, and common in Florida and Georgia. Based on studies in population genetics and evolutionary biology, the specimens brought to Europe for aquaristic purposes originated from the Everglades subpopulation of the slough crayfish (Gutekunst *et al.* 2021, Maiakovska *et al.* 2021). The "creation" and the extremely rapid development of the Marbled Crayfish has an impact on several fields of science (e.g. oncogenetics, evolutionary biology, ecology) (Gutekunst *et al.* 2018).

Introduction to Europe and Hungary

The population of *Procambarus* species from which the Marbled Crayfish developed reached Germany and Austria in the early 1990s, through the pet trade, which was gaining momentum at the time. The first European populations of the "new species" were found in Germany in 2003, and in the Netherlands in 2005. These were also the first Marbled Crayfish populations established in natural habitats anywhere in the world (Holdich *et. al.* 2009, Lukhaup 2001, Martin *et al.* 2010b, Kozák *et al.* 2015). Due to the pet trade, the species entered many countries throughout the world (Faulkes 2015). Free-living populations have been reported from 16 European countries (Kouba *et al.* 2014, www.faculty.utrgv.edu).

In Hungary, its presence was first reported from the Páhoki channel, near Keszthely, in 2013 (Lőkkös *et al.* 2016). In 2014, it was found in Lake Hévíz as well. In the following years, it was observed in several warm and cold lakes in Budapest, the main-arm of the River Danube, many of its channals and natural or artificial tributaries, the thermal lakes near Egerszalók and the Laskó stream, their outlets, the Fényes Spring in Tata and its outflows, Békás and Csónakázó ponds in Miskolctapolca, and their outflows, the Hejő stream, the Keszthely Basin of Lake Balaton and several of its rivers, and the canals and ditches of Kis-Balaton (Ludányi *et al.* 2016, Mozsár *et al.* 2021, Seprős *et al.* 2018a, Szajbert *et al.* 2021, Szendőfi *et al.* 2018, Weiperth *et al.* 2015, 2020d).

Biology of the species

Several colour morphs of the species are commercially available, but the adult specimens in free-living populations usually have a marbled pattern, in accordance with their name, and are mostly brown or green, with a light brown median longitudinal stripe from the rostrum, which protrudes between the eyes, all the way to the caudal margin (Kawai *et al.* 2009). The colour is influenced by water pH. It is a species of medium size, it rarely reaches a length of 15 cm. Relative to the body, the claws are small, with small tubercles in a row on the dorsal edge. Its head is elongated, the triangular rostrum lacks the median carina, and tapers to the front. There is a large spine by each of the eyes on the cephalothorax. The surface of the cephalothorax is smooth, with a groove behind the eyes (postorbitally) in the centre. The lateral surfaces of the carapace are slightly granulate, with a large spine on each side, and a varying number of tubercles above and below (Souty-Grosset *et al.* 2006). Juvenile specimens are lighter, but the marble pattern is already present. The abdomen is wide, not tapering, therefore the caudal margin (*telson*) is large. Due to this, it can move very quickly in the water.

Although, being only recently described, it has not been researched long yet, according to research published so far, the Marbled Crayfish is remarkably adaptable, e.g. it can survive in clean Scandinavian lakes as well as in natural thermal waters, or habitats

© András Weiperth

polluted by used or industrial thermal water or other pollutants. Its reproduction rate is high, so populations are able to adapt rapidly to changing environmental conditions. It is omnivorous, its diet consists typically of algae, plants, organic debris, aquatic invertebrates, and sometimes higher organisms (e.g. fish) as well (Kawai *et al.* 2009, Kozák *et al.* 2015, Vesely *et al.* 2021). According to most published data, it tolerates temperatures between 8–30°C, so it prefers habitats with warm water discharge or exposed to other effects of urbanisation, but it is able to survive in colder and hotter waters as well, but mortality rates increase and reproduction stops (Kozák *et al.* 2015, Vesely *et al.* 2021). Its presence in natural and urbanised habitats in Scandinavia and also in Hungary without any thermal pollution contradict the above, and prove its great adaptability (www.faculty.utrgv.edu, Takács *et al.* 2015, Weiperth *et al.* 2020d). It rarely burrows deeper than 30-40 cm, usually into fine particle sediments or among the roots of aquatic plants.

Its life is relatively short, usually not more than three years. According to current knowledge, the Marbled Crayfish is the only decapod (Decapoda) which reproduces exclusively by parthenogenesis. All-female populations lay unfertilised eggs, from which genetically uniform offspring hatch (Scholtz *et al.* 2003, Martin *et al.* 2010a, Vogt *et al.* 2008). Male specimens have not been found either in laboratories or in nature (Seitz *et al.* 2005, Jones *et al.* 2009). It usually becomes sexually mature in less than a year. Average generation time is six months, and an individual has up to seven breeding cycles in the course of its life. The number of eggs increases with the number of completed cycles and the size of the mother. A female can carry 500–700 eggs at a time. The eggs are kept attached to the underside of the abdomen. Embryogenesis takes 17–28 days, depending on the temperature. During the first two juvenile stages, they only feed on the chorion, and remain under the mother's abdomen. From the third juvenile stage, they look like the adults, become free-swimming and start exogenous feeding, but they still go back to their mother for shelter. They develop through a further 12 juvenile stages, followed by 10 adult developmental stages (Martin *et al.* 2010a, Vogt 2010).

Ecological conditions in Hungary

In colonised habitats, the Marbled Crayfish forms abundant populations in a short time, and may become a dominant element of the communities. Its rapidly growing populations put enormous predatory pressure on natural ecosystems. According to Hungarian research, the entire species pool and food web are transformed in habitats invaded by the Marbled Crayfish (Szendőfi *et al.* 2018, Vesely *et al.* 2021). According to research carried out so far, the Marbled Crayfish is able to impact the populations of several native species and previously introduced alien species as well.

Ecological concern

In suitable habitats, the Marbled Crayfish grows rapidly, has high fecundity rates, behaves aggressively, and transfers the pathogen of the Crayfish Plague (*Aphanomyces astaci*) on susceptible native species (Keller *et al.* 2014, Svoboda *et al.* 2017). Specimens getting into infected water bodies may carry the disease as a vector organism in the course of further expansion. Although its claws are among the smallest of Hungarian crayfish species, it is very strong and sharp, and it is able to cut into large (e.g. fish carcass) or stiff (e.g. shoots of water lilies) food sources. Insect larvae, aquatic plants, and organic debris form a considerable part of its diet, but it also eats the eggs and larvae and juvenile of fish, and eggs and larvae (tadpoles) of amphibians (Jones *et al.* 2009, Vesely *et al.* 2021).

Economic impact

Large populations of the Marbled Crayfish impact the entire community of the colonised waterbodies. Although its burrows are not extensive, they still cause bank erosion both in urbanised and natural habitats. Specimens settling in garden ponds or urban ornamental lakes have a significant impact on aquatic vegetation and fish and amphibian fauna (Patoka *et al.* 2014, Weiperth *et al.* 2020a). Its introduction to Madagascar demonstrates the complexity of its impact. It was introduced to Madagascar in 2005, and by 2017, it had extended its range to approximately 100 000 km^2. Apart from excluding numerous endemic species and damaging rice fields, it also affects the populations of snails, e.g. *Biomphalaria pfeifferi*, which are intermediate hosts of blood fluke species, e.g. *Schistosoma haematobium*, which pose a threat to humans, and they also alter aquatic plant communities the snails feed on. The eggs of the flukes released by humans still enter the waters, but hatching larvae are not able to find suitable intermediate hosts anymore. As a result, the number of blood fluke infections decreased in habitats colonised by the Marbled Crayfish (Andriantsoa *et al.* 2019). Apart from its impact on human health, it also gained importance in Madagascar as a food source for both animals and people (Food and Agriculture Organisation of the United Nations 2020).

© András Weiperth

Potential control measures

Trading the Marbled Crayfish was banned in Hungary in 2016. Despite this, Hungarian aquarists breed it to this day (Weiperth *et al.* 2020d), and in the pet trade, the species can be found disguised by various names. It is critical to prevent the offspring produced in aquariums from being released into natural waters by every possible means. Awareness-raising, informative campaigns are needed to call attention to the dangers of releasing it into natural habitats, garden ponds, or urban lakes (Botta-Dukát 2016, Faulkes 2015, Weiperth *et al.* 2020d). Educating and raising awareness of the public about the dangers of the Marbled Crayfish are important, as in Hungary, many pet traders are ignorant or their knowledge is deficient. Voluntary regulations already exist among aquarists, owing to the negative effects of the Marbled Crayfish on aquarium communities. Some shops stopped selling it because of its bad reputation, but it is still widespread and easily available in Europe (Chucholl & Pfeiffer 2010, Faulkes 2015). The eradication of Marbled Crayfish populations usually requires a combination of site specific control measures (Gherardi *et al.* 2011). In the United States of America and Switzerland, native predatory fish species succeeded in reducing non-native crustacean populations (Frutiger & Müller 2002, Hein *et al.* 2006). In Hungary, an increasing amount of data is available on its predators, including native fish species, e.g. asp (*Leuciscus aspius*), Northern Pike (*Esox lucius*), European Catfish (*Silurus glanis*), European Perch (*Perca fluviatilis*), and Pikeperch (*Sander lucioperca*), adult specimens of the Marsh Frog (*Pelophylax ridibundus*), and, in the area of the Kis-Balaton, several alien cichlids (Cichlidae), and the Eurasian Otter (*Lutra lutra*) (Seprős *et al.* 2018a, Weiperth *et al.* 2020d).

Also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

Andriantsoa *et al.* 2019, Botta-Dukát 2016, Chucholl & Pfeiffer 2010, Faulkes 2015, Food and Agriculture Organisation of the United Nations 2020, Frutiger & Müller 2002, Gherardi *et al.* 2011, Gutekunst *et al.* 2018, 2021, Hein *et al.* 2006, Holdich *et al.* 2009, Huner 2002, Jones *et al.* 2009, Kawai *et al.* 2009, Keller *et al.* 2014, Kouba *et al.* 2014, Kozák *et al.* 2015, Lőkkös *et al.* 2016, Ludányi *et al.* 2016, Lukhaup 2001, Maiakovska *et al.* 2021, Martin 2010a, 2010b, Mozsár *et al.* 2021, Patoka *et al.* 2014, Scholtz *et al.* 2003, Seitz *et al.* 2005, Seprős *et al.* 2018a, Souty-Grosset *et al.* 2006, Svoboda *et al.* 2017, Szajbert *et al.* 2021, Szendőfi *et al.* 2018, Takács *et al.* 2015, Veselý *et al.* 2021, Vogt 2010, Vogt *et al.* 2008, Weiperth *et al.* 2020d

András Weiperth

Spiny-cheek Crayfish

Faxonius limosus (Rafinesque, 1817)

Native range

The Spiny-cheek Crayfish is native to North America. It is widespread in the United States, in the catchment of the Connecticut and Columbia Rivers, in the states Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Virginia, Vermont, and West Virginia, and in Canada, in the provinces Quebec and New Brunswick (Hobbs 1974b, Jezerinac *et al.* 1995, Souty-Grosset *et al.* 2006).

Introduction to Europe and Hungary

The Spiny-cheek Crayfish arrived in Europe in 1890, when 100 specimens were introduced into a fishery in Poland (Holdich *et al.* 2009, Kozák *et al.* 2015). Today, it is one of the most common non-native decapod (Decapoda) species in the waters of Europe. It became naturalised in more than 20 countries (Adams *et al.* 2015, Kouba *et al.* 2014, Souty-Grosset *et al.* 2006). There are also reports of its successful establishment on other continents. It is also colonising new areas in North Africa and Asia (Adams *et al.* 2015, Holdrich *et al.* 2009, Kouba *et al.* 2014, Schulz & Smietana 2001, Souty-Grosset *et al.* 2006, www.cabi.org).

It was introduced to Hungary from Germany in the 1950s, for farming purposes (Thuránszky 1960), but its industrial breeding was soon abandoned. According to research, it was not recorded in natural waters in Hungary before 1985. It was first found in a side arm of the River Danube near Újpest (presumably in the Újpesti bay) (Thuránszky & Forró 1987), and since then, it spread throughout the country. It occurs in the catchment of Lake Balaton, in the entire Hungarian section of the River Danube, in the River Tisza in its middle section and about the River Körös confluence, and it also invaded the catchments of the Bodrog, Ipoly, Tarna and Zagyva rivers (Ludányi *et al.* 2016, Seprős *et al.* 2018a, Weiperth *et al.* 2020a, 2020c, 2020d, Mozsár *et al.* 2021). It is spreading downstream in the River Danube at an average rate of 15 km per year (Puky & Schád 2006). It also occurs at several locations in our lowland watercourses, and its expansion is unstoppable (Kovács *et al.* 2005, 2015, Bódis *et al.* 2012). By the middle of the 2000s, it was the third (Puky & Schád 2006), and as of today, it is the most widespread decapod species in Hungary, including the native species as well (Ludányi *et al.* 2016, Mozsár *et al.* 2021, Weiperth *et al.* 2020d). Apart from spontaneous expansion, the Spiny-cheek Crayfish colonised fishponds in the catchment of Lake Balaton via fish stocking from one of our rivers (Danube, Tisza) (Ferincz *et al.* 2014). Today, it occurs in all four basins of the lake, in the section of the River Zala downstream from the Kis-Balaton, and in several tributaries of Lake Balaton (Weiperth *et al.* 2020c).

Biology of the species

The head of the Spiny-cheek Crayfish is rotund from above, with small spines on the edge of the carapace, in front of and behind the cervical groove. Its colour is usually brown, with brownish red patches on the dorsal side of the abdominal segments. (It got its Hungarian name, "fancy crayfish", from these.) Young specimens are lighter and uniform in colour, the specific patterns on the abdomen and the tips of the claws develop at the time of sexual maturation. Relative to the body, its claws are smaller than those of the native species. The inside of the carpus joint bears a spur. The tips of both the fixed (*propodus*) and the moveable finger (*dactylus*) are orange, with a dark band below. Its length rarely exceeds 11-12 cm. The division of its body in two main parts is conspicuous. On the dorsal surface of the carapace, the cervical groove indicates the border between the head and the thorax. It can retract its deepset eyes under the broadened posterior part of the rostrum for protection (Souty-Grosset *et al.* 2006, Kozák *et al.* 2015). Young specimens can be distinguished from other species by the spines around the cervical groove.


© András Weiperth

The outstanding adaptability of the Spiny-cheek Crayfish is one of the key factors of its rapid dispersal. Besides clean watercourses and standing waters, it also inhabits polluted canals, eutrophic lakes, and brackish waters. It is able to survive in various habitats, but it prefers rivers and river banks with soft bed material (sand, silt, clay), and overgrown areas (Souty-Grosset *et al.* 2006). In Hungary, it becomes abundant in slow-flowing running water sections with sediment deposition, but it also occurs in standing waters of varying size and polluted canals (Szendőfi *et al.* 2018). It has been observed to cross between habitats overland on the floodplain of the River Danube (Puky 2014) and near Lake Tisza as well (Szepesi & Harka 2011). Insect larvae, aquatic plants, and other organic matter (plant debris, carcasses) form a significant part of its diet, but it also eats the eggs and juvenile fish (Kozák *et al.* 2015). Unlike native species, the Spiny-cheek Crayfish is not susceptible to Crayfish Plague (*Aphanomyces astaci*), but it is a vector of the pathogen (Kozubíková *et al.* 2010, Svoboda *et al.* 2017). As such, it can infect highly susceptible native species, e.g. Noble Crayfish (*Astacus astacus*), Narrow-claw Crayfish (*A. leptodactylus*), Stone Crayfish (*Austropotamobius torrentium*), and it has a major part in spreading this disease in Hungary. It migrates easily, has a rapid life cycle, is highly fecund, and spreads aggressively (Souty-Grosset *et al.* 2006, Puky 2014). It successfully colonises habitats vacated because of the crayfish plague, and establishes abundant populations. Its ability of both sexual and asexual (parthenogenetic) reproduction also contributes to its successful establishment and rapid dispersal. It is extremely fecund. Under favourable conditions, it reproduces twice a year, producing up to 400 eggs at a time. Its average lifespan is four years.

It has been observed to co-exist with native species, partly because not all European Spiny-cheek Crayfish populations carry the pathogen of the Crayfish Plague (Kozubikova *et al.* 2010, Mozsár *et al.* 2021).

Ecological conditions in Hungary

As it is able to become abundant in suitable environments, it has a huge impact on aquatic communities. It can remove large amounts of decomposing organic matter, and by turning the sediment, it can also cleanse the water (Hegedűs 2007). Thus, it maintains water clarity as some kind of "public cleanliness officer". Apart from this, it has a central position in the food web, as specimens of varying size are important prey for several predator species (Souty-Grosset *et al.* 2006, Vesely *et al.* 2021). Unfortunately, its abundant populations cause increasing concern in Western Europe, because, after escaping clear lakes and entering slow-flowing canals, they consume the aquatic macrovegetation, which results in considerable eutrophisation, and on hot days, even leads to algal blooms (Souty-Grosset *et al.* 2006, Kozák *et al.* 2015). It has also been observed in some Hungarian ponds, lakes, and canals, that the abundant populations of Spiny-cheek Crayfish graze all rooted aquatic macrophytes entirely by the beginning of summer, and, consequently, formerly clear lakes become dense with algae by late August (Botta-Dukát 2016). The species is a heavy burrower. In Hungary, it is active during most of the year, from March to November, putting a significant predatory pressure on numerous aquatic organisms.

Ecological concern

If conditions are suitable, the Spiny-cheek Crayfish establishes abundant populations rapidly. It behaves aggressively, and may spread the pathogen of the Crayfish Plague (*Aphanomyces astaci*), which is highly dangerous to indigenous species. It poses a great ecological threat to water habitats, as it can replace entire populations of native, even protected species in a short time, and, by consuming all the aquatic macrophytes, it may also cause algal growth (Kozák *et al.* 2015).

Economic impact

The extensive burrow systems of the Spiny-cheek Crayfish may cause the erosion of river banks, both in urban and natural environments. In fishponds and fisheries, it causes damage by eating the commercial fish feed, preying on young fish, spreading diseases, and by burrowing in the canals and embankments of fishponds (Seprős *et al.* 2018a). An increasing amount of information in Hungary shows its importance as prey for several predatory fish species, including the European Eel (*Anguilla anguilla*), the Asp (*Leuciscus aspius*), the Pike (*Esox lucius*), the Smallmouth (*Micropterus dolomieu*) and the Largemouth Bass (*M. salmoides*), the European Catfish (*Silurus glanis*), the Volga Pikeperch (*Sander volgensis*), the Pikeperch (*S. lucioperca*), the Burbot (*Lota lota*), and the Perch (*Perca fluviatilis*) (Weiperth *et al.* 2020a). It is also eaten by some omnivorous members of the carp family, e.g. the Common Chub (*Squalius cephalus*), the Common Barbel (*Barbus barbus*), and the Eurasian Carp (*Cyprinus carpio*), some heron species (Ardeidae), and the Eurasian Otter (*Lutra lutra*).

Potential control measures

As the species is not commercially available, it is usually acquired for aquaristic purposes by personal collection. In Hungary, apart from spontaneous spreading, it can also reach isolated water systems via fish stocking. This is how it entered the catchment of Lake Balaton (Ferincz *et al.* 2014). These cases point out that, without adequate treatments, the Spiny-cheek Crayfish can travel far with fish transports, and it is possible to "infect" new catchments this way. New habitats are usually colonised this way by young specimens just separated from their mothers, not by adults, as it is easier for juvenile individuals to get through the various instruments used in the course of water removal. The risk of hitch-hiking crayfish can be reduced significantly by the proper treatment of the water fish are transported in (for example, by not discharging it into the recipient water body). Lately, the species has been used with increasing frequency as a fishing bait. Crayfish torn off the hooks poses two threats. If it is still alive, it may colonise the waterbody, and it may also infect native decapods with crayfish plague. The complexity of the problems detailed above make it critical to launch awareness-raising and informative campaigns. Besides the Spiny-cheek Crayfish, these should include every other alien decapod species as well. It is essential to highlight that no alien decapods should ever be released into either natural waters, or garden or urban ponds (Botta-Dukát 2016, Faulkes 2015, Weiperth *et al.* 2020d). It is usually difficult to reduce established populations of the Spiny-cheek Crayfish. In some isolated waterbodies, biocides may be applied, or native predatory fish species, e.g. pike (*Esox lucius*), European Catfish (*Silurus glanis*), or pikeperch (*Sander lucioperca*) may be introduced, which are able to contain the populations. However, as the Spiny-cheek Crayfish is able to spread overland, there is no comprehensive solution against its expansion to new habitats so far. The results of long-term surveys show that the population growth of the invasive Spiny-cheek Crayfish cannot be stopped by artificially disturbing the concerned water bodies (e.g. by vegetation thinning, population regulating interventions, or water management).

Also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

Adams *et al.* 2010, Botta-Dukát 2016, Bódis *et al.* 2012, Ferincz *et al.* 2014, Hegedűs 2007, Hobbs 1974b, Holdich *et al.* 2009, Jezerinac *et al.* 1995, Kouba *et al.* 2014, Kovács *et al.* 2005, 2015, Kozák *et al.* 2015, Kozubíková *et al.* 2010, Ludányi *et al.* 2016, Mozsár *et al.* 2021, Puky 2014, Puky & Schád 2006, Schulz & Smietana 2001, Seprős *et al.* 2018a, Souty-Grosset *et al.* 2006, Svoboda *et al.* 2017, Szendőfi *et al.* 2018, Szepesi & Harka 2011, Veselý *et al.* 2021, Weiperth *et al.* 2020a, 2020c, 2020d

András Weiperth

PERACARIDES

Peracarida

Red Split-legged Shrimp* (Bloody-Red Mysid)

Hemimysis anomala G. O. Sars, 1907

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).

Introduction to Hungary

Due to its hidden lifestyle, data on the expansion of *H. anomala* are uncertain, but genetic analyses revealed that it spread via two, unrelated routes (Audzijonyte *et al.* 2008). It was deliberately introduced to several locations in the then Soviet Union in the 1950s and 1960s, in the course of which it entered Lithuania (Arbačiauskas *et al.* 2011), and could spread on into the Baltic and the Rhine estuary (Audzijonyte *et al.* 2008). The Rhine–Main–Danube Canal, completed in 1992, provided the other corridor. It also reached the Rhine estuary through this corridor, and mixed with the other population (Audzijonyte *et al.* 2008). Records of its occurrence are not sufficient to retrace the stages of its dispersal, as it was already present on nearly the entire way by 1997–1998 (Tittizer *et al.* 2000). After the turn of the millennium, it was found in England (Holdich *et al.* 2006), and then in the Great Lakes of North America as well (Pothoven *et al.* 2007), making it the most widespread Ponto-Caspian mysid. The

© Jean-François Cart

* Translated from the Hungarian common name

American populations are genetically related to the populations in the Danube (Audzijonyte *et al.* 2008).

The species was first recorded in Hungary in the Danube, in 1997 (Borza *et al.* 2011). In 2011, it was also found in the Tisza (Borza & Boda 2013).


© Imre Potyó

Biology of the species

The species is medium-sized among the mysids of Hungary. It grows 7-8 mm long in the summer, and approximately 11 mm long in the overwintering generation. The reddish spots adorning its body make it easy to recognise. Unlike the other species, it is entirely free-floating, and only touches the substrate while feeding. It occurs in still and slow-flowing waters. It hides in dark crevices (e.g. among rocks) during the day, and only comes into the open after dark. Its life cycle is somewhat slower than that of the similar-sized *Limnomysis benedeni*. It produces four generations a year (Borza 2014). Although it can feed on filtered phytoplankton, animal-source food often forms a significant part of its diet (Evans *et al.* 2018). It is remarkably efficient as a predator of slow-moving water fleas (Cladocera) (Iacarella *et al.* 2015).

Ecological conditions in Hungary

According to current knowledge, *H. anomala* occurs in the entire Hungarian section of the Danube, the connected side branches and canal systems, and in the Tisza, downstream from Szolnok (Borza *et al.* 2011, Borza & Boda 2013). Populations are most abundant in inlets sheltered by ripraps (e.g. winter harbours).

Ecological concern

As an efficient predator, it can alter the composition of zooplankton communities, primarily by reducing the number of water fleas (Cladocera), which it catches easily (Ketelaars *et al.* 1999). This may increase the quantity of phytoplankton, which is favourable to other filter-feeding organisms (and their predators) (Ricciardi *et al.* 2012). Although it is an important food source for quick fish species (Pisces) with good vision (Lantry *et al.* 2012), its overall effect on their food supply is not necessarily positive, as it may reduce available food sources for the young. Its presence causes the lengthening of the food chain, and thus may increase heavy metal accumulation in aquatic organisms (Brown *et al.* 2022), and cause changes in parasite transmission pathways (Ricciardi *et al.* 2012).

Overall, the ecological impact of *H. anomala* may extend to every level of the food web, but this was neither predicted (Ricciardi *et al.* 2012), nor afterwards comprehensively documented. To further complicate matters, its impact may vary considerably in habitats with different conditions.

Economic impact

The presence of the species probably affects economically important fish species (Pisces), but we have no information about the direction and degree of this impact.

Potential control measures

Eradication or reduction of established populations is not a real possibility. Based on its considerable ecological impact, it is justified to prevent further expansion, for example by using filtered water in fish stocking procedures (Borza *et al.* 2011), and disinfecting boats and water sports gears transported overland (Coughlan *et al.* 2020).

References

Arbačiauskas *et al.* 2011, Audzijonyte *et al.* 2008, Borza 2014, Borza & Boda 2013, Borza *et al.* 2011, Brown *et al.* 2022, Coughlan *et al.* 2020, Evans *et al.* 2018, Holdich *et al.* 2006, Iacarella *et al.* 2015, Ketelaars *et al.* 1999, Lantry *et al.* 2012, Pothoven *et al.* 2007, Ricciardi *et al.* 2012, Tittizer *et al.* 2000

Péter Borza

Broad Split-legged Shrimp*

Katamysis warpachowskyi G. O. Sars, 1893

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).

Introduction to Hungary

The first non-native occurrence of *Katamysis warpachowskyi* was detected in 2001, in the Austrian and Slovakian-Hungarian sections of the Danube (Wittmann 2002). It appeared in the German section as well in 2008 (Wittmann 2008). In 2009, it was found in Lake Constance (Hanselmann 2010), but no further expansion in the Rhine has yet been reported.

Biology of the species

K. warpachowskyi is a relatively small species, it grows up to 6-7 mm long. Specimens of the wintering generation may be longer, up to 9 mm. Its body is slightly flattened, and broadens in the middle. Due to its streamlined body form, it can withstand currents relatively well, (Wittmann 2002), but requires solid substrates (rocks, pebbles). It is usually more abundant in stillwaters, where its substrate preference is not so pronounced. Due to its small size, it has a quick life cycle, and can produce up to six generations per year (Borza 2014). Although it can use various food sources, according to a study conducted in Lake Constance, it chiefly feeds on periphyton (Rothhaupt *et al.* 2014).

Ecological conditions in Hungary

In Hungary, the species is only present in the Danube, and its side branches and canals (Borza *et al.* 2011), with abundant populations usually in sheltered inlets (e.g. winter harbours).

© György Kriska

Ecological concern

According to current information, predatory feeding is probably less common to *K. warpachowskyi* compared to other invasive mysids (Mysida), so the problems this implies (e.g. decreasing the food sources of young fish) are lesser or nonexistent. On the other hand, several mainly quick-moving fish species (Pisces) searching for prey visually may eat *K. warpachowskyi* itself.

Economic impact

We have no information about actual economic effects, but its presence may influence the populations of some fish species (Pisces).

Potential control measures

Eradication or reduction of established populations is not a real possibility. It could probably colonise many more of our waters once it reached them, so its human mediated spreading, e.g. via fish stocking (Borza *et al.* 2011), is to be prevented.

References

Borza 2014, Borza *et al.* 2011, Hanselmann 2010, Rothhaupt *et al.* 2014, Wittmann 2002, 2008

Péter Borza

* Translated from the Hungarian common name

Common Split-legged Shrimp* (Caspian Slender Shrimp)

Limnomysis benedeni Czerniavsky, 1882

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).

Introduction to Hungary

The expansion of *Limnomysis benedeni* was first observed in the Hungarian section of the Danube in 1946. At the time of its detection, it was thought to be a tertiary relict, and was named "Pontic witness shrimp" in Hungarian. However, genetic analyses have

© Imre Potyó

* Translated from the Hungarian common name

disproven its relict status (AUDZIJONYTE *et al.* 2009). It was deliberately introduced into Lake Balaton in 1950 as a new food source for the fish (WOYNÁROVICH 1954). It appeared in the Austrian section of the Danube in the 1970s, and reached Germany in the 1990s. From here, via the Rhine–Main–Danube Canal, it also entered the Rhine (TITTIZER *et al.* 2000). In 2006, it was observed in Lake Constance as well (GERGS *et al.* 2008). It got to Lithuania in the 1960s, by way of intentional introductions in the then Soviet Union, but, opposed to several other species, it did not start expanding its range in the Baltic catchment (ARBAČIAUSKAS *et al.* 2011). A genetic analysis confirmed that the invasive populations originate from the Danube. Their genetic diversity is relatively high, implying repeated and/or mass spreading (AUDZIJONYTE *et al.* 2009).


© György Kriska

Biology of the species

L. benedeni is medium-sized among the mysids (Mysida) occurring in Hungary: its body is 7-8 mm long in the summer, and up to 11 mm long in the overwintering generation. It prefers still and slow-flowing waters, and occurs abundantly chiefly among aquatic plants (GERGS *et al.* 2008), but it is also present on other solid substrates (rocks, pebbles, plant debris). Its life cycle is relatively quick, it may produce up to five generations a year (BORZA 2014). It has a mixed diet, but its consuming significant amounts of animal source food has only been observed among experimental conditions (FINK *et al.* 2012). According to field studies, it chiefly feeds on fine pelagic particles, and to a lesser extent, on periphyton (FINK & HARROD 2013, HANSELMANN *et al.* 2013, ROTHHAUPT *et al.* 2014).

Ecological conditions in Hungary

L. benedeni is the most common mysid species (Mysida) in Hungary. It occurs in our large rivers (Danube, Drava, Tisza, and their main tributaries), in their side branches, canals, and also in Lake Balaton, Lake Fertő, and numerous smaller lakes and reservoirs (BORZA *et al.* 2011). In Lake Balaton, among submersed macrophytes, its density may be over than 10 000 specimens per m^2 (MUSKÓ & LEITOLD 2003).

Ecological concern

L. benedeni was intentionally introduced to Lake Balaton to contribute to the breeding of fish by transforming phytoplankton into a form of food they can utilize better (WOYNÁROVICH 1954). Studies conducted in Lake Balaton confirm that the species is significant in the diet of numerous fish, especially the young of predatory species (SPECZIÁR 2010). But, as *L. benedeni* is omnivorous, and the proportion of animal-source food (zooplankton) it consumes depends on environmental conditions, it may also be a competitor to young fish. This means that its overall impact on the fish stock is not necessarily positive, but, as comprehensive studies are lacking, clear conclusions cannot be drawn.

Economic impact

L. benedeni forms a considerable part of the diet of certain economically important fish species, e.g. the zander (*Sander lucioperca*) (SPECZIÁR 2010), but on the basis of available data, it is not possible to conclude whether its introduction had an overall positive or negative effect on their populations.

Potential control measures

Eradication or reduction of established populations is not a real possibility. Although it is already present in most of our large waters, there are still some lakes and reservoirs left which it could colonise, so further human mediated spreading, e.g. by fish stocking (BORZA *et al.* 2011), is to be avoided.

References

ARBAČIAUSKAS *et al.* 2011, AUDZIJONYTE *et al.* 2009, BORZA 2014, BORZA *et al.* 2011, FINK & HARROD 2013, FINK *et al.* 2012, GERGS *et al.* 2008, HANSELMANN *et al.* 2013, MUSKÓ & LEITOLD 2003, ROTHHAUPT *et al.* 2014, SPECZIÁR 2010, TITTIZER *et al.* 2000, WOYNÁROVICH 1954

PÉTER BORZA

Lake Split-legged Shrimp*

Paramysis lacustris (Czerniavsky, 1882)

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution). Its genetic diversity is remarkable (Audzijonyte *et al.* 2015).

Introduction to Hungary

Paramysis lacustris first started its expansion by way of deliberate introductions in the then Soviet Union in the 1950s and 1960s. This way, it reached the Baltic drainage area (Arbačiauskas *et al.* 2011, Audzijonyte *et al.* 2017). It became established in the low salinity lagoons of the sea, and from these, it reached Northeastern Germany as well (Zettler 2015).

It started spreading in the Danube catchment area independently of the above, in the 2010s (Audzijonyte *et al.* 2017). It was first found in the Tisza (Borza & Boda 2013), and later spread to the entire section of the Danube in the Carpathian Basin (Borza *et al.* 2019).

© Imre Potyó

* Translated from the Hungarian common name

© György Kriska

Biology of the species

P. lacustris is the largest mysid in Hungary. In the summer, its body length is 12 mm, while the overwintering generation is up to 16 mm long. Contrary to its Latin name (*lacustris* ~ of the lake), it occurs in flowing waters as well. It is relatively well able to withstand currents, and in slow-flowing waters, it can even actively spread upstream. Unlike the other three mysids occurring in Hungary, it has a pronounced preference for fine-particle substrates. It has a mixed diet. It can feed on phytoplankton and decomposing plant material, but large specimens often consume animal-source food (zooplankton, benthic invertebrates) as well (Lesutienė *et al.* 2007, 2008, Rakauskas 2019).

Ecological conditions in Hungary

P. lacustris occurs in the entire Hungarian section of the Danube, in the Tisza downstream from Balsa, in the Körös rivers, and their side branches and canals (Borza & Boda 2013, Borza *et al.* 2019). Despite its recent introduction, it rapidly established abundant populations in suitable habitats.

Ecological concern

The reason for the deliberate introduction of Ponto-Caspian crustaceans, i.e. that they form a suitable food source for fish (Pisces) by processing plant-source food, was definitely proven mistaken in the case of *P. lacustris*. This mysid consumes large amounts of zooplankton and benthic invertebrates itself, thereby decreasing the amount of food available for young fish and lengthening the food chain (Arbačiauskas *et al.* 2010, Rakauskas 2019).

Economic impact

The introduction of the species had no detectable positive effects on the fish stock of lakes and reservoirs in Lithuania (Arbačiauskas *et al.* 2010, Rakauskas 2019).

Potential control measures

Eradication or reduction of established populations is not a real possibility. It could probably colonise many more habitats in Hungary, e.g. lakes and reservoirs, with potentially significant ecological and even economic consequences (e.g. in the case of Lake Balaton). It is therefore highly justified to prevent its further expansion, for example by using filtered water in fish stocking procedures (Borza *et al.* 2011), and by thoroughly cleaning ships, boats, and other water sports gears when being transported overland.

References

Arbačiauskas *et al.* 2010, 2011, Audzijonyte *et al.* 2015, 2017, Borza & Boda 2013, Borza *et al.* 2011, 2019, Lesutienė *et al.* 2007, 2008, Rakauskas 2019, Zettler 2015

Péter Borza

Quiver Shrimps*

Chelicorophium spp.

Native range

Nine endemic *Chelicorophium* species occur in the so-called Ponto-Caspian region (the area of the Caspian Sea, the Black Sea and the Sea of Azov), and three of them became invasive.

Introduction to Hungary

In Hungary, *C. sowinskyi* was first found in the Danube in the 1910s (Borza 2011, Unger 1918). Not much later a second species, *C. curvispinum* also appeared in the country. This was first detected in Lake Balaton in the late 1920s. The third species, *C. robustum* started spreading in the Danube much later, after the turn of the millennium. Interestingly, a fourth species, *C. maeoticum* also occurred in the Carpathian Basin earlier, but it disappeared in the second half of the 20th century. Its only documented Hungarian record is from the Tisza (Szeged), from 1943 (Borza 2011).

© Jean-François Cart

* Translated from the Hungarian common name

C. curvispinum was the first to reach Western Europe, from Poland. This species became abundant in Germany in the 1910s, and also appeared in England in the 1930s (Crawford 1935). The other two species arrived in the early 2000s, through the Rhine–Main–Danube Canal (Bernerth & Stein 2003, Bernerth & Dorow 2010).

Biology of the species

Chelicorophium species are relatively small, usually up to 5-6 mm long, but *C. robustum* has a maximum length of about 8 mm. Their cylindrical bodies and strikingly large, thick second pair of antennae make them easy to distinguish from the gammarids (Gammaridae), another group of amphipods (Amphipoda). They construct tubes with threads drawn from their spinning glands and tiny particles of debris from the environment. They induce water currents inside their tubes with their swimming legs, and feed on suspended matter filtered with the densely ciliated bristles on their gnathopods. Different species specialise on different particles sizes (Borza *et al.* 2018b).

Ecological conditions in Hungary

C. curvispinum is the most widespread species in Hungary. Besides our three largest rivers (and their major tributaries, side branches, and connected canals), it also occurs in Lake Balaton and the Sió river (Borza 2011). *C. sowinskyi* is only present in the Danube, the Drava, and the system of the Tisza (Tisza, Nagykunság canals, Körös rivers). Till recently, *C. robustum* was only known from the Danube (Borza 2011), but in 2019, it was also recorded in the Tisza, downstream from Szeged (Borza *et al.* 2021).

Chelicorophium species build their tubes in sheltered nooks of solid substrates (stones, pebbles, pieces of wood, aquatic plants), protected from predators. If conditions are particularly favourable (ample food, few predators), they may form thick colonies covering every surface, with tens or even hundreds of thousands of specimens per m^2.

Ecological concern

In the years after its appearance, *C. curvispinum* became extremely abundant in the Rhine, which was then highly polluted and hypertrophic. At densities of up to a hundred thousand specimens per m^2, their tubes formed a thick, muddy coating on every available surface, literally suffocating Zebra Mussels (*Dreissena polymorpha*), which were highly abundant earlier, and excluding other invertebrates (Van den Brink *et al.* 1993). The situation later normalized, after the improvement of water quality, and the introduction of large Ponto-Caspian gammarids (Gammaridae) and gobies (Gobiidae), which prey on these species. According to this experience, *Chelicorophium* species are probably able to assist the successful establishment of other invasive species arriving after them.

Economic impact

They may influence the populations of fish (Pisces) preying on them. Cleaning the muddy layers of their tubes from submersed objects may have high costs.

Potential control measures

Eradication or reduction of established populations is not a real possibility. Because of their tubes, they can easily disperse attached to the submersed parts of ships or boats, so to prevent further dispersal, it is essential to clean these when trailed overland.

References

Bernerth & Dorow 2010, Bernerth & Stein 2003, Borza 2011, Borza *et al.* 2018b, 2021, Crawford 1935, Unger 1918, Van den Brink 1993

Péter Borza

Two-Spined Flea Shrimp*

Dikerogammarus bispinosus Martynov, 1925

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).

© Imre Potyó

* Translated from the Hungarian common name

Expansion in Europe and introduction to Hungary

The presence of *Dikerogammarus bispinosus* in the Hungarian section of the Danube has been known since the 1920s (Dudich 1927). It appeared in the upper sections of the river, in Austria and Germany in the 1990s (Müller *et al.* 2002). By this time, it could expand further through the Rhine–Main–Danube Canal, and after the turn of the millennium, it was detected in the Dutch and French sections of the Rhine as well (Labat *et al.* 2011).

Biology of the species

D. bispinosus is the smallest of the three invasive *Dikerogammarus* species in Hungary, its maximum body length is ca. 16 mm. It has two spines on each of the protuberances on its urosomes (the other two *Dikerogammarus* species have a varying number of spines). It prefers strong currents, it is able to establish stable populations in the fast-flowing sections of large rivers with gravelly bed material (Borza *et al.* 2017). It also inhabits ripraps, but it may be excluded by its larger relative, *Dikerogammarus villosus* (Borza *et al.* 2017).

Ecological conditions in Hungary

Recently, it has only been recorded in the Danube. In fast-flowing sections with gravelly beds, it may become abundant, sometimes reaching densities of over 1000 specimens per m^2 (Borza *et al.* 2017). It entered Lake Balaton in 1950 incidentally, in the course of the deliberate introduction of *Limnomysis benedeni*. It became established, along with *Dikerogammarus haemobaphes* (Ponyi 1956), but after the turn of the millennium, it disappeared entirely (Borza *et al.* 2017), presumably as a result of the appearance of *D. villosus*. Previously, its presence was reported from several rivers, canals, and streams (Juhász *et al.* 2006), but these occurrences have not been confirmed lately.

Ecological concern

In the wake of the introduction of *D. bispinosus* and *D. haemobaphes* to Lake Balaton, *Gammarus roeselii* disappeared (Ponyi 1956), but the exact contribution of the two *Dikerogammarus* species to this event cannot be clearly distinguished. Probably *D. bispinosus* has the least ecological significance of the three invasive *Dikerogammarus* species, being smaller and a weaker competitor. At the same time, it may be significant as a food source for fish (Pisces), especially for those in fast-flowing waters.

Economic impact

We have no information about actual economic effects, but its presence may influence the populations of certain fish species (Pisces) as a potential food source.

Potential control measures

Eradication or reduction of established populations is not a real possibility. It could probably invade further habitats (e.g. in the Drava or the Upper Tisza), therefore, its human mediated further spreading is to be avoided.

References

Borza *et al.* 2017, Dudich 1927, Juhász *et al.* 2006, Labat *et al.* 2011, Müller *et al.* 2002, Ponyi 1956

Péter Borza

Pontic Flea Shrimp* (Demon Shimp)

Dikerogammarus haemobaphes (Eichwald, 1841)

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).

Expansion in Europe and introduction to Hungary

The presence of *Dikerogammarus haemobaphes* was detected in the Hungarian sections of the Danube and the Tisza in the 1920s (Dudich 1927), and it has been present in Lake Balaton since its inadvertent

© Denis Copilaş-Ciocianu

* Translated from the Hungarian common name

introduction in 1950 (Ponyi 1956). It reached the German section of the Danube in the 1970s, and, shortly after the completion of the Rhine–Main–Danube Canal (1992), it appeared in the Rhine as well (Tittizer *et al.* 2000). After the turn of the millennium, it also became established in numerous rivers in France (Labat *et al.* 2011), and even appeared in England in 2012 (Gallardo & Aldridge 2013). It had another dispersal route, starting from the Dnieper catchment. This way, it reached Belarus, Poland, and Germany (Bij de Vaate *et al.* 2002). A genetic analysis has shown that individuals of the latter population reached England, and it also detected the presence of a cryptic species in the original distribution area (Jażdżewska *et al.* 2020).

Biology of the species

D. haemobaphes is somewhat smaller and less robust than *Dikerogammarus villosus*, with a maximum body length of 18 mm. It has a better dispersal ability than its better-known relative, and in the course of its range expansion, it appeared at most locations earlier. But it is a weaker competitor than *D. villosus* (Kobak *et al.* 2016), so after the appearance of the latter, its populations are usually reduced (Kley & Maier 2006). Predation is of similar importance in their feeding (Bacela-Spychalska & Van der Velde 2013), but its individual effects are weaker than those of *D. villosus* (Bovy *et al.* 2014). It tolerates a wide range of substrates. Besides stones or pebbles, it also occurs on aquatic plants, and Zebra Mussel (*Dreissena polymorpha*) colonies (Kobak *et al.* 2009).

Ecological conditions in Hungary

D. haemobaphes is one of the most widespread Ponto-Caspian invasive crustaceans in Hungary, it is present in most of our significant rivers and canals. In the Danube, it prefers medium or low current velocity and gravelly substrates (Borza *et al.* 2017). In Lake Balaton, it occurs in the deeper parts of the riprap protecting the shoreline, in colonies of the Zebra (*Dreissena polymorpha*) and the Quagga Mussel (*D. rostriformis bugensis*), and among submersed macrophytes. In some sites, it reaches high densities (Muskó & Leitold 2003, Muskó *et al.* 2007).

Ecological concern

D. haemobaphes is a weaker competitor and a less voracious predator than *D. villosus*, so its significance may be most pronounced where the other species is not yet present, or in habitats unsuitable for it. After the introduction of *D. haemobaphes*, native gammarids (Gammaridae) usually do not disappear immediately (Kley & Maier 2006), but this does not necessarily imply the possibility of permanent co-existence. In Hungary, *D. haemobaphes* may have contributed to the disappearance of *Gammarus roeselii* from Lake Balaton (Ponyi 1956), but it is impossible to clearly distinguish its impact from that of the simultaneously introduced *Dikerogammarus bispinosus*.

Economic impact

We have no information about actual economic effects, but its presence may influence the populations of certain fish species (Pisces).

Potential control measures

Eradication or reduction of established populations is not a real possibility. Although it has presumably reached the limits of its dispersal capacity in our large rivers, it is quite possible that it is able to colonise isolated lakes and reservoirs as well. Therefore, its further human mediated spreading (e.g. attached to boats) is to be prevented.

References

Bacela-Spychalska & Van der Velde 2013, Bij de Vaate *et al.* 2002, Borza *et al.* 2017, Bovy *et al.* 2014, Dudich 1927, Gallardo & Aldridge 2013, Jażdżewska *et al.* 2020, Kley & Maier 2006, Kobak *et al.* 2009, 2016, Labat *et al.* 2011, Muskó & Leitold 2003, Muskó *et al.* 2007, Ponyi 1956, Tittizer *et al.* 2000

Péter Borza

Two-Humped Flea Shrimp* (Killer Shimp)

Dikerogammarus villosus (Sowinsky, 1894)

Native range

The species originates from the so-called Ponto-Caspian region, which encompasses the area of the Caspian Sea, the Black Sea, and the Sea of Azov. It occurs in the low salinity waters of these seas, and the lower reaches of rivers flowing into them (Rewicz *et al*. 2014). In the Danube, it is only native to the Delta (Borza *et al*. 2017).

Expansion in Europe and introduction to Hungary

The Rhine–Main–Danube system was the main invasion corridor via which this species reached numerous countries in Central and Western Europe. Unrelated to this, it spread towards Poland from the Dnieper, and also appeared in the upper reaches of the Volga (Rewicz *et al*. 2015). Its occurrence was first authentically recorded in Hungary in the 1970s, from the Danube. Earlier observations mention *Dikerogammarus bispinosus*, then regarded a subspecies. It appeared in Lake Balaton around the turn of the millennium (Borza *et al*. 2017). Its expansion was primarily assisted by navigation, but it also appeared in many isolated lakes, probably via the overland transport of small ships, boats, and other water sports gears (Bacela-Spychalska *et al*. 2013).

© György Kriska

* Translated from the Hungarian common name

Biology of the species

D. villosus is a relatively large species, its adult length may exceed 2 cm. It has two characteristic protuberances on the dorsal side of the urosomes (a shared characteristic of the species of the *Dikerogammarus* genus). Its body is often spectacularly spotted, but some specimens have a uniform colour, without any patterns.

D. villosus is one of the most successful invasive species, chiefly due to its remarkably wide food spectrum. It can feed on a great variety of sources from microalgae through decomposing plants to periphyton, and predatory feeding is also common (Platvoet *et al.* 2009). Its rapid growth and reproduction may also contribute to its success (Pöckl 2009), just like its relatively hard exoskeleton, which may make it a less desirable prey for predators compared to other gammarids (Gammaridae) (Błońska *et al.* 2015).

Ecological conditions in Hungary

D. villosus occurs in our large rivers (Danube, Drava, Tisza, and their major tributaries), and Lake Balaton. It is usually found under stones, large pebbles, or pieces of wood. In Lake Balaton, it is a dominant species in the shallow parts of the riprap protecting the shore, with densities of up to several thousand specimens per m^2 (Muskó *et al.* 2007).

Ecological concern

The ecological significance of this species is mainly related to its predatory feeding, as the populations of some of its preys – including other gammarids – may decrease or even disappear (Dick *et al.* 2002). The direct effect is enhanced if *D. villosus* forces a prey to leave its shelter, making it more exposed to predation by others (de Gelder *et al.* 2016). This effect probably played a part in the reduction of the populations of several gammarid species in Europe, both native (e.g. *Gammarus* species) and invasive. In Hungary, the disappearance of *Dikerogammarus bispinosus* from Lake Balaton is presumably due to the activity of *D. villosus* (Borza *et al.* 2017). On the other hand, native species of the Danube had probably been reduced earlier, when the other two alien *Dikerogammarus* species arrived. But the native species could persist in habitats unsuitable for *D. villosus* (e.g. in streams), just as the other Ponto-Caspian species are capable of co-existence, in the case of habitat separation, and if conditions are suitable (Borza *et al.* 2018b).

Economic impact

The changes which *D. villosus* induces in the food web probably affect economically important fish species (Pisces), but the degree of this effect is unknown.

D. villosus is able to cause perceptible, although only superficial injuries on human skin with its claws, typically to people standing still in the water with bare skin for a long time (e.g. while angling). However, as this behaviour is not common and the injuries are slight, health concerns related to the species are negligible.

Potential control measures

Eradication or reduction of established populations is not a real possibility. As it has already reached the limits of its dispersal capacity in our large waters, the only possibility is to prevent its further spreading into small, isolated waterbodies. This may be achieved by the proper cleaning of boats and sports gears transported overland between waterbodies.

References

Bacela-Spychalska *et al.* 2013, Błońska *et al.* 2015, Borza *et al.* 2017, 2018b, de Gelder *et al.* 2016, Dick *et al.* 2002, Muskó *et al.* 2007, Platvoet *et al.* 2009, Pöckl 2009, Rewicz *et al.* 2014, 2015

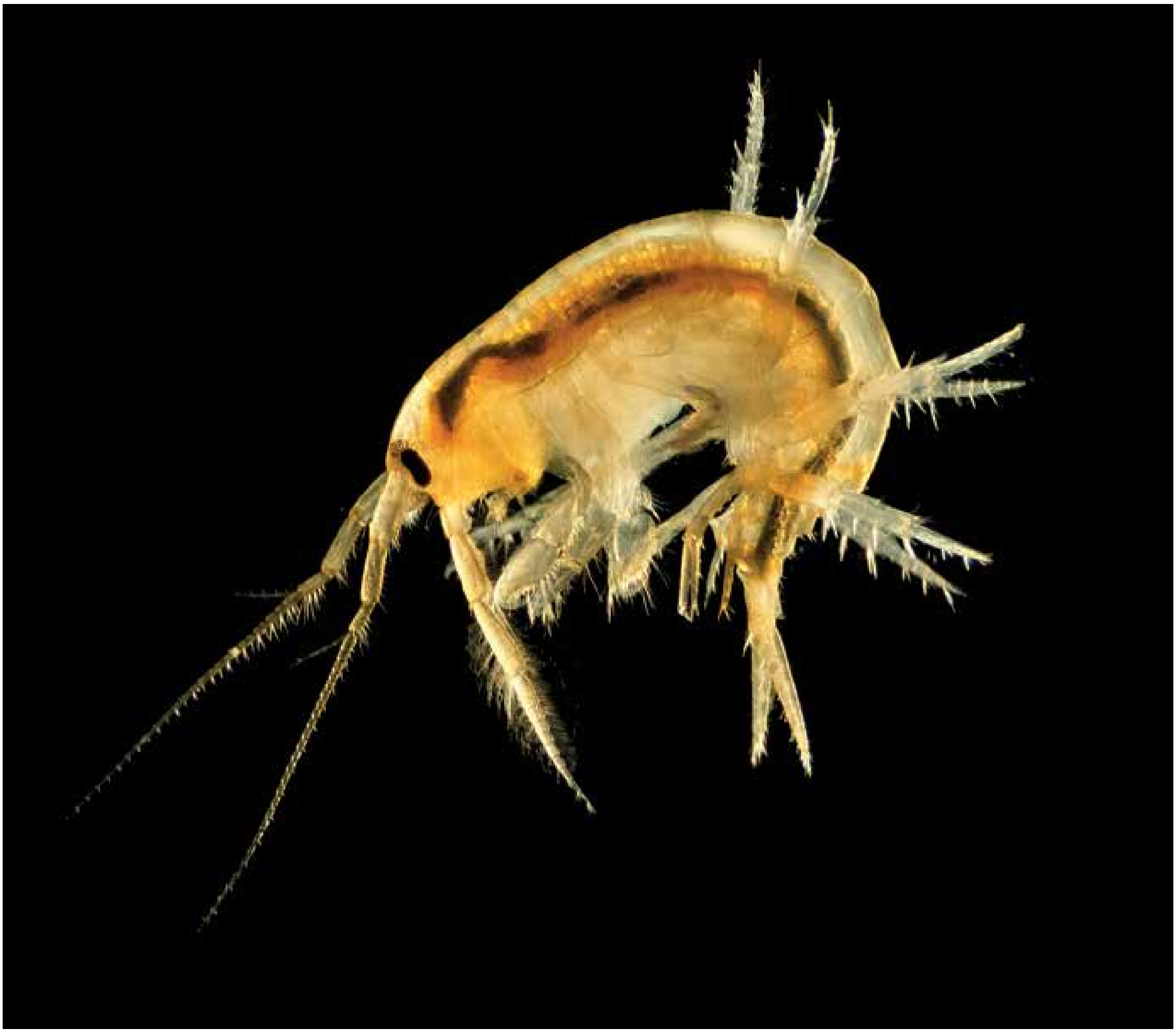
Péter Borza

Slender Flea Shrimp*

Chaetogammarus ischnus (Stebbing, 1899)

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).



© Imre Potyó

* Translated from the Hungarian common name

Expansion in Europe and introduction to Hungary

Its first, presumably non-native occurrence was reported in Hungary in the 1920s (Dudich 1927), but the actual introduction probably happened earlier, as at this point, it was already present in the Danube and the Tisza as well. Not much later, it was detected in Poland, and started spreading west (Cristescu *et al.* 2004). It reached Germany and the Netherlands before the completion of the Rhine–Main–Danube Canal (1992), and it was recorded in France in the 2000s (Labat *et al.* 2011). It also reached North America, possibly in the ballast water of ocean liners, and it established stable populations there in the 1990s, as the only Ponto-Caspian gammarid (Gammaridae) so far (Witt *et al.* 1997).

Biology of the species

Chaetogammarus ischnus is a relatively small species, its maximum length is about 8-9 mm. It has a laterally flattened body, which enables it to squeeze into narrow crevices among pebbles or mussel shells, thus avoiding contact with other gammarids (Gammaridae) (Borza *et al.* 2018a). It presumably feeds on periphyton and floating particles. Predatory behaviour is less common than in larger species (Bacela-Spychalska & Van der Velde 2013, Van Riel *et al.* 2006).

Ecological conditions in Hungary

C. ischnus is present in the three largest rivers of Hungary (Danube, Tisza, Drava). It prefers strong currents, it is most abundant (up to several thousand specimens per m^2) in the fast-flowing, gravelly sections of the Danube, and in habitats with plenty of accumulated empty mussel shells (Borza *et al.* 2018a).

Ecological concern

According to some studies, it reduced the populations of native gammarids (Gammaridae) when it became established in North America, but other studies do not support these results (Cooper *et al.* 2012). No such impact has been suggested related to its European spreading. Its main ecological significance lies in its being a potential food source for fish (Pisces), especially those in fast-flowing waters.

Economic impact

We have no information about actual economic effects, but its presence may influence the populations of certain fish species (Pisces) as a potential food source.

Potential control measures

Eradication or reduction of established populations is not a real possibility. Although it has probably reached most suitable habitats, its human mediated further spreading (e.g. attached to boats) should be prevented.

References

Bacela-Spychalska & Van der Velde 2013, Borza *et al.* 2018a, Cooper *et al.* 2012, Cristescu *et al.* 2004, Dudich 1927, Labat *et al.* 2011, Van Riel *et al.* 2006, Witt *et al.* 1997

Péter Borza

Hirsute Flea Shrimp*

Trichogammarus trichiatus (Martynov, 1932)

Native range

Its original distribution area was limited to the low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and the lower reaches of rivers flowing into them (e.g. the Danube) (Borza *et al.* 2015).

Expansion in Europe and introduction to Hungary

Its first occurrence outside of its native range was observed in the German section of the Danube in 1996, where it presumably got attached to ships from the

© Jean-François Cart

* Translated from the Hungarian common name

Lower Danube. Later, advancing through the Rhine, it spread to several other countries (Bij de Vaate *et al.* 2002, Labat *et al.* 2011, Rachalewski *et al.* 2013). Its spreading continued downstream in the Danube, and it also appeared in the uppermost part of the Hungarian section. In 2009, it was found for the first time near Rajka (Borza 2009), but afterwards, its spreading in the Danube apparently stopped.

Simultaneously, the species also started spreading along the Dnieper, and reached Belarus (Lipinskaya *et al.* 2018a).

Biology of the species

Trichogammarus trichiatus is a medium-sized species (up to ca. 15 mm long), with a relatively robust build. The male is adorned by dense, curled setae, while the setae of females are straight. Information about its biology is scarce. Outside of its native range, most records are from dammed river sections and canals. According to sporadic observations published so far, it is mostly found among decomposing plant material, but it also requires good oxygen supply (Borza *et al.* 2018). It probably feeds on plant parts.

Ecological conditions in Hungary

According to current knowledge, *T. trichiatus* is only present in Hungary in the Szigetköz branch system of the Danube. It has an established population at the site of its first record, but apart from this, only sporadic occurrences are known. Its downstream dispersal past this branch system is probably prevented by the absence of suitable habitats. However, it could probably become established in further waterbodies as well (e.g. canals, reeds in lakes), once it reached them.

Ecological concern

The presence of *T. trichiatus* has not yet raised any actual ecological problems (such as replacing other species). Despite its special habitat requirements, it may become abundant if conditions are favourable (Borza *et al.* 2018), and thus may be of consequence as a food source for fish (Pisces).

Economic impact

We have no information about actual economic effects, but its presence may influence the populations of some fish species (Pisces).

Potential control measures

Eradication or reduction of established populations is not a real possibility. Although it is apparently not a particularly problematic species, its human mediated further spreading (e.g. attached to boats) should be prevented.

References

Bij de Vaate *et al.* 2002, Borza 2009, Borza *et al.* 2015, 2018, Labat *et al.* 2011, Lipinskaya *et al.* 2018a, Rachalewski *et al.* 2013

Péter Borza

Obese Flea Shrimp*

Obesogammarus obesus (G. O. Sars, 1894)

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).

© Imre Potyó

* Translated from the Hungarian common name

Expansion in Europe and introduction to Hungary

The first occurrence of *Obesogammarus obesus* outside of its native range was reported from the Danube in Hungary, in the early 1990s (Nesemann *et al.* 1995). Later it also appeared in the upper sections, and spread further along the Rhine, via the Rhine–Main–Danube Canal (Nehring 2006, Boonstra *et al.* 2016). Simultaneously, its dispersal in the Dnieper catchment was also observed, as far as Belarus (Semenchenko & Vezhnovetz 2008).

Biology of the species

O. obesus is a relatively small species with a maximum length of 10 mm, named for its remarkably thick build. Its body is thick in the middle and tapers to the ends, and it has short, strong legs. These make this species an able burrower, which is useful as a form of defence from predators in fine sediments. It probably feeds among sediment particles.

Ecological conditions in Hungary

It prefers habitats with solid substrates, but fine particle size (fine gravel, sand, clay). If conditions are favourable (e.g. in the colonies of corophiids with ample nutrient supply), its density can reach several thousand specimens per m^2 (Borza *et al.* 2018a). In Hungary, it only occurs in the Danube and the Lower Tisza.

Ecological concern

Its ecological significance may mostly lie in its being a food source for fish. Its presence may promote the establishment of other invasive species, e.g. gobies (Gobiidae).

Economic impact

We have no information about actual economic effects, but its presence may influence the populations of certain fish species (Pisces).

Potential control measures

Eradication or reduction of established populations is not a real possibility. It could probably invade further habitats (e.g. in the upper section and tributaries of the Tisza, the Drava, or even Lake Balaton), therefore, its human mediated further spreading is to be prevented.

References

Boonstra *et al.* 2016, Borza *et al.* 2018a, Nehring 2006, Nesemann *et al.* 1995, Semenchenko & Vezhnovetz 2008

Péter Borza

Robust Flea Shrimp*

Pontogammarus robustoides (G. O. Sars, 1894)

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).

Expansion in Europe and introduction to Hungary

Pontogammarus robustoides was introduced to many lakes and reservoirs in the then Soviet Union, as a food source for fish. In the 1960s, via its successful introduction to Lithuania, it reached the Baltic catchment (Arbačiauskas *et al.* 2010), and spread towards Poland in the 1980s (Grabowski *et al.* 2007). Later it appeared in Germany (Tittizer *et al.* 2000) and the Netherlands as well (Moedt & van Haaren 2018). Its expansion in the Danube drainage area is unrelated and began much later. In Hungary, it was first detected, quite unexpectedly, in the Maros river, not in the Danube, in 2019 (Csabai *et al.* 2020).

© Denis Copilaş-Ciocianu

* Translated from the Hungarian common name

Biology of the species

P. robustoides is a relatively large (maximum length 18 mm), robust species. Similarly to *Obesogammarus obesus*, it is a burrowing species, occurring chiefly on soft substrates. If conditions are favourable, it also likes crevices among rocks or pieces of wood, but in the presence of *Dikerogammarus villosus*, it is usually excluded from these shelters (Jermacz *et al.* 2015). Similarly to *D. villosus*, predatory feeding is common (Bacela-Spychalska & Van der Velde 2013).

Ecological conditions in Hungary

In Hungary, according to current knowledge, *P. robustoides* only occurs in the Maros river and the Tisza, downstream from the Maros confluence. Its population is presumably stable, as many specimens were found at several sampling sites. As it has a wide tolerance for habitat conditions (it can colonise lakes and reservoirs as well as rivers and canals), further, significant expansion is to be expected.

Ecological concern

It has been shown in Lithuanian lakes that the biomass and species richness of the littoral invertebrate community decreased significantly as a consequence of the introduction of *P. robustoides* (Gumuliauskaitė & Arbačiauskas 2008). Although fish (Pisces) like to eat it, their overall food supply is not increased, and some native invertebrates may even be excluded (Arbačiauskas *et al.* 2010). Similar processes may have already taken place in the large rivers of Hungary due to the earlier expansion of *D. villosus*, but *P. robustoides*, due to its wider habitat spectrum, may induce similar changes in other types of waterbodies as well.

Economic impact

The introduction of the species had no detectable positive effects on the fish stock in Lithuania (Arbačiauskas *et al.* 2010).

Potential control measures

Eradication or reduction of established populations is not a real possibility. Apart from its current, limited range, it could probably colonise many more waters, both still and flowing. Therefore, human mediated spreading is to be prevented.

References

Arbačiauskas *et al.* 2010, Bacela-Spychalska & Van der Velde 2013, Csabai *et al.* 2020, Grabowski *et al.* 2007, Gumuliauskaitė & Arbačiauskas 2008, Jermacz *et al.* 2015, Moedt & van Haaren 2018, Tittizer *et al.* 2000

Péter Borza

Pontic Aquatic Isopod

Jaera sarsi Valkanov, 1936

Native range

It was originally distributed in low salinity waters of the Caspian Sea, the Black Sea, and the Sea of Azov, and in the lower sections of rivers flowing into them (including the Danube; so-called Ponto-Caspian distribution).

Introduction to Hungary

Jaera sarsi is relatively difficult to notice, due to its tiny size and hidden lifestyle, so information about its dispersal history is quite uncertain. Its first, presumably non-native occurrence was reported from the Hungarian section of the Tisza in 1930 (Dudich 1930).

© Jean-François Cart

© Jean-François Cart

A few years later, it was also found in the Danube by Budapest (Kesselyák 1938). It already occurred in the German section of the Danube in the 1960s, and spread further towards Western Europe after the completion of the Rhine–Main–Danube Canal (1992) (Bij de Vaate *et al.* 2002). It was detected in Lake Balaton in the 1990s (Nesemann *et al.* 1995; Ponyi & P. Zánkai 1996).

Biology of the species

J. sarsi is only 2-3 mm long, and occurs exclusively on solid substrates. It has a highly flattened body, so it can hide into the narrowest crevices between rocks, large pebbles, or plant debris, where larger predators cannot follow it (Borza *et al.* 2018a). It presumably feeds on periphyton covering rocks, and on decomposing plant material.

Ecological conditions in Hungary

In Hungary, *J. sarsi* is present in the three largest rivers (Danube, Tisza, Drava) and Lake Balaton. In rivers, it prefers strong currents and gravelly or rocky substrates. Its density may reach several thousand specimens per m^2 in such habitats (Borza *et al.* 2018a). In Lake Balaton, it is a characteristic and often abundant species of the shore protection ripraps (Muskó *et al.* 2007), but it also occurs among submersed macrophytes (Muskó & Leitold 2003).

Ecological concern

Its ecological significance may mostly lie in its being a food source for small predators, e.g. gammarids (Gammaridae), gobies (Gobiidae), and other small fish species (Pisces), therefore its presence may promote the establishment of other invasive species, e.g. gobies (Gobiidae).

Economic impact

We have no information about actual economic effects, but its presence may influence the populations of certain fish species (Pisces).

Potential control measures

Eradication or reduction of established populations is not a real possibility. Although it has probably reached most suitable habitats, its human mediated further spreading (e.g. attached to boats) is to be avoided.

References

Bij de Vaate *et al.* 2002, Borza *et al.* 2018a, Dudich 1930, Kesselyák 1938, Muskó & Leitold 2003, Muskó *et al.* 2007, Nesemann *et al.* 1995, Ponyi & P. Zánkai 1996

Péter Borza

HEMIPTERANS

Hemiptera

Oak Lace Bug

Corythucha arcuata (Say, 1832)

Native range

It is native to North America, in the Eastern United States, up to the south of Canada (Barber 2010).

Introduction to Hungary

It was first detected in Europe in 2000, in Italy (Bernardinelli & Zandigiacomo 2001). At this point, it was already suggested that it may spread throughout Europe, and stopping it is probably hopeless. Precise details of the introduction are unknown, but it probably entered our continent with live plant material. Although adult Oak Lace Bugs can fly, the species is a typical "hitch-hiker", its rapid dispersal to large distances is assisted by road and railroad traffic. This means that it does not spread along a "front line", but instead appears at distant, isolated locations, which, by way of continuous expansion, merge in the end.

© György Csóka


© György Csóka

Oak lace bugs wintering under peeling bark

In 2002, two individuals were caught in a Malaise trap in Switzerland (Forster *et al.* 2005). Also in 2002, it was detected in Turkey as well, about 200 km east of Istanbul (Mutun 2003). In 2005, it was recorded in Iran (West Azerbaijan Province) (Samin & Linnavouri 2011). By the summer of 2008, its range in Turkey covered 28,000 km^2 (Mutun *et al.* 2009). It probably spread on later towards the Balkan Peninsula from this Western Asian infestation centre. The reconstruction of dispersal route(s) aided by population genetic analyses is in progress.

The species was recorded in Bulgaria in July 2012 (Dobreva *et al.* 2013), in Hungary (Szarvas, Vácrátót) (Csóka *et al.* 2013), Croatia (Hrašovec *et al.* 2013), and Serbia in 2013 (Poljaković-Pajnik *et al.* 2015, Pap *et al.* 2015), and near Krasnodar in Russia in 2015 (Neimorovets *et al.* 2017). In 2016, it appeared in Albania (E. Cota *pers. comm.*), at two locations in Romania, about 400 km distant from each other (Don *et al.* 2016, Chireceanu *et al.* 2017), and also near the Croatian border in Slovenia (Jurc & Jurc 2017). In Bosnia-Herzegovina (Glavendekić & Vuković Bojanović 2017, Dautbašić *et al.* 2018), Southwestern France (Streito *et al.* 2018), and Ukraine (V. Meshkova *pers. comm.*), it was first detected in 2017. In May 2018, it was observed in Northern Greece (Csóka *et al.* 2020), and in June, in Slovakia (Zúbrik *et al.* 2018). It was also recorded in Moldavia in that year (Derjanschi & Mocreac 2018). It was registered in July 2019 in North Macedonia, near Skopje (Sotirovski *et al.* 2019). In the course of a survey conducted in September 2019, it was found at 21 locations in Southeastern Austria (Sallmanshofer *et al.* 2019), and also in 2019, it appeared in Czechia as well (Mertelík & Liška 2020). In Europe, it was most recently (summer 2021)

Larvae of the oak lace bug

recorded in Portugal, near Porto (Gil & Grosso-Silva 2021). In the coming years, it will probably invade many more European countries.

Biology of the species

The adult bug is approximately 3 mm long, with lace-like wings. There are three brown markings on each of the forewings, two on the outer margin, and one near the centre, on the inner side of the wing (Tuba *et al.* 2012). The eggs are dark, elliptical, and 0.3–0.4 mm high. The brown spotted nymphs are flattened, oval, and spiny.

It has at least two generations a year. A third may also develop, but this may be inhibited by, for example, the total consumption of the food supply. The generations overlap, so every developmental stage is present simultaneously from May to October. Adult Oak Lace Bugs winter from October to April, in bark crevices, under peeling bark, or in tree forks covered in leaf litter, in aggregated groups (up to more than 1,000 specimens). They leave their wintering microhabitats at the time of budburst. For a few weeks, they need so-called mature feeding, and suck on the undersides of leaves. After mating, females lay their eggs in clusters on the undersides of leaves. The nymphs start feeding there, similarly to adults.

Numerous natural enemies are known from its original distribution area in North America. It is probably mostly due to their activity that the Oak Lace Bug is not considered either economically or ecologically significant in those areas. One of the main reasons for its success in Europe is most likely its "escaping" the natural enemies which are capable of controlling its populations in its native range. Since its appearance in Europe, only sporadic data have been published on its natural enemies. Ladybirds

© György Csóka

Leaves damaged by the oak lace bug

(Coccinellidae), lacewing larvae (Neuropterida), spiders (Araneae), and predatory bugs (Heteroptera) occasionally prey on its various developmental stages, but they cannot be expected to regulate the species (Paulin *et al.* 2020a). The situation of a close relative, the Sycamore Lace Bug (*Corythucha ciliata*) is very similar. This species has been present in Europe for more than half a century, but no natural enemy capable of controlling it has been found so far. Curiously, even the generalist Red Wood Ants (*Formica rufa*) avoid eating it, even if oak leaves covered in adult bugs or larvae are placed directly next to their nests (Paulin *et al.* 2020a).

From Croatia, Kovač *et al.* (2020) report on several entomopathogenic fungi infecting wintering Oak Lace Bugs. Some of these were also found in Hungary, but caused only very low mortality. Although some show significant mortality rates in vitro (Sönmez *et al.* 2016, Kovač *et al.* 2021), none of them can be expected to have a significant effect in reducing the abundance of this species in nature.

Ecological conditions in Hungary

In fact, every native Eurasian deciduous oak species (*Quercus* spp.) is a suitable host plant for the Oak Lace Bug (Csóka *et al.* 2020). It equally prefers the three most important native oak species in Hungary, Pedunculate Oak (*Quercus robur*), Sessile Oak (*Qu. petraea*), and Turkey Oak (*Qu. cerris*). However, it cannot survive on American red oaks, e.g. Northern Red Oak (*Quercus rubra*), Scarlet Oak (*Qu. coccinea*), and Pin Oak (*Qu. palustris*). Besides oaks, its damage is commonly found on several other trees, shrubs and subshrubs as well, e.g. on maples (*Acer* spp.), limes (*Tilia* spp.), roses (*Rosa* spp.), and blackberries (*Rubus* spp.) (Bernardinelli 2006, Csóka *et al.* 2020, Nagy *et al.* 2021), but eggs and larvae are rarer on these. There are ca. 600,000 ha of oak forests in Hungary and well over 30 million ha in Europe. Most of these supply suitable food for the Oak Lace Bug, so the lack of host plants will hardly limit its further expansion.

According to research conducted in Hungary, wintering mortality is usually low. So winters, which are becoming ever milder anyway, are also incapable of restricting its spreading or population growth (Csepelényi *et al.* 2017a, Paulin *et al.* 2021).

It had probably occurred in Békés county even before its first documented detection in May 2013 (Szarvas) (Danyik T. *pers. comm.*). Also in May 2013, it was found in Vácrátót, in the National Botanical Garden. Afterwards, it spread rapidly to the north and west (Csepelényi *et al.* 2017b). By autumn 2019, it already occurred in every county in Hungary, and except for the north-western counties (Vas, Győr-Moson-Sopron), it also has some mass infestation centres (Paulin *et al.* 2020b). There are practically no native oak stands in the southern counties without clearly visible traces of its presence and effects. If it keeps on spreading at this rate, it will be highly abundant in most our oak forests within a few years.

Ecological concern

In case of severe Oak Lace Bug infestation, discoloration, drying and early abscission of foliage of entire stands may take place by the end of June, and the effects are conspicuous by late July or early August in every impaired stand. According to studies conducted in Serbia, compared to the leaves of healthy trees, the photosynthetic activity of Pedunculate Oak (*Quercus robur*) leaves with severe symptoms decreases by 58,8%, and their transpiration activity by 21,7% (Nikolić *et al.* 2019). Such degree of damage repeated year after year probably has severe negative effects on the nutrient and water transport of oaks (*Quercus* spp.) in the long run. This is all the more important as oak species are of outstanding economic and ecological importance in a significant part of European forests.

Nitrogen content decreases significantly in severely affected leaves, which is unfavourable to leaf-feeding insects developing in the second half of the vegetation period. In Europe, the richest herbivorous insect communities are associated to oaks. 423 such species have been recorded in the United Kingdom

(Kennedy & Southwood 1984), 298 in Germany (Altenkirch 1986), and over 670 in Hungary (Csóka & Ambrus 2016). From the herbivorous Lepidotera of Hungary, over 300 species feed on oaks. From all the herbivorous insect species developing on oak, nearly 300 are oak specialists (Csóka & Ambrus 2016). A recent study conducted in the United Kingdom found altogether 326 obligate oak specialist species: 57 fungi (Fungi), 257 invertebrates, and 12 lichens (Lichenophyta) (Mitchell *et al.* 2019). In Hungary, nearly 450 arthropod species (Arthropoda) have been recorded to feed on oak leaves, one way or another (sucking, chewing, gall forming, mining etc.), some of them are rare and protected (Csóka & Ambrus 2016). These are most abundant on young leaves at the beginning of the vegetation period (April–May), so they are probably not severely threatened directly by the activity of the Oak Lace Bug. However, there are still many leaf feeding species active in the second half of the vegetation period, and these, especially oak specialists, may be much more heavily affected.

According to our preliminary research, caterpillars of the oak specialist Tawny Prominent (*Harpyia milhauseri*), Oak Marbled Brown (*Drymonia querna*), and some geometrids (*Cyclophora* spp.) starved and later died if only offered leaves severely infested by the Oak Lace Bug. Significant mortality of gall wasps *Cynips quercusfolii*, *Neuroterus quercusbaccarum* and *N. numismalis* was observed on infested leaves (Paulin *et al.* 2019). If the abundance of herbivorous insects decreases considerably for a long time, it will have significant effects on their natural enemies, such as birds (Aves), predatory arthropods, parasitoids etc. as well.

Although not yet proven, physiological and nutrient transport disturbances caused by the Oak Lace Bug presumably also affects other species and communities, the nutrient supply of which is connected to oaks (e.g. mycorrhizal fungi).

In Northwestern Greece, the sycamore lace bug (*Corythucha ciliata*), a species closely related to the Oak Lace Bug, caused the mortality of fish on trout farms after being washed into the water in great amounts (Savvidis *et al.* 2009). Based on this, we have reason to assume that the Oak Lace Bug may affect fish (Pisces) or even aquatic invertebrates of forest surface waters similarly.

Today, the Oak Lace Bug has regular outbreaks in inhabited areas as well, so interactions between humans and Oak Lace Bugs become increasingly common.

© György Csóka

Damaged oak trees with discoloured leaves. Next to them, the leaves of healthy ashes are green

According to Dutto & Bertero (2013) and Izri *et al.* (2015) , the closely related sycamore lace bug often caused inflammation of the human skin. In these cases, human blood has been detected in specimens collected from clothing, meaning that these bugs are able to suck blood. Although no similar results have been published about the Oak Lace Bug, public reports of this kind are increasingly common, supported by our own experiences in the field, i.e., that Oak Lace Bugs do sometimes try to bite humans, and occasionally cause an unpleasant sensation and a mild inflammation of the skin.

Economic impact

The trunk diameter of most of our oak species – Pedunculate Oak (*Quercus robur*), Sessile Oak (*Qu. petraea*), Turkey Oak (*Qu. cerris*) – grows most intensively in the first half of the vegetation period. 80% of yearly growth is usually reached by the end of July (Szőnyi 1962, Járó & Tátraaljai 1985, Hirka 1991). Based on this, we assume that the Oak Lace Bug's direct (within a given year) impact is probably less expressed on yearly diameter growth, although its repeated outbreaks year after year may still have a significant long term effect on it.

Long lasting disturbances of the nutrient transport probably harm the overall health of the trees. Therefore, the Oak Lace Bug will, and partly has already become a significant actor in the complex damage trends (drought, defoliators, pathogens etc.) already known to cause the deterioration of our oak forests.

According to observations in Croatia and Hungary, it is quite unambiguous that heavily affected trees produce smaller acorns, and a much higher rate of immature dropping can also be observed. Acorn growth is most intensive in and after July, and by this time, photosynthetic activity and transpiration are significantly impaired by the activity of the Oak Lace Bug. Deterioration of the quality and quantity of acorn production (especially when it is persistent) hinders the natural regeneration of oak forests significantly, and also makes the production of seedlings in nurseries more difficult, thus affecting artificial regeneration as well. The diminishing of acorn production is also of ecological significance, as acorns are an important food source for many forest animals.

Potential control measures

In Romania (Bălăcenoiu *et al.* 2021) and Serbia (Drekić *et al.* 2021), chemical controlling of the Oak Lace Bug has been tested experimentally. These were basically successful, i.e., chemicals capable of significantly decreasing the abundance of the Oak Lace Bug at a given time at a given location have been found. But, as the species has several generations in a season, even after a seemingly effective control treatment, the lace bugs are highly likely to reappear. For chemical control to be effective, several treatments per vegetation period would be necessary. Chemical control methods may only be applied in parks and gardens, but they are out of the question in forests. Apart from the extremely high cost of repeated treatments, the undesirable side effects of insecticides make chemical controlling of this species obviously unacceptable.

Unfortunately, its native, European natural enemies and entomopathogens have no real chance of regulating its populations. A successful classic biocontrol programme seems to be the only possible solution. For this, one or more specialist natural enemies of the species should be tracked down in its original range, and introduced to Europe. Obviously, a possible introduction needs to be preceded by thorough impact analyses, to avoid unwanted side effects, as demonstrated by the case of the Harlequin Ladybird (*Harmonia axyridis*). It is worth mentioning that in the United States, there is a known Oak Lace Bug specialist egg parasitoid (*Erythmelus klopomor*), a potentially promising candidate for a biological control programme (Puttler *et al.* 2014).

References

Altenkirch 1986, Bălăcenoiu *et al.* 2021, Barber 2010, Bernardinelli 2006, Bernardinelli & Zandigiacomo 2001, Chireceanu *et al.* 2017, Csepelényi *et al.* 2017a, 2017b, Csóka & Ambrus 2016, Csóka *et al.* 2013, 2020, Dautbašić *et al.* 2018, Derjanschi & Mocreac 2018, Dobreva *et al.* 2013, Don *et al.* 2016, Drekić *et al.* 2021, Dutto & Bertero 2013, Forster *et al.* 2005, Gil & Grosso-Silva 2021, Glavendekić & Vuković Bojanović 2017, Hirka 1991, Hrašovec *et al.* 2013, Izri *et al.* 2015, Járó & Tátraaljai 1985, Jurc & Jurc 2017, Kennedy & Southwood 1984, Kovač *et al.* 2020, 2021, Mertelík & Liška 2020, Mitchell *et al.* 2019, Mutun 2003, Mutun *et al.* 2009, Nagy *et al.* 2021, Neimorovets *et al.* 2017, Nikolić *et al.* 2019, Pap *et al.* 2015, Paulin *et al.* 2019, 2020a, 2020b, 2021, Poljaković-Pajnik *et al.* 2015, Puttler *et al.* 2014, Sallmannshofer *et al.* 2019, Samin & Linnavuori 2011, Savvidis *et al.* 2009, Sönmez *et al.* 2016, Sotirovski *et al.* 2019, Streito *et al.* 2018, Szőnyi 1962, Tuba *et al.* 2012, Kennedy 1984, Zúbrik *et al.* 2019

György Csóka & Márton Paulin

Sicilian Shield Bug

Deraeocoris flavilinea (Costa, 1862)

Native range

It is a Mediterranean species. It was first described from Sicily (Costa 1862), and was thought endemic for nearly a century (Rabitsch 2008). In 1961, however, it was found in Corsica (Péricart 1965), and there are also records from the regions Campania, Liguria and Puglia in Italy (Tamanini 1981).

Introduction to Hungary

The first records of *Deraeocoris flavilinea* spreading east and north are from the 1980s. It was found in France in 1984, in the Netherlands (Aukema 1989) and Germany in 1985 (Göllner-Scheiding 1991), and in Switzerland in 1987. In the 1990s, it was also observed in Luxembourg (1992), Malta, Belgium (1994) (Chérot 1998), the United Kingdom (1996) (Miller 2001), and Slovenia (1997) (Gogala 2006). Then, in Central Europe, it appeared in Austria in 2002 (Rabitsch 2002), in Czechia in 2003 (Kment *et al.* 2005), and in Serbia in 2005 (Jerinić-Prodanović & Protić 2011), but it was reported from Slovakia only after its Hungarian detection in 2017 (Cunev & Kment 2017). The northern border of its current distribution area is Sweden (Gillerfors & Coulianos 2005), but in the Mediterranean region, it is known to occur from Spain (Gessé 2011) to Turkey (Çerçi & Koçak 2016, Kiyak 2020).

In Hungary, the first specimens were collected from several locations in Budapest (e.g. the Arboretum of Buda, Gellért Hill, Vérmező), from the canopies of maple species (*Acer* spp.) in parks (Varga *et al.* 2014). Its documented occurrence in Hungary is limited to the capital and its neighbourhood.

Biology of the species

It is a medium-sized mirid bug (Heteroptera: Miridae). Males are 6.5–7.0 mm, females 6.3–6.8 mm long. The body is yellowish brown, with fine black dots on the dorsal side. The species is sexually dimorphic. The pronotum and scutellum of males are black with yellow margins (the pronotum and scutellum of females are yellowish brown with a brown pattern),

© Péter Kóbor

and the femora of males are mostly black, with a yellowish ring near the apex, and a yellow apex (femora of females are brown, with a yellowish brown ring and apex) (Wagner 1971).

The species produces one generation per year (univoltine), and overwinters in the egg form. They are in the larval form from May to June, mating and oviposition take place in June and July (sometimes in August) (Wachmann *et al.* 2004). So far, it has been mostly observed in the canopy of maples (*Acer* spp.), but it was also seen on lime (*Tilia* spp.), ash (*Fraxinus* spp.), and apple trees (*Malus* sp.) (Viggiani 1971, Wachmann *et al.* 2004, Kondorosy *et al.* 2010). Similarly to other *Deraeocoris* species, it is omnivorous (zoophytophagous), but feed mostly on animals. It preys on aphids (Aphidoidea), and the larvae of whiteflies (Aleyrodidae) and plant lice (Psylloidea), but it is also known to eat the eggs of other bugs (Simov *et al.* 2012).

Ecological conditions in Hungary

D. flavilinea is only known in Hungary from Budapest and its neighbourhood. Although it is not yet widespread in the country, it probably has viable populations elsewhere as well. We presume that it finds the environmental conditions of Hungary favourable, and may be regarded as established in Hungary.

Ecological concern

D. flavilinea has only been recorded in Central Europe sporadically, in cultural landscapes and urban environments (Rabitsch 2008, Putchkov 2013). Its widespread dispersal and proliferation has not yet been reported from this region. It is even uncertain whether it should be regarded as an invasive species, but this may easily change as a result of climate change. If it does become aggressively invasive, its populations may alter the qualitative and quantitative characteristics of canopy food webs, putting competitive pressure on native predators and zoophytophagous arthropods (Arthropoda).

Economic impact

As a generalist, zoophytophagous species, it does not damage crops or plantations, so its occurrence has no economic significance. It may be suitable as a biological control agent against arthropod (Arthropoda) pests in horticultures, but its significance is unknown.

Potential control measures

According to current knowledge, there is no need to control this species.

References

Aukema 1989, Çerçi & Koçak 2016, Chérot 1998, Costa 1862, Cunev & Kment 2017, Gessé 2011, Gillerfors & Coulianos 2005, Gogala 2006, Göllner-Scheiding 1991, Jerinić-Prodanović & Protić 2011, Kiyak 2020, Kment *et al.* 2005, Kondorosy *et al.* 2010, Miller 2001, Péricart 1965, Putchkov 2013, Rabitsch 2002, 2008, Simov *et al.* 2012, Tamanini 1981, Varga *et al.* 2014, Viggiani 1971, Wachmann *et al.* 2004, Wagner 1971

Péter Kóbor & Előd Kondorosy

Lime Seed Bug

Oxycarenus lavaterae (Fabricius, 1787)

Native range

The Lime Seed Bug originates from the western part of the Mediterranean region. It was first described from Tunisia (Fabricius 1787), and later, as *Stenogaster tardus*, from Sardinia (Hahn 1835). Still in the 19th century, it was found in the area expanding from Portugal (Bolívar & Chicote 1879) across Southern Switzerland (Frey-Gessner 1863) to Dalmatia (Fieber 1852). In North Africa, it is dispersed from Tunisia to Morocco and the Canary Islands (Lindberg 1932, 1953). Its records from tropical Africa and South Africa (Schouteden 1912) are false, the results of confusing it with related species native to those areas (Samy 1969), although several researchers debate this opinion. Its records from Saudi Arabia and Yemen (Péricart 1998, 2001) are also uncertain, as its occurrence in Libya, Egypt, or the Middle East is not known.

© László Haraszthy

Mass of lime seed bugs

Introduction to Hungary

In Europe, its expansion was first reported from Montenegro (Velimirović *et al.* 1992). It might have been present there earlier as well, but it had an outbreak at this time. The next records are from Hungary, from the middle of the 1990s. Kondorosy (1995) observed masses of Lime Seed Bugs preparing for wintering (Keszthely, Balatonfüred, Nagykanizsa). Soon after, in 1995, it was also found in Slovakia (Bianchi & Stehlík 1999), in 1996, in Serbia (Protić & Stojanović 2001), and later in Bulgaria (Kalushkov 2000) and Austria (Rabitsch & Adlbauer 2001). After a short break, it reached other countries: Germany (Billen 2004), Czechia (Kment *et al.* 2006), and Romania (Kment 2009), and it also appeared in Northern France (Denosmaison 2001) and Switzerland (Wermelinger *et al.* 2005). More recently, it was observed in Greece (Simov *et al.* 2012), Poland (Hebda & Olbrycht 2016), Turkey (Arslangündoğdu *et al.* 2018), and Russia (Neimorovets *et al.* 2020) On the internet, photos taken in Great Britain, the Benelux States, Moldavia, Ukraine, and even Puerto Rico can be found.

Biology of the species

It is a typical member of the Oxycarenidae family, but it is brighter coloured than any of the native European species. It is 4.5–6 mm long. Its body is black, with a conspicuous red corium and a glittering, transparent membrane. Péricart (1998) provides a detailed description. To distinguish it from related African species, see the key of Samy (1969).

It feeds exclusively on plants. Both imagoes and larvae, similarly to most related species, suck the sap of mallows (Malvaceae), especially on linden trees (*Tilia* spp.). Related species living in hotter climate, especially the Cotton Seed Bug (*Oxycarenus hyalinipennis*), are important pests of the cotton. It has been long known to feed on tree mallows (*Lavatera* sp.), hence the specific in its Latin name (Fabricius 1787), Common Hollyhock (*Alcea rosea*) (Cuní y Martorell 1881), hibiscus shrubs (*Hibiscus* spp.) (de Bergevin 1932), and cotton (*Gossypium* sp.) (Alvarado *et al.* 1998). More recently, it has been detected on common mallow (*Malva sylvestris*) as well (Péricart 1998). It has been observed feeding on several plants from different families, for example, it was the dominant bug on Mandarin Orange (*Citrus reticulata*) in Spain, although it probably did not cause any damage (Ribes *et al.* 2004). It did, however, cause considerable damage to Apricots (*Armeniaca vulgaris*) and Peaches (*Persica vulgaris*) in Italy (Ciampolini & Trematerra 1987).


© László Haraszthy

Lime seed bugs on a trunk

Scientists from Switzerland (Wermelinger *et al.* 2005) and Turkey (Arslangündoğdu *et al.* 2018), reviewing many studies, list numerous host plants, but, apart from the mellows, most are only mentioned by single studies. I was found two times on cranesbills (*Geranium* spp.). Kalushkov & Nedvěd (2010) examined its development on various host plants in the laboratory, and found that it can develop on Small-leaved Linden (*Tilia cordata*), hibiscus shrub (*Hibiscus* sp.), and Sunflower (*Helianthus annuus*), while, contrary to literary data, it cannot develop on Large-leaved Lime (*T. platyphyllos*), wheat (*Triticum* sp.), Maize (*Zea mays*), or grape vine (*Vitis* sp.).

In Italy, two generations in a year were observed (Ciampolini & Trematerra 1987). About the number of generations per year, published data are somewhat contradictory. For example, in a series of studies in Bulgaria (Simov *et al.* 2012), it produced three generations in 1999, while single generations developed between 2004 and 2006.

Adults overwinter, and winter mortality is usually not significant (Wermelinger *et al.* 2005), although other data contradict this (Kalushkov 2000). Mortality rates increase significantly at temperatures lower than –15°C (Kalushkov *et al.* 2007). Its fertility and life span were examined in Bulgarian studies. Depending on circumstances, its egg production was between 20 and 600 (Nedvěd *et al.* 2014). Typically, the longer it spent in the field, the fewer eggs it laid.

Ecological conditions in Hungary

Currently, it is widespread in the country, but its abundance varies. In one year, it forms aggregations on lime trees (*Tilia* sp.) in the winter, and in the next, it is only sporadically observed. Most of them live on urban trees, but some occur on limes in natural habitats as well. Hungary's climate suits this species well, as it finds favouring conditions from Scandinavia to North Africa.

Ecological concern

Apart from a few cases in Italy, also associated to lime trees (*Tilia* sp.) (Saunders 1906, Burlini 1949), its mass aggregations have only been observed since the 1990s, even in its original distribution area (Dioli 1993, Goula *et al.* 1999). In most cases, the presence of the species in new places was noticed at the time of outbreaks (Velimirović *et al.* 1992, Kondorosy 1995, Rabitsch & Adlbauer 2001, Neimorovets *et al.* 2020).

It damages lime and mallow seeds, but this concerns only a few competitors, e.g. Firebug (*Pyrrhocoris apterus*), Hollyhock Weevil (*Rhopalapion longirostre*), and hollyhock Seed Moth (*Pexicopia malvella*), by limiting their food supply.

Economic impact

From its wide range of host plants, the Lime Seed Bug causes considerable damage primarily to cotton (*Gossypium* sp.), but this is irrelevant in Hungary. Even in Spain, its damage was found insignificant (Alvarado *et al.* 1998). Damaging Apricot (*Armeniaca vulgaris*), Peach (*Persica vulgaris*), and citrus species (Aurantioideae) seem to be one-time events, no further observations of this kind have been published.

Potential control measures

Knowledge on the natural enemies of the Lime Seed Bug is scarce. Recently, a flagellated protozoa new to science (*Phytomonas oxycareni*) has been described from its salivary gland (Seward *et al.* 2017). Much more information was published about its close relative, the Cotton Seed Bug (*Oxycarenus hyalinipennis*), the natural enemies of which have been thoroughly studied in Ghana (Adu-Mensah & Kumar 1977). Numerous mites (Acari), and some tachinid flies (Tachinidae) have been discovered. Its most significant predators were some native members of the Reduviidae family (*Nagusta* sp., *Rhynocoris* sp.), these species also occur in Hungary. In Australia, big-eyed bugs of the *Geocoris* genus (Geocoridae) destroyed the species *Oxycarenus luctuosus*, indigenous in that region (Malipatil 1979). However, natural enemies have only a minor role as biocontrol agents of the Lime Seed Bug.

References

Adu-Mensah & Kumar 1977, Alvarado *et al.* 1998, Arslangündoğdu *et al.* 2018, de Bergevin 1932, Bianchi & Stehlík 1999, Billen 2004, Bolívar & Chicote 1879, Burlini 1949, Ciampolini & Trematerra 1987, Cuní y Martorell 1881, Denosmaison 2001, Dioli 1993, Fabricius 1787, Fieber 1852, Frey-Gessner 1863, Goula *et al.* 1999, Hahn 1835, Hebda & Olbrycht 2016, Kalushkov 2000, Kalushkov & Nedvěd 2010, Kalushkov *et al.* 2007, Kment 2009, Kment *et al.* 2006, Kondorosy 1995, Lindberg 1932, 1953, Malipatil 1979, Nedvěd *et al.* 2014, Neimorovets *et al.* 2020, Péricart 1998, 2001, Protić & Stojanović 2001, Rabitsch & Adlbauer 2001, Ribes *et al.* 2004, Samy 1969, Saunders 1906, Schouteden 1912, Seward *et al.* 2017, Simov *et al.* 2012, Velimirović *et al.* 19922, Wermelinger *et al.* 2005

Előd Kondorosy & Péter Kóbor

Western Conifer Seed Bug

Leptoglossus occidentalis Heidemann, 1910

Native range

Its native distribution area is the western coast of North America (it is most common in California, but occurs in other states, too). It started spreading east in the middle of the 20th century. Crossing the Rocky Mountains (Koerber 1963), it reached the Great Lakes (McPherson *et al.* 1990) and the East Coast (Gall 1992) by the end of the century.

Introduction to Hungary

In Europe, it was first recorded in Italy in 1999 (Tescari 2001). It spread rapidly: it was detected in Switzerland in 2002 (Colombi & Brunetti 2002), and in Slovenia (Gogala 2003) and Spain in 2003 (Ribes *et al.* 2004). In the following year (2004), it reached Croatia (Tescari 2004) and Hungary (Harmat *et al.* 2006). The rapid expansion continued, and by 2009, it had several records in Europe, from England and Norway, all the way to Turkey (Malumphy & Reid 2007, Mjøs *et al.* 2010, Fent & Kment 2011). After reaching Russia (Gapon 2012), it slowly invaded the entire continent. Based on DNA analyses, it probably colonised Europe following several independent introductory events from the Eastern United States (Lesieur *et al.* 2018). In the

© György Csóka

meantime, it reached East Asia as well: it first appeared in Japan (Ishikawa & Kikuhara 2009), and afterwards reached China (Zhu 2010) and the Korean Peninsula as well (Ahn *et al.* 2013). Later it also appeared in the Middle East (Nemer 2015, van der Heyden 2019b). It had been observed on the Mediterranean coast of Africa in 2011 (Ben Jamâa *et al.* 2013), and it was introduced to South Africa, too (van der Heyden & Faúndez 2020). Simultaneously, it appeared in South America (Faúndez *et al.* 2017, van der Heyden & Faúndez 2020), and also started spreading south in Central America (van der Heyden 2019a). An overall picture of its actual and potential dispersal is provided by Zhu *et al.* (2014).

Biology of the species

With a length of 15–22 mm (İpekdal *et al.* 2019), it is larger than any of our native Coreidae species (Vásárhelyi 1983). Its special characteristic, distinct from every European species, is the conspicuous, leaf-like expansion on the tibia of the hind legs (also present on the larvae, making them easy to identify as well). Its body is brown, adorned by several light or dark spots and stripes. Perhaps the most striking of these is the zigzagged line running in the centre of the corium, and the black and yellow striped abdomen, visible when the wings are spread.

It feeds on plants, both adults and larvae suck the sap of conifers. Koerber (1963) mentions its feeding on six American species of the pine family (Pinaceae), e.g. Douglas Fir (*Pseudotsuga menziesii*), also commonly planted in Hungary, some American pines (*Pinus* spp.), and also California Incense Cedar (*Calocedrus decurrens*), from the cypress family (Cupressaceae), but according to his experiments, it can feed on several other species, e.g. firs (*Abies* spp.) as well. Schaffner (1967) was the first to record its presence on Scots Pine (*Pinus sylvestris*), McPherson *et al.* (1990) detected it on Black Pine (*P. nigra*) and two other species. In Canada, it was also found on Bog Pine (*P. mugo*) and Eastern Hemlock (*Tsuga canadensis*) (Gall 1992). Barta (2009) reports its feeding on 11 pine (*Pinus* spp.) and five spruce species (*Picea* spp.) in a Slovakian arboretum. Recently, in Lebanon, it was observed on Greek Juniper (*Juniperus excelsa*) and Cedar of Lebanon (*Cedrus libani*) (Nemer *et al.* 2019). Its only known angiospermous host plant is the Pistachio (*Pistacia* sp.), to which it caused damage in California (Rice *et al.* 1985, Uyemoto *et al.* 1986).

The Western Conifer Seed Bug has a single generation a year in most of its distribution area, but in Spain (Mas *et al.* 2013) and Turkey, two generations were observed (İpekdal *et al.* 2019, Oğuzoğlu & Avci 2020), and even three generations may develop in Mexico (Hedlin *et al.* 1981). Barta (2016) reviewed European countries, and when estimating its potential, predicted a maximum of four generations.

It usually overwinters in the imago form, in crevices in bark, leaf litter, or inside buildings.

Ecological conditions in Hungary

Currently, it occurs everywhere in the country where it can find suitable conifers (Pinaceae). It is present in gardens, in parks, but also in planted pine forests. Hungary's climate suits this species well, as it finds favouring conditions from Scandinavia to North Africa.

Ecological concern

Its extremely rapid dispersal suggests that it has the potential to become dominant in the colonised areas. By its feeding habits, it may outcompete other species and cause them to withdraw to less favourable sites. This way, it may transform entire communities (Lis *et al.* 2008). By damaging pine seeds, it reduces the food supply of insects and birds eating the same.

Economic impact

Koerber (1963) was the first to provide a detailed description of its damage to pine seeds. The affected seeds shrivel and become spongy. It is established in the same study that neither larvae nor imagoes can survive feeding on leaves or branches. In America, the seed yield of Douglas Fir (*Pseudotsuga menziesii*) was reduced by 41% (Hedlin *et al.* 1981). Its early damage may cause young pine cones to decay, but the above described damage to seeds is more common (Connelly & Schowalter 1991). As pines are not planted for seed production in Hungary, this aspect does not cause any problems.

The species often aggregates in buildings for wintering (Marshall 1991), with the help of the aggregation pheromones emitted by the male (Blatt & Borden 1996). This may necessitate the application of chemical control in warehouses (Blatt 1994). Occasionally, it also attempts to bite humans (Hornok & Kontschán 2017). Specimens wintering in buildings may also prick so-called PEX pipes made of cross-linked polyethylene, and cause seepage of water (Bates 2005).

Potential control measures

Bates & Borden (2004) published a study on its parasitoids in British Columbia. Three different parasitoid wasps hatched from its eggs. The

© György Csóka

Feather-legged Fly (*Trichopoda pennipes*) is also a parasite of the Western Conifer Seed Bug (Ridge-O'Connor 2001). As regards predators, the European Mantis (*Mantis religiosa*) and the wasp spider (*Argiope bruennichi*) have been observed to prey on this species (İpekdal *et al.* 2019).

Barta (2009) also perceived a Fungal Disease (*Isaria fumosoroseus*) in Slovakia, and conducted experiments with three entomopathogenic fungi, with varying degrees of success (Barta 2010).

In Turkey, a pheromone trap developed for another American Leaf-footed Bug species (*Leptoglossus zonatus*) has also been tested, but without success (İpekdal *et al.* 2019).

The numerous possibilities listed above may only be applicable in the far future. Currently, mechanical control can be applied, by way of destroying wintering individuals. Although chemical control is possible in gardens and parks, it is not recommended. The application of chemical control methods in near natural pine forests or pine plantations is highly inadvisable.

parasitic infestation rate of one of them, a Coreidae specialist, *Gryon pennsylvanicum* (Platygastridae), often reached 80%. In Europe, an egg parasitoid, *Anastatus bifasciatus* (Eupelmidae) was the first to be found, in Italy (Camponogara *et al.* 2003). Also in Italy, *Gryon pennsylvanicum* was thoroughly studied in laboratories, to establish details about its fecundity and life span (Sabbatini Peverieri *et al.* 2012), and various respects of its applicability, including host specificity. This was examined by offering the eggs of four closely related Coreidae species, and also the eggs of four more distant bug cousins (Alydidae, Pentatomidae, Reduviidae) to these parasitoid wasps (Roversi *et al.* 2014). The results were promising, as the parasitoid did not develop in the eggs of the other species. This species was also studied in Turkey (Oğuzoğlu & Avci 2020). Altogether six parasitoid wasp species (Platygastridae, Eupelmidae, Encyrtidae) have been reared from its eggs so far (İpekdal *et al.* 2019). Even more recently, two new parasitoids were found in Spain from a genus (*Ooencyrtus*) of the Encyrtidae family (Ponce-Herrero *et al.* 2022). In America, the Tachinid

References

Ahn *et al.* 2013, Barta 2009, 2010, 2016, Bates 2005, Bates & Borden 2004, Blatt 1994, Blatt & Borden 1996, Camponogara *et al.* 2003, Colombi & Brunetti 2002, Connelly & Schowalter 1991, Faúndez *et al.* 2017, Fent & Kment 2011, Gall 1992, Gapon 2012, Gogala 2003, Harmat *et al.* 2006, Hedlin *et al.* 1981, Hornok & Kontschán 2017, İpekdal *et al.* 2019, Ishikawa & Kikuhara 2009, Ben Jamâa *et al.* 2013, Koerber 1963, Lesieur *et al.* 2018, Lis *et al.* 2008, Malumphy & Reid 2007, Marshall 1991, Mas *et al.* 2013, McPherson *et al.* 1990, Mjøs *et al.* 2010, Nemer 2015, Nemer *et al.* 2019, Oğuzoğlu & Avci 2020, Ponce-Herrero *et al.* 2022, Ribes *et al.* 2004, Rice *et al.* 1985, Ridge-O'Connor 2001, Roversi *et al.* 2014, Sabbatini Peverieri *et al.* 2012, Schaffner 1967, Tescari 2001, 2004, Uyemoto *et al.* 1986, van der Heyden 2019a, 2019b, van der Heyden & Faúndez 2020, Vásárhelyi 1983, Zhu 2010, Zhu *et al.* 2014

Elők Kondorosy & Péter Kóbor

Brown Marmorated Stink Bug

Halyomorpha halys (Stål, 1858)

Native range

The Brown Marmorated Stink Bug is native to east palearctic and oriental regions, i.e. East and Southeast Asia. It is dispersed throughout China (except for the Xinjiang Uygur Autonomous Region and Qinghai), Japan (except for Hokkaidō), the Korean Peninsula, Taiwan, Vietnam, and Myanmar (Wang & Liu 2005).

Introduction to Hungary

The first record of the species in Europe is from Zürich, in 2007 (Wermelinger *et al.* 2008). It rapidly spread in Switzerland, reached Konstanz in Southern Germany by November 2011, and appeared in Alsace, near Strasbourg, in Eastern France, in 2012 (Callot & Brua 2013). In Northern Italy, its first specimens were observed in autumn 2012, from Emilia-Romagna (Maistrello *et al.* 2014), and in August 2013, it was also found in Piedmont (Pansa *et al.* 2013). In the United Kingdom, it was found in the luggage of a traveller from the United States in 2010. In 2013, a single specimen was found in a stone shipment from China (Teesport, Yorkshire) (Malumphy 2014). In autumn 2011, it was already causing public inconvenience in Greece (Athens) (Milonas & Partsinevelos 2014). This was then about 1000 km away from the nearest known European population. In Hungary, its first specimens were collected in Péterimajor, Budapest, in autumn 2013 (Vétek *et al.* 2014). In a few years, it spread throughout the country, as reported by Vétek *et al.* (2018), partly on the basis of community data collection. Of the countries surrounding Hungary, its appearance was reported from Romania (a botanical garden in Bucharest) in 2014 (Macavei *et al.* 2015), Austria (Vorarlberg in the west, Vienna in the east) and Serbia in 2015 (Rabitsch & Friebe 2015, Šeat 2015), Slovakia (Hemala & Kment 2017) and Croatia in 2017 (Šapina & Jelaska 2018), and Slovenia in 2018 (Rot *et al.* 2018).

According to the analysis of the qualitative and quantitative relations of haplotypes specified by mitochondrial genome sequencing, the European distribution and dispersal of the species originate from several independent introductory events, the "bridgehead effect" (human assisted spreading from source populations), and spontaneous spreading. Consequently, the species expanded its range on the continent in a relatively short time (Gariepy *et al.* 2014, 2015, 2021, Cesari *et al.* 2018). The population first discovered in Liechtenstein and Switzerland originates from individuals introduced from China, the one in Northern Italy comes from North America (where it had also been introduced), and the Greek population was also introduced from China, but independently of the other one. Other parts of Europe were invaded by spontaneous spreading from these populations, and by secondary introduction ("bridgehead effect"). Simultaneously, based on haplotype analyses, the species has probably been introduced repeatedly to Italy and Greece from the Far East.

Biology of the species

It is a relatively large shield bug (Pentatomidae), reaching a length of 12–17 mm. Females are usually larger than males. It is yellowish, with a dark brown, marmorated pattern on the dorsal side. Light and dark rings alternate on its legs and antennae. Of the native species, it may be confused with the Mottled Shieldbug (*Rhaphigaster nebulosa*), but the mottled shieldbug has a chitin spine reaching forward from the second segment of the abdominal sternum to the centre of the thorax. A detailed description of the differences from native species can be found in Kóbor (2017).

In its original distribution area, the brown marmorated stinkbug produces several generations a year (multivoltine species). The development of five generations in one year has been reported from Southern China. In the temperate zone, generation number

© Tamás Deli

is limited by the length of the unfavourable periods (cold periods in autumn and spring, and winter), and is influenced by food availability in the spring. On the Atlantic coast of the United States, the species has usually two generations a year (bivoltine) (Nielsen *et al.* 2008). In temperate areas, its diapause starts in late autumn, and lasts till April. Hibernating stink bugs often aggregate to take shelter in buildings. In residential areas, where it cannot cause agricultural damage, this is the main problem with this species (Hancock *et al.* 2019). Brown Marmorated Stink Bugs use aggregation pheromones and vibrational signals on solid surfaces to attract conspecifics to good hibernating sites. Immature specimens start feeding after the diapause. When sexual maturation is complete, they mate and lay eggs. The eggs are deposited in clutches of 28 on the undersides of leaves (Kawada & Kimura 1983). Hatching larvae first feed on the chorion, probably for the same reason as the Southern Green Shield Bug (*Nezara viridula*).

The Brown Marmorated Stink Bug is extremely polyphagous. It feeds on many plants of agricultural or horticultural importance, ornamental plants, and flora elements of natural habitats. According to available data, they probably switch hosts several times during their development, thus accommodating to their actual nutrient needs and the phenology of plants (Hamilton *et al.* 2018).

Ecological conditions in Hungary

The species finds favourable conditions in Hungary for its development, reproduction, and wintering. It is widespread in the country (Vétek *et al.* 2018). Although it is not scientifically established yet, according to personal communications and unpublished observations, the species is probably bivoltine in Hungary, similarly to the Atlantic regions of the United States.

Ecological concern

The mass appearance of the Brown Marmorated Stink Bug may cause problems in some habitats, as it is a strong competitor of native insect communities.

© Tibor Hadarics

Larvae of the brown marmorated stink bug

Economic impact

Several crop and ornamental plants are among its hosts. Its damage of economic significance has been reported from several countries (Leskey & Nielsen 2018). Most severe of these was damaging apple plantations in the United States (Morrison *et al.* 2019). In Europe, damage caused by its sucking has been reported from the Mediterranean region, on apple, nectarine, and olive plantations (Bosco *et al.* 2018, Candian *et al.* 2018, Damos *et al.* 2020). In Hungary, damage caused to kidney beans and hot peppers has been documented (Vétek & Korányi 2017), and, according to recent data, it has also appeared on apples (Kóbor *et al.* 2022).

Potential control measures

Because of its wide area of distribution and severe damaging capacity, the Brown Marmorated Stink Bug has been in the focal point of plant protection research for years. For a long time, the only solution against it seemed to be the application of broad spectrum pesticides. Later, parasitoid wasps of the Platygastridae family (*Trissolcus japonicus* and *T. mitsukurii*) have been identified, which are native to the original range of the Brown Marmorated Stink Bug, but also appeared in Europe (Peverieri *et al.* 2018). These parasitoid insects can control populations effectively, but their application – because of their possible spreading – may mean ecological risk, for the assessment of which further research is necessary (Van Lenteren *et al.* 2003). Some other promising ideas for controlling the species include the application of exclusion nets (Candian *et al.* 2018) or heated shelters (Bozsik *et al.* 2021). Further elaboration of these methods is in progress.

References

Bosco *et al.* 2018, Bozsik *et al.* 2021, Callot & Brua 2013, Candian *et al.* 2018, Cesari *et al.* 2018, Damos *et al.* 2019, Gariepy *et al.* 2014, 2015, 2021, Hamilton *et al.* 2018, Hancock *et al.* 2019, Hemala & Kment 2017, Kawada & Kitamura 1983, Kóbor 2017, Kóbor *et al.* 2022, Leskey & Nielsen 2018, Macavei *et al.* 2015, Maistrello *et al.* 2014, Malumphy 2014, Milonas & Partsinevelos 2014, Morrison *et al.* 2019, Nielsen *et al.* 2008, Pansa *et al.* 2013, Peverieri *et al.* 2018, Rabitsch & Friebe 2015, Rot *et al.* 2018, Šapina & Jelaska 2018, Šeat 2015, Van Lenteren *et al.* 2003, Vétek & Korányi 2017, Vétek *et al.* 2014, 2018, Wang & Liu 2005, Wermelinger *et al.* 2008

Péter Kóbor & Előd Kondorosy

Southern Green Stink Bug

Nezara viridula (Linnaeus, 1758)

Native range

The Southern Green Stink Bug was described as *Cimex viridulus* from India (Linnæus 1758), and not much later, its occurrence was reported from North America as well (Fabricius 1798). Then it was detected in Central and South America (Amyot & Serville 1845), and later (1874–1879), also in Japan (Yukawa *et al.* 2007). Based on these records, its early dispersal with trade may be presumed. According to current knowledge of animal geography, its original range was in tropical Africa, and it probably reached Asia 3.7–4 million years ago (Kavar *et al.* 2006, Ferrari *et al.* 2010). This, however, is somewhat uncertain, as only specimens from Botswana were examined, while no genetic analyses were conducted on individuals from either tropical or North Africa.

Introduction to Hungary

The description of the taxon *Cimex smaragdulus* from Madeira (Fabricius 1775) can be considered as the first European record of the Southern Green Stink Bug, as later this was discovered to be identical to the species *Cimex viridulus* (today *Nezara viridula*) already described by Linnæus (1758) (Stål 1872). The occurrence of the species was later reported from several locations in Southern Europe. According to the distribution map drawn on the basis of the records (DeWitt & Godfrey 1972), the northern border of its range coincides with that of the Mediterranean biogeographical region, and it may be considered indigenous south of the Alps. North of this, its occurrence is due to its current expansion (Rabitsch 2008). The presence of the Southern Green Stink Bug north of its original distribution area was first reported from Germany (Reichensperger 1922), then from the United Kingdom in the 1920s and 1930s (Salisbury *et al.* 2009). According to subsequent records, the species currently has stable populations in these countries, after a long break. It appeared in Belgium (Schmitz 1986), European Russia (Kirichenko 1951), Finland (Kontkanen 1956), and Austria (Dethier 1989) in the 1950s and 1960s. The vast majority of records from before 2000, however, are the results of occasional introductory events. Its permanent establishment only became common since then (Hanselmann 2017). At the beginning of the 2000s, it also appeared in Bulgaria (Simov *et al.* 2012) and Switzerland (Werner 2005).

In Hungary, its first individuals were collected in 2000 (Rédei & Torma 2003). Since then, its naturalised populations have spread throughout the country. Later, its appearance was also reported from Romania (Grozea *et al.* 2012), Slovakia (Vétek & Rédei 2014), and the Netherlands (Aukema 2016), but the situation of the populations in these countries is not yet clear. New records are mostly from urbanized areas, gardens, or agricultural landscapes, which indicates human assisted introduction rather than natural dispersal (Esquivel *et al.* 2018).

Biology of the species

The Southern Green Stink Bug is a bright green, 11–15 mm long bug (Heteroptera). From species occurring in Hungary, it may be confused with the Native Green Shield Bug (*Palomena prasina*), and two adventive species, *Acrosternum millierei* and *A. heegeri*, but there are some traits which make them easy to distinguish (Kóbor 2017). The Southern Green Stink Bug has a protuberance on the second abdominal sternum (the green shield bug does not), and the membrane of the forewing is transparent (that of the green shield bug is brownish, sometimes amber coloured). It can be distinguished from *Acrosternum* species by the roof-like shape of the ventral side of the abdomen (the ventral side of the abdomen of *Acrosternum* species is flat), and the uniform green colour of the tip of the scutellum (*Acrosternum* species have yellow spots

© György Csóka


© György Csóka

on the sides by the tip of the scutellum). The Southern Green Stink Bug has three types (aberratio), of which *N. viridula* ab. *torquata* occurs in Hungary. This type differs from the basic form only in its colour: the anterior two-thirds of the head are yellowish, a yellow stripe runs across the front margin of the pronotum, and a yellowish longitudinal stripe can be seen on the dorsal margins of the abdominal sterna.

The species overwinters in leaf litter, under bark, or in other protected shelters, in the imago form, in a state of reproductive diapause (Jones & Sullivan 1983). As the time of winter diapause approaches, its colour changes to brownish red, but it becomes green again in the next active period (Musolin *et al.* 2007). After the diapause, females become sexually mature after a few days of feeding, the males somewhat later. Males ready for mating attract females from long distances by emitting pheromones (Mitchell & Mau 1971), and across small distances, they communicate via substrate-born vibrational signals (Čokl *et al.* 2001). Females mate repeatedly and lay 50–70 eggs, depositing them on the undersides of leaves, usually in one, but maximum three hexagonal clusters (Musolin & Numata 2003). The freshly hatched larvae are very colourful, and develop through five nymphal instars, approximately in a month, depending on temperature and relative humidity. The colour and pattern of the Southern Green Stink Bug larvae are very typical, they are easy to distinguish from every other Hungarian species. If conditions are favourable, the species can have several generations in one vegetation period.

The Southern Green Stink Bug is extremely polyphagous, it has a wide range of host plants. Many plants of agricultural or horticultural importance, ornamental plants, and flora elements of natural habitats are suitable hosts.

Ecological conditions in Hungary

The species finds favourable conditions in Hungary for its development, reproduction, and wintering. It is widespread in the country (www.izeltlabuak.hu). Although we have no published evidence, according to personal communications and unpublished observations, the species probably has two generations in a season in Hungary (P. Kóbor).

© György Csóka

Larva of the southern green stink bug

Ecological concern

An outbreak of the Southern Green Stink Bug may cause problems in natural habitats, as it may be a strong competitor to some elements of the native insect communities.

Economic impact

Reports of its damaging cultivated plants in the newly colonised European areas are mostly anecdotal. However, it has been observed to damage Tomatoes (*Lycopersicon esculentum*) in Bulgaria and Romania (Grozea *et al.* 2012, Simov *et al.* 2012). Its sucking on tomato and several other plants is also reported from Hungarian vegetable gardens (Rédei & Vétek 2005).

Potential control measures

Currently, the Southern Green Stink Bug is mostly controlled by the application of broad spectrum insecticides. Although experiments have been conducted with potential biocontrol agents (predators and parasitoids) and trap cropping, these alone are not enough to control an outbreak of the species (Knight & Gurr 2007).

References

Amyot & Serville 1843, Aukema 2016, Čokl *et al.* 2001, DeWitt & Godfrey 1972, Dethier 1989, Esquivel *et al.* 2018, Fabricius 1775, 1798, Ferrari *et al.* 2010, Grozea *et al.* 2012, Hanselmann 2017, Jones & Sullivan 1983, Kavar *et al.* 2006, Kirichenko 1951, Knight & Gurr 2007, Kóbor 2017, Kontkanen 1956, Linnæus 1758, Mitchell & Mau 1971, Musolin & Numata 2003, Musolin *et al.* 2007, Rabitsch 2008, Rédei & Torma 2003, Rédei & Vétek 2005, Reichensperger 1922, Salisbury *et al.* 2009, Schmitz 1986, Simov *et al.* 2012, Stål 1872, Vétek & Rédei 2014, Werner 2005, Yukawa *et al.* 2007

Péter Kóbor & Előd Kondorosy

Citrus Flatid Planthopper

Metcalfa pruinosa (Say, 1830)

Native range

The Citrus Flatid Planthopper is a widespread species in the eastern and central parts of North America, from Ontario in Canada to Florida in the United States (Pénzes & Hári 2016).

Introduction to Hungary

Its presence was first recorded in Europe in Northeastern Italy (Veneto), where it was introduced in 1979 (or earlier) with nursery material (Zangheri & Donadini 1980). It expanded its range rapidly in Italy, and reached many more European countries, including France in 1985 (Anonym 1995), Switzerland in 1993 (Jermini *et al.* 1995), Austria in 2003 (EPPO Global Database 2022), Croatia (Gotlin Čuljak *et al.* 2007, Matošević & Pernek 2011) and Serbia in 2006 (Mihajlović 2007), Russia in 2010 (Gninenko *et al.* 2011), Romania in 2011 (Grozea *et al.* 2011), and Germany in 2016 (Nickel 2016). Today, it occurs in most European countries south of Germany and Czechia. In 2005, it was found in South Korea, its first record in Asia (Lee & Wilson 2010).

© György Csóka

Larva of the citrus flatid planthopper

It was first observed in Hungary in July 2004, in Budapest, on plane trees (*Platanus* sp.) (Pénzes 2004). Nursery material was imported from Italy to nursery stores around the capital several times. The species was probably introduced this way (Pénzes & Hári 2016). It spread rapidly after its first detection, and in less than ten years, it became common in the entire country. It was caught in several forestry light traps (Csóka *et al.* 2012). Kiss *et al.* (2013) studied its occurrence at service stations on motorways. They found it at more than half of the sites, especially along the roads M0 and M7. Its rapid dispersal was probably assisted by the domestic and international transport of infested ornamental plants, and facilitated by its extremely wide range of host plants.

Biology of the species

Adult Citrus Flatid Planthoppers are small, only 5–8 mm long, and look like moths. When at rest, they fold their wings on their backs like a tent. Newly hatched adults have a light cream-colour, later they become greyish. The species has one generation a year. Eggs overwinter hidden in crevices in the bark of its woody host plants. This itself accounts for its high ability to spread with live plants. The larvae hatch in the spring, in Hungary, typically in May, but this depends on the climatic conditions of the habitat. Newly hatched larvae are yellowish green. They usually moult four times, and feed on the shoots of woody plants or herbs. The wax they produce and their larva skins can remain on the host plants for a long time. An average of 50–70 days pass from the hatching of the larvae till the appearance of the imagoes, so adult Citrus Flatid Planthoppers usually appear from the middle of summer (Pénzes & Hári 2016).

The species is extremely polyphagous, it has several hundred, mostly woody host plants, but it also survives on some herbs. In Europe, it is mostly found on ornamental trees and shrubs in towns, but it also occurs on forest trees and shrubs. Its host plants include Black Locust (*Robinia pseudoacacia*), Tree

Waxy secretion of the citrus flatid planthopper

of Heaven (*Ailanthus altissima*), elders (*Sambucus* spp.), hackberries (*Celtis* spp.), cherries (*Cerasus* spp.), walnuts (*Juglans* spp.), mulberries (*Morus* spp.), privet (*Ligustrum* spp.), hawthorns (*Crataegus* spp.), False Indigo Bush (*Amorpha fruticosa*), maples (*Acer* spp.), Blackthorn (*Prunus spinosa*), pears (*Pyrus* spp.), ashes (*Fraxinus* spp.), hazels (*Corylus* spp.), Lilac (*Syringa vulgaris*), plane trees (*Platanus* spp.), roses (*Rosa* spp.), dogwoods (*Cornus* spp.), elms (*Ulmus* spp.), oaks (*Quercus* spp.), and horse chestnuts (*Aesculus* spp.) (Souliotis *et al.* 2008, Csóka *et al.* 2012, Pénzes & Hári 2016). It even feeds on the Toxic Yew (*Taxus baccata*) and Ivy (*Hedera helix*). As regards herbs and dwarf shrubs, it is frequent on nettles (*Urtica* spp.), blackberries and raspberries (*Rubus* spp.), plantains (*Plantago* spp.), goldenrods (*Solidago* spp.), and ragweeds (*Ambrosia* spp.), to name just a few (Pénzes & Hári 2016).

It has generalist natural enemies native to Hungary, such as species of the groups Neuropterida, Coccinellidae, and Syrphoidea, but they have no significant regulatory effect on its populations (Pénzes & Hári 2016). The situation is the same in other parts of Europe as well, so, its most effective natural enemy, the parasitic wasp *Neodryinus typhlocybae* was repeatedly introduced to Italy since 1987 (Girolami & Camporese 1994, Girolami & Mazzon 1999, Girolami *et al.* 1996). This parasitoid was later also introduced to Croatia, Greece, the Netherlands, Slovenia, Spain, and Switzerland (Vétek *et al.* 2019).

Neodryinus typhlocybae was first detected in Hungary in spring 2015, in the Arboretum of Buda (Szöllősi-Tóth *et al.* 2017). By 2018, it was found in numerous locations in the country, quite distant from each other (Vétek *et al.* 2019), and today, it is present practically everywhere where the Citrus Flatid Planthopper is also abundant. *Neodryinus typhlocybae* has two generations per year. Females lay their eggs into third, fourth and fifth instars of the Citrus Flatid Planthopper, under the winglets. The parasitoid larva forms an oval cocoon, the second generation overwinters in this. *Neodryinus typhlocybae* is capable of spontaneous spreading, and seems to be able to control Citrus Flatid Planthopper populations increasingly (Vétek 2020).

Ecological conditions in Hungary

As the Citrus Flatid Planthopper is extremely polyphagous, it can find suitable host plants anywhere, so the lack of food cannot restrict either its dispersal or its population growth. In the green spaces of Budapest, according to a survey conducted between 2004 and 2014, Hungarian winters did not diminish its populations significantly (Pénzes & Hári 2016). In little more than a decade after its appearance, it became common practically throughout the country, and in some places, even abundant. In recent years, however, most of its populations show a decreasing trend most likely due to the spreading of *Neodryinus typhlocybae* in Hungary.

Ecological concern and economic impact

According to Hungarian studies, the Citrus Flatid Planthopper may act as a vector of several plant diseases (Vétek 2020), thereby causing ecological as well as economic damage. Its honeydew production peaks in late summer or early autumn, when the amount of honeydew secreted by other insects is usually less. As the Citrus Flatid Planthopper occurs partly on tree species covering expansive sites – Black Locust (*Robinia pseudoacacia*), hybrid poplars (*Populus* ×) etc. –, it can become abundant in large areas, and the volume of its honeydew may also be considerable (Csóka 2017). Its honeydew is difficult to digest for Western Honey Bees (*Apis mellifica*), which are at this time preparing for wintering. The honeydew often causes diarrhoea, making them defecate inside the hive, which promotes the spreading of a spore forming protozoa (Microsporidia) from the genus *Nosema*, which may infect bee colonies (Csóka 2017). This negative impact probably also affects some wild bee species (Apidae).

According to current knowledge, the feeding of its larvae and adults does not necessarily cause severe damage. The wax produced by larvae and the honeydew, on which a species of sooty mould, *Cladosporium herbarum* often settles, mainly cause aesthetic damage, which may mean considerable loss of value in the case of ornamental plants. Apart from this, the species has a perceptible negative effect on numerous cultivated plants. It caused 30–40% production loss in soy plantations in Italy (Ciampolini *et al.* 1987). Keszthelyi & Vanyúr (2012) mention its damage on Maize (*Zea mays*), but they do not quantify their results. It may become abundant on Grape Vine (*Vitis vinifera*), and several types of fruit trees, including Apple (*Malus domestica*), Apricot (*Armeniaca vulgaris*), Peach (*Persica vulgaris*), and Fig (*Ficus carica*) (Vétek 2020). Its sucking may impair shoot growth, and deform shoots and leaves.

Potential control measures

In ornamental plant stores and nurseries, the application of chemical control may become necessary. In this case, contact insecticides (e.g. pyrethroids) should be used against young larvae. Controlling larvae is made difficult by their protracted hatching (Pénzes & Hári 2016). Control measures against adults are less effective.

In the long run, saving or assisting its most important natural enemy may be effective. Leaves with several wintering cocoons of *Neodryinus typhlocybae* on their undersides should not be burnt (Vétek 2020). Although this parasitoid also spreads by itself, the translocation of wintering cocoons to potential sites of Citrus Flatid Planthopper infestation may also be useful.

References

Anonym 1995, Ciampolini *et al.* 1987, Csóka 2017, Csóka *et al.* 2012, EPPO Global Database 2022, Girolami & Camporese 1994, Girolami & Mazzon 1999, Girolami *et al.* 1996, Gninenko *et al.* 2011, Gotlin Čuljak *et al.* 2007, Grozea *et al.* 2011, Jermini *et al.* 1995, Keszthelyi & Vanyúr 2012, Kiss *et al.* 2013, Lee & Wilson 2010, Matošević & Pernek 2011, Mihajlović 2007, Nickel 2016, Pénzes 2004, Pénzes & Hári 2016, Souliotis *et al.* 2008, Szöllősi-Tóth *et al.* 2017, Vétek 2020, Vétek *et al.* 2019, Zangheri & Donadini 1980

Anikó Hirka & György Csóka

Buffalo Treehopper

Stictocephala bisonia Kopp & Yonke, 1977

Native range

The Buffalo Treehopper is native to the Eastern United States. From here, it was introduced, probably with branches of fruit trees for grafting, to the western side of North America, Hawaii, North Africa, and also Europe (Świerczewski & Stroiński 2011).

Introduction to Hungary

It was first recorded in Europe in 1912, in today's Kovin, Serbia, then the area of the Kingdom of Hungary (Horváth 1912). A few years later, in 1918, it was also observed in Southern France, near Montpellier (Lallemand 1920). Still in the first half of the 20th century, it was found in the then Yugoslavia (Bosnia-Herzegovina, Croatia, Serbia) (Uvarov 1939). Today, it is widespread throughout Europe. It has been reported from Albania, Austria, Belgium, Bulgaria, Czechia, Greece, Croatia, Poland, Macedonia, Moldavia, Germany, Portugal, Romania, Spain, Switzerland, Slovakia, Slovenia, Turkey, Ukraine, and present-day Hungary (Hoffrichter & Tröger 1973, Okali 1974, Drosopoulos 1980,

© Szilveszter Kis

© Szilveszter Kis

Günthart 1980, Arzone *et al.* 1987, Nast 1987, Janský *et al.* 1988, D'Urso 1995, Lauterer 1995, Seljak 2002, Holzinger *et al.* 2003, Gjonov & Shishiniova 2014, www.fauna-eur.org).

Biology of the species

It is a bright green treehopper, its body is 6–9 mm long. It has hornlike projections on the front of its pronotum. The caudal part of the pronotum tapers into a dorsal spine. The tips of the horns and the carina of the pronotum are often reddish. The Buffalo Treehopper belongs to the order Auchenorrhyncha, suborder Cicadomorpha, and family Membracidae. This family has two members native to Hungary, the Broom Treehopper (*Gargara genistae*) and the-Horned Treehopper (*Centrotus cornutus*), the latter somewhat similar to the Buffalo Treehopper. The horned treehopper can most easily be distinguished from the Buffalo Treehopper by its dark, brown or blackish colour, and the wavy spine on its pronotum (the dorsal spine of the Buffalo Treehopper is straight).

Its temperature tolerance range is wide. In a series of studies conducted in Slovakia, active specimens were observed from August to November, between temperatures of –1 and +36°C. Oviposition was most intensive at 22°C (Krištín *et al.* 1987). The phenology of the species is not well known, but according to data from other Central European countries, the abundance of adult specimens is highest from mid-August to mid-September (Walczak *et al.* 2018), larvae are first observed in May (Schedl 1991, Taszakowski *et al.* 2015), and the species overwinters in egg form. Females deposit their eggs inside shoots, by slicing the young shoots of the host plant with their ovipositors. This causes scarring on the plant. Buffalo Treehoppers are strong fliers, so, once introduced, they spread and colonise new areas easily (Janský *et al.* 1988). They are polyphagous, and damage several plants significant for agriculture, e.g. Grape Vine (*Vitis vinifera*) and Pear (*Pyrus communis*), or forestry, e.g. oaks (*Quercus* spp.) and Common Alder (*Alnus glutinosa*) (Walczak *et al.* 2018).

Ecological conditions in Hungary

Both the climatic conditions and the vegetation of Hungary are suitable for the Buffalo Treehopper. It is widespread in the country (www.izeltlabuak.hu).

Ecological concern

In case of an outbreak, severe damage is to be expected mostly in forests, as some important dominant and mixing tree species are among its host plants, such as oaks (*Quercus* spp.), maples (*Acer* spp.), poplars (*Populus* spp.), and elms (*Ulmus* spp.) (Walczak *et al.* 2018). In case of a gradation, females laying their eggs cause the main damage. The scarred young shoots may decay, and pathogenic fungi or bacteria may attack the plant through the injuries caused by the ovipositors (Lauterer 1995, Seljak 2002).

Economic impact

The Buffalo Treehopper may significantly damage vineyards and fruit plantations. In the first half of the 20th century, it was considered an important pest in the United States of America (Yothers 1934). Its damage mainly manifests, as described above, by mechanical injuries inflicted on young shoots during oviposition.

Potential control measures

Currently, there is no need to apply control measures against this species. In case of a gradation, chemical treatments are effective.

References

Arzone *et al.* 1987, Drosopoulos 1980, D'Urso 1995, Gjonov & Shishiniova 2014, Günthart 1980, Hoffrichter & Tröger 1973, Holzinger *et al.* 2003, Horváth 1912, Janský *et al.* 1988, Krištín *et al.* 1987, Lallemand 1920, Lauterer 1995, Nast 1987, Okali 1974, Schedl 1991, Seljak, 2002, Świerczewski & Stroiński 2011, Taszakowski *et al.* 2015, Uvarov 1939, Walczak *et al.* 2018, Yothers 1934

Péter Kóbor

BEETLES

Coleoptera

Japanese Beetle

Popillia japonica Newman, 1838

Native range

The Japanese Beetle is certainly native to the northern parts of Japan (Honsū, Hokkaidō). As for the rest of its Asian range – China, the Russian Far East (Kuril Islands) –, it is doubted by several authors, mentioning a closely related species in these areas (Fleming 1972). Its first documented occurrence in the United States of America (1916) is connected to a nursery selling perennials in New Jersey (Dickerson & Weiss 1918, Metcalf & Metcalf 1993, Petty *et al.* 2015). In North America, it became worse as a pest than it had been in its native range (EPPO 2006).

Introduction to Hungary

In Europe, it was first detected in the Azores, the autonomous region of Portugal. It was probably introduced in the early 1970s (Martins & Simões 1988), spreading from an American air base (Porter & Held 2002). By 1984, it was present on most islands of the archipelago (Simões & Martins 1985, Martins & Simões 1985, Vieira 2008). In 2014, damage was reported from continental Europe, from Ticino valley to the north of Milan (EPPO Reporting Service 2014, Pavesi 2014). It has an established, increasing population in Northern Italy. It probably got to Switzerland from here in 2017. Here, eradication was first successful, due to efficient measures taken by the plant protection authorities (EPPO Reporting Service 2017). In 2020, specimens were found again in Switzerland, in two vineyards. Imagoes have also been trapped in the course of monitoring (EPPO 2022).

It is a priority pest. Its introduction and assistance of spreading is prohibited in Hungary, according to Decree No. 7 of 2001 (I.17.) FVM of the Minister of Agriculture and Rural Development on the rules of the implementation of phytosanitary measures.

© David Cappaert (bugwood.org)

Accordingly, it is featured on the A2 List of quarantine pests of the European and Mediterranean Plant Protection Organization (EPPO) as well.

Biology of the species

The Japonese beetle is a small June bug. The adults are 8–12 mm long and 5–7 mm wide. They are metallic green with coppery bronze coloured elytra. The abdominal segments bear tufts of white hair on their edges (altogether five on both sides of the beetle), and there are two white spots on the final uncovered abdominal segment. The antennae have three lamellae. Females are larger than males (EPPO 2006), but they can be distinguished with certainty by their legs: males have sharper tibial spurs than females. The Japanese Beetle looks very similar to the Garden Chafer (*Phyllopertha horticola*), and may also be confused with the Vine Chafer (*Anomala vitis*), *Anomala dubia*, and a Leaf Chafer species, *Mimela junii*, although the latter has not yet been observed in Hungary.

The larvae are typical grubs. They can be distinguished from other scarab larvae (Scarabaeidae) by the two V-shaped rows of spines on the ventral side of the last abdominal segment (with six or seven spines on both sides) (Sim 1934, Klausnitzer 1978). The age of the larvae can be determined by the head capsule size.

The Japanese Beetle usually has one generation per year, but on the northern edge of its distribution range, or in unusually cold years, some populations may take two years to develop (Fleming 1972, Vittum 1986, Potter & Held 2002). Time of development varies by approximately six weeks, depending on latitude and year (Fleming 1972). Accordingly, adults in Europe hatch in late May or early June, depending on location and year (Martins & Simões 1988, Vieira 2008). The eggs are usually laid between early August and late September, singly or in small clusters (two to four eggs per cluster) in a hole in the ground, 4–10 cm deep, in humid, grassy spots (Metcalf & Metcalf 1993). One female usually deposits 40–60 eggs (Campbell *et al.* 1989). Newly hatched larvae feed in the ground, until the start of wintering. They overwinter as larvae, usually in the third instar, in a hole in the ground, approximately 15–30 cm deep. In the spring, when soil temperature is over 10°C, larvae crawl nearer the surface and start chewing roots, but this period of damage lasts only a few weeks. The pupal stage lasts for one or two weeks. Average


© Gerald Holmes (bugwood.org)

lifespan of the adults is 30–45 days, in which they mate repeatedly (Potter & Held 2002).

Its natural dispersal capacity is limited. Both American and Italian studies report that it flies on average 400-500 m per day (Hamilton 2003). Increase of population density probably enhances flight activity and distance. Greatest activity was detected on warm (21–35°C), sunny days. It does not feed on rainy days, and scarcely on overcast or windy days (Potter & Held 2002).

The Japanese Beetle emits an aggregation pheromone, attracting other individuals to a food source. Therefore, it often happens that while they chew one tree nearly bare, the one standing next to it is practically free from damage (Campbell *et al.* 1989).

Ecological conditions in Hungary

Its occurrence has not yet been reported from Hungary. By natural expansion, it will probably reach the western part of the country first, in a few years. Considering its host plants and the climatic conditions of Hungary, we may expect it to become established in the entire country, but its mass appearance and damage on an economic scale will probably mainly affect the western part of the Transdanubia region.

Ecological concern

The Japanese Beetle may act as a competitor to several native arthropod (Arthropoda) species. In Hungary, the damage period of the imagoes coincides with the hottest and driest time of summer, when damaged plants are less capable of regeneration.

Several of its preferred host plants also had to face other alien pests in the last hundred years. For example, Sweet Chestnut (*Castanea sativa*) and elm species (*Ulmus* spp.) are already severely impaired, chiefly by non-native fungal pathogens, but also by alien pests. The appearance of yet another pest will not at all be beneficial.

Economic impact

The Japanese Beetle is remarkably polyphagous. Adult specimens have been observed on over 300 plant species in the United States (Potter & Held 2002), from which, it caused economic damage to 106 (Borchert *et al.* 2003). Fleming (1972) published a nearly complete list of its host plants. According to surveys conducted in the United States, its host preference changed in the course of the years. Simultaneously, its damage became more substantial and regular on many trees. The imagoes feed on foliage, flowers and fruits, usually in groups. They eat the tissues between the veins of the leaves, first chewing only holes, but later skeletonizing it entirely. As a consequence of the chewing, remaining leaf tissue often becomes brown, and the leaf falls off. Adults chew irregularly on the petals. Their damage is very conspicuous on rose (*Rosa* spp.), they may even devour all of the flowers. They bore crater-like holes into fruits. Their preferred hosts are maples (*Acer* spp.), horse chestnuts (*Aesculus* spp.), alders (*Alnus* spp.), birches (*Betula* spp.), Sweet Chestnut (*Castanea sativa*), walnuts (*Juglans* spp.), Apple (*Malus domestica*), plane trees (*Platanus* spp.), poplars (*Populus* spp.), some drupes (*Prunus* spp.), roses, brambles and raspberry (*Rubus* spp.), willows (*Salix* spp.), lindens (*Tilia* spp.), elms (*Ulmus* spp.), and also grape vine (*Vitis* spp.) (Vieira 2008, EPPO Reporting Service 2014).

The larvae mainly impair the nutrient uptake of the roots of host plants, but severe physiological effects are uncommon. Herbaceous hosts are only known to wither if many larvae chew their roots simultaneously, and for a long time (Vail *et al.* 1999). The traces of their damage on the roots are not typical, and cannot be distinguished from alterations caused by other pests living in the soil. Apart from roots of grasses, larvae like chewing the roots of numerous vegetables and ornamental plants as well (VIEIRA 2008, EPPO REPORTING SERVICE 2014).

The number of damaged plant species was observed to increase parallel to population growth (EPPO 2022). Interestingly, its host plant range is much narrower in its native Japan (EPPO REPORTING SERVICE 2014).

If the species is present, significant economic damage can be expected in nurseries, orchards, gardens, and mosaic landscapes of forests and meadows in the vicinity of towns. In these areas, it may cause both direct (loss of fruits) and indirect (cost of monitoring and control) economic damage.

Potential control measures

In case of its appearance in Hungary, at the beginning, predictions and the spreading of information need to get top priority. One pheromone of the species and another, flower based scent attractive to it are known. These two are usually used in the traps. Traps need to be positioned carefully, so that adult specimens will not be attracted to sites that were not infested earlier. The species is also attracted to light traps. If these types of traps are unavailable, a basic indication is also sufficient to track the movement of the species in space and time reliably, as it is most active during the day, and its lifestyle is not at all hidden.

To improve efficiency, control of the species needs to apply various methods simultaneously. As a type of mechanical control in small areas, at low population densities, shaking of swarming adults is suggested (AGRICULTURAL RESEARCH SERVICE 1982, SWITZER & CUMMING 2014). Valuable, not too large stands are protected with nets in Italy (EPPO 2022). Soil water balance has a varying but always significant effect on the different developmental stages of the Japanese Beetle. At the time of oviposition, eggs laid in dry soil cannot swell, therefore, high mortality is expected. In the case of damage caused by larvae and imagoes, supplying the concerned area with a sufficient amount of water may mitigate the damage by enhancing the regeneration capacity of plants. The lack of herbs on the ground during the time of oviposition also decreases the number of larvae, as they will have less roots to feed on. According to Italian research, a biopesticide (azadirachtin) extracted from the Indian Neem (*Azadirachta indica*) may repel imagoes.

From biological control methods, the most effective against the Japanese Beetle so far proved to be a nematode (Nematoda), *Heterorhabditis bacteriophora*, and an insect pathogenic fungus, *Metarhizium anisopliae* (CIAMPITTI *et al.* 2016, MARIANELLI *et al.* 2018, PAOLI *et al.* 2017). In an experiment, they placed ten Japanese Beetle larvae (third instar) by yew trees (*Taxus baccata*) planted in 3.8 l containers, in the field. Then the plants in the containers were supplied with water containing varying amounts of nematodes (46, 92, 192, 385 nematode / cm^2 soil surface). The nematodes *Heterorhabditis heliothidis* and *Steinernema glaseri* caused over 90% mortality of the third instar larvae, depending on concentration, an impressive result. In other experiments searching for effective biocontrol agents against the Japanese Beetle, preparations containing a nematode, *Neoaplectana carpocapsae*, and a bacterium, *Paenibacillus popilliae* were also found effective (WRIGHT *et al.* 1988, SIMÕES *et al.* 1993, POTTER & HELD 2002). However, the efficiency of insect pathogen nematodes significantly decreases in dryer conditions. Currently, the effects of the nematode *Hexamermis popilliae* on the Japanese Beetle is being tested (MAZZA *et. al.* 2017). But when deciding to use biological control, native nematode populations should be the first to be considered. Alien nematodes are only to be applied as a last resort, following serious ecological consideration.

By combining chemical and biological methods, control efficiency in dryer conditions can be increased, and, at the same time, chemical loading of the environment can be diminished.

In the United States of America, several generalist natural enemies were found effective in reducing the populations of the Japanese Beetle, such as ants (Formicidae), rove beetles (Staphylinidae), ground beetles (Carabidae), moles (Talpidae), and birds (Aves). Species of these groups mainly eat eggs and young larvae (POTTER & HELD 2002).

References

AGRICULTURAL RESEARCH SERVICE 1982, BORCHERT *et al.* 2003, CAMPBELL *et al.* 1989, CIAMPITTI *et al.* 2016, DICKERSON & WEISS 1918, EPPO 2006, 2022, EPPO REPORTING SERVICE 2014, 2017, FLEMING 1972, HAMILTON 2003, KLAUSNITZER 1978, MARIANELLI *et al.* 2018, MARTINS & SIMÕES 1985, 1988, MAZZA *et al.* 2017, METCALF & METCALF 1993, PAOLI *et al.* 2017, PAVESI 2014, PETTY *et al.* 2015, POTTER & HELD 2002, SIM 1934, SIMÕES & MARTINS 1985, SIMÕES *et al.* 1993, SWITZER & CUMMING 2014, VAIL *et al.* 1999, VIEIRA 2008, VITTUM 1986, WRIGHT *et al.* 1988

KATALIN TUBA & FERENC LAKATOS

Emerald Ash Borer

Agrilus planipennis Fairmaire, 1888

Native range

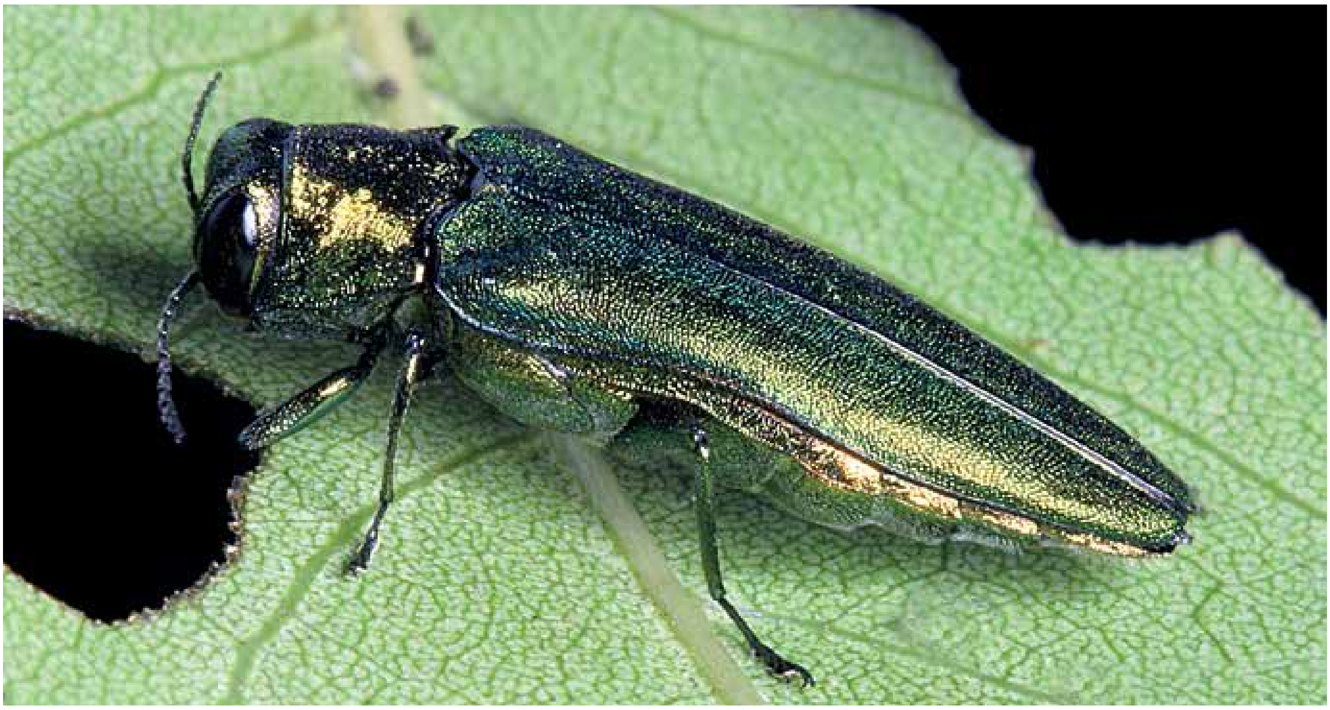
It is native to the Russian Far East, Northeastern China and the Korean Peninsula (Tuba *et al.* 2012, Herms & McCullough 2014).

Introduction to Hungary

The species was detected in 2002, in Michigan in the United States, and in Ontario in Canada, but the circumstances of the introduction remain unknown. According to growth ring analyses, it was already present in Michigan in the early 1990s (Herms & McCullough 2014). Today, it occurs in 35 eastern and central states of the United States, and five Canadian provinces (USDA APHIS PPQ 2020).

Several entomologists collected individuals of this species in Moscow, between 2003 and 2006 (Baranchikov *et al.* 2008). Since then, it has been spreading continuously to the south and the west. Imagoes fly relatively well, even over 1 km by themselves, but the wind also effectively promotes their spreading. However, the species usually covers great distances with human assistance (Herms & McCullough 2014). It is mostly dispersed to long distances by transport of infested wood. Wood with the bark intact (e.g. firewood) or with pieces of bark (e.g. coarse chips), packing crates, and pallets pose the greatest threat.

In 2019, the species was detected in Ukraine. The speed of dispersal, supposing an invasion centre at Moscow, is about 50 km/year (Drogvalenko *et al.* 2019). It has not yet appeared in any countries of the European Union. However, knowing how far it can spread, and its considerable latency period (up to ten years), it is possibly much closer to our borders than the location of its known Ukrainian habitats, approximately 1,300–1,400 km distant.



© David Cappaert (bugwood.org)

Biology of the species

Larvae ready to pupate are 25–30 mm long, flat, thin, with a broad prothorax. Pupae are 10–15 mm long and yellowish white. Adult beetles are 8–15 mm long and 2–3,5 mm wide. Their colour is metallic bluish green, and they are really pretty. Larvae, pupae, and imagoes all closely resemble several *Agrilus* species native to Hungary, for example *Agrilus convexicollis*, which may also live in ash (*Fraxinus* spp.). For the reliable identification of the species, a specialist is needed. Volkovitsh *et al.* (2020) offer some help for distinguishing the similar species.

It usually has one generation a year, but a part of the population may take two years to develop, depending on environmental conditions. Most adults hatch from May to July. Their exit holes are 2–3 mm wide, and, similarly to other jewel beetles, have a typical, lying D-shape. The beetles feed on the leaves of the host plant, and live for 3 to 6 weeks (Wang *et al.* 2010). After mating, the female deposits the eggs singly, usually on the lower third of the tree trunk, on the bark or in crevices. The larvae hatch after about two weeks (Wang *et al.* 2010), and chew long, serpentine, gradually widening galleries into the sapwood, filled by brownish faeces and frass. Mature larvae pupate in the spring, near the surface.

Woodpeckers (Picidae) are significant natural enemies of the species in China (Wang *et al.* 2010), and also in North America (Lindell *et al.* 2008). Infestation of the Emerald Ash Borer – as that of our native species as well – is often noticed by woodpeckers practically barking the tree while searching for pupae in or under the bark. Getting in through the holes made by woodpeckers, several ant species (Formicidae) also eat the larvae (Wang *et al.* 2010). In Asia, its most important parasitoid is a wasp, *Spathius agrili*, which has several (three or four) generations per year, and may infect up to 60% of the larvae (Yang *et al.* 2005). Besides this, several less significant hymenopteran parasitoids, parasitic mites (Acari), and entomopathogenic fungi are also mentioned as natural enemies or pathogens of the Emerald Ash Borer (Wang *et al.* 2010). In European Russia, the most effective natural enemy was a parasitoid wasp, *Spathius polonicus*. This species is native to Europe, parasites jewel beetles, and causes approximately 50% mortality (Orlova-Bienkowskaja 2015).

Ecological conditions in Hungary

All European ash species (*Fraxinus* spp.) are suitable host plants for the Emerald Ash Borer (Baranchikov *et al.* 2014). In Russia and Ukraine, the alien, planted Green Ash (*Fraxinus pennsylvanica*) was the most severely damaged species (Orlova-Bienkowskaja *et al.* 2020).

Regarding climate, most of our continent is suitable for this species, although it is possible that development would usually take not one but two years in the northern countries (e.g. Norway, Sweden, Finland)

© György Csóka

(Flø *et al.* 2015). Consequently, should the Emerald Ash Borer appear, either as a result of introduction or gradual natural expansion, it would probably find favourable conditions and cause considerable damage in Central Europe, including Hungary.

Ecological concern

In its native range, the species usually attacks stressed, weakened ash trees (*Fraxinus* spp.), and rarely causes severe damage (Herms & McCullough 2014). It has a similar role to *Agrilus* species native to Hungary, for example the Two-spotted Oak Borer (*Agrilus biguttatus*), which usually appears abundantly after severe droughts or serious leaf loss caused by other insects, for example the Gypsy Moth (*Lymantria dispar*). Contrarily, in America and in experimental sites is China, it readily attacked healthy, unstressed ashes belonging to species native to America (young and old as well), and killed them in the course of a few years. Information on its effects on the ash species of Europe is scarce so far, but it is certainly able to damage European Ash (*Fraxinus excelsior*) seriously (Orlova-Bienkowskaja 2015). If it becomes established, it may worsen the already weak health of ash trees in Europe further, either by itself, or together with already known pests/pathogens associated to ash species, eg. the fungus causing Ash Dieback (*Hymenoscyphus fraxineus*), bark beetles (*Hylesinus*), ash weevil (*Stereonychus fraxini*) etc. (Csóka *et al.* 2013, Tuba *et al.* 2021).

Several fungi may colonise the galleries of Emerald Ash Borer larvae, which accelerate tree decline (even in the case of relatively resistant ash species), and the rotting of living trunks, significantly reducing their expected life span and causing structural failure (Held *et al.* 2021).

The mass death of ash trees would have a negative effect on associated insect communities, especially on monophagous or oligophagous species, for example the protected scarce fritillary (*Euphydryas maturna*), or the strictly protected *Asteroscopus syriaca*, to name just a few ash specialist species (Csóka & Ambrus 2016).

In the gaps forming as a result of the death of single ash trees or groups of trees, light demanding invasive species may become abundant, which leads to a significant, unfavourable alteration of stand structure. As ash species are widespread in Europe, these negative effects may manifest on a continental scale.

Economic impact

In the United States of America, the Emerald Ash Borer is considered one of the most important invasive forest insects (Herms & McCullough 2014). Apart from killing trees in forests, the mass mortality of valuable trees experienced in alleys, parks, and residential areas is of special significance. Apart from the primary costs of this mortality (removal and replacement of dead trees), severe damage was suffered by approximately ten thousand nurseries and two thousand wood processing facilities all over the country because of the imposed quarantine measures, and even the value of properties afflicted by ash decline significantly decreased. Donovan *et al.* (2013) showed serious negative effects on human health as well. Kovacs *et al.* (2011) estimated potential damage between 2009 and 2019 to amount to over 10 billion (!) dollars.

Damage and costs of the presence of the species in the countries of the European Union cannot even be guessed at yet. At the same time, it is well known that the timber of e.g. the European Ash (*Fraxinus excelsior*) is highly valuable, and the ashes are popular ornamental trees, among those most frequently planted in towns. Therefore, it is clear that the establishment and outbreaks of the invasive Emerald Ash Borer would have severe economical consequences. These may be worsened by possibly necessary quarantine measures, control measures, and the considerable additional costs of pest monitoring.

Potential control measures

As in the case of most invasive species which are expected to appear, prevention and early detection are of critical importance in the case of the Emerald Ash Borer as well. These, however, may only postpone its appearance, as its expansion westwards from Russia and Ukraine can at best be slowed down, stopping it is hardly a real possibility.

The natural enemies of the species mentioned above – woodpeckers (Picidae), parasitoids, entomopathogens etc. –, together with other, native natural enemies may somewhat decrease the rapidity of the expansion, and may to some degree regulate Emerald Ash Borer populations, but they will certainly not provide a comprehensive, reassuring solution to the problems it will cause.

To protect trees of especially high value or cultural significance, injecting systemic insecticides into the trunk may be effective (Herms & McCullough 2014).

The chances of sufficiently early detection can be increased by strengthening forest protection and plant health monitoring, and by educating and involving the public (“citizen science”). Monitoring tools can be improved by the development of efficient traps specific to jewel beetles (Buprestidae), also in progress in Hungary (Imrei *et al.* 2019, 2021).

In Austria, specially trained search dogs are employed to detect the Emerald Ash Borer, similarly to the Asian Longhorn Beetle (*Anoplophora glabripennis*) (Hoyer-Tomiczek & Hoch 2020).

Dancsházy (2019) provides a summary of the international experiences about the expansion of the species, and possible long-term management possibilities.

The detection or even the suspicion of the presence of the Emerald Ash Borer has to be reported to competent authorities (NÉBIH). After performing the necessary examinations, applicable quarantine regulations must be observed regarding the infested trees.

References

Baranchikov *et al.* 2008, 2014, Csóka & Ambrus 2016, Csóka *et al.* 2013, Dancsházy 2019, Donovan *et al.* 2013, Drogvalenko *et al.* 2019, Flø *et al.* 2015, Held *et al.* 2021, Herms & McCullough 2014, Hoyer-Tomiczek & Hoch 2020, Imrei *et al.* 2020, 2021, Kovacs *et al.* 2011, Lindell *et al.* 2008, Orlova-Bienkowskaja 2015, Orlova-Bienkowskaja *et al.* 2020, Tuba *et al.* 2012, 2021, USDA APHIS PPQ 2020, Volkovitsh *et al.* 2020, Wang *et al.* 2010, Yang *et al.* 2005

György Csóka & Anikó Hirka

Harlequin Ladybird

Harmonia axyridis (Pallas, 1773)

Native range

The Harlequin Ladybird is native to Eastern Asia. Its original range comprises China, the Korean Peninsula, Japan, Mongolia, Northeastern Kazakhstan, and Southern Siberia in Russia. It reaches the southern provinces of China to the south, the latitude of Krasnoyarsk to the north, the Altai Mountains to the west, and the Pacific coast to the east (Brown *et al.* 2011).

Introduction to Hungary

The harlequin was repeatedly introduced to several continents, including Europe, from the second half of the 20th century, as a biological control agent against aphids (Aphidoidea) and plant lice (Psylloidea). By the end of the century, this process was promoted by the intentional mass breeding and commercial availability of the species.

At first, the species failed to become established after the event of introduction. In Europe, the first attempts at its introduction were made in the east, in the area of the then Soviet Union, in Ukraine from 1964, and in Belarus from 1968. Authorized release of harlequins took place later, from 1982 onwards in France, and later in Belgium, Czechia, Germany, Greece, Italy, the Netherlands, Portugal, Spain, and Switzerland (Brown *et al.* 2008). From the 1990s, the species became commercially available in several countries, such as France, Belgium,

© György Csóka

Most Harlequin Ladybirds have a spotted pattern on an orange blackground

The colouration of the Harlequin Ladybird is very diverse. Some specimens have black patterns

and the Netherlands. Established, permanent populations were first detected in Europe at the beginning of the 2000s, in Germany and Belgium. The species spread quickly in Western Europe. In 2006, it appeared in four countries (Austria, Denmark, the United Kingdom, Norway), but it did not establish stable populations (Brown *et al.* 2008). Today, it occurs in every country in Europe, apart from Finland, Estonia, and Iceland (https://gd.eppo.int).

In Hungary, the first Harlequin Ladybird was recorded in 2008 (Merkl 2008), but later, several specimens were found in a sample collected in the summer of 2007, in Fejér county (Markó 2016). The species probably entered Hungary from the west, but, characteristic of the rapidity of its dispersal, it was already present in the eastern counties by 2009, and also by this time, it was already one of the most commonly caught ladybird species in several locations in the country (Markó & Pozsgai 2009). Today, it is a dominant ladybird species in the entire country.

Biology of the species

The imagoes of the Harlequin Ladybird are somewhat larger than those of the well-known Seven-Spot Ladybird (*Coccinella septempunctata*). The elytra are strongly domed, resulting in the regular hemisphere shape of the beetle. The elytra are red and black, but have several very different colour forms, determined by genetic factors. The colour forms have two main groups, one which is red with a black pattern (f. *succinea*), and the other, which is black with a red pattern, the so-called melanic forms. More than 99 percent of the individuals in nature carry alleles determining one of the four main patterns (forma *succinea*, f. *axyridis*, f. *spectabilis* and f. *conspicua*). The forms differ in several biological aspects as well (life span, mating preference, speed of development, alkaloid content etc.) (Mezőfi & Korányi 2017). In the invaded regions, the proportion of f. *succinea* forms is typically high. The vast majority of Hungarian individuals belong to this form as well.

The females lay eggs on a great variety of woody plants, near aphid (Aphidoidea) colonies, in clusters. The hatching larvae have a characteristic orange pattern on black background and chitin spines. The larvae, as the imagoes, are voracious predators. Apart from aphids, they devour nearly any soft-bodied arthropod, egg, larva, or pupa they can reach, even other harlequins. They pupate on plants, following four, gradually growing instars. The females lay several


© Tamás Deli

Enormous masses may assemble for wintering

hundreds of eggs during their lives of a few months. In Hungary, they have three complete generations and a partial one. Overwintering imagoes start laying eggs in April, and imagoes of the first generation appear in late May. Further generations overlap due to the protracted laying of eggs (Markó & Pozsgai 2009). Only imagoes are able to overwinter. Harlequin Ladybirds in search of a place for wintering cover suitable surfaces en masse.

Ecological conditions in Hungary

The climatic conditions in Hungary are favourable to the Harlequin Ladybird. Similarly to native species, it tolerates winters considered unusually cold in Hungary, and extremely hot summers as well. Its abundance on various plants and in various habitats is mostly determined by prey availability, especially the availability of aphids (Aphidoidea). As the number of aphids on woody plants lowers significantly after June, harlequins regularly face a time of food shortage in the summer months, which is only partly compensated by changing their diet, e.g. to plant lice (Psylloidea) (Markó & Pozsgai 2009).

Ecological concern

The best documented problem caused by the Harlequin Ladybird is its replacing native ladybird species (Coccinellidae). It eats not only their preferred prey, but their eggs, larvae, and pupae as well (intraguild predation). The harlequin's larvae and imagoes feed mainly in the canopies of trees or shrubs, so their presence mainly affects species of these habitats. In Hungary, the species most severely declining as a result of the spreading of the Harlequin Ladybird are *Oenopia conglobata*, Two-spot Ladybird (*Adalia bipunctata*), Ten-spotted Ladybird (*Adalia decempunctata*), and Cream-spot Ladybird (*Calvia quatuordecimguttata*), whereas the frequency of the Seven-spot Ladybird (*Coccinella septempunctata*), which feeds mainly on the grass level, has changed less (Markó

© György Csóka

Larva of the Harlequin Ladybird

2016). Information on the effects of the invasion on other arthropod (Arthropoda) groups is scarce, but presumably, several species of the food webs around aphids (Aphidoidea) feeding on woody plants are severely hit by the mass presence of the harlequin, and in natural habitats, it may reduce the populations of several lesser-known native arthropod species.

Economic impact

The Harlequin Ladybird is an effective natural enemy of several plant pests, so, in the respect of plant protection, it may be regarded decidedly useful on various plantations. It is known chiefly to reduce the number of aphids (Aphidoidea), but its food range is very wide. It also feeds on plant lice (Psylloidea), scale insects (Coccoidea), Tenthredinoidea larvae, butterfly and moth (Lepidoptera) eggs, mites (Acari) etc., so it is useful in controlling other pest species as well.

Although it occasionally also feeds on injured fruit, this is no reason for concern. If many individuals (i.e. over one beetle per kg) fall into harvested Grapes (*Vitis vinifera*), they cause an unpleasant smell and aftertaste, thus impairing wine quality. The masses of beetles looking for wintering quarters may cause inconvenience in inhabited areas, even in dwellings.

Potential control measures

To avoid spoiled wine, it is useful to assess the abundance of harlequins directly before harvesting the Grapes (*Vitis vinifera*). If necessary, their abundance can be reduced by applying repellent scents or an adequate harvesting technology (Kenis *et al.* 2008). Regarding agriculture, apart from the marginal case of spoiled wine, control measures are not called for, as the presence of the harlequin may be regarded useful. From the conservation point of view, reducing a species which is currently abundant in the entire country and has a great dispersal ability, is not possible. Although there are some natural enemies which also occur in Europe – pathogenic fungi, parasitoids, nematodes (Nematoda) etc. –, their effects on the harlequin populations are meagre and usually not species specific (Kenis *et al.* 2008).

References

Brown *et al.* 2008, 2011, Kenis *et al.* 2008, Markó 2016, Markó & Pozsgai 2009, Merkl 2008, Mezőfi & Korányi 2017

Balázs Kiss

Asian Longhorn Beetle

Anoplophora glabripennis (Motschulsky, 1853)

Native range

There are 36 known species of the genus *Anoplophora*, all of them native to Asia (Lingafelter & Hoebke 2002). The most well-known is the Asian Longhorn Beetle. This is mostly because it has been introduced to North America (United States, Canada), and several countries in Europe, where it caused serious concern, and was the cause for starting intensive, targeted research projects. The species originates from China and the Korean Peninsula, but it has also been long known from Japan (Lingafelter & Hoebke 2002).

Introduction to Hungary

It was found in Europe for the first time in 2001 in Austria (Braunau, Upper Austria) (Tomiczek 2001). Later, it was detected in nine more countries (Belgium, Finland, France, the United Kingdom, the Netherlands, Montenegro, Germany, Italy, Switzerland). It has been successfully eradicated in Belgium, the United Kingdom, Finland, and the Netherlands (https://gd.eppo.int/), but repeated introduction to these countries in the future is still possible. It probably entered Europe with stone, paving stone and marble shipments, and also in the wooden packaging of large machines (pallets, planks etc.). Due to this, it has nearly exclusively appeared in or near inhabited areas, or near the premises of companies trading internationally (Favaro *et al.* 2013).

Biology of the species

Most of the adult beetles are 25–35 mm long (Lingafelter & Hoebke 2002, Tuba *et al.* 2012). Antennae of the females are only slightly longer than the body, but those of the males are 2–2.5 times as long. Approximately twenty, irregular white spots adorn the shiny, black elytra. The antennae have 11 segments, the lower half of every segment is light blueish grey.

© György Csóka

Adult Asian Longhorn Beetles usually fly only a few hundred meters, so spreading by their "own resources" is not particularly fast (Straw *et al.* 2016). Young longhorn beetles in the course of their maturation feed on the bark of thin branches. The traces of this may indicate their presence (Csóka & Hirka 2016). The mated female lays 10–100 eggs into tiny pits chewed through the bark of the host. Eggs occur on thick branches, trunks, and lower trunks as well. The eggs are 5–7 mm long, with


© György Csóka


© György Csóka

an elongated, flattened, oval shape. Freshly laid eggs are dirty white, but they become brownish yellow before hatching. The larvae are typical roundheaded borers, growing approximately 50 mm long. Ejected lumps of faeces and frass often show the presence of developing larvae in the trunks or branches. The larvae pupate at the end of the larval tunnel, in a pupal chamber closed off with frass. Their development usually takes two or three years, depending on weather conditions and food quality. Branches and trunks bored by larvae may die within a few years (Csóka & Hirka 2016). The exit holes are large, with diameters of approximately 10 mm. They are very conspicuous, especially when in groups. It is important to note that boring dust and large exit holes on trunks may also indicate the presence of other species, native to Hungary, such as the Goat Moth (*Cossus cossus*), large Poplar Borer (*Saperda carcharias*), or the Hornet Moth (*Sesia apiformis*) (Tuba *et al.* 2012, Csóka *et al.* 2013). To distinguish these traces, a thorough examination and considerable expertise are necessary.

The Asian Longhorn Beetle is highly polyphagous. In its native range, it mainly feeds on poplars of the Aigeiros section, i.e. relatives of the Black Poplar (*Populus nigra*), and their hybrides. Faccoli & Favaro (2016) report that it develops in cherries (*Prunus* spp.), willows (*Salix* spp.), maples (*Acer* spp.), poplars (*Populus* spp.), birches (*Betula* spp.), and elms (*Ulmus* spp.) in Italy, and prefers maples, birches, elms, and willows. In North America (where it was first detected in 1996), most significant damage was caused (among others) on maple species, such as Boxelder Maple (*Acer negundo*), Norway Maple (*A. platanoides*), Sycamore Maple (*A. pseudoplatanus*), Red Maple (*A. rubrum*), Sugar Maple (*A. saccharum*), and Silver Maple (*A. saccharinum*), and on Horse Chestnut (*Aesculus hippocastanum*) (Haack *et al.* 2017). The above species, which are especially sensitive to the attacks of the Asian Longhorn Beetle, are also common in the parks and streets of European towns, and in the forests as well.

Significant natural enemies are not known from Europe, so their role in regulating the species cannot yet be counted on (Helbig & Müller 2018).

The native range, appearance and life history of the Asian citrus Longhorn Beetle (*Anoplophora chinensis*) are similar to those of the Asian Longhorn Beetle. This species is also polyphagous, its range of host plants overlaps with that of the Asian Longhorn Beetle, but the Asian citrus longhorn beetle mostly appears on citruses (Aurantioideae), and on fruit trees of the rose family (Rosaceae), for example apple (*Malus* spp.) and pear (*Pyrus* spp.) (Tuba *et al.* 2012, Csóka & Hirka 2016). The probable means of introduction also differs from the other species. It probably got and can get into Europe again with imported live plants, for example bonsai trees, larger ornamental trees, shrubs, and fruit trees in containers. It is mostly expected to appear in horticultural stores or nurseries, where imported plants are traded. Similar signs indicate its presence as that of the Asian Longhorn Beetle (Csóka & Hirka 2016).

Ecological conditions in Hungary

To the best of our knowledge, the Asian Longhorn Beetle is not yet present in Hungary. Nonetheless, it would be unreasonably optimistic to suppose that this will remain so. It may enter Hungary at any time (if it has not entered already), by way of goods imported from Asia, the wooden packaging of which contains one of its developmental stages. Our beloved trees in parks and towns, and many of our native forest tree species are potential hosts for the species.

Ecological concern

Although in Europe, damage has only been reported so far from inhabited areas, it may eventually invade forests as well. Its presence may pose an especially severe threat to forest tree species which have already become rare for other reasons, such as rowans (*Sorbus* spp.), or which are already attacked by alien pathogenic fungi, such as the European Ash (*Fraxinus excelsior*) afflicted by *Hymenoscyphus fraxineus*, or elms (*Ulmus* spp.) afflicted by *Ophiostoma novo-ulmi*. The Asian Longhorn Beetle is featured on the list compiled first in 2000, and modified in 2013 by the IUCN ISSG (Invasive Species Specialist Group), "*100 of the World's Worst Invasive Alien Species*", as one of only two beetle (Coleoptera) species (Helbig & Müller 2018).

Economic impact

The Asian Longhorn Beetle damages valuable trees in alleys and parks, so it is regarded as a significant alien pest both in North America and Europe. In the United States, the possible cost of the potential damage of this species is estimated to several billion (!) dollars. In Austria, at the location of the first European detection of the species, over 2 million euros were spent between 2001 and 2006 on surveying the spreading of the species, and the elimination of the infestation centre (Csóka & Hirka 2016).

According to the calculations of Faccoli & Gatto (2016), the removal of 367 infested trees in Northern Italy cost about 48,000 euros (including expert fees and surveys of the sites). By this, they were able to reduce the damage expected for next year approximately by half, which amounts to saving about 300,000 euros (850 euro/tree), about six times the cost of the intervention.

From the above, it is clear that the species, in case of its appearance in Hungary, has a significant damage potential, both in urbanized and forest environments.

Potential control measures

It applies to both above mentioned species that no effective eradication technologies (chemical control, mass trapping) are known against them. Early removal of infested trees seems to be the only solution (Faccoli & Gatto 2016, Straw *et al.* 2016). Therefore, in order to avoid severe damage, early detection is of critical importance. If the presence of the species is detected on time, and the infested trees are removed and annihilated before the subsequent generation has time to develop, the risk of more serious damage can be significantly reduced.

To assist early detection, specially trained Dogs (*Canis familiaris*) are used to check potential introduction spots. Dogs were first employed in Austria, but currently, the method is used in other countries as well. Target-trained dogs can detect the insects (larvae, pupae) in the wood more effectively than humans visually examining the trees. A specialist group of the BFW (Federal Research and Training Centre for Forests, Natural Hazards and Landscape) conducts detections with dogs (Hoyer-Tomiczek *et al.* 2016, Csóka & Hirka 2016).

It is also important to note that several years may pass between the actual introduction and the first detection of the species. According to Straw *et al.* (2016), this period was almost ten years (!) in case of its introduction to Southern England. This once more calls our attention to the necessity of regular, widespread monitoring. The chance of the successful eradication of established infestation centres decreases significantly with time, while the costs of the treatments increases just as badly. The Asian Longhorn Beetle and the Asian citrus longhorn beetle are both priority pests, therefore detection and even suspicion of their presence has to be reported to the NÉBIH, the National Food Chain Safety Office in Hungary immediately (Csóka *et al.* 2013, Csóka & Hirka 2016).

References

Csóka & Hirka 2016, Csóka *et al.* 2013, Faccoli & Favaro 2016, Faccoli & Gatto 2016, Favaro *et al.* 2013, Haack *et al.* 1997, Helbig & Müller 2018, Hoyer-Tomiczek *et al.* 2016, Lingafelter & Hoebke 2002, Straw *et al.* 2016, Tomiczek 2001, Tuba *et al.* 2012

György Csóka & Anikó Hirka

Red-headed Ash Borer

Neoclytus acuminatus (Fabricius, 1775)

Native range

The Red-headed Ash Borer is native to America, the central region of the Eastern United States, but its exact original range cannot be determined. The reason for this is that the "artificial" spreading of the species happened simultaneously to the development of road traffic. Back then, faunistic data were hardly recorded, and their importance was not recognized either.

Introduction to Hungary

The Red-headed Ash Borer was introduced to numerous locations with infested wood, both in America and the Atlantic region: to further states of the USA, Madeira, Cuba, Argentina, Canada, Puerto Rico, and Mexico. In Europe, it was first noticed in two sea ports on the Adriatic, in Fiume (today Rijeka) in 1851, and in Zára (today Zadar) in 1891. Later, it was also

© Tibor Kovács

Red-headed Ash Borer on the trunk of a recently dead staghorn stumac found in the following countries, in chronological order (Keszthelyi 2021): Northern Ireland, Italy*, Germany, Switzerland*, Slovenia*, Czechia, Bosnia and Herzegovina*, France, Hungary*, the United Kingdom, Montenegro*, Serbia*, Romania*, Slovakia, Austria* – in the countries marked with *, it became naturalised.

In the *Magyarország állatvilága* (Fauna of Hungary) series, in the remarkable volume on capricorn beetles written by Zoltán Kaszab (Kaszab 1971), the scientific name of the Red-headed Ash Borer is featured in brackets signalling that its appearance is to be expected. The prediction came true in a few years: the first individual was detected in Vetyehát, a district of Szeged, on bundles of brushwood used for flood control made of willows (*Salix* sp.), on 21 May 1982. In 1984, on the floodplain, near Makó, the species already swarmed en mass on prunings of fruit trees. By the late 1990s, it became common in the southern part of the Tiszántúl and Danube-Tisza Interfluve regions (Gaskó 1998). Later it crossed the Danube, and went on spreading westwards and northwards. By 2008, it reached Budapest. Its spreading continues to this day, documented by published studies (Traser 1996, Merkl & Vig 2009, Kovács 2010, Keszthelyi 2021, Kovács & Gebei 2021) as well as fresh records published on the website www.izeltlabuak.hu. It bred for years in the boughs of fig (*Ficus carica*) in Sátoraljaújhely; on grape vine prunings in Legyesbénye, near the Tokaj-Hegyalja region; and, near Háromhuta, in a woodpile consisting mostly of Beech (*Fagus sylvatica*), also visited by the Rosalia Longicorn (*Rosalia alpina*), although it was observed on the log of a Field Maple (*Acer campestre*) (G. Hegyessy *pers. comm.*). In June 2022, it was detected in Farkasmály, a district of Gyöngyös, on a freshly whithered Staghorn Stumac (*Rhus typhina*). Apart from the most elevated mountain regions, it will probably shortly spread throughout Hungary.

Biology of the species

One of the main reasons for the success of the Red-headed Ash Borer is its wide host plant spectrum. The following long list of such data from Hungary is primarily based on the results of Gaskó (1998), but also of Kovács & Gebei (2021) and Gábor Hegyessy. Fruit trees are of the greatest importance: Apple (*Malus domestica*), European Plum (*Prunus domestica*), Quince (*Cydonia oblonga*), Wild Cherry (*Cerasus avium*), Carpathian Walnut (*Juglans regia*), Fig (*Ficus carica*), Apricot (*Armeniaca vulgaris*), Blackthorn (*Prunus spinosa*), Common Pear (*Pyrus communis*), Sour Cherry (*Cerasus vulgaris*), Peach (*Persica vulgaris*), Damson Plum (*Prunus insititia*), Common Grape Vine (*Vitis vinifera*). These are followed by alien species from various locations, some from the "native land" of the Red-headed Ash Borer, e.g. Green Ash (*Fraxinus pennsylvanica*), eastern American Black Walnut (*Juglans nigra*), Honey Locust (*Gleditsia triacanthos*), Common Hackberry (*Celtis occidentalis*), and Boxelder Maple (*Acer negundo*); and others from Asia, e.g. White Mulberry (*Morus alba*) and Russian Olive (*Elaeagnus angustifolia*). The third, smallest group comprises native forest tree species, e.g. Pedunculate Oak (*Quercus robur*), Field Maple (*Acer campestre*), Field Elm (*Ulmus minor*), European white Elm (*U. laevis*), and, surprisingly, also a gymnosperm, European Silver Fir (*Abies alba*).

The Red-headed Ash Borer lays its eggs in cracks on recently dead branches, boughs and tree trunks with the bark intact, with diameters of 3–30 cm. Newly hatched larvae feed first on the boundary of the bark and the xylem, scratching it deeply, and later tunnel into the xylem, criss-crossing it thoroughly. The pupal chamber is also in the xylem (Csóka & Kovács 1999). The typical pattern of the burrows under the bark adds up to a nearly continuous surface, indicating that the female lays many eggs in a small space. The larva enters the xylem from the bark through an oval hole, which it blocks with frass. It overwinters as a larva. Larval development usually takes a year, occasionally several years. Hatching imagoes leave the trunk through a round exit hole. Their mass presence is indicated by 10-15 exit holes on a palm-sized area. The Red-headed Ash Borers swarm from mid-April to late July, on warm, sunny days, on drying branches and trunks of their host plants, or on woodpiles consisting thereof. They reach up to 10 m high in the canopy, as proven by broken ash branches with their typical gallery patterns (Gyöngyös, Orczy Garden). Similarly to jewel beetles (Buprestidae), it is an agile species. When disturbed, it escapes quickly, or flies away.

Ecological conditions in Hungary

Its good flight ability, wide food spectrum, and the global warming experienced in the last decades all contributed to the Red-headed Ash Borer's dispersal to most parts of Hungary, except for the western and the most northeastern lowland areas. The "pathways" of this rapid dispersal are partly man-made habitats: the mainly introduced tree species of orchards, allées, cemetaries, and parks, but the soft- and hardwood forests of the floodplains of our large rivers also contributed to its spreading, both through native and

© Tibor Kovács

The galleries of Red-headed Ash Borer larvae under the bark (above) and in the xylem (below) of a white mulberry branch

invasive tree species, which spread aggressively in these habitats. Its becoming established was secured by its ability to use several widespread and common native tree species as its host plant.

Ecological concern

Although the rapid invasion of the Red-headed Ash Borer may cause concern, it does not have any measurable negative effect on its host plants or the native fauna (Cocquempot & Lindelöw 2010).

This is demonstrated by observations in the operating area of the Hortobágy National Park Directorate. The species was perceived in all of its natural habitats (six sampling sites) together with a native species of flat bark beetle, *Cucujus cinnaberinus*. This species is similarly polyphagous as the Red-headed Ash Borer, but its entire development – from larva through pupa to the hatching of adult beetles – happens on the boundary of the bark and the xylem, just like the first period of the Red-headed Ash Borer's larval stage. Despite similar habitat demands, the two species occur together, as they can divide host plants: the Red-headed Ash Borer was reported from Ash (*Fraxinus* sp.) in five sampling sites, and from Boxelder Maple (*Acer negundo*) in one, while the flat bark beetle was observed on Pedunculate Oak (*Quercus robur*) in three of the sites, on poplar (*Populus* sp.) in two, and on ash in only one (Kovács & Gebei 2021).

From the past 63 years, besides the Red-headed Ash Borer, three more longhorn beetle species are known to have been introduced to Hungary. *Monochamus urussovii* was first detected in 1969 (Kovács & Hegyessy 1992), the Velvet Longhorn Beetle (*Trichoferus campestris*) in 1997 (Hegyessy & Kutasi 2010), and the Bamboo Tiger Longicorn (*Chlorophorus annularis*) in 2006 (Kovács 2010). From these, only the velvet longhorn beetle became naturalised, similarly to the Red-headed Ash Borer, but it did not cause serious ecological problems either.

Economic impact

The name of the Red-headed Ash Borer is really apt, as the larvae, when tunnelling into the xylem from under the bark, may mechanically damage the xylem by boring galleries into it, although not deeper than 5 cm from the surface. Damage of this kind was reported from Germany (Horion 1974), but there is no available information on similar cases from Hungary.

Apart from damaging timber, Szeőke & Hegyi (2002) give an account of the Red-headed Ash Borer as a new pest of the Grape Vine (*Vitis vinifera*). Grape vine is already mentioned among its host plants by Gaskó (1998), noting, however, that the assessment of its damage on fruit trees is "*particularly difficult*". Szeőke & Hegyi (2002) conducted their rearing experiments on "*dead and dying vines*", so there is no evidence that the Red-headed Ash Borer attacks healthy vines. It is common knowledge that the Red-headed Ash Borer has an exceptional sense of smell, so it perceives the smell of stressed or dead plants. As it has only been observed to lay its eggs on these, it is probably not the cause, but an indicator of decay.

Potential control measures

Should control of the Red-headed Ash Borer become necessary in orchards or vineyards, the removal of stressed, decaying and recently dead branches and trunks is suggested.

References

Cocquempot & Lindelöw 2010, Csóka & Kovács 1999, Gaskó 1998, Hegyessy & Kutasi 2010, Horion 1974, Kaszab 1971, Keszthelyi 2021, Kovács 2010, Kovács & Gebei 2021, Kovács & Hegyessy 1992, Merkl & Vig 2009, Szeőke & Hegyi 2002, Traser 1996

Tibor Kovács

Black Stem Borer

Xylosandrus germanus (Blandford, 1894)

Native range

The Black Stem Borer is of Asian origin, it is native to China, Japan, the Korean Peninsula, Taiwan, Thailand, and Vietnam (Beaver & Liu 2010).

It was introduced to North America (1932), where it first fed on grape vines cultivated in greenhouses. It later escaped, and damaged several host plants (Alonso-Zarazaga *et al.* 2017, Wood & Bright 1992).

Introduction to Hungary

It probably entered Europe at the beginning of the 20th century, in oak timber imported from Japan, but it was only detected in Germany in the late 1940s (Groschke 1952, Kamp 1968, Wichmann 1955, 1957). After this, it was probably repeatedly introduced to various parts of Europe with infested timber (Fiala *et al.* 2020). Later, its occurrence was reported from Switzerland (Maksymov 1987) and Austria (Holzschuh 1993). Today it occurs in a large part of Europe (Sauvard *et al.* 2010, Galko *et al.* 2019). In Hungary, its first individuals were found in 2005 in Baranya county (Nagymátyé), but it was probably already present in our country several years earlier (Lakatos & Kajimura 2007, Lakatos 2019).

Biology of the species

The Black Stem Borer is an ambrosia beetle (Curculionidae, Scolytinae) developing in the xylem. The beetle has a tiny (1.0–1.5 mm), rotund, shiny black body. It looks similar to the native *Xyleborus dispar*, but it is much smaller (Pfeffer 1995). Its galleries mostly consist of straight tunnels boring into the wood, with small chambers at their ends. The larvae develop in these. It cultivates various fungi in its galleries, on which both larvae and adults feed. The most common of these is *Ambrosiella hartigii*, but the Black Stem Borer is also known as the vector of other *Ambrosiella*, *Fusarium* and *Ophiostoma* species (Batra 1967, Buchanan 1940, Ito & Kajimura 2017, Weber & McPherson 1985). Like most ambrosia beetles that develop in the xylem, it has a special structure (mycangium), in which the spores of fungi are carried and stored. These fungi are usually pathogenic to the host plant. A healthy tree attacked by the Black Stem Borer is likely to die (dieback of branches and canopy). It usually has one generation per year, but a second generation has been observed in several European countries (Germany, Italy, Hungary) (Tuba *et al.* 2012).

Ecological conditions in Hungary

It is a highly polyphagous species and occurs both on broadleaf and coniferous species (Weber & McPherson 1983). As both developing larvae and adults feed on the mycelia of fungi cultivated inside the galleries, the host tree does not have any significant effect on the development of the Black Stem Borer. Its appearance and occurrence are strongly influenced by the moisture content of the wood. Its most important hosts are Beech (*Fagus sylvatica*) and oak species (*Quercus* spp.), but it is frequent on

© Jiri Hulcr

Black Stem Borer in its tunnel

Galleries of the Black Stem Borer

various conifers as well (Graf & Manser 2000). On some locations, it has become the dominant species in the bark and ambrosia beetle community developing in the bark or the xylem.

Ecological concern

The most common ecological problem caused by non-native ambrosia beetles (Curculionidae, Scolytinae) is caused by the fungi they carry, and their highly pathogenic character (Ploetz *et al.* 2013). Apart from this, they may alter the native saproxylophagous community considerably, especially species capable of mass proliferation, e.g. the Black Stem Borer.

The Black Stem Borer remained almost entirely unnoticed for a long time in Europe, as, after the introduction, its range remained limited to a few countries for several decades. In the last two decades, however, both its range and its abundance have increased considerably. Damage done to healthy trees has not yet been reported, but by developing in harvested trees, its populations can grow rapidly, which may sooner or later lead to its infesting standing trees as well. In Europe, knowledge on the fungi carried by

© György Csóka

Exit holes of the Black Stem Borer on a damaged tree

© Ferenc Lakatos

Frass of the Black Stem Borer

the beetle and their pathogenicity is still scarce. The species keeps dispersing to new areas, and is becoming increasingly frequent (Fiala *et al.* 2020).

Economic impact

The presence of the Black Stem Borer is usually noticed by traces of frass sticking out of the attacked wood like toothpicks (this is also typical of other *Xylosandrus* species, also non-native to Hungary, e.g. *X. crassiusculus*). It can infest a great variety of wood, practically of any dimension (from branches a few cm in diameter to broad trunks). In Hungary, it has only been detected in felled trees so far, but from other countries, it has been reported to attack living trees as well. As long as damage is limited to firewood or thin timber, its economic significance is minimal. However, it can cause much greater economic damage by infesting valuable, large dimension logs.

In America, where it has also been introduced, it causes significant damage on healthy trees as well, and, accordingly, it is regarded as a primary pest (Rabaglia *et al.* 2006, Reding *et al.* 2015). From Turkey, it was reported as a significant pest of the hazelnut (*Corylus* sp.) (Tuncer *et al.* 2019). In Europe, however, it usually appears in forests, and mainly on felled trees (Björklund & Boberg 2017, Bussler *et al.* 2011).

At the present, it is considered a secondary pest in Hungary, i.e. it does not attack healthy trees and did not kill them. But it can become multitudinous in cut trees, and in trees damaged by snow or wind (Bouget & Noblecourt 2005).

Potential control measures

Controlling this species is difficult. Its damage remains hidden for a long time (latent period). Due to its hidden lifestyle, it can cover large distances mainly with human assistance (wood transports). It is attracted by traps lured with ethanol, so its presence is simple to detect, and population fluctuations can also be easily monitored this way (Reding *et al.* 2011).

References

Alonso-Zarazaga *et al.* 2017, Batra 1967, Beaver & Liu 2010, Björklund & Boberg 2017, Bouget & Noblecourt 2005, Buchanan 1940, Bussler *et al.* 2011, Fiala *et al.* 2020, Galko *et al.* 2019, Graf & Manser 2000, Groschke 1952, Holzschuh 1993, Ito & Kajimura 2017, Kamp 1968, Lakatos 2019, Lakatos & Kajimura 2007, Maksymov 1987, Pfeffer 1995, Ploetz *et al.* 2013, Rabaglia *et al.* 2006, Reding *et al.* 2015, Sauvard *et al.* 2010, Tuba *et al.* 2012, Tuncer *et al.* 2019, Weber & McPherson 1983, 1985, Wichmann 1955, 1957, Wood & Bright 1992

Ferenc Lakatos & Katalin Tuba

American Utilizable Wood Bark Beetle

Gnathotrichus materiarius (Fitch, 1858)

Native range

The genus *Gnathotrichus* is native to North and South America. All species of this genus lay their eggs in conifers. During development, they feed on fungi cultivated in their galleries. The American Utilizable Wood Bark Beetle is native to the eastern part of North America and the Antilles (Wood & Bright 1992, Rabaglia *et al.* 2006).

Introduction to Hungary

The species was first identified in Europe in Northwestern France in 1933 (Balachowsky 1949). First, it spread slowly (the Netherlands 1965, Germany 1966), but in the last decades, its dispersal accelerated (Witkowski *et al.* 2016, Mazur *et al.* 2018). Today, it is present in most of Western Europe, also in Scandinavia (Sauvard *et al.* 2010, Alonso-Zarazaga *et al.* 2017). It was first detected in Hungary in 2017, but it had probably appeared earlier (Lakatos 2019).

Biology of the species

It is a small (3.0–3.5 mm) beetle with an elongated, shiny, dark brown body. It cultivates the fungus *Endomycopsis fasciculata* along its galleries in the wood. Hatching larvae feed on its mycelia (Postner 1974, Kirkendall & Faccoli 2010). Adults of the first generation fly from April to mid-June. If weather conditions are favourable, a second generation may develop, swarming at the height of summer (July and August). It is a monogamous species, however, males are rarely seen. While the male protects the entrance of the tunnels from invaders (by blocking it with its abdomen), the female looks after the fungus cultures and the development of the larvae. The female collects frass and transports it to the male, which removes it from the tunnels through the entrance hole (Tuba *et al.* 2012).

Ecological conditions in Hungary

The American Utilizable Wood Bark Beetle is a polyphagous ambrosia beetle attacking various conifers, e.g. pine (*Pinus* spp.), fir (*Abies* spp.), spruce (*Picea* spp.), larch (*Larix* spp.), and Douglas fir (*Pseudotsuga* spp.). Currently, it is only present in low numbers in the coniferous forests of the Western Transdanubia, but its further spreading to the east is to be expected. It is yet uncertain whether it will occur more frequently in the warm lowland regions, or in the cooler mountainous areas.

Ecological concern

It is a wood inhabiting ambrosia beetle, the colour of the frass falling from the entrance holes is identical to the colour of wood. Its fungal mycelia covered tunnels are whitish in the beginning, but quickly become black. The tunnels are bored deep inside the wood, with a diameter of 1 mm and a length of 10–15 cm. The gallery pattern with ladder-like larval chambers closely resembles that of the Striped Ambrosia Beetle (*Trypodendron lineatum*), but the larval chambers of the American Utilizable Wood Bark Beetle are much longer. Damage to standing, healthy looking trees has not yet been recorded, it is probably not able to attack these. Its presence may transform saproxylophagous insect communities in our coniferous forests. It is also interesting whether its currently known fungal community will change, and possibly comprise species more destructive to trees.

Economic impact

It is a secondary pest. Its presence so far has only been detected in felled timber, or trees killed by other insects, for example other bark beetles (Scolytinae). It bores its tunnels deep into the xylem (10–15 cm), causing considerable loss of timber value. It is mainly significant because of its quick appearance on felled trees, and value loss caused by its boring. Its dispersal

© Pest and Diseases Image Library (bugwood.org)

is assisted by long distance transportation of timber with the bark intact. If it becomes widespread in Hungary, considerable infestation may be expected primarily on pine species (*Pinus* spp.).

© Ferenc Lakatos

Some related species of the genus (e.g. *Gnathotrichus sulcatus, G. retusus*) are known as pests in North America. The American Utilizable Wood Bark Beetle is a secondary pest there as well.

Potential control measures

This beetle is usually spread by the transportation of infested timber. It spends a period of up to two months in the attacked wood, so it has time to travel far with human assistance. The components of its pheromone are known, partly owing to research conducted on the Western Hemlock Wood Stainer (*Gnathotrichus sulcatus*), a related species in North America (Byrne *et al.* 1974, Bordon *et al.* 1980). The pheromone is not commercially available, but, like every ambrosia beetle (Scolytinae) living in wood, it is strongly attracted by traps with ethanol lure (monitoring). Information on its natural enemies is scarce.

References

Alonso-Zarazaga *et al.* 2017, Balachowsky 1949, Bordon *et al.* 1980, Byrne *et al.* 1974, Kirkendall & Faccoli 2010, Lakatos 2019, Mazur *et al.* 2018, Postner 1974, Rabaglia *et al.* 2006, Sauvard *et al.* 2010, Tuba *et al.* 2012, Witkowski *et al.* 2016, Wood & Bright 1992

Ferenc Lakatos & Katalin Tuba

HYMENOPTERANS

Hymenoptera

Elm Zigzag Sawfly

Aproceros leucopoda Takeuchi, 1939

Native range

The species was originally described from Japan (Takeuchi 1939), but later, its presence in China was also reported (Wu 2006, Wu & Xin 2006). Blummer (2015) reported it from the Russian Far East, and Antropov *et al.* (2017), from Kazakhstan. It is unclear whether the latter are native or secondary occurrences. As elms (*Ulmus* spp.) are widespread throughout Eurasia (Fragnière *et al.* 2021), potential host plants are available in all of the above countries.

Introduction to Hungary

The first records of the Elm Zigzag Sawfly in Europe are from Poland and Hungary (the area of Dejtár in Nógrád county), from approximately the same time (June 2003) (Blank *et al.* 2010, Vétek *et al.* 2010). Identification of the species, and the recognition that it is an alien sawfly (Tenthredinoidea; Argidae) of Asian origin took nearly seven years (Blank *et al.* 2010, Vétek *et al.* 2010, Tuba *et al.* 2012). The circumstances of its introduction are unknown, but it probably entered Europe with imported live plants.

© György Csóka


© György Csóka

As of today, it has been recorded in many European countries, including Romania in 2005, Ukraine in 2006 (Blank *et al.* 2010), Slovakia (Blank *et al.* 2010), Italy (Zandigiacomo *et al.* 2011), and Austria in 2009 (Blank *et al.* 2010), Germany (Kraus *et al.* 2011) and Croatia in 2011 (Matošević 2012), Serbia (Glavendekić *et al.* 2017) and Russia in 2012 (Lengesova & Mishchenko 2013, Blummer 2015), Belgium in 2013 (Boevé 2013), Bulgaria in 2015 (Doychev 2015), and Switzerland (Hölling 2018), Bosnia-Herzegovina (Dautbašić *et al.* 2018), and the United Kingdom in 2017 (Forest Research 2018).

In 2020, for the first time on the American continent, it was found in Canada (Quebec) as well (Martel *et al.* 2022).

After the first detection, rapid spread and outbreaks were experienced in a relatively short time everywhere it appeared.

Biology of the species

The Elm Zigzag Sawfly is parthenogenetic, no males are known. The females are 5–6 mm long, black or dark brown, with light yellow legs. They are relatively strong fliers, which partly accounts for their successful dispersal, besides human assistance. Parthenogenetic reproduction is an extremely significant factor in their introduction and spreading, as the appearance of a single individual may be enough to establish a stable population. The Elm Zigzag Sawfly has up to four generations per year (Wu 2006, Blank *et al.* 2010, Csóka *et al.* 2013, Papp *et al.* 2018), another basis for rapid dispersal and population growth. Blank *et al.* (2014) estimate the rate of spreading at 45–90 km per year, while Roques *et al.* (2016), at 100 km per year.

It overwinters in the soil, in a cocoon. Females fly from April to October, and lay their eggs on the edges of leaves. The larvae hatch in 4–8 days (Blank *et al.* 2010). Newly hatched larvae make characteristic, zig-zagging feeding traces in the leaves (hence the name), but later, they consume leaves entirely, usually leaving only the main leaf veins intact. The larvae are green and moult five times. Before pupating, they are about 1 cm long. The entire larval stage lasts 14–18 days (Blank *et al.* 2010). Fully grown larvae spin weblike, transparent cocoons on the remains of leaves or on shoots, and pupate in these. The pupal stage lasts 4–7 days (Blank *et al.* 2010). The wintering cocoons of autumn larvae are stronger, more densely woven.

So far, two species of bugs (Heteroptera), *Arma custos* and *Dryophilocoris flavoquadrimaculatus*, the Common Green Lacewing (*Chrysoperla carnea*), one species of ichneumon wasps (Ichneumonidae), *Itoplectis alternans*, and the Harlequin Ladybird (*Harmonia axyridis*) have been identified as its natural enemies in Hungary (Lovas 2012, Papp 2018). Quantitative data on the mortality they cause are not available yet.

Ecological conditions in Hungary

The most important host plant of the Elm Zigzag Sawfly is the widely planted Siberian Elm (*Ulmus pumila*) of Asian origin, but it may also develop on our native elm species (*Ulmus* spp.). In research conducted in Hungarian arboreta and botanical gardens, Vétek *et al.* (2017) identified twenty native and alien *Ulmus* taxa as its hosts. It was also established that other species of the Ulmaceae family, e.g. the thorn-elm (*Hemiptelea davidii*) or the Japanese Elm (*Zelkova serrata*), are not its host plants (Vétek *et al.* 2022).

Papp *et al.* (2018) estimated the optimal temperature for its development, based on fecundity and survival, between 15.0–19.5°C. The results of laboratory examinations of Vétek *et al.* (2020) suggest that cold spells in winter do not cause considerable mortality in its populations.

In Hungary, it first became common and even abundant in the southern and southeastern regions (Békés, Csongrád-Csanád, Bács-Kiskun counties), but today, it occurs throughout the country. Mass outbreaks can be expected practically anywhere.

Ecological concern

Although the elms (*Ulmus* spp.), in respect of their relative cover, are not among the most significant tree species in Hungary, but they are important, irreplaceable mixing species in our broadleaf forests. According to Csóka & Ambrus (2016), for example, the herbivorous insect community associated with elms consists of well over one hundred species. From these, some feed exclusively on elm, e.g. leaf miners, native elm sawflies (Tenthredinoidea), woolly aphids (Eriosomatidae) etc., and some are protected, e.g. *Dicranura ulmi* (Lepidoptera; Notodontidae) and *Saperda punctata* (Coleoptera; Cerambycidae)

In the last decades, native elms in Hungary have been severely decimated by Dutch elm disease caused by the alien pathogenic fungus (*Ophiostoma novo-ulmi*). The case is similar in large parts of Europe as well (Csóka *et al.* 2013). As the Elm Zigzag Sawfly

Fully grown larvae of the summer generation pupate in weblike cocoons spun on leaves or shoots

causes repeated severe defoliation, it alone significantly weakens elms. If it becomes abundant, it may also worsen the negative effects of other, biotic and abiotic damaging factors. In the long term, this may cause the further reduction of elms, resulting the diminishing of the number of specialists feeding on elms, and the decrease species richness and biodiversity of forests.

Economic impact

Elms (*Ulmus* spp.), apart from their ecological significance, are popular as urban trees (e.g. arboreta, botanical gardens, parks) and on roadsides. Recently, Siberian Elm (*Ulmus pumila*) has been planted both as the dominant species of stands and also in the form of hedges, on sites with extreme environmental conditions. In inhabited areas and gardens, spectacular foliage loss may cause aesthetic and economic damage, including the control costs if necessary.

Potential control measures

In order to avoid aesthetic damage to gardens and public places, chemical treatments without negative effects on human health may be considered. Density assessment and monitoring of the Elm Zigzag Sawfly can be accomplished with so-called yellow traps, which strongly attract the females (Vétek *et al.* 2016).

In forests, chemical control is not an option, because of its cost and unacceptable side effects. Planting even-aged monocultures of elms (*Ulmus* spp.) – mostly Siberian Elm (*Ulmus pumila*) – increases, while mixing with other tree species decreases the risk of severe damage.

References

Antropov *et al.* 2017, Blank *et al.* 2010, 2014, Blummer 2015, Boevé 2013, Csóka & Ambrus 2016, Csóka *et al.* 2013, Dautbašić *et al.* 2018, Doychev 2015, Forest Research 2018, Fragnière *et al.* 2021, Glavendekić *et al.* 2017, Hölling 2018, Kraus *et al.* 2011, Lengesova & Mishchenko 2013, Lovas 2012, Martel *et al.* 2022, Matošević 2012, Papp 2018, Papp *et al.* 2018, Roques *et al.* 2016, Takeuchi 1939, Tuba *et al.* 2012, Vétek *et al.* 2010, 2016, 2017, 2020, 2022, Wu 2006, Wu & Xin 2006, Zindigiacomo *et al.* 2011

Anikó Hirka & György Csóka

Invasive Garden Ant

Lasius neglectus Van Loon Boomsma & Andrasfalvy, 1990

Native range

Information on the origin of this species is highly uncertain. It occurs in the western parts of the Palaearctic, from the Canary Islands to Kyrgyzstan (Espadaler & Bernal 2020), but it has probably been introduced to most of its distribution area (Ugelvig *et al.* 2008). It even occurs in areas with mean temperatures of –5°C in January (Seifert 2000). It was long presumed to originate from Anatolia (Schultz & Seifert 2005). Recently, colonies with a single nest (monocalic) have been found in near natural areas in Uzbekistan, suggesting the species may be native to Central Asia (Stukalyuk *et al.* 2020). The Hungarian colonies are regarded introduced (Ugelvig *et al.* 2008).

Introduction to Hungary

The species was described from Hungary, from a supercolony of then (1988) 2 km² extension in Budatétény (Budapest), among others. Based on the size of this supercolony, the species must have been with us for some time. The scientific name refers to its being neglected, i.e. that it was in front

© András Fekete

Invasive Garden Ant in the Botanical Garden in Debrecen: workers resemble the workers of related species…

…but unlike those, it has several relatively small queens in a single nest of our eyes, and yet went unnoticed for a long time (Van Loon *et al.* 1990). Later, it was found numerous times (Espadaler *et al.* 2007). In Hungary, 22 locations are known: Budapest (15), Debrecen (2), Ercsi (1), Érd (1), Pilisszentiván (1), Solymár (1), and Tahi (1) (Tartally & Báthori 2015). In the part of its range where it is not native, females do not leave the colony after the nuptial flight (Espadaler & Rey 2001), suggesting that it is most probably spread with topsoil (van Loon *et al.* 1990). This is supported by the frequent presence of a non-native ant guest woodlouse (Oniscidea), *Platyarthrus schoblii* in the nests of this ant (Tartally *et al.* 2004). Once established, it can expand the boundaries of its supercolony by up to 89 m per year (Espadaler *et al.* 2007).

Biology of the species

The Invasive Garden Ant is smaller and browner (i.e. lighter) than the Black Garden Ant (*Lasius niger*), which is common is inhabited areas, although in Hungary, some even more similar species also occur. The workers are 2.5–3.5 mm, the queen 6 mm long (Van Loon *et al.* 1990). Contrary to most of the related ant species (*Lasius* spp.) occurring in Hungary, the Invasive Garden Ant does not have a single queen, but establishes colonies with several queens (polygynous colonies) (Espadaler *et al.* 2004). These colonies may become very large (supercolonies). For example, the supercolony in Budatétény, the largest known, was estimated at 6 km^2 in 2005 (Espadaler *et al.* 2007). The presence of the Invasive Garden Ant may be indicated by high density, or by its presence in the soil for tens of metres nearly continuously. If we dig regularly at 0.5 m intervals, and find a small, brown, quick ant with formic acid (recognisable from the smell) in most of the samples, we probably found the Invasive Garden Ant. Its occurrence may also be indicated by the presence of entrance holes with hardly an interruption, over tens of metres along kerbs (Tartally *et al.* 2016). In the field, it can best be identified if after some rain in the spring, we find several mated (already wingless) queens under stones. Supercolonies may collapse after a while (Tartally *et al.* 2016). One of the reasons for this is probably inbreeding, as females do not leave their colonies for mating, so they mate with their brothers (Cremer *et al.* 2008). It is uncertain whether such collapsed supercolonies are able to regenerate over time.

Ecological conditions in Hungary

The species was most often found in habitats with high levels of human disturbance, e.g. in residential areas, botanical gardens, and nurseries (Tartally & Báthori 2015), where it was probably introduced with soil (Tartally *et al.* 2004). In less disturbed areas, it is less successful, especially if other dominant ant species (Formicidae) are also present (Tartally 2006). Based on our experience in Hungary, it prefers sparsely wooded areas, where it can nest in the sunny sites, and climb the trees and shrubs to hunt, or visit aphid colonies.

Ecological concern

The presence of the Invasive Garden Ant impacts native communities severely. In the area of the supercolonies, hardly any other ant species (Formicidae) are present, as it successfully outcompetes them. Without competitors, its density becomes much higher than normal for the given habitat. Besides, it reduces the mosaicity of habitats, as large areas are dominated by a single colony of a single ant species, instead of several colonies of several ant species (Tartally 2000). Inside supercolonies, the density of most arthropods (Arthropoda) decreases, many species disappear, while a few become extremely abundant (Nagy *et al.* 2009).

Economic impact

People inhabiting the areas of supercolonies describe the Invasive Garden Ant as extremely disagreeable. According to their reports, "there are loads of ants everywhere", and defence is useless. It invades gardens, and cultivates aphid colonies (Aphidoidea), and it also enters flats several stories up, to search for food and nest in the pots of plants.

Potential control measures

The eradication of supercolonies with many queens is practically impossible, especially in inhabited areas. Some queens will survive, especially if some of the residents do not consent to the treatment. It would, however, be important to contain its spreading in soil. In nurseries and garden stores, care should be taken not to sell earth-balled or container plants containing the nests of this ant. It is also important not to introduce it to new areas with soil while gardening.

References

Cremer *et al.* 2008, Csathó *et al.* 2021, Espadaler & Bernal 2020, Espadaler & Rey 2001, Espadaler *et al.* 2004, 2007, Nagy *et al.* 2009, Schultz & Seifert 2005, Seifert 2000, Stukalyuk *et al.* 2020, Tartally 2000, 2006, Tartally & Báthori 2015, Tartally *et al.* 2004, 2016, Ugelvig *et al.* 2008, Van Loon *et al.* 1990

András Tartally

LEPIDOPTERANS

Lepidoptera

Japanese Oak Silkmoth

Antheraea yamamai (Guérin-Méneville, 1861)

Native range

The Japanese Oak Silkmoth originates from Japan (Tuba *et al.* 2012, Nahirnić & Beshkov 2015, Pittaway 2022). It also occurs in the Russian Far East (Amur region, Sikhote-Alin), the Korean Peninsula, East China, and Taiwan (Nahirnić & Beshkov 2015, Pittaway 2022), but it is debated whether the latter are native or secondary occurrences. Some scientists even suggest that the Japanese Oak Silkmoth is not a natural species, but a cultured breed. Some individuals might have escaped from the plantations used for their breeding, become established in the wild, and formed local races, which dispersed in the subtropical regions of Asia, and have so far been identified as distinct species (Bálint & Katona 2018).

Introduction to Hungary

In Japan, its silk was used for weaving cloth for the imperial family, therefore, its export was forbidden under pain of death until the middle of the 19th century (Medzini 1971). Later, it became easier to acquire eggs, but the Japanese (probably because of the strict regulations of earlier times) often sold "false eggs" made of wood to inexperienced buyers (Wallace 1867). It was repeatedly brought to Western Europe in the middle of the 19th century in order to produce silk, but attempts at its breeding failed. In 1861, French merchants brought eggs to Europe, which the French imperial government handed over to the organisation responsible for the acclimatization of presumably useful animals

© György Csóka

© György Csóka

© György Csóka

the area of Carniola (Veliki Slatnik, today Slovenia) as well, and a few specimens escaped (Nahirnić & Beshkov 2015). It probably spread from here towards Austria, Croatia, Bosnia-Herzegovina, Serbia, and Romania. It has also been detected in Germany, Italy, and Czechia (Nahirnić & Beshkov 2015, Pittaway 2022). As its breeding was attempted in several countries, such "escapes" probably also happened elsewhere, but they were not documented properly. It was also introduced to Sri Lanka (Rougeot & Viette 1978) and North India, for silk production (Macek *et al.* 2007).

In Hungary, it appeared in the 1950s. The first specimens were collected in 1954, near Csákánydoroszló (Vas county) (Uherkovich 1984), and in August 1956, near Lentikápolna (Zala county) (Kovács 1957). It soon appeared in several locations in Zala county, and later, also in the south of Somogy county. By the end of the 1970s, it became common in Belső-Somogy and the Zselic, and also appeared in the Mecsek Mountains (Uherkovich 1984). It was found in the Sopron Mountains in the middle of the 2000s (Sáfián & Szegedi 2008).

Biology of the species

The Japanese Oak Silkmoth is a large moth, with a wing span of 11–15 cm. Its colour may vary between different hues of yellow, reddish, or dark brown, with translucent eyespots. Males have feathery, while females slightly serrate antennae. It looks very similar to its close relative, the Chinese Tussar Moth (*Antheraea pernyi*), which is also native to Asia and has been introduced to Europe, but has known established populations only in Northeastern Spain and Mallorca (Pittaway 2022).

Both the male and the female are attracted to artificial light, so they are easy to collect with light traps. It has one generation a year. In Hungary, the adults fly from mid-July to late September (Szőcs *et al.* 2016), with the peak of abundance usually in mid-August.

from the colonies and other distant lands (*Société Zoologique d'Acclimatation de France*). The caterpillars hatching from the first eggs became ill (a black liquid was oozing from their bodies), and all but five of them died (Wallace 1867). Some eggs found their way to a French entomologist, Félix Édouard Guérin-Méneville (Herman 2001), who succeeded in rearing a single female, which he first described as *Bombyx yama-maï*, a species new to science (Guérin-Méneville 1861). Learning from earlier failures, the eggs which arrived in 1865–1866 were distributed to illustrious entomologists throughout Europe, but most attempts at rearing them failed again (Wallace 1867). In 1867, the species entered

The females lay dark brown eggs in small or large clusters (altogether 150–250 eggs), onto the twigs of their host plants, mostly oaks (*Quercus* spp.), sometimes hornbeams (*Carpinus*) and chestnuts (*Castanea*), and, occasionally, on other broadleaf tree species. After overwintering, young caterpillars hatch at the time of budburst, and reach their final body length of up to 8–9 cm by early summer. Newly hatched larvae have brown heads and yellow bodies with thin black stripes. Later, the background becomes bright green, with yellow and blue tubercles. Larvae moult four times. Mature caterpillars spin some leaves together, weave a strong, bright yellowish green, 35–45 mm long cocoon, and spend the first half of summer inside it as pupa.

Information on its natural enemies in Hungary or Europe is scarce, but according to sporadic observations, native insectivores presumably eat it in various developmental stages. Large caterpillars wandering about in the canopy with relatively sparse setae may attract the attention of passerines (Passeriformes), insectivorous mammals (Insectivora), and predatory and parasitoid insects (Insecta) as well. Pittaway (2022) mentions the Eurasian Golden Oriole (*Oriolus oriolus*) as a predator of the moths. In Southeast Asia, several parasitoids – egg parasite wasps (Trichogrammatidae), ichneumonids (Ichneumonidae), tachinids (Tachinidae) – of the Japanese Oak Silkmoth are known.

Ecological conditions in Hungary

It is a termophilous species, mainly associated with oaks (*Quercus* spp.). In Hungary, it is currently widespread and sometimes abundant solely in the Transdanubia region, especially in Baranya, Somogy, Zala, and Vas counties. The traps of the Hungarian Forestry Light Trap Network have caught the most specimens in Acsád (maximum catch: 165 specimens in 1999), Szentpéterfölde (maximum catch: 123 specimens in 1987), Sasrét (maximum catch: 116 specimens in 2003), Sumony (maximum catch: 81 specimens in 1997), and Szalafő (maximum catch: 49 specimens in 2003). From the traps in the Danube–Tisza Interfluve, the one at Tompa caught the first specimen in 2019. Data on its spreading and distribution in Hungary were collected by Szőcs *et al.* (2016), and continuously updated information on its Hungarian situation is available on the website http:///www.izeltlabuak.hu. According to these, it occurs in the Transdanubia region, approximately to the south of an imaginary line between Szekszárd and Mosonmagyaróvár. It seems that it rarely crosses the Danube. Apart from the individual caught at Tompa, so far, only one male and one female were found in Baja, on the left bank of the Danube, and a single male specimen in the village Rém. The Danube probably forms a natural barrier which is difficult to cross for the Japanese Oak Silkmoth, especially the females. The presence of expansive, contiguous stands of oak, its main host plant, is probably an important factor in its successful dispersal in the Transdanubia region. Some climatic factors probably also limit its dispersal. Overall, it spreads relatively slowly. Strictly speaking, it should not even be considered an invasive species, but as it is a large, spectacular insect, it draws a lot of attention, so we find it useful to provide a summary of its current situation in this volume. On the other hand, it is entirely possible that, as a consequence of climate change, the distribution and abundance of the Japanese Oak Silkmoth will change considerably in the future.

Ecological concern

Hardly any documented information is available on its ecological role in our oak forests (as a prey for predators, a host of parasitoids, a competitor etc.). As far as we currently know, the Japanese Oak Silkmoth has not taken the place of or damaged any native species in Hungary, therefore, it is not considered an aggressive, dangerous invasive species which would pose a threat to biodiversity (Bálint & Katona 2018).

Economic impact

The most significant aspect of its economic role could be the past attempts at silk production, but these are of no practical importance today.

No Hungarian or foreign studies report on damage caused by the Japanese Oak Silkmoth. But although in the course of its presence for a century and a half in Europe, and nearly seven decades in Hungary, it did not cause any damage to forests worth mentioning, it is impossible to predict how climate change will influence the dispersal, abundance, and impact of this termophilous species.

References

Bálint & Katona 2018, Guérin-Méneville 1861, Kovács 1957, Macek *et al.* 2007, Medzini 1971, Nahirnić & Beshkov 2015, Herman 2001, Pittaway 2022, Rougeot & Viette 1978, Sáfián & Szegedi 2008, Szőcs *et al.* 2016, Tuba *et al.* 2012, Uherkovich 1984, Wallace 1867

Csaba Gáspár, Levente Szőcs & György Csóka

Fall Webworm

Hyphantria cunea (Drury, 1773)

Native range

The Fall Webworm is a North American species. It occurs in nearly every state of the USA, and also in Mexico (EPPO Global Database 2022). To the north, its range reaches Southern Canada (Tuba *et al.* 2012, Szeőke & Csóka 2012, Haltrich & Bodor 2017).

Introduction to Hungary

In Europe, it was first detected in 1940, in the free port of Csepel (Issekutz 1946, Surányi 1946, Győrfi 1954). It began spreading in radial directions, and dispersed throughout the country in about ten years, then crossed our borders, and became established in the neighbouring countries as well. Nagy *et al.* (1953) provide a detailed documentation of the initial phases of its expansion in Hungary.

In 1977, it was introduced again, independently of the first case, this time to France (Bordeaux), but without further expansion. Its present distribution in France is restricted (EPPO Global Database 2022).

© György Csóka

Except for countries in the north, it has invaded most of Europe. It also reached several Asian countries (China, Japan, South Korea, Iran, Kazakhstan), and became widespread in some of them (EPPO Global Database 2022). It was also introduced to New Zealand, but its establishment could be prevented (Kean & Kumarasinghe 2007).

Biology of the species

The Fall Webworm overwinters in the pupal stage. First generation adults hatch in May. Their wings are white, sometimes with black spots, with a wingspan of 25–35 mm. Females are somewhat larger than males. They lay 0.5 mm diameter eggs in clusters. Fresh eggs are spherical and apple green, later becoming grey. Newly hatched caterpillars are yellowish green. They feed in groups on leaves, later, on entire shoots woven together. In some cases, their webs cover the entire canopy. Mature caterpillars are densely haired and 20–30 mm long. They pupate in sheltered spots (e.g. under the bark) in groups, in soft cocoons (Reichart 1993).

In Hungary, it has two generations a year. In some years, a partial third generation may develop. Generations often overlap. Hot, dry summers affect the abundance of the second generation negatively.

The species is extremely polyphagous. It has over 250 known host plants in Hungary and Central Europe (Reichart 1993). It may develop on most broadleaf trees and shrubs, e.g. on locusts (*Robinia* spp.), apples (*Malus* spp.), elders (*Sambucus* spp.), cherries (*Cerasus* spp.), walnuts (*Juglans* spp.), mulberries (*Morus* spp.), willows (*Salix* spp.), maples (*Acer* spp.), pears (*Pyrus* spp.), ashes (*Fraxinus* spp.), and poplars (*Populus* spp.) (Szeőke & Csóka 2012).

It has numerous natural enemies in Europe. Over twenty bird (Aves) species prey on varying developmental stages (Nagy *et al.* 1953). These include the House Sparrow (*Passer domesticus*), the Eurasian Tree Sparrow (*P. montanus*), tits (Paridae), the Eurasian Golden Oriole (*Oriolus oriolus*), and the Common Blackbird (*Turdus merula*) (Keve & Reichart 1960). Apart from birds, its enemies include egg parasitoids (Szelényi 1957), braconid wasps (Braconidae) (Győrfi 1954), tachinid flies (Tachinidae) (Nagy 1953, Jermy 1957), and predatory arthropods (Arthropoda), for example bugs (Heteroptera) and wasps (Vespidae) as well.

Ecological conditions in Hungary

It is a termophilous species, and finds the climate conditions of Hungary favourable. Being highly polyphagous, it can find a suitable host plant practically anywhere. It is spread throughout the country, and occasionally has local mass outbreaks.

Ecological concern

Locally, it may cause total defoliation, and so it is a significant competitor of other insects (Insecta) feeding on leaves. However, it usually does not cause severe loss of foliage in large contiguous areas, so its impact is probably not too heavy. When examining the ecological effects of the Fall Webworm comprehensively, some minor positive elements can be found as well, despite its being an invasive, alien species. At the times of mass outbreaks, for example, it is an important food source for many birds (Aves), small mammals (Insectivora), and predatory arthropods (Arthropoda). Numerous parasitoid species, e.g. tachinid flies (Tachinidae) and ichneumon wasps (Ichneumonidae) may develop in it in great numbers, so it may function as an alternative host or even a kind of reservoir for the natural enemies of defoliators of higher economic or ecological importance, e.g. Gypsy Moth (*Lymantria dispar*), *Agriopis* spp. (Geometridae), leafroller moths (Tortricidae) etc. (Csóka & Traser 1995). Besides, it consumes several alien, invasive woody plants, e.g. Boxelder Maple (*Acer negundo*) and Green Ash (*Fraxinus pennsylvanica*), which are hardly or not at all eaten by our native insect (Insecta) defoliators.

Economic impact

In the past (1975–1999), the species was featured on the "quarantine list" of the European and Mediterranean Plant Protection Organization (EPPO). This meant some export and import restrictions, and an obligation to control the species. In some countries (e.g. Belarus, Israel, Tunisia), it is still considered a priority pest (EPPO Global Database 2022).

According to Reichart (1993), its damage concentrates to Southern Hungary. It may become highly abundant in orchards, roadside alleys, forest edges, or even inhabited areas. According to the forest damage database of the Hungarian Forest Research Institute, it caused some foliage loss in an average of 300 hectares of forest a year, since the early 1960s (the highest recorded affected area was 2,800 hectares in 1964). Reported area of forest damage per year shows a decreasing trend. Its economic effects are mainly felt in home orchards and gardens. With the application of up-to-date plant protection and pruning practices, its significance in industrial orchards is marginal. Overall, the Fall Webworm is considered much less significant today than in the four or five decades following its introduction. This is partly because its native natural enemies are able to effectively control its populations.

© György Csóka

Potential control measures

Following its introduction, the Fall Webworm caused serious concern and triggered significant research activity. Accordingly, several potential control methods have been suggested, including numerous chemical methods, from the beginning. If control is inevitable, the application of chitin synthesis inhibitors, or even more, of biopreparations based on *Bacillus thuringiensis* is recommended. The latter does not harm its natural enemies, and has no negative effects on human health either (Haltrich & Bodor 2017).

© György Csóka

Apart from these, several alternative control strategies have been developed. In case of a minor infestation, branches with caterpillar nests can be removed and destroyed (e.g. burned). Notice, however, that in this case, natural enemies of the species developing on or in the caterpillars will be destroyed as well. To avoid this, Nagy (1953) offers practical advice on how to save parasitoid insects. His method is termed "strawband parasitoid rescue". In the process, bands made of straw are fixed on the tree trunks. This attracts pupating caterpillars. Later, the straw bands are removed, and collected into barrels. The barrels are covered with screens, with a mash size large enough for the smaller parasitoid insects (Insecta) to get through, but keeping the bigger moths inside the barrel. Up to 1,000 pupae may hide in a single band of straw, so by this method, reckoning with the average degree of parasitic infestation, several hundreds, perhaps even a thousand useful parasitoids per band can be rescued.

Machay (1954) give an account of a spore forming protozoa called *Nosema bombycis* (Microsporidia), a pathogen of the Fall Webworm. Machay & Lovas (1955) mention a viral disease destroying the caterpillars. Both are suggested as possible biological control methods.

Overall, at least for the present it seems that its natural enemies are enough to control the abundance of the Fall Webworm. Chemical control may only become necessary rarely, and on a small scale.

References

Csóka & Traser 1995, EPPO Global Database 2022, Győrfi 1954, Haltrich & Bodor 2017, Jermy 1957, Kean & Kumarasinghe 2007, Keve & Reichart 1960, Machay 1954, Machay & Lovas 1955, Nagy 1953, Nagy *et al.* 1953, Reichart 1993, Surányi 1946, Szelényi 1957, Szeőke & Csóka 2012, Tuba *et al.* 2012

Marcell Kárpáti, Anikó Hirka & György Csóka

Lime Leaf Miner

Phyllonorycter issikii (Kumata, 1963)

Native range

Its first description is from Hokkaidō Island, Japan (Kumata 1963). It was found in the Far East of the late Soviet Union in 1974 (Ermolaev 1977), and in South Korea, in 1983 (Kumata *et al.* 1983). According to the most recent genetic studies performed on samples in herbariums, the species had been widely spread in Japan, the Far East, South Korea, and China well before its description in 1963 (Kirichenko *et al.* 2022).

Introduction to Hungary

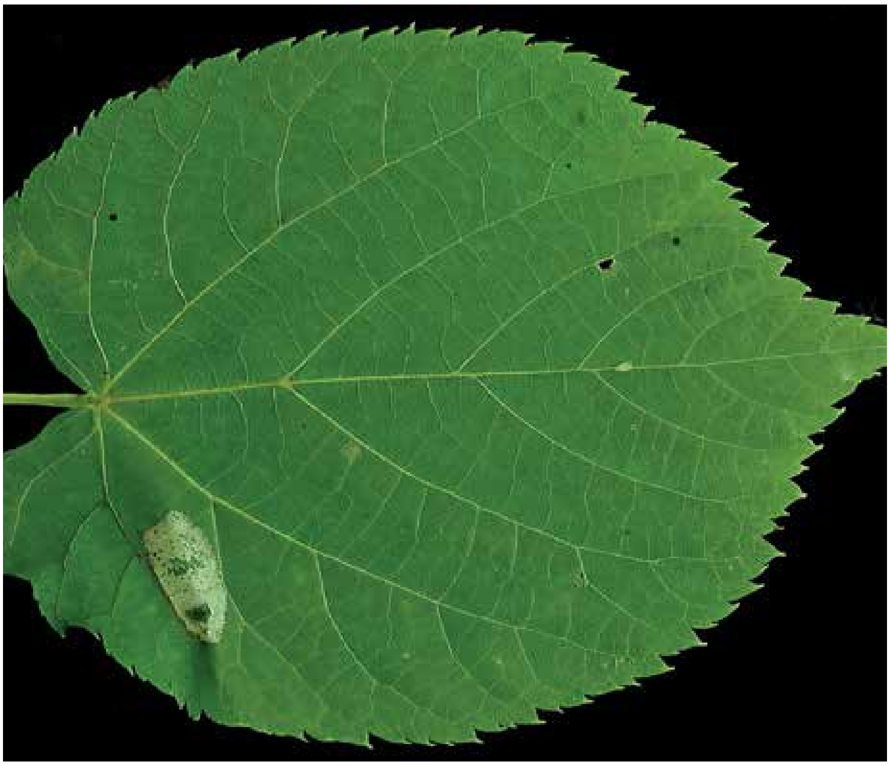
The Lime Leaf Miner probably reached Europe with human assistance. It was first observed near Moscow in 1985 (Kozlov 1991), and spread relatively rapidly to the Baltic States. It was discovered in Lithuania in 1998 (Noreika 1998), and in Estonia in 2003 (EPPO Reporting Service 2003a). Today, it occurs everywhere in Europe, except for Spain, Portugal, Denmark, Great Britain, Norway, and Sweden. Its dispersal rate and time of appearance in European countries are well known. In Hungary, it was first detected in 2002 (Szabóky & Csóka 2003). As its host plants, the limes (*Tilia* spp.) are widespread in Hungary, its blotch mines appeared on the lower surfaces of leaves all over the country within a few years.

Biology of the species

The Lime Leaf Miner is a small moth (Microlepidoptera) with a wing span of 7.0–7.5 mm. It has seasonal dimorphism, i.e. the summer and overwintering forms have a slightly different colour. The thorax and forewings of the summer generation are golden yellow or

© György Csóka

© György Csóka



Mines look like light spots on the upper surface of the leaf

© György Csóka

Fresh mine of the Lime Leaf Miner on the lower surface of a leaf, with accumulated excrement

brown, with a whitish pattern on the wings. The thorax of the wintering generation is dark brown, and the forewings are dark grey, with patterns of white and dark scales (Kuznetsov 1981, Kozlov 1991, Orlinskiy *et al.* 1991). As the wing pattern is similar to several other *Phyllonorycter* species, e.g. Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella*), the species can only be accurately identified based on the genitalia. The caterpillar is yellowish white.

Caterpillars mine between two veins on the lower leaf surfaces of lime trees (*Tilia* spp.), possibly near the tip (Mészáros 2005). They accumulate excrement in a corner of the mine. From the upper surface of the leaf, the mines look like patches made of light spots. No definite preference has been detected for any lime species, but there is some preference for smooth leaved trees. Damage can be more severe on young, suppressed trees growing in the shade (EPPO Reporting Service 2003b). Eggs are rarely laid on leaves fully exposed to the sun (CABI 2022). According to the observations of Yermolayev & Zorin (2011), the number of mines is closely related to shadedness, and it increases in the canopy from top to bottom, and on a single branch, from tip to base.

The Lime Leaf Miner has two generations in a year, the first in May and June, and the second, from late July to the end of August or the beginning of September. If the summer is hot, the generations may become indistinct. Small caterpillars hatch from the eggs laid on the undersides of leaves in four to eight days, and start forming their blotch mines. Every caterpillar has its own mine. The larva has five instars, and develops in 15–40 days. Instars 1–3 feed exclusively on plant sap. Instar four and five eat plant tissue as well. Larval development is strongly influenced by weather conditions and the nutrient supply of the host plant. Larvae pupate in the mines. The pupal stage lasts 10–15 days (Yermolayev 1977, Kozlov 1991, Orlinskiy *et al.* 1991). The imagoes overwinter in crevices of the bark, or under the bark of deadwood (Šefrová 2003).

Adults hide on the underside of leaves during the day and fly at dusk. They are attracted by light traps (Klepikov 2005).

Ecological conditions in Hungary

The Lime Leaf Miner has a wide ecological tolerance, as demonstrated by its new distribution areas in Europe, where it became established both in the north and the south. In Europe, it prefers lowland or hilly habitats (up to a maximum of 600-700 m above sea level) (CABI 2022). Based on these and actual observations, it can occur anywhere in Hungary if a suitable host plant is available. The degree of damage depends on the weather conditions of the given year.

Ecological concern

Its host plants are lime species (*Tilia* spp.). It is most frequent on Small-leaved Lime (*Tilia cordata*), but it also sometimes develops on Large-leaved Lime (*T. platyphyllos*), Silver Lime (*T. tomentosa*) (Buszko *et al.* 2000, Šefrová 2002), European lime (*T.* × *europaea*), and several other lime species native to Europe and Asia. As small-leaved lime is an important admixed species in our broadleaf forests, comprehensive monitoring of the Lime Leaf Miner would be important.

There are often several blotch mines on a single leaf. The photosynthetic activity of heavily infested trees may be impaired by such leaves and their premature dropping. In natural habitats, trees, especially young trees are weakened by heavy infestations repeated year by year, and they become more susceptible to abiotic (e.g. frost, draught) and biotic (e.g. *Verticillium* infection) damaging factors. These combined may result in the untimely death of trees. In such stands, the proportion of lime trees may be severely reduced in the long term. This rather extreme eventuality, however, is only to be expected in areas where an adequate parasitoid community associated to the Lime Leaf Miner cannot develop.

Economic impact

Lime trees (*Tilia* spp.) are popular in towns and other woody areas. As a result of the Lime Leaf Miner's activity, leaves become deformed, roll up, drop, causing considerable loss of ornamental value in the trees. The damage caused by caterpillars enhances stress induced by abiotic factors, for example draught, which is of special interest in an urban environment. Several mines on a single leaf induce premature leaf drop, and this way contribute to a reduction of photosynthetic activity and the overall deterioration of tree health. Infestations repeated year by year may damage the fitness of trees severely, even resulting in their death. In towns, especially in alleys, the replacement of dead trees is difficult, often unsuccessful, and also very costly.

The activity of the first generation may cause the reduction of flower yield in May and June, heavily affecting nectar production as well (Yermolayev & Zorin 2011).

The Lime Leaf Miner may become most dangerous in transition sites (connecting settlements to agricultural or forested areas), where effective parasitoid communities cannot form, and options for other types of intervention (arboriculture, chemical control) are limited.

Potential control measures

The restriction/limitation of the Lime Leaf Miner's dispersal routes should be attempted. It can cover long distances attached to plants and in the soil, while it is assisted by the wind on short distances. It is able to fly, but it is not persistent. In towns and associated woody areas, the host plants should be arranged mosaically, for communities to become as heterogeneous as possible.

The Lime Leaf Miner has numerous natural enemies, both in its original distribution area in East Asia, and in the recently invaded European range. Its parasitoids have been studied by Mey (1991), Matošević (2007), Yefremova & Mishchenko (2008, 2010), Yermolayev *et al.* (2011, 2018), and in Hungary, by Szőcs *et al.* (2014, 2015). According to Austrian data, its rate of parasitic infestation is between 50 and 90% (Perny 2007), while Szőcs *et al.* (2015) conclude a much lower value (less than 40%) in their study summarizing relevant data from several European countries. In natural habitats, the reduction of populations can only be based on natural control mechanisms, i.e. on diverse and abundant parasitoid communities. The species richness and effectiveness of such a community can only be preserved or enhanced by supporting diversity in the entire habitat.

The application of pesticides may become necessary when the infestation is severe in frequented areas, or if the abundance of the leafminer has to be reduced rapidly. In such cases, well-timed treatments with chitin synthesis inhibitors will yield acceptable results in a relatively short time.

References

Buszko *et al.* 2000, CABI 2022, EPPO Reporting Service 2003a, 2003b, Kirichenko *et al.* 2022, Klepikov 2005, Kozlov 1991, Kumata 1963, Kumata *et al.* 1983, Kuznetsov 1981, Matošević 2007, Mészáros 2005, Mey 1991, Noreika 1998, Orlinskiy *et al.* 1991, Perny 2007, Šefrová 2002, 2003, Szabóky & Csóka 2003, Szőcs *et al.* 2014, 2015, Yefremova & Mishchenko 2008, 2010, Yermolayev 1977, Yermolayev & Zorin 2011, Yermolayev *et al.* 2011, 2018

Katalin Tuba & Ferenc Lakatos

DIPTERANS

Diptera

Asian Tiger Mosquito

Aedes albopictus (Skuse, 1894)

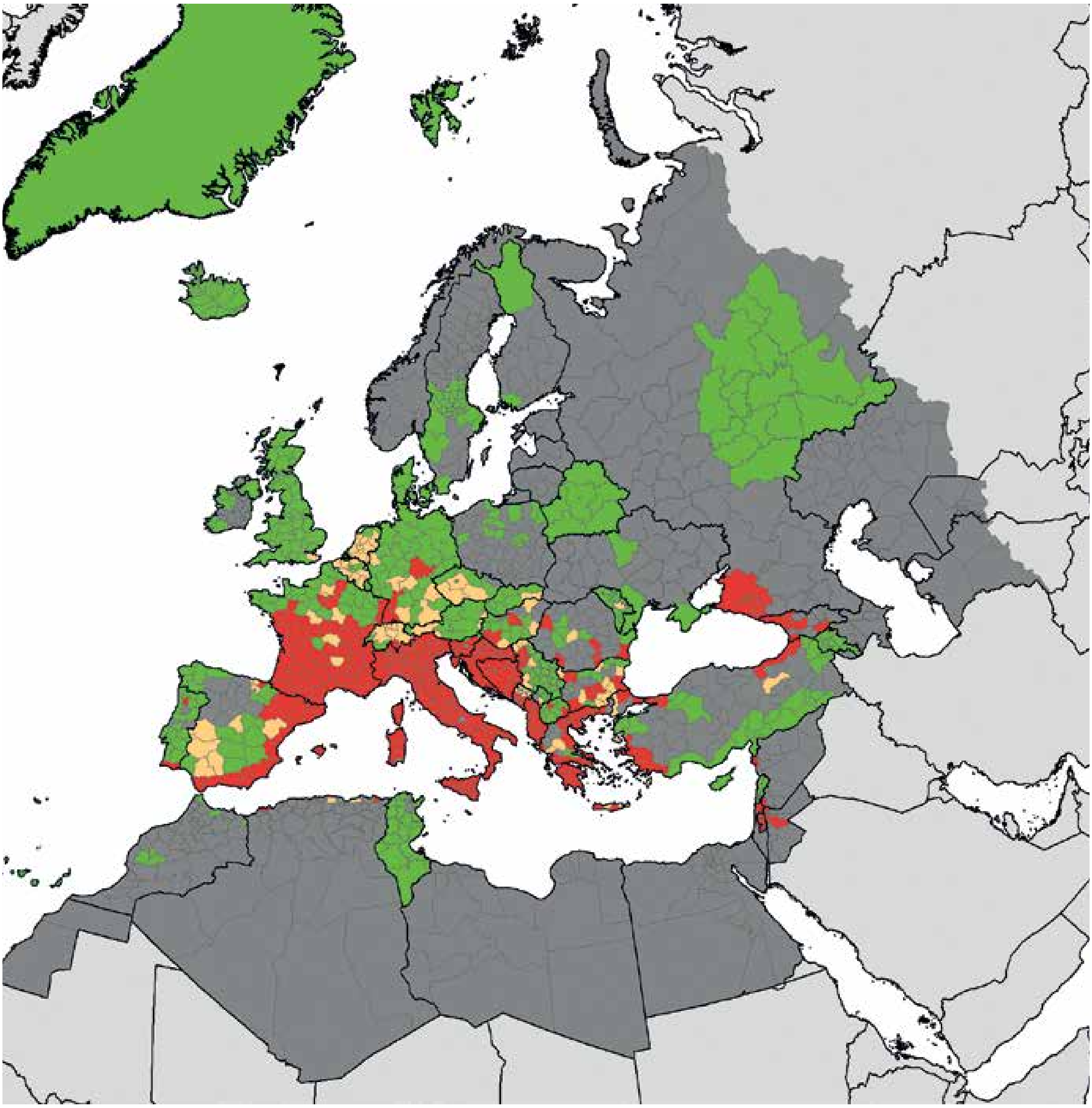
Native range

The Asian Tiger Mosquito is native to the tropical and subtropical regions of Southeast Asia. It first invaded islands of the Pacific Ocean to the east, and islands of the Indian Ocean to the west (Knudsen 1995). Its recent, ongoing expansion started in the 1980s. Out of its range, it was first detected in Texas, North America in 1985 (Sprenger & Wuithiranyagool 1986), and in Brazil, South America in 1986 (Forattini 1986).

Introduction to Hungary

In Europe, it was first recorded in Albania, in 1979 (Adhami & Reiter 1998). By the time it was detected in Italy (Scholte & Schaffner 2007), it has already invaded most of the country below 600 m a.s.l. Italy is still the most affected country in Europe. The species is most common in Veneto, Friuli-Venezia Giulia, Lombardy, and Emilia-Romagna regions, and in the coastal areas of Central Italy (Scholte &

© Zoltán Soltész

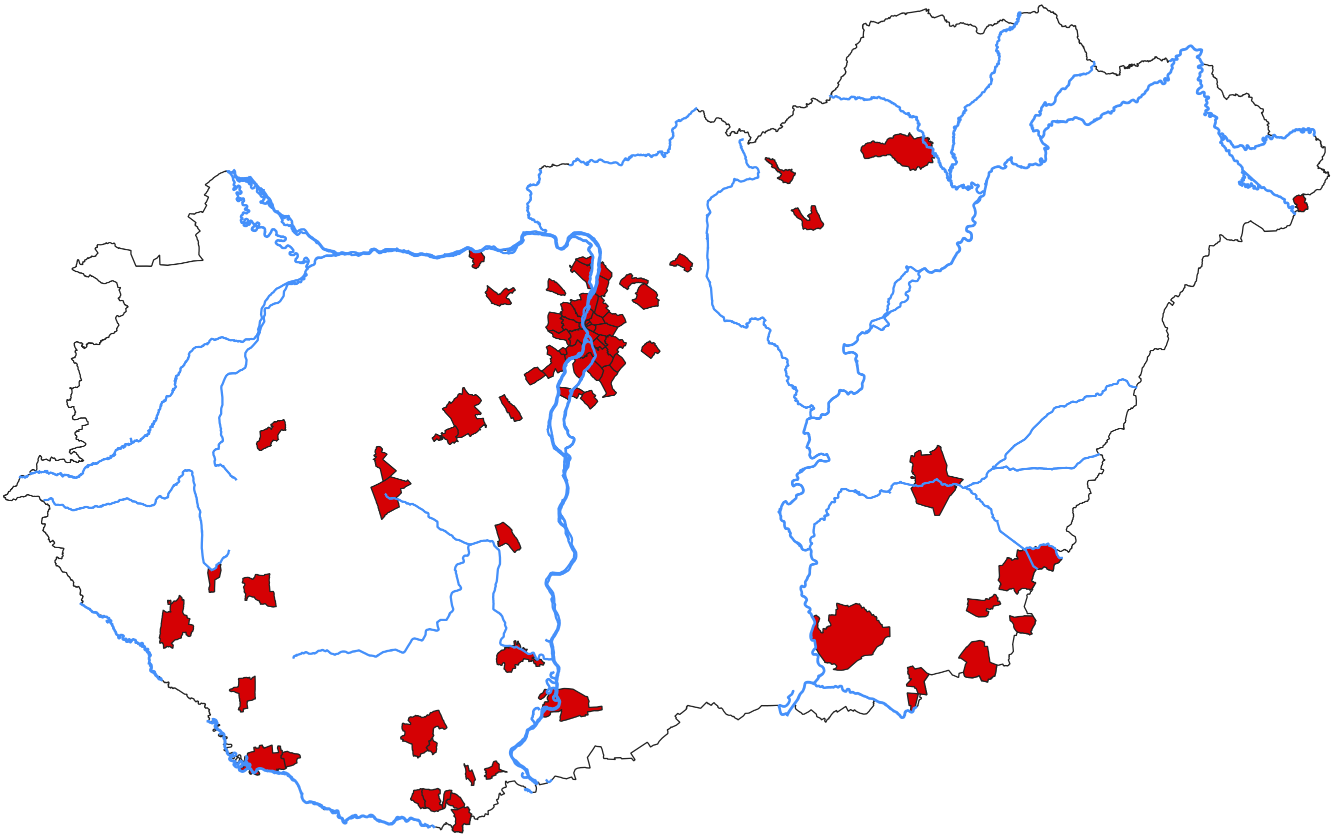


Distribution of the Asian Tiger Mosquito in Europe. Red – established populations; yellow – populations not proven stable; green – studied but not found; grey – not yet studied (source: www.ecdc.europa.eu; 25 October 2021)

Schaffner 2007). The Asian Tiger Mosquito was reported in 1999 from France, and in 2000, from Belgium as well (Medlock *et al.* 2012). Since then, it has been recorded in several other countries. It was first observed in Hungary in 2014, near Baja. In the following years, it was collected near the south-western border of Hungary (Soltész & Zöldi 2017). Survey conducted with public involvement (www.szunyogmonitor.hu) shows that besides the western region of the country, there is an infestation centre in Budapest, and it is reported from an increasing number of locations throughout the country.

Biology of the species

The Asian Tiger Mosquito is easy to distinguish from native mosquitoes (Culicidae), as it has a highly contrasted colouration. Its body and legs are adorned with spots and stripes of bright white or silver scales on a black background. There are no other mosquito species in Hungary patterned this conspicuously black and white, apart from the Tree Hole Mosquito (*Ochlerotatus geniculatus*), which is also black, but without white rings on the legs. The Asian Tiger Mosquito is smaller than our native species, the size of the imagoes is approximately 5 mm. The most



Distribution of the Asian Tiger Mosquito in Hungary, based on reports from the public. The settlements and districts of Budapest where the species was found between 2019–2021 are marked in red. Due to the nature of the survey, the species is not necessarily absent from the white areas (source: www.szunyogmonitor.hu)

important differentiating trait of the imagoes of this species is a single longitudinal white stripe running along the dorsal side of the thorax. White scales form various patches on both sides of the abdomen. The legs are jet black, with bright white rings on the tarsomeres, and the tips of the labial palps are also white. There are no spots on the wings. The other two invasive mosquito species, the Korean Bush Mosquito (*Aedes koreicus*), and the Asian Bush Mosquito (*Ae. japonicus*), have several yellowish white stripes on their thorax.

All three invasive mosquito species in Hungary are so-called container breeding species, i.e., any water body is suitable for larval development that has no direct contact with the ground. In its original habitats, larvae develop in tree hollows (dendrotelma), cavities in rocks (litotelma), or in water collected in artefacts (technotelma). In Europe, it has been most frequently detected in technotelmata: tires, vases, toys left in the open, objects covered in plastic wrap, or rainwater barrels (Medlock *et al.* 2012). Females lay their eggs above the surface of the water. As the eggs are draught tolerant, drying of the container does not damage them. When the water level rises and reaches the eggs, and the temperature is suitable, the larvae hatch and start their development. Larvae of the *Aedes* genus feed on organic matter, bacteria, and fungi settled on or attached to the substrate. The imagoes of the Asian Tiger Mosquito are opportunistic, they feed on humans (*Homo sapiens*), domesticated and wild mammals (Mammalia), reptiles (Reptilia), birds (Aves), and amphibians (Amphibia) as well. Nevertheless, they prefer human blood, according to laboratory examinations and blood analyses (Paupy *et al.* 2009).

The successful expansion of the Asian Tiger Mosquito is due to its ecological plasticity and rapid reproduction, and the growth of trade and tourism.

Ecological conditions in Hungary

Asian Tiger Mosquito populations in the tropics and subtropics are active throughout the year, without diapause. In the temperate climate zone, temperature and daytime affect the populations. The majority of eggs laid in the autumn do not hatch due to short photoperiods. This capability of diapause makes it possible for the species to overwinter in the temperate zone, promoting its spreading in Europe (Medlock *et al.* 2006). The adaptability of the Asian Tiger Mosquito is aptly demonstrated by the fact that the eggs of established European populations can survive cold spells of –10°C, while those of tropical populations die below –2°C (Thomas *et al.* 2012). In Italy, imagoes have adapted to the cooler climate, and remain active throughout the year (Romi *et al.* 2006).

Ecological concern

The larvae of all three invasive mosquito species (*Aedes* spp.) develop in water collected in hollow trees, rocks, or artefacts. There are container breeding species native to Hungary as well, which develop in so-called telmata: in the course of samplings, The Tree Hole Mosquito (*Ochlerotatus geniculatus*), *Anopheles plumbeus*, and the Common House Mosquito (*Culex pipiens*) were most frequently found (Tóth 2004). These species can also be collected with egg-traps adequate for invasive mosquito species. These are dark containers with a volume of 2 l, containing some plant debris, water, and a piece of wood. Eggs laid on the wood can be monitored. Information on the effects of the presence of alien mosquitoes on native mosquito species is scarce. In the course of a laboratory study, the presence of the Asian Tiger Mosquito was shown to have a negative effect on the larval development of the Common House Mosquito (Marini *et al.* 2017). Additionally, the presence of Asian Tiger Mosquito had a negative effect on the Asian Bush Mosquito (*Aedes japonicus*), another invasive species (Armistead *et al.* 2008). The Asian Tiger Mosquito is one of the one hundred most dangerous invasive species (Global Invasive Species Database 2022), mainly due to its ability to spread various pathogens. Being opportunistic, it bites animals as well as humans, and therefore possibly has a role in pathogen transfer and spread from animals to humans. In laboratory examinations, 22 types of arboviruses (viruses spread by insects) have been isolated from this mosquito species so far (Medlock *et al.* 2012). Of these, the most significant pathogens regarding human health are the dengue virus, the yellow fever virus, the West Nile virus, and the Japanese encephalitis virus. During the Italian Chikungunya epidemic between 2006 and 2007, the Asian Tiger Mosquito was identified as a vector of this pathogen (Bonilauri *et al.* 2008). It is also a potential vector for the Zika virus (Wong *et al.* 2013). Apart from spreading viruses, it is also a vector of several nematodes (Nematoda), and Can Spread Heart (*Dirofilaria immitis*) and Skin Worms (*D. repens*) of Dogs (*Canis familiaris*) and Cats (*Felis catus*) (Cancrini *et al.* 2003a, 2003b).

Economic impact

The economic impact of this species is mainly caused by the spreading of various pathogens. It may pose a threat to human health as a vector of the dengue virus and the yellow fever virus. No cases of patients infected with these pathogens in Hungary have been reported so far, but sometimes infections carried from abroad have been discovered within the country. The National Public Health Centre reports 5–10 dengue and yellow fever cases per year in Hungary. If infected patients meet a competent vector, a chain of infection may develop in Hungary. As for animal health, the most severe threat is posed by the ability of this species to spread the West Nile virus, which is also transmitted by native mosquitoes. Futhermore, it is able to transmit nematodes causing heartworm and *Cutaneous* Diseases (*Dirofilaria repens*, *D. immitis*). The West Nile virus is also significant for nature conservation, as it has been isolated from over 20 wild bird species in Hungary so far (Bakonyi *et al.* 2006, 2013, Barna 2010). This virus has caused the death of livestock as well, including Domestic Geese (*Anser anser domesticus*) (Glávits *et al.* 2005), Sheep (*Ovis aries*) (Kecskeméti *et al.* 2007), and Horses (*Equus caballus*) (Sárdi *et al.* 2012).

Potential control measures

In Europe, control measures applied against mosquitoes (Culicidae) fall into four categories: environmental (reducing sources), mechanical (trapping), biological (*Bacillus thuringiensis* var. *israelensis*, *Wolbachia* sp.), and chemical (insect growth regulators, pyrethroids) (Baldacchino *et al.* 2015). These methods are suitable for reducing the populations of invasive mosquitoes, but local conditions should always be considered. As invasive species are usually most frequent in or near inhabited areas, the active participation of the public is essential. Prevention is the best defence, achieved by the elimination of breeding sites (e.g. taking a look around the garden after rain, and pouring out collected rainwater, as hundreds of mosquitoes may develop in a single dl of water). Mosquito screens should be applied, and in the open, repellents should be used to avoid being bitten.

References

Adhami & Reiter 1998, Armistead *et al.* 2008, Bakonyi *et al.* 2006, 2013, Baldacchino *et al.* 2015, Barna 2010, Bonilauri *et al.* 2008, Cancrini *et al.* 2003a, 2003b, Forattini 1986, Glávits *et al.* 2005, Global Invasive Species Database 2022, Kecskeméti *et at.* 2007, Knudsen 1995, Marini *et al.* 2017, Medlock *et al.* 2006, 2012, Paupy *et al.* 2009, Romi *et al.* 2006, Sárdi *et al.* 2012, Scholte & Schaffner 2007, Soltész & Zöldi 2017, Sprenger & Wuithiranyagool 1986, Thomas *et al.* 2012, Tóth 2004, Wong *et al.* 2013

Zoltán Soltész & László Zsolt Garamszegi

Korean Bush Mosquito

Aedes koreicus (Edwards, 1917)

Native range

The Korean Bush Mosquito is native to Japan, Northeastern China, South Korea, and the eastern parts of Russia (Tanaka *et al.* 1979).

Introduction to Hungary

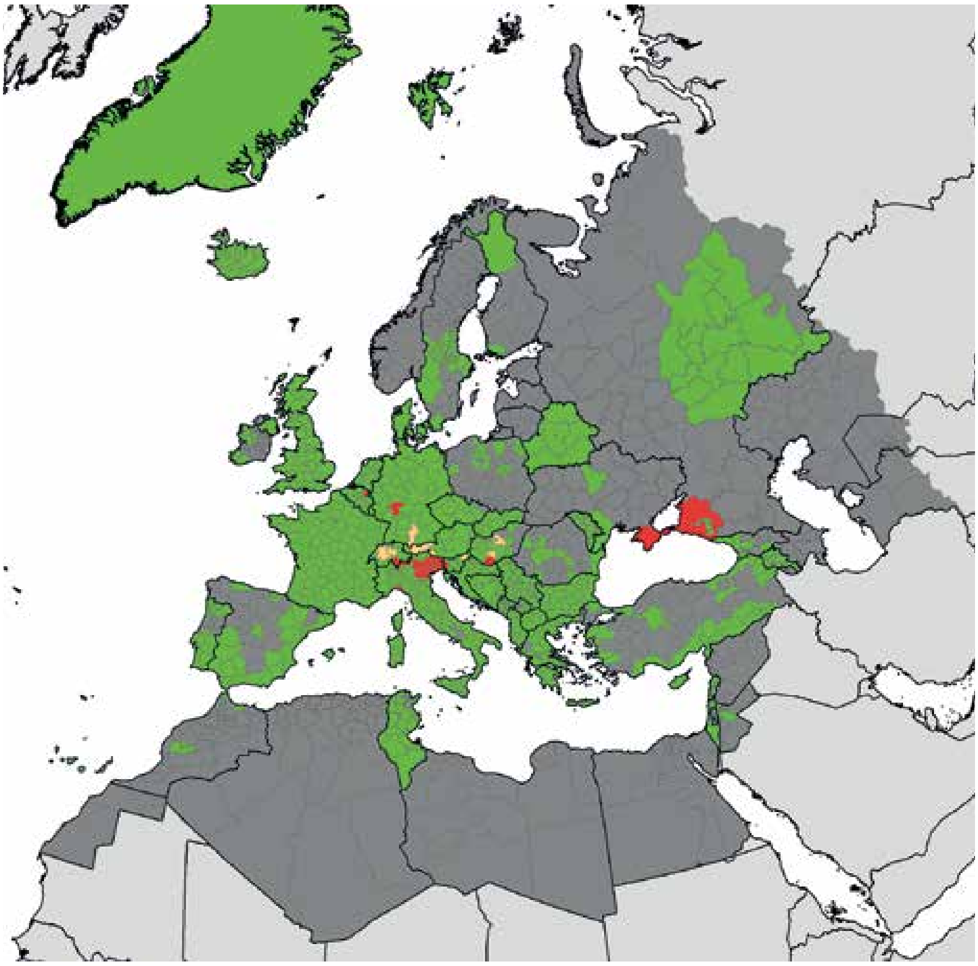
In Europe, the Korean Bush Mosquito was first observed in Belgium, in 2008, where it became established in a short time (Versteirt *et al.* 2012). Afterwards, it was found in several more European countries: Italy in 2011 (Capelli *et al.* 2011), the coast of the Black Sea, Western Russia (Bezzhonova *et al.* 2014, Ganushkina *et al.* 2016), near the border between Switzerland and Italy (Suter *et al.* 2015), and Slovenia in 2013 (Kalan *et al.* 2017), Germany in 2015 (Werner *et al.* 2016), Hungary in 2016 (Kurucz *et al.* 2016), and Austria (Fuehrer *et al.* 2020), and the southern coast of Crimea and Kazakhstan in 2020 (Andreeva *et al.* 2021), suggesting the ongoing rapid expansion of the species on our continent. In Hungary, the first individuals were caught in Baranya County in 2016 (Kurucz *et al.* 2016), where it established a stable population in a short time (Kurucz *et al.* 2020). According to a survey conducted with public involvement (www.szunyogmonitor.hu), the species is present in several locations near Pécs.

Biology of the species

The body of the Korean Bush Mosquito is brownish black. It has white rings on the legs, similarly to the Asian Tiger Mosquito (*Aedes albopictus*), but there are several yellowish white stripes on its

© Zoltán Soltész

thorax. It looks very similar to the Asian bush mosquito (*Aedes japonicus*), but the pattern of the thorax and the legs is different. On the thorax of the Korean Bush Mosquito, the stripes on both sides of the central line are shorter than those of the Asian bush mosquito; and the Korean Bush Mosquito has white stripes on all five (or four, depending on morphotype) of its tarsomeres on the hind legs, making the contrast stronger. Opposed to native mosquitoes (Culicidae), they are active during the day as well as in the evening (Montarsi *et al.* 2013).



Distribution of the Korean bush mosquito in Europe. Red – established populations; yellow – populations not proven stable; green – studied but not found; grey – not yet studied (source: www.ecdc.europa.eu; 25 October 2021)

All three invasive mosquito species in Hungary are so-called container breeding species, i.e., water bodies without direct contact with the ground is suitable for larval development. In its original habitats, larvae develop in tree hollows (dendrotelma), cavities in rocks (litotelma), or in water collected in artefacts (technotelma). In Europe, it has been most frequently detected in technotelmata: tires, vases, toys left in the open, objects covered in plastic wraps, or rainwater barrels (Medlock *et al.* 2012). Females lay their eggs above the water surface. The eggs are resistant to draught, therefore the drying of the container due to evaporation does not damage them. When the water level rises and reaches the eggs, and the temperature is suitable, the larvae hatch and start their development.

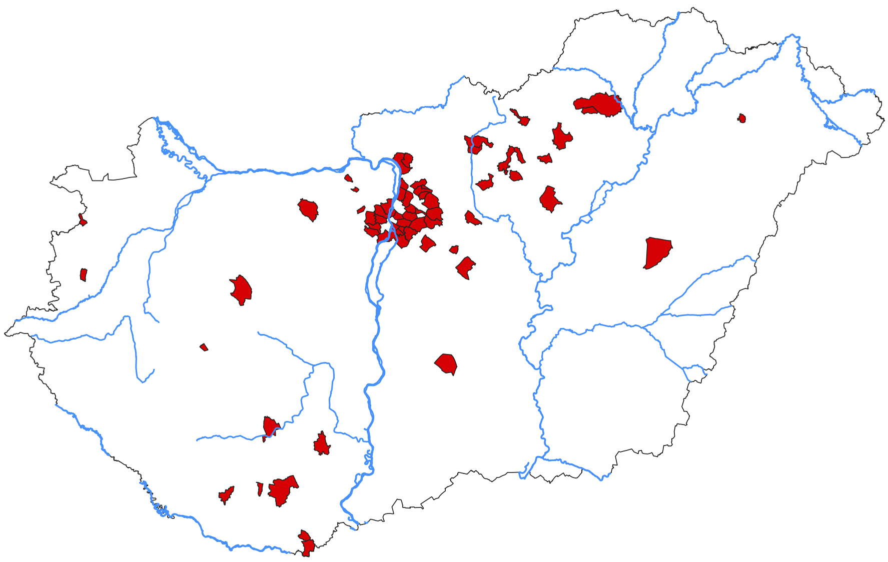
Larvae of the *Aedes* genus feed on organic matter, bacteria, and fungi settled on or attached to the substrate. Adult females bite warm blooded animals, including humans, livestock (Tanaka *et al.* 1979, Kurucz *et al.* 2018), and pets (Capelli *et al.* 2011) as well.

Ecological conditions in Hungary

As most *Aedes* species, the Korean Bush Mosquito survives the cold winter months in the egg form. The eggs start development when environmental conditions become favourable again, early in the spring (potentially as early as March). Adults may be active till late autumn, by the end of October (Versteirt *et al.* 2012). Its dispersal in Europe is therefore scarcely hindered by cold winters. Currently, our knowledge on the behaviour of this species is scarce. It is less sensitive to cold and draught than the Asian Bosh Mosquito (*Aedes japonicus*), and can also better adapt to urbanized environments (Marini *et al.* 2019).

Ecological concern

The larvae of all three invasive mosquito species (*Aedes* spp.) develop in water collected in hollow trees, rocks, or artefacts. There are container breeding species native to Hungary as well, which develop in so-called telmata: in the course of collectings, the Tree Hole Mosquito (*Aedes geniculatus*), *Anopheles plumbeus*, and the Common House Mosquito (*Culex pipiens*) were most frequently found (Tóth 2004). These species can also be collected with egg-traps adequate for invasive mosquito species. These are dark



Distribution of the Korean bush mosquito in Hungary, based on reports from citizens. The settlements and districts of Budapest where the species was found between 2019–2021 are marked in red. Due to the nature of the survey, the species is not necessarily absent from the white areas (source: www.szunyogmonitor.hu).

containers with a volume of 2 l, containing some plant debris, water, and a piece of wood. Eggs laid on the wood can be monitored. Information on alien mosquito species in Hungary is scarce, therefore we have little understanding on the way their occurrence and establishment may affect the local mosquito fauna. In the neighbourhood of Pécs, Kurucz *et al.* (2020) found that sometimes this species may outcompete other dominant native mosquito species.

The role of this species in spreading diseases is not yet clear. In Asia, in its original distribution area, it is known as a vector of the Japanese encephalitis virus, and as the intermediate host of a parasitic nematode (Nematoda), *Brugia malayi*, which causes elephantiasis by obstructing lymph vessels, but these pathogens are not a threat in Europe yet. In laboratory tests, it was shown that the species is a potential vector of a Heartworm (*Dirofilaria immitis*) and a Cutaneous Disease (*D. repens*) of dogs and cats (Montarsi *et al.* 2015), which have a high veterinary importance throughout Europe, including Hungary. It is also possible that the Korean Bush Mosquito is able to spread the Chikungunya virus, which poses an increasing threat to Europe, but this has only been proven under laboratory conditions (Ciocchetta *et al.* 2018).

Economic impact

The economic impact of this species is mainly due to its potential to transmit pathogens. It may pose a threat to human health as a vector of the Japanese encephalitis virus and the Chikungunya virus. The latter has caused several epidemics in Italy (Riccardo *et al.* 2019) and France (Calba *et al.* 2017). Chikungunya is expected to spread to other countries, but it is uncertain whether the Korean Bush Mosquito will be one of its vectors. As regards veterinary importance, it can be a vector of nematodes causing heart and cutaneous diseases (*Dirofilaria repens*, *D. immitis*), both of which are also spread by native mosquitoes (Culicidae). These parasites infect and potentially cause the death of many pets, such as dogs (*Canis familiaris*) and cats (*Felis catus*), and they are present in the entire country (Farkas *et al.* 2020).

Potential control measures

In Europe, control measures applied against mosquitoes (Culicidae) fall into four categories: environmental (reducing sources), mechanical (trapping), biological (*Bacillus thuringiensis* var. *israelensis*, *Wolbachia* sp.), and chemical (insect growth regulators, pyrethroids) (Baldacchino *et al.* 2015). These methods are all suitable for reducing the populations of invasive mosquitoes, but local conditions should always be considered. As invasive species are usually most frequent in or near inhabited areas, the active participation of the public is essential. Prevention is the best defence, achieved by the elimination of breeding sites (e.g. taking a look around the garden after rain, and pouring out collected rainwater, as hundreds of mosquitoes may develop in a single dl of water), and thereby, the limitation of the reproductive success of these species. Besides, mosquito screens should be applied to windows, and repellents should be used outdoors to avoid being bitten.

References

Andreeva *et al.* 2021, Baldacchino *et al.* 2015, Bezzhonova *et al.* 2014, Calba *et al.* 2017, Capelli *et al.* 2011, Ciocchetta *et al.* 2018, Farkas *et al.* 2020, Fuehrer *et al.* 2020, Ganushkina *et al.* 2016, Kalan *et al.* 2017, Kurucz *et al.* 2016, 2018, 2020, Marini *et al.* 2019, Medlock *et al.* 2012, Montarsi *et al.* 2013, 2015, Riccardo *et al.* 2019, Suter *et al.* 2015, Tanaka *et al.* 1979, Tóth 2004, Versteirt *et al.* 2012, Werner *et al.* 2016

Zoltán Soltész & Kornélia Kurucz

Asian Bush Mosquito

Aedes japonicus (Theobald, 1901)

Native range

The Asian Bush Mosquito is native to the Korean Peninsula, Japan, Taiwan, Northern China, and the eastern parts of Russia (Tanaka *et al.* 1979). Its expansion has been monitored, along with the other invasive mosquito species (Culicidae), since the 1990s. Apart from its original distribution area, it was first detected in New Zealand in 1993, where it was introduced in used tires (Laird *et al.* 1994). It arrived in the United States of America in the 1990s. Its dispersal within the country may have been assisted by horses trade (*Equus caballus*), as early detections in New York and New Jersey were associated to horse trailers and stables (Gaspar *et al.* 2012).

Introduction to Hungary

In Europe, it was first found in Normandy, France, in 2000. In 2002, a breeding site was detected in Belgium, near a tire depot (Schaffner *et al.* 2003). It was first detected in Switzerland in 2008, and it rapidly expanded in an 1400 km^2 area. This way, it reached Germany as well (Schaffner *et al.* 2009). In Hungary, it was first recorded in 2012, near the Austrian-Slovenian-Hungarian tripoint (Seidel *et al.* 2016). Three years later, it was detected 40 km to the east from the tripoint. The results of a survey conducted with public involvement (www.szunyogmonitor.hu) show that today the species is present in the entire country.

Biology of the species

Adult Asian Bush Mosquitoes are bigger than Asian Tiger Mosquitoes (*Aedes albopictus*). They are black, with hairs and scales of light or dark brown. Five golden yellow stripes run along the dorsal side of the thorax. The two stripes next to the central stripe on the longitudinal axis are long and well defined. White scales form patches on both sides of the abdomen. The legs are black with white rings, but the white ring is absent from the final tarsomere of the hind legs. It can be confused with the Korean Bush Mosquito (*Aedes koreicus*), but their thorax pattern differs. The stripes next to the longitudinal axis are wider and longer on the Asian Bush Mosquito. Besides, the final tarsomere of the hind legs is entirely black on the Asian Bush Mosquito, whereas white on the other two invasive *Aedes* species. All three invasive mosquito species in Hungary are so-called container breeding species, so their larval development can take place in any water body which has no direct contact with the ground. In its original habitats, larvae develop in tree hollows (dendrotelma), cavities in rocks (litotelma), or in water collected in artefacts (technotelma). In Europe, it has been most frequently detected in technotelmata: in tires, vases, toys left in the garden, objects covered in plastic wrap, or rainwater barrels (Lorenz *et al.* 2013, Schaffner *et al.* 2009, Kampen *et al.* 2012). Females lay their eggs above the surface of the water. As the eggs are draught tolerant, drying of the container does not harm them. When the water level rises and reaches the eggs, and the temperature is suitable, the larvae hatch and start their development.

Larvae of the *Aedes* genus feed on organic matter, bacteria, and fungi settled on or attached to the substrate. The imagoes are mainly nocturnal, but sometimes also active during the day. The female feed on the blood of mammals (Mammalia), and may attack humans (*Homo sapiens*) even inside houses (Apperson *et al.* 2004). Feeding on birds (Aves) has only been proven in laboratories so far (Sardelis *et al.* 2003).

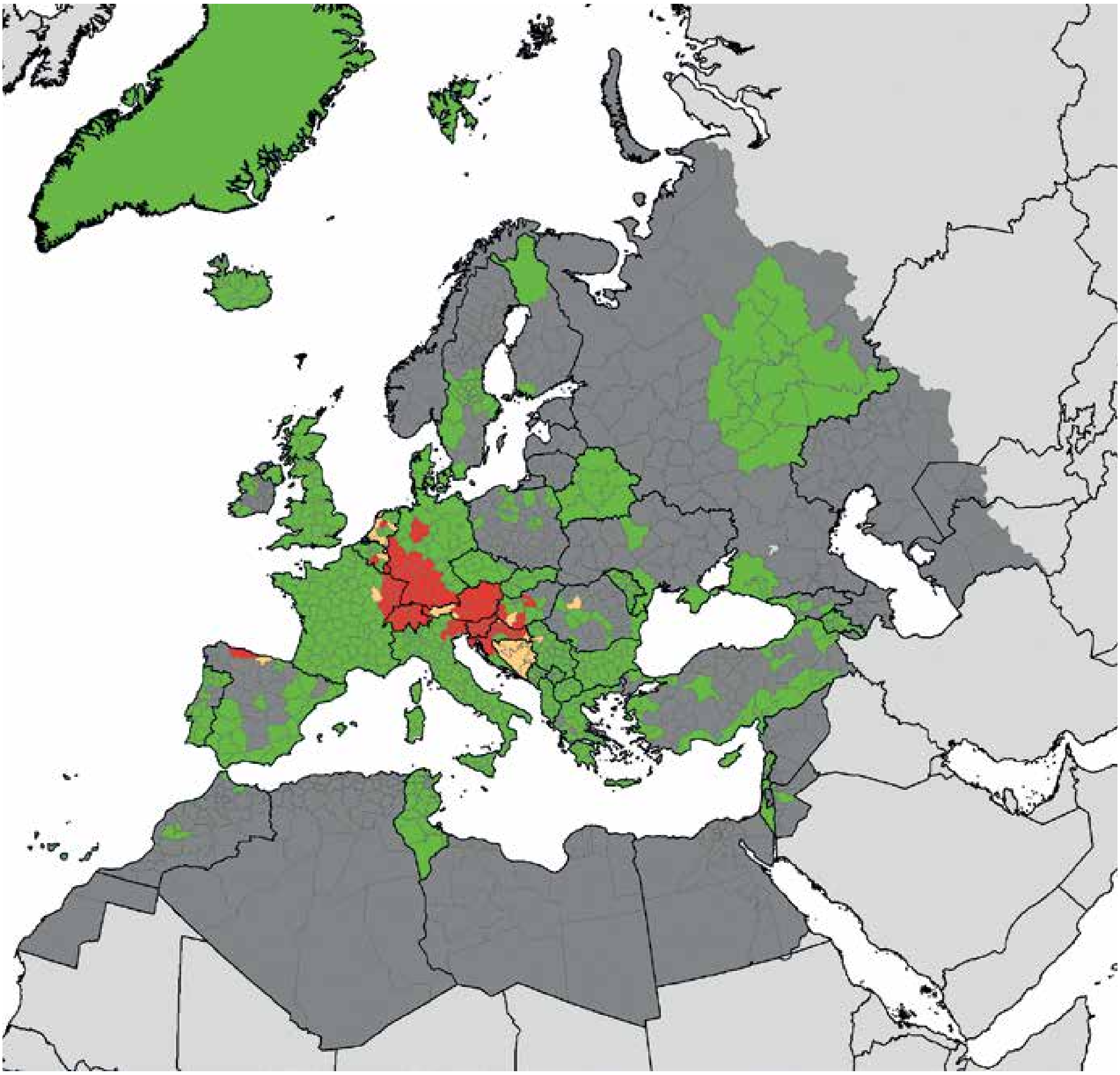
Ecological conditions in Hungary

The eggs of the Asian Bush Mosquito are extraordinarily resistant, they tolerate both draught and freeze. This enables the species to spread via eggs laid on various objects (containers) (Medlock *et al.* 2005). In its

© Zoltán Soltész

native range, in the north of Japan, and also in Europe, it overwinters in egg or larval form (Armistead *et al.* 2012, Versteirt *et al.* 2009, Schaffner *et al.* 2003, Medlock *et al.* 2012). The eggs resist long spells of cold and draught (Andreadis & Wolfe 2010), and lie dormant until stagnant water of a suitable temperature covers them. As soon as the conditions are right, they start developing. Larvae are unable to pupate above 30°C (Andreadis & Wolfe 2010), this may limit the future expansion of the species. In its native habitats, the Asian Bush Mosquito remains active till late autumn, and has several generations a year (Andreadis *et al.* 2001), which is probably the case in Hungary as well.

The larvae of all three invasive mosquito species (*Aedes* spp.) develop in water collected in hollow trees, rocks, or artefacts. Some container breeding species are native to Hungary, developing in so-called telmata: in the course of collectings, the Tree Hole Mosquito (*Aedes geniculatus*), *Anopheles plumbeus*, and the Common House Mosquito (*Culex pipiens*) were most frequently found (Tóth 2004). These species can also be collected with egg-traps suitable for invasive mosquito species. These are dark-walled containers with a volume of 2 l, containing plant debris, water, and a piece of wood. Eggs laid on the wood can be monitored.



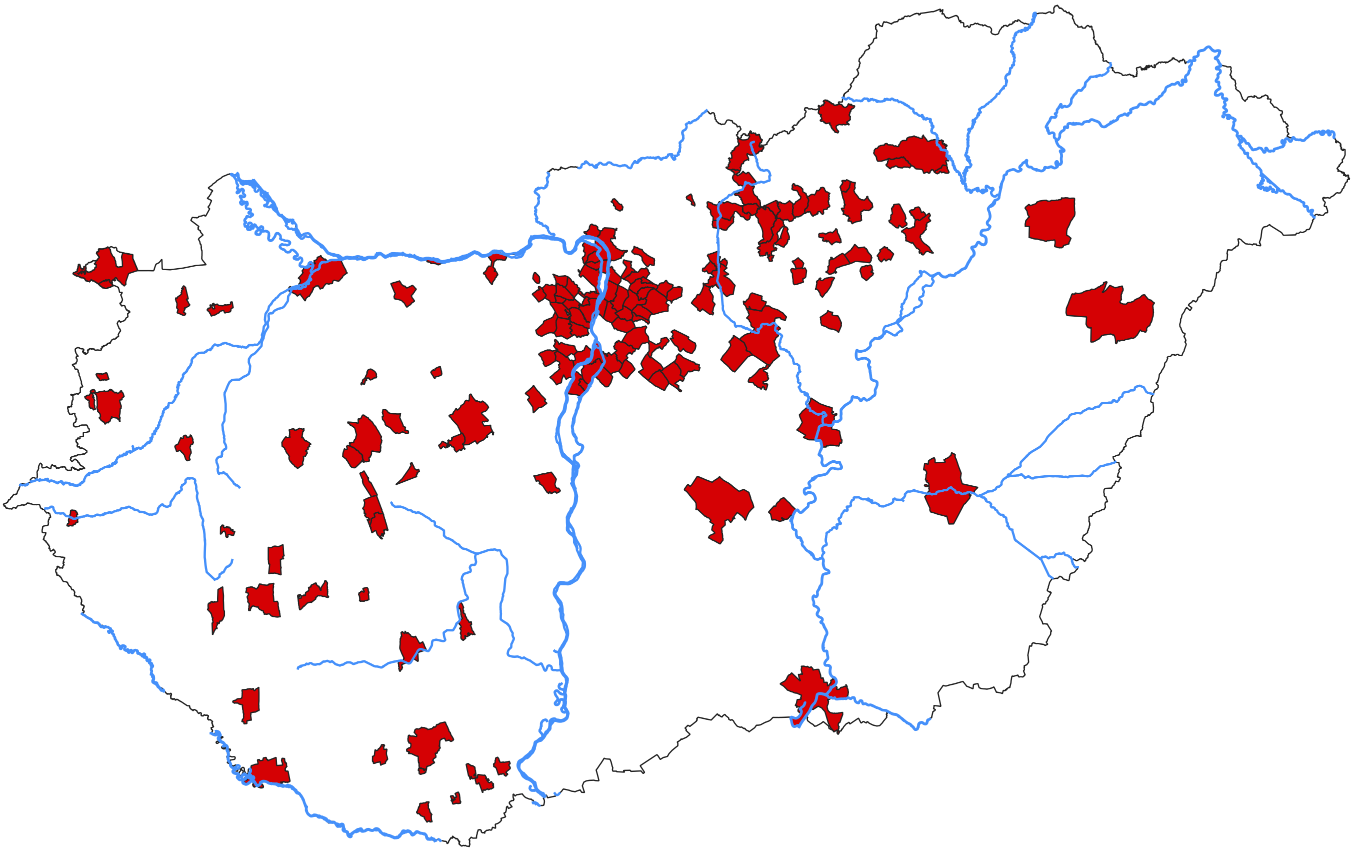
Distribution of the Asian Bush Mosquito in Europe. Red – established populations; yellow – populations not proven stable; green – studied but not found; grey – not yet studied (source: www.ecdc.europa.eu; 25 October 2021)

Ecological concern

Information on the effects of alien mosquito presence on native mosquito species is scarce. Under laboratory conditions, no negative effect was found on the larval development of the common house mosquito (Hardstone & Andreadis 2012).It was also shown that the presence of the Asian Tiger Mosquito (*Aedes albopictus*) has a negative effect on the Asian Bush Mosquito (Armistead *et al.* 2008). The Asian Bush Mosquito can transmit the West Nile virus, it has even caused an epidemic in America. According to the results of several laboratory tests, it acts as a vector of the Japanese encephalitis virus, the Chikungunya virus, the Rift Valley fever virus, and the dengue virus as well (Schaffner *et al.* 2011, Takashima & Rosen 1989, Turell *et al.* 2013).

Economic impact

The economic impact of this species is probably chiefly indirect, caused by its spreading various pathogens. It may pose a threat to human health as a potential vector of the dengue virus. No cases of patients infected with dengue in Hungary have been reported so far, but infections carried home from abroad have been discovered in Hungary. The National Public Health Centre reports 4–6 dengue fever cases every year. If infected people meet a competent vector, a chain of infection may develop in Hungary. Regarding animal



Distribution of the Asian Bush Mosquito in Hungary, based on reports from the public. The settlements and districts of Budapest where the species was found between 2019–2021 are marked in red. Due to the nature of the survey, the species is not necessarily absent from the white areas (source: www.szunyogmonitor.hu).

health, the most severe threat is posed by its being a vector of the West Nile virus, also transmitted by native mosquitoes, and by its ability to transfer nematodes causing heartworm and cutaneous diseases (*Dirofilaria repens*, *D. immitis*). The West Nile virus is important in nature conservation as well, as it has been isolated from over 20 wild bird species in Hungary so far (Bakonyi *et al.* 2006, 2013, Barna 2010). This virus has caused mortality in livestock as well. Infection reports about Domestic Geese (*Anser anser domesticus*) (Glávits *et al.* 2005), Sheep (*Ovis aries*) (Kecskeméti *et al.* 2007), and Horses (*Equus caballus*) are available (Sárdi *et al.* 2012).

Potential control measures

In Europe, control measures applied against mosquitoes (Culicidae) can be divided into four categories: environmental (reducing sources), mechanical (trapping), biological (*Bacillus thuringiensis* var. *israelensis*, *Wolbachia* sp.), and chemical (insect growth regulators, pyrethroids) (Baldacchino *et al.* 2015). These are all suitable for reducing the populations of invasive mosquitoes, but local conditions should always be considered. As invasive species are usually most frequent in or near inhabited areas, the active involvement of the public is essential. Prevention is the best defence, achieved by inhibiting reproduction by the elimination of breeding sites (e.g. monitoring the garden breeding sites after rain, and pouring out collected rainwater, as hundreds of mosquitoes may develop in a single dl of water). To avoid being bitten, mosquito screens should be placed on doors and windows, and outdoors, repellents should be used.

References

Andreadis & Wolfe 2010, Andreadis *et al.* 2001, Apperson *et al.* 2004, Armistead *et al.* 2008, 2012, Bakonyi *et al.* 2006, 2013, Baldacchino *et al.* 2015, Barna 2010, Gaspar *et al.* 2012, Glávits *et al.* 2005, Hardstone & Andreadis 2012, Kampen *et al.* 2012, Kecskeméti *et al.* 2007, Laird *et al.* 1994, Lorenz *et al.* 2013, Medlock *et al.* 2005, 2012, Sardelis *et al.* 2003, Sárdi *et al.* 2012, Schaffner *et al.* 2003, 2009, 2011, Seidel *et al.* 2016, Takashima & Rosen 1989, Tanaka *et al.* 1979, Tóth 2004, Turell *et al.* 2013, Versteirt *et al.* 2009

Zoltán Soltész & Edina Török

Spotted Wing Drosophila

Drosophila suzukii (Matsumura, 1931)

Native range

The Spotted Wing Drosophila originates from East Asia. Its native distribution area spreads from Japan to Pakistan, so it occurs in China, the Korean Peninsula, some parts of the Russian Far East, and also on the northern island of Japan, Hokkaidō (Cini *et al.* 2014). The species is best adapted to the ecological conditions of temperate forests. In some parts of its native range, it is known as a moderately significant pest of cherries.

Introduction to Hungary

The occurrence of the Spotted Wing Drosophila was almost simultaneously reported from North America and from Italy and Spain in Europe, in 2008. Due to its propensity to seasonal migration, its natural dispersal rate is high, and in a few years, it became a common fruit pest in considerable areas on both continents (Asplen *et al.* 2015). Heading east from Europe, it will shortly reach the western border of its original range through the Caucasus (Japoshvili *et al.* 2018) and Turkey. According to population genetic analyses, the species has been repeatedly introduced to Europe in the past ten years from various source populations (Fraimout *et al.* 2017), demonstrating its ability to spread via trade and passenger traffic.

The first individuals in Hungary were caught in 2012 at a service station on a motorway. In 2013, it was found at several service stations in Western Hungary. In 2014, the species suddenly expanded its range in Hungary and was caught in large numbers practically everywhere in the country, in bottle traps baited with apple cider vinegar (Kiss *et al.* 2016). At the height of summer, imagoes in the Mediterranean region migrate in multitudes from hot valleys and coastal areas to higher, mountainous areas (Tait *et al.* 2018). It is unclear whether the Spotted Wing Drosophila was introduced to Hungary, or it arrived naturally, with air currents from the south. In Hungary, it became a major fruit pest within a few years. It also becomes abundant in woody or wet natural habitats, far from inhabited or cultured areas.

Biology of the species

Female Spotted Wing Drosophilas have a heavily sclerotised, serrated ovipositor, which enables them to lay eggs in healthy fruits with thin skin. This is an important difference from related native species, which are only secondary pests of injured or rotting fruits. The males have a characteristic black spot at the tip of their wings, which makes them easy to distinguish from several native fruit fly species (*Drosophila* spp.).

Similarly to related species, the Spotted Wing Drosophila reproduces extremely rapidly, mostly due to its quick ontogeny. At favourable temperatures (20–25°C), larvae (maggots) hatch within one or two days. They feed on the fruit for eight to ten days, go through three instars, and finally, after a pupal stage of five to six days, the adults hatch, meaning that a generation may develop in two weeks. Adult females need a maturing period of four or five days before egg production starts. Then, females produce five to ten eggs per day. During their lives of several months (in the vegetation period, typically 60-70 days), they may lay hundreds of eggs, so in nature, consecutive generations overlap (Tochen *et al.* 2014). Usually several larvae live in a single fruit. In a blackberry, for example, up to 50 imagoes may develop. Females distinctly prefer laying their eggs in already inhabited fruits. It is probably because the yeasts, which form an important part of the larval diet, can penetrate the entire fruit more easily if many larvae are present. The females inoculate the food source of their offspring with yeast when laying the eggs.

When exposed to cold, so-called winter morphs, i.e. darker, larger specimens hatch from the pupae, in a state of reproductive diapause. These are somewhat

© Balázs Kiss

Summer and...

better able to overwinter than summer morphs (Stockton *et al.* 2018). In Hungary, winter morphs are caught in traps from October. Overwintering females are able to store sperms, and so they can lay fertilised eggs in the spring without mating again (Ryan *et al.* 2016).

Ecological conditions in Hungary

Despite its rapid expansion, the Spotted Wing Drosophila tolerates climatic extremes badly. Mortality is significant below freezing point, and practically total below –5 °C, even in winter morphs (Enriquez & Colinet 2017). In Hungary, populations decline to or below the detection threshold after the first severe colds, and hardly any specimens are caught from spring to July. Cold winters, however, do not effect the proliferation of the species in late summer, probably partly due to recolonising individuals arriving from the Mediterranean regularly in the summer months. Imagoes tolerate the hot, dry spells in summer with equal difficulty, reproduction rates decrease over 28°C, and over 32°C, most specimens die within a few hours (Enriquez & Colinet 2017). In rainy, cool summers (in Hungary, for instance in 2016), they cause orders of magnitudes more damage, while in draughty, hot summers, their mass proliferation may be delayed till late September (Orosz *et al.* 2018). Regarding host plants, they are not choosy; they can develop in a great variety of fruits, even in Mistletoe (*Viscum album*), Ivy (*Hedera helix*), and species of the oleaster family (Elaeagnaceae) (Poyet *et al.* 2015).

...winter morphs of the spotted wing drosophila

Ecological concern

The Spotted Wing Drosophila got in the focus of attention mainly because of the great damage it causes to fruit farmers, but it is important to pay attention to its mass presence in natural ecosystems, like broadleaf forests and wet habitats as well. After August, in these habitats, the Spotted Wing Drosophila is regularly caught in greater numbers in traps lured with apple cider vinegar than the Lesser Fruit Fly (*Drosophila melanogaster*), or other native fruit flies (*Drosophila* spp.).

Knowledge on the influence of the Spotted Wing Drosophila on food webs of natural habitats is scarce. It is able to develop in numerous wild fruits (Poyet *et al.* 2015). As fruits with larvae in them start fermenting and rotting earlier, they are accessible to vertebrates (Vertebrata) for a shorter time. This may also decrease the natural spreading and regeneration of some plant species.

Economic impact

In the course of a few years, the Spotted Wing Drosophila became one of the most prominent fruit pests in great parts of North America and Europe. In parts of Europe with a mild climate, with no severe colds, it also severely damages spring fruits, e.g. garden strawberry (*Fragaria* × *ananassa*), cherry (*Cerasus* sp.) etc. In Hungary, it usually becomes

© Balázs Kiss

Blackberry damaged by spotted wing drosophila larvae

highly abundant by late August, so the most severe primary damage is caused on blackberry (*Rubus* spp.), autumn raspberry (*Rubus* ×), and Elder (*Sambucus nigra*) (Orosz *et al.* 2018). The species can damage numerous other fruits as well. As a secondary pest, it also affects Grapes (*Vitis vinifera*).

Potential control measures

Despite intensive research activity, controlling the Spotted Wing Drosophila remains unsolved for many types of fruit plantations. For example, its presence in Hungary led to the abandonment of blackberry plantations. The main difficulty with chemical control is the continuous supply of imagoes from outside of the plantations and, in the case of freshly eaten fruits, the observance of wait times after treatments. By removing damaged fruits, the number of individuals can be decreased. The Spotted Wing Drosophila has numerous known natural enemies, and a pupa parasitoid wasp species, *Trichopria drosophilae* (Diapriidae) is commercially available (Tait *et al.* 2021).

In natural habitats, there is no means for the selective reduction or containment of the Spotted Wing Drosophila. A main competitive advantage of invasive species is the absence of natural enemies. This also applies to the spotted wing drosophila: in freshly invaded areas, the limiting effect of natural enemies is weaker than in its original habitats. Although several native parasitoid species destroy its larvae or pupae, their impact is not significant so far (Tait *et al.* 2021).

References

Asplen *et al.* 2015, Cini *et al.* 2014, Enriquez & Colinet 2017, Fraimout *et al.* 2017, Japoshvili *et al.* 2018, Kiss *et al.* 2016, Orosz *et al.* 2018, Poyet *et al.* 2015, Ryan *et al.* 2016, Stockton *et al.* 2018, Tait *et al.* 2018, 2021, Tochen *et al.* 2014

Balázs Kiss

FISHES

Pisces

Siberian Sturgeon

Acipenser baerii Brandt, 1869

Original area of the species

The Siberian Sturgeon is native to the large rivers of Siberia (Ob, Lena, Kolima, Angara, Yenisei) and Lake Baikal. It is a potamodromous species, and spends its whole lifecycle in freshwater, migrating only within the freshwater body between spawning and feeding areas (lakes and rivers). Currently, three subspecies have been described; one from the water system of River Ob (ssp. *baerii*), another from the water system of eastern Siberian rivers (ssp. *stenorhynchus*), and the third from Lake Baikal (ssp. *baicalensis*). However, the validity of these subspecies is questioned by several authorities. In its native range, the Siberian Sturgeon is a threatened species, and the IUCN categorize it as 'Endangered'. This species plays an important role in the caviar production of the world, hence special attention is paid both to the protection and sustaining of their natural populations and to the farming them in aquacultures (Ruban & Mugue 2022, Urbányi & Horváth 2019).

The introduction of the species to Europe and Hungary

In Europe, the first Siberian Sturgeons were imported to France in 1975, where breeding experiments were initiated in sturgeon farms (Welcomme 1988, Williot *et al.* 1991). The species was imported to Hungary with the same intentions in 1981 from the former Soviet Union (Harka & Sallai 2004). Today, the Siberian Sturgeon is one of the most frequently kept species from among the aqua-cultured sturgeons (Acipenseridae) in the world. Additionally both pure breed Siberian Sturgeons and its hybrids are released into supposedly closed fishing lakes, as the Siberian Sturgeon and its hybrids tolerate best stagnant water.

The first confirmed Siberian Sturgeon specimen was caught in a natural water body in Hungary in 2005 on the joint Hungarian-Slovakian Section of the Danube near Almásfüzitő (1759 river kilometre) (Masár *et al.* 2006). Then, in 2012, two further specimens were caught by researchers at the river section between Izsa (Iža) and Dunaradvány (Radvaň nad Dunajom) (1759–1749 kfmk (Farský *et al.* 2013). Earlier, there were reports from anglers on the catching of Siberian Sturgeons (or possibly alien sturgeon hybrids) from the Hungarian sections River Dráva (Barcs, 2005), and the River Rába (Nick, 2005; Szentgotthárd, 2006) (Weiperth *et al.* 2013). It is almost certain that the specimens of both the Siberian Sturgeon or its hybrids with other sturgeons were escapees from fish farms or, to a lesser extent, from private ponds (Weiperth *et al.* 2014a). Genetic studies carried out on specimens caught from the German section of the Danube (Jochenstein) proved that the Siberian Sturgeons can successfully breed there. Also the results showed that it can hybridise with the vulnerable Sterlet (*Acipenser ruthenus*), native to the Danube and its tributaries (Ludwig *et al.* 2008).

Life history of the species

Just like all the sturgeons (Acipenseridae), the Siberian Sturgeon is a cartilaginous fish, (i.e. the ossification of its skeleton is low) and its skeleton is almost entirely cartilaginous. The notochord (*chorda dorsalis*) is unconstricted and retained throughout life. The skull is also cartilaginous, with very low ossification. Its body, as is characteristic in sturgeons, is elongated, on its dorsal and ventral side there are five rows of scutes that does not protrude far from the skin. Its belly is usually white, or light yellow, its dorsal surface can vary from dark brown to light grey. The number of scutes is 10–19 dorsally, 32–59 laterally and 7–16 ventrally. The number of gill rakers is 20-49. Its nose is elongated and the barbels are located nearer to the tip of the nose than to the opening of its mouth, but if they are combed back the reach the upper lips. Its mouth is medium-sized, the lower lip is split. The meristic characters of the hybrids of the Siberian Sturgeon and other related sturgeons vary between those counted in the parents.

© Árpád Ferincz

It searches for food on the bottom with the receptors located on its nose and barbels. Its diet is dominated by aquatic vertebrates: insect larvae (Insecta), clams, mussels (Bivalvia), snails (Gastropoda), crabs, Crustaceans such as decapods (Crustacea), but larger specimens also consume small fish (Pisces) (Urbányi & Horváth 2019).

The age at sexual maturity is very variable. On average, males reach sexual maturity at the age of 10–14 years, and females at 14–18 years. They search gravelly bottomed river sections to spawn, where water depth is at least 4–8 m, and the flow rate is greater than 0.5–1 m/sec. The timing and length of spawning is mainly influenced by water temperature, usually starts from 10–15 °C. Depending on female size, 20,000–420,000 eggs are released, the diameter of eggs is 3.7–4 mm. Specimens do not usually spawn annually, and 4-5 years might pass between spawning.

Similarly to other sturgeons, the Siberian Sturgeon is a slow-growing but very long-lived fish, which can grow to immense size. There are significant differences in the growth-rates of the different natural populations. This is primarily caused by differences in food availability and water temperature. The largest specimens might grow to a length of 2 metres, and can weigh 210 kg (Urbányi & Horváth 2019).

The ecological requirements of the species in Hungary

The environmental conditions are adequate for the Siberian Sturgeon in the middle section of the Danube and in its larger tributaries (for example Dráva, Mura, Rába, Tisza). Sturgeon can also tolerate stagnant waters, and hence both pure breed and hybrid Siberian Sturgeons are released into fishing lakes, and garden ponds. Unfortunately there is no information on the stock used for release, nor on its distribution in our natural waters.

Ecological problems

The Siberian Sturgeon and its hybrids are rarely caught in the natural water bodies of Hungary. The greatest ecological and conservation risk associated with alien sturgeon species is that they are able to hybridise with native sturgeon species, in Hungary with the Sterlet (*Acipenser ruthenus*) (Ludwig *et al.* 2009, Friedrich *et al.* 2018, 2019, Takács *et al.* 2017b). Hybridization threatens directly the genetic integrity of the Hungarian Sterlet, which became rare due to other threats.

Economic effects

Its direct economic damage cannot be proven nowadays. Its hybridization with native sturgeon species is treated as an ecological hazard, as the Sterlet (*Acipenser ruthenus*) being a protected species cannot be caught and sold in Hungary.

Methods of control

The Siberian Sturgeon and its hybrids with other sturgeon species can be commercially sold in Hungary by certain pet shops and sturgeon farms. It can be kept in a larger garden pond, and its release into privately owned fishing lakes is still practiced. Usually, large mature individuals are released into these fishing lakes. Both pure bred Siberian Sturgeons and its hybrids can hybridise with the native Hungarian sturgeon (Acipenseridae) species, and hence educational campaigns should be initiated to show the threats posed by the release of either Siberian Sturgeon or its hybrids being released into natural waters, into fish lakes connected to natural waters and to garden ponds (Urbányi & Horváth 2019. The control and eradication of invasive fish species is usually a very difficult task. Especially in the case of those species which live in a habitat partially unknown and difficult to study, even for researchers.

References

Farský *et al.* 2013, Friedrich *et al.* 2018, 2019, Ludwig *et al.* 2009, Harka & Sallai 2004, Masár *et al.* 2006, Ruban & Mugue 2022, Takács *et al.* 2017b, Urbányi & Horváth 2019, Welcomme 1988, Weiperth *et al.* 2013, 2014a, Williot *et al.* 1991

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

Prussian Carp

Carassius gibelio (Bloch, 1782)

Original area of the species

The Prussian Carp's precise native distribution is unknown. For a long time researchers thought its original native area was East Asia, but results from the latest genetic studies suggest that its original range could be an area from Siberia to Ukraine. However, these genetic results contradict the findings of parasitological studies of the *Carassius* species (Bănărescu 1992, Rylková *et al.* 2013, Molnár *et al.* 2018).

In its native range it occurs in marshlands, tributaries, and eutrophic waters.

The introduction of the species to Europe and Hungary

The date of its first occurrence in Hungary is unknown. Some experts believe that the Prussian Carp can be regarded native in the water system of the Danube (Oțel 2019). This view is partly based on the written account of Ottó Herman in his landmark volume on Hungarian fishery *"A magyar halászat könyve"* (Herman 1887) – based on earlier sources – mentioning a species named "kövi kárász" (Stone Carp) (*Carassius gibelio* Nilsson), which he regards a variety of the Crucian Carp

© Zoltán Sallai

(*C. carassius*). But, later authors identified the mentioned species based on the morphological description as the Prussian Carp (Heckel 1863, Györe 1995). Another hypothesis states that the Prussian Carp is not native to the Carpathian Basin. Earlier, some authors thought that the species might have expanded its area from the lower reaches of River Danube through Romania, but they could only prove this around the end of the 1970s with genetic studies (Holcik 1980, Rylková *et al.* 2013). The situation is even more complex if we take into account that the Prussian Carp was imported from Bulgaria – where it was introduced from the Soviet Union – to Hungary for commercial breeding in 1954 (Szalay 1954). Its Hungarian and Central European spread was most intense in the 1970s, it could enlarge its area by 20,500 km^2/year. Prussian Carp were first mentioned as a species present in the Danube in 1975 (Tóth 1977). In its spread, either intentionally or unintentionally, anglers played an important role (Tóth & Váradi 2000). On the one hand they happily released the Prussian Carp into the waters they managed because it was cheaper than the European Carp (*Cyprinus carpio*), but on the other hand it is often mistakenly mixed with European Carp lots. Today, the Prussian Carp, with the exception of Great Britain, occurs in the whole of Europe and in the northern part (Canada) of North America (Pintér 2015, Elgin *et al.* 2014).

Life history of the species

The Prussian Carp is characterised by a very wide ecological tolerance, and especially true for their tolerance of dissolved oxygen and ammonia content of water. It is adapted to surviving low or oxygen deficient periods. Probably the extreme increase of nutrients of the water (hypertrophy) is disadvantageous for this species (Tsoumani *et al.* 2006).

All the *Carassius* species, and hence Prussian Carp also, possess a special physiological mechanism to tolerate oxygen deficiency. Compared to other vertebrate the glycogen content of their brain is higher, and in low oxygen environments they cease terminal oxidation, and the ATP molecules produced in the glycolysis process yield enough energy for the fish to survive. The end product of the decomposition process in oxygen deficient environment is ethanol that is expelled from the body through the gills, and hence does not cause acidosis (Lutz & Nilsson 1994).

The Prussian Carp reaches sexual maturity at the age of two-three years. Females can lay 100,000–400,000 eggs of 1.5 mm diameter between May and July, but there are observations on their successful breeding in August. They primarily choose plant material as a surface on which to oviposit but, under extreme conditions, they are less specific regarding spawning surface (Berinkey 1966, Balon 1975).

Breeding biology of the Prussian Carp is very special. At the edges of its distribution there are usually gynogeneticly breeding populations. The egg carrying triploid females can produce fertile female Prussian Carp females, if they get sperm from any male from a group-spawning carp species (Cyprinidae). The reason is the foreign sperm does not fertilize their eggs, it only initiates its embryonic development. Some decades ago this alternative asexual reproduction was thought of as the norm but, in most of the Hungarian waters, it was replaced by traditional sexual reproduction. The reason for this shift is not yet clear, but, probably, a whole set of limiting environmental factors are at play affecting the species at the population level. As a consequence, clonal reproduction, which is fast and enables out-competing other fish species, but later loses its competitive edge against sexual reproduction. Although sexual reproduction is less productive, it might produce the genetic variability (through the recombination of parental genomes) necessary to adapt to the new environmental conditions (Váradi & Tóth 1998, Beukeboom & Vrijenhoek 1998).

The Prussian Carp is an omnivorous species, and it can feed on zooplankton, detritus, macroscopic aquatic invertebrates and, under extreme conditions, on fish fry. It will chose food on the basis of the abundance and energy requirement of feeding on a certain type of prey, in order to maximize energy intake from them. Its feeding on detritus is exceptional and unique in the Hungarian fish fauna (Specziár & Rezsu 2009).

The ecological requirements of the species in Hungary

With the exception of fast flowing streams and rivers, Prussian Carp is a dominant species and occurs in large numbers in most of our lowland and hill-land lentic and flowing water bodies. Its distribution in Hungary is linked to the presence of fishery infrastructure (e.g. commercial fisheries, fishing-lakes). As a consequence of its invasion, Crucian Carp (*Carassius carassius*) have disappeared from our waters, hence the latter species cannot be caught by fishermen at present, and its protection is proposed. In the majority of the surviving, and based on their morphological characters seemingly Crucian Carp, populations' genome also contains sequences, which originally belonged to the Crucian Carp. Gynogenetic reproduction helped the Prussian Carp to outcompete other Cyprinid fishes, and create very dense populations, as the breeding success of those individuals of other species that mistakenly pair with Prussian

© Árpád Ferincz

Carp will have lower breeding success (Takács *et al.* 2017b, Müller *et al.* 2007). Fish fry consumption might occasionally be significant, but only occurs under extreme habitat conditions (Specziár 1999).

Ecological problems

Fishing-lakes, commercial fisheries and the water bodies connected to them might become overcrowded with excessive breeding by Prussian Carp. The situation is similar in several natural water bodies (wetlands, Hanság, Turjánvidék, Kis-Balaton) that are valuable nature protection sites. The possible key to their extremely fast proliferation is that they can tolerate and survive the periods of low oxygen content and extreme low water levels. If there are only a handful of surviving specimens, due to their advantageous gynogenetic breeding mechanism Prussian Carps can start a new population. This population can multiply very efficiently, and outcompete the native species, especially the Crucian Carp (Ferincz *et al.* 2016a, Takács *et al.* 2017b).

Economic effects

As the Prussian Carp is feeding on fodder provided for the cultivated fish species in commercial fisheries – most often the European carp (*Cyprinus carpio*) – the cultivated fish specimens grow slower, hence the net meat yield decreases, therefore fisheries can suffer substantial loss of revenue. In those waters where the Prussian Carp breeds gynogenetically, it considerably reduces the breeding output of the commercially valuable species. Although some anglers like to catch them, in many fishing lakes, if they proliferate excessively, they make fishing impossible.

Methods of control

The control of invasive species is usually a demanding task. Long-term studies shows that the decrease in frequent anthropogenic disturbance of a given water body (for example, excessive water level changes, draining and desiccation) stabilizes the population size of the Prussian Carp at a relatively low level. The same was shown in some less-regulated or natural flowing waters. Possibly the local native fish fauna can outcompete the Prussian Carp under such natural conditions, and hence can control its population size.

References

Bănărescu 1992, Berinkey 1966, Beukeboom & Vrijenhoek 1998, Ferincz *et al.* 2016a, Györe 1995, Heckel 1863, Hensel 1971, Herman 1887, Lutz & Nilsson 1994, Molnár *et al.* 2018, Müller *et al.* 2007, Otel 2019, Pintér 2015, Rylková *et al.* 2013, Szalay 1954, Specziár & Rezsu 2009, Specziár 1999, Takács *et al.* 2017b, Tóth 1977, Tóth & Váradi 2000, Tsoumani *et al.* 2006, Váradi & Tóth 1998

Árpád Ferincz, András Weiperth,
Vera Lente & Ádám Staszny

Goldfish

Carassius auratus (Linnaeus, 1758)

Original area of the species

The Goldfish is native to the Far East, and its wild form inhabits the waters of south-east Asia, characterized by temperate climate. It occurs in Vietnam, on the Korean Peninsula and in China. The first cultivated forms were bred in China around 900–1000BC. In its native range, the species prefers lentic and occasionally eutrophic water bodies (Pénzes & Tölg 1993, Takada *et al.* 2010).

The introduction of the species to Europe and Hungary

The ornamental form was introduced during the 14th century from China to other parts of the world. It was first imported to Portugal in Europe in 1611.

It was probably first imported to Hungary from Germany in the second half of the 1800s, as an aquarium fish. The first released population formed in the effluent water of the Római Bath in Budapest in 1891 but, later, as a consequence of drying out of this habitat, the population disappeared. Thereafter, several independent intentional releases happened to natural habitats, which is still practiced by aquarists (Pénzes & Tölg 1993).

Life history of the species

It is almost impossible to differentiate the 'wild' colour variety of the Goldfish and the Gibel Carp (*Carassius gibelio*) based on external body traits. The ornamental forms can easily be distinguished based on their colour (reddish golden-yellow, black spotted, cream or red) from the congener, but the descendants of feral individuals usually lose their conspicuous colouration in the wild, hence their identification is a serious task even for specialists. Positive identification can only be carried with genetic methods. Based on the latest molecular genetic studies, the mitochondrial genome of several Hungarian Gibel Carp

© Árpád Ferincz


© László Haraszthy

During fishpond harvesting, individuals with colourations much paler than those intended for ornamental purposes, make up a large proportion of the catch. These are often hybrids of the Prussian Carp.

populations contains gene sequences of the Goldfish (Keszte *et al.* 2021).

The age when Goldfish reach sexual maturity is significantly influenced by environmental factors, especially water temperature. Exceptionally, maturity is reached within a year (Ortega-Salas & Reyes-Bustamante 2006). The spawning of the Goldfish is repeated (in the breeding season several times in approx. 10 days). In Hungary this usually occurs during May-June, when water temperature reaches 20 °C. An average-sized female (ca. 15 cm in length) releases approximately 9,000 eggs onto any structure under the water. The fry will hatch from the eggs within 4–5 days (Pénzes & Tölg 1993).

There is little information on Goldfish diet in natural waters, but it is an omnivore, benthic feeding species.

The ecological requirements of the species in Hungary

Similarly to other carp in the genus *Carassius*, it can easily tolerate warming and muddy, nutrient-rich waters, characterized by occasional oxygen-deficit. It can even survive being frozen into ice, as well as water temperature above 30 °C. Since identification is only possible using genetic methods, it is only exceptionally listed among the species found in fish fauna studies. Consequently, there are no exact data on the size of its population and spatial distribution in Hungary. It can inhabit almost any waterbody in Hungary, with the exception of mountain streams.

Ecological problems

As the Goldfish mainly forages on the bottom, it might damage the roots of submerged aquatic plants (Richardson *et al.* 1995), and it does decrease the breeding success of amphibians by predating their eggs (Winandy *et al.* 2015). It can hybridise with closely related carp species, for example the Crucian Carp (*Carassius carassius*), which has decreasing populations and should be protected. Hybridization with the Common Carp (*Cyprinus carpio*) also occurs, and consequently the carp's breeding success might be lower in natural water bodies (Hänfling *et al.* 2005).

Economic effects

Ornamental varieties have outstanding importance in the aquarium fish trade. The potential economic damage caused by the Goldfish is not separated from those caused by other crucian carp, especially Gibel Carp (*Carassius gibelio*).

Methods of control

The feral Goldfish stock is always replenished with unwanted specimens from garden ponds and fish tanks that are released illegally to natural waters. To change this attitude, the education of aquarists would be the most appropriate and effective method (Ferincz *et al.* 2019). It is important that the present legislation regarding the Goldfish forbids the release of caught specimens or their transfer to natural waters.

References

Ferincz *et al.* 2019, Hänfling *et al.* 2005, Keszte *et al.* 2021, Ortega-Salas & Reyes-Bustamante 2006, Pénzes & Tölg 1993, Richardson *et al.* 1995, Takada *et al.* 2010, Winandy *et al.* 2015

Árpád Ferincz, András Weiperth,
Vera Lente & Ádá m Staszny

Silver Carp

Hypophthalmichthys molitrix (Valenciennes, 1844)

Original area of the species

In its native range, in East Asia, the Silver Carp has been cultured and stocked for commercial fishing for a long period, hence it is hard to map its original distribution range. In Asia, this species is common and widespread in most of the catchment areas of rivers which flow into the Pacific Ocean. It occurs from the Pearl River (Xi Jiang River) to the Amur River (Kottelat & Freyhof 2007). It is a subtropical species, and usually lives in rivers with both great discharge and high water level changes, but is also at home in great lakes or large water reservoirs with a large open surface area (Billard 1997).

The introduction of the species to Europe and Hungary

The introduction of the Silver Carp began in the 1960s in the European territory of the former Soviet Union. Following its successful artificial reproduction, the Silver Carp was imported to several countries within Europe. It was imported to Hungary from China in 1963 in order to complement European Carp monocultures (Pintér 2002). The idea was that Silver Carp – which grow quickly and attain a large size – would mainly utilize the fodder (predominantly phytoplankton) which was not taken up by the European Carp (*Cyprinus carpio*), so it could utilize an untapped source to produce good quality meat, hence fish production could becom e more profitable (Kovács & Urbányi 2019).

Life history of the species

The body of the Silver Carp is elongated, laterally flattened, and of medium height. On the ventral side there is a distinct edge from the throat to the cloaca. Its head is relatively large, the forehead is wide, its eyes are deep-set, and in line with the corner of the mouth. The mouth is up-turned, its fins are well-developed, and its tail fin is deeply bifurcated. Colouration is silvery, and the back is darker grey, sometimes greenish, and the belly is light. It is a pronouncedly large fish, which can grow to 1.0 m in length (Harka & Sallai 2004).

Adult individuals tolerate the changes of water temperature very well (0–40 °C), but grow most intensely between 24–31 °C. Silver Carp can tolerate brackish, semi-salty water to a certain extent. As it grows older and/or larger, it can tolerate the decrease of the oxygen content better and better. It is a fish that usually occupies and feeds near the surface of the water (Froese & Pauly 2021c).

In its native range, breeding coincides with the monsoon period. At these periods it migrates from a considerable distance to the river sections characterised by high water discharge and fast flow, and seeks out pebbled, stony bottoms (potamodromous species). Its eggs are pelagic, they float adrift with the current in the riverbed. After the eggs hatch and develop into fry, they will move to the inundated areas (Kottelat & Freyhof 2007).

It feeds mainly by filtering the phytoplankton with a fine filtering apparatus that develops from the comb of the gills, which can filter out the rcorrectly-sized particles from the water. It often consumes a significant amount of zooplankton besides phytoplankton. In Hungary it reaches sexual maturity at the age of 5-6 years (Kovács & Urbányi 2019).

The ecological requirements of the species in Hungary

In Hungary, the Silver Carp is a widespread and common fish species. Due to voluntary release and escapees the Silver Carp not only occurs in the fisheries, but also in most of the natural waters, rivers, canals, and dead arms. In some years, when the environmental conditions are right, it might even breed successfully, and this probability is higher and higher, due to global warming.


© Árpád Ferincz

Most of the Silver Carp stock in Lake Balaton are hybrids (*Hypophthalichtys molitrix* × *nobilis*) (Molnár *et al.* 2021), and its appearance mostly exhibits the characteristics of the Silver Carp, while its feeding is more similar to that of the Bighead Carp (*H. nobilis*). Most probably these hybrids do not breed in the water catchment area of Lake Balaton and, after its intentional release was halted, their populations were restocked and sustained by escapees from fisheries (Vitál *et al.* 2017). Although the precise size of the population in Lake Balaton was never completely known, based on the results of research fishing and the number of Silver Carp carcasses collected, a declining tendency is clearly shown.

Ecological problems

Although earlier researchers thought that the diet of the Silver Carp consisted exclusively of phytoplankton, it was later proven that this species also consumes zooplankton in high volumes (Smith 1989, Sass *et al.* 2014). As these planktonic organisms form the diet of the fry of all the native fish species, Silver Carp can become a direct competitor of all of these species (Kovács & Urbányi 2019). As the Silver Carp preferentially filters out certain sized food, and might only partially digest some food items, it might facilitate the fast growth and increased abundance of some algae. These might be the small species, or those cyanobacteria possessing a hard-to-digest mucous capsule. Therefore, the Silver Carp is exerting a negative effect on native fish species, initially as it diminishes the availablity of plankton and, secondly, it changes the species composition of algae in an unfavourable way (Nico *et al.* 2022a, Petr 2002, Sass *et al.* 2014).

Economic effects

Silver Carp are stocked into fisheries to complement the commercially bred European Carp monocultures. When stocked in the right density, and in appropriately managed fishery ponds, the Silver Carp has a certain economical potential. It was released to various water bodies as a phytoplankton feeder in order to improve water quality, and to biologically treat sewage water. (Xie & Liu 2001). The results are far from concordant regarding the success of these trials. As it feeds on zooplankton, the Silver Carp is a significant competitor of the fry of several native species, and exert negative effect on them (Nico *et al.* 2022a, Kovács & Urbányi 2019). Due to the fact, that it is a specialised filter-feeder, thus is difficult to catch on typical hook and line fishing gear. Its accidental catching makes it uninteresting for anglers.

Methods of control

As with other invasive species, the most effective way to control the Silver Carp is to inhibit its further spread. In the case of this species, the importance of the blocking of its escape from fisheries is imperative (Perea 2002). For the direct depletion of its populations the application of chemical methods (piscicid) is less effective, hence they are on the one hand less sensitive for these control agents, and on the other, they occur in enormous catchment systems where these chemicals cannot be applied effectively. The only effective reduction method is selective fishing, for which the optimal time is during the breeding season. The damming of smaller flowing waters also achieves worthwhile results (Kovács & Urbányi 2019).

References

Billard 1997, Froese & Pauly 2021c, Harka & Sallai 2004, Kottelat & Freyhof 2007, Kovács & Urbanyi 2019, Nico *et al.* 2022a, Perea 2002, Petr 2002, Pintér 2002, Sass *et al.* 2014, Xie & Liu 2001, Vitál *et al.* 2017

Vera Lente, Ádám Staszny,
András Weiperth & Árpád Ferincz

Bighead Carp

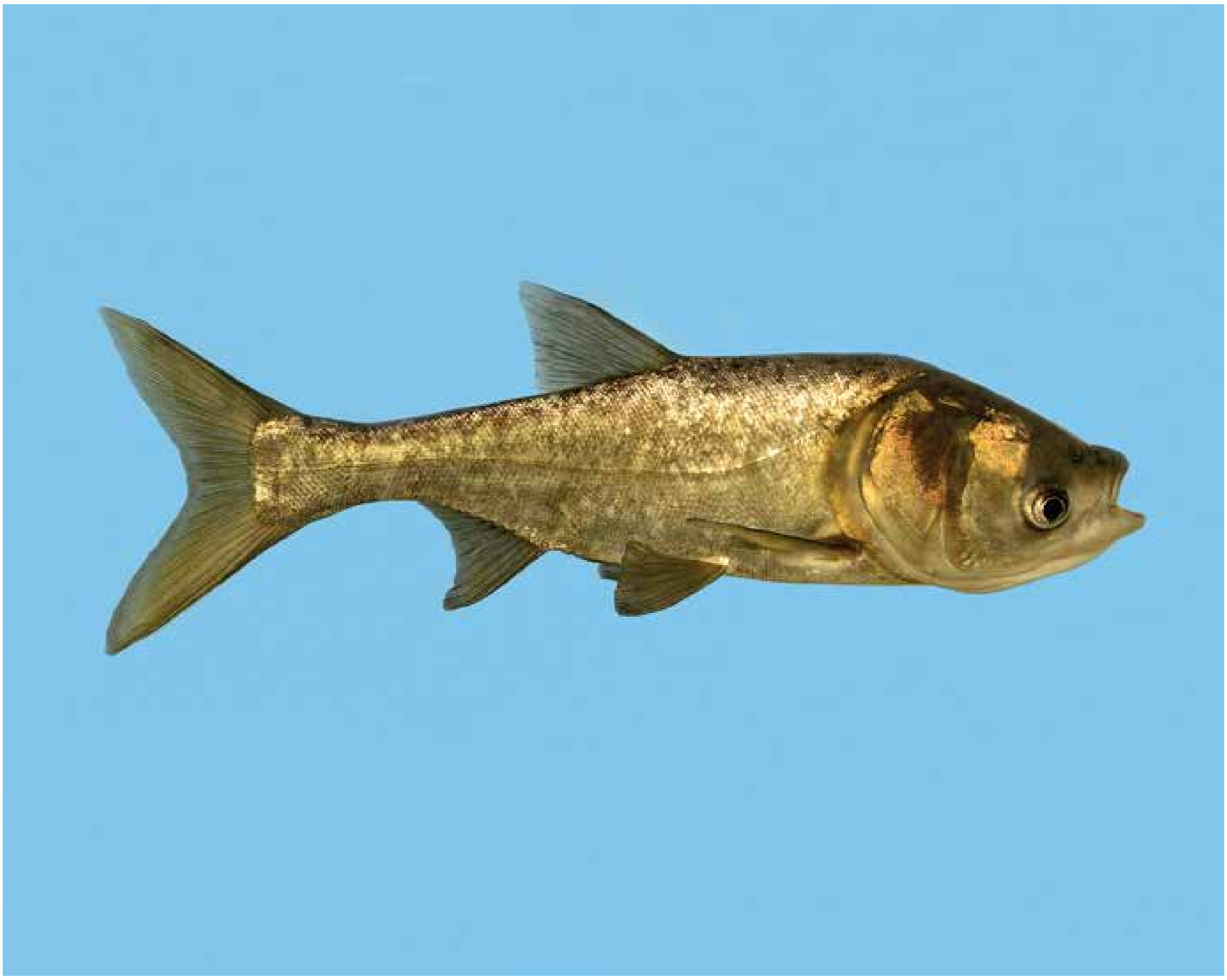
Hypophthalmichthys nobilis (Richardson, 1845)

Original area of the species

The Bighead Carp is native to eastern China and eastern Siberia, and occurs in the water systems of Amur, Yellow, Pearl, Yangtze, Tumen and Razdolnaya Rivers (Jennings 1988). It also inhabits lakes and canals with large open water surface, but its typical habitats are the rivers characterised by great water-level changes and high water discharge. Its development is fastest in waters with high nutrient content, and offering copious food resources (FAO 2021).

The introduction of the species to Europe and Hungary

Its introduction to Europe started at the beginning of the 1960s, and often was unintentional; Bighead Carp fry specimens were mixed into the released



© Zoltán Sallai

shipments of Silver Carp (*Hypophthalmichthys molitrix*) fry.

The Bighead Carp was introduced to Hungary in the same way. Subsequently, the species was intentionally introduced to several fisheries, and escapees from the fisheries infiltrated the natural waters (Pintér 1976). In the 1980s there were trials to hybridise the Bighead Carp with the Silver Carp, with the intention of creating a sterile form that could be safely released into natural waters (Marián *et al.* 1984). But the hypothetical solution did not work in reality (Kovács & Urbányi 2019).

Life history of the species

The body of the Bighead Carp is elongated, flattened laterally, and of medium height. Its abdomen is rounded from the throat to the pelvic fins. Between the pelvic fins and the anus there is an edge. Compared to its body, its head is pronouncedly large, the forehead is wide. Its eyes are deep-set, and are in line with the corner of the mouth, and positioned under the midline of the body. The filtering surface in the gill is lamella-like, and its gill openings are larger than that of the Silver Carp's (*Hypophthalmichthys molitrix*). Its fins are large, the pectoral fins reach considerably over the origin of the pelvic fins. Its body is mottled silver-grey coloured, but somewhat darker than the Silver Carp. It is a big fish, can grow to a 1ength of 1.0 m (Kottelat & Freyhof 2007).

In Hungary, it reaches sexual maturity at the age of 7-8 years. Similarly to the Silver Carp, Bighead Carp seeks out fast flowing river sections with pebbled or stony bottoms for spawning, where the oxygen content of the water is high. It will migrate large distances in the water system of its river to find the appropriate spawning site (potamodromous species). Its eggs are pelagic, they float adrift with the current in the riverbed. After the eggs have hatched and developed into fry, it will move to the inundated areas (Huckstorf 2012).

It feeds almost exclusively on zooplankton (FAO 2021).

The ecological requirements of the species in Hungary

As a typical temperate zone fish, mature Bighead Carp can tolerate large changes in water temperature (0–40 °C). For the Bighead Carp the optimal water temperature is 25–27°C, and it quite well tolerates the changes of salt and oxygen content.

Although the release of Silver, Bighead (*Hypophthalmichtys* spp.) and Grass Carp (*Ctenopharyngodon idella*) into natural waters was banned in 1996, the populations of these fishes do not show any decline. Most of the specimens in stagnant water bodies are the hybrids of Silver and Bighead Carps (*Hypophthalmichtys molitrix* × *nobilis*), and their phenotypic features (i.e. appearance) resembles dominantly the Silver Carp. But its filtering apparatus is more similar to that of the Bighead Carp. In flowing waters mainly Silver Carps occur (Molnár *et al.* 2021). At present, the pure-breed Bighead Carp stock is declining in Hungary.

Ecological problems

The negative effect of the Bighead Carp on the native fauna and natural habitats was sooner discovered, than that of the Silver Carp (*Hypophthalmichtys molitrix*). Even under the conditions in fisheries. it was clearly demonstrated that the Bighead Carp and the European Carp (*Cyprinus carpio*) are competing for food. Moreover the zooplankton species that the Bighead Carp consumes are the main fodder for all the native fishes' fry. And for some pelagic fishes the same zooplankton remain the main food source during their whole life (Nico *et al.* 2022b). Therefore high density Bighead Carp stocks deplete the zooplankton sources, and the smaller sized planktonic species become dominant (Sass 2014). By changing the food-web the Bighead Carp might negatively affect /reduce biodiversity (Freedman *et al.* 2012).

Economic effects

Today, the economic importance of Bighead Carp production is negligible. By consuming zooplankton, it poses a serious threat to more valuable fish species, both from ecological and economical point of view (Nico *et al.* 2022b).

Methods of control

The methods available for the control of the Bighead Carp are the same as detailed for the Silver Carp (*Hypophthalmichtys molitrix*). The main effort should be focused on the preventing its further spread (Wittenberg & Cock 2001). Its number could also be controlled with selective fishing (Kovács & Urbányi 2019).

References

FAO 2021, Freedman *et al.* 2012, Huckstorf 2012, Jennings 1988, Kottelat & Freyhof 2007, Kovács & Urbanyi 2019, Márián *et al.* 1984, Molnár *et al.* 2021, Nico *et al.* 2022b, Pintér 1976, Sass *et al.* 2014, Wittenberg & Cock 2001

Vera Lente, András Weiperth,
Ádám Staszny & Árpád Ferincz

Grass Carp

Ctenopharyngodon idella (Valenciennes, 1844)

Original area of the species

The Grass Carp is native to the temperate and continental areas of East Asia, and occurs from Eastern Siberia to China in the water system of the Amur River, and in the lower and middle sections of the Yangtze and Yellow Rivers (Nico *et al.* 2022c). It typically occurs in those waters that have great surface and are densely overgrown with vegetation, such as slowly flowing river sections, oxbow lakes and, occasionally, even in lakes. The Grass Carp migrate only in fresh water to spawn, i.e. a potamodromous fish species (Kottelat & Freyhof 2007).

The introduction of the species to Europe and Hungary

The Grass Carp is one of the most important fish species bred in aquacultures, and was introduced to Europe and Hungary with intentions to produce revenue in fishponds. The first trials for its aquaculture breeding started in the southern part of the former Soviet Union in 1950. In 1961 it was successfully bred in Turkmenistan, and it facilitated the following introduction trials to more westerly situated areas. Both fishery and natural stocks are significant (Froese & Pauly 2021a).

It was first imported to Hungary in 1963, and the first successful breeding attempt was performed in the Dinnyés commercial fishery in 1967 (Tölg 1970). Subsequently, the single-species European Carp fisheries were replaced step-by-step with multi-species aquacultures with integrated herbivorous auxiliary fish species, the Grass Carp being one of them. It was released in high volumes into our natural waters following the 1980s, after the export to Near East markets had collapsed completely. The fry stocks reared to adulthood that were not sold for human food consumption, were released into natural waters and sport fishing lakes (Kovács & Urbányi 2019). Even today, the idea of introducing the species to the canals of the Great Hungarian Plain is still discussed, in order to control the growth of submerged aquatic vegetation.

Life history of the species

The Grass Carp is characterised by an elongated, torpedo-like body that is only slightly laterally compressed. It can grow to a very large size. Its head compared to its body is very small, its eyes are situated low, and the nose is flattened and pronouncedly short. It has a terminal mouth, which is slightly oblique, possesses non-fleshy, firm lips, and no barbels, and its fins are relatively small and rounded. Young specimens are silver-coloured, whilst he dorsal surface and flanks of adults are greenish, and the belly is light (Harka & Sallai 2004).

© Árpád Ferincz

The optimum temperature range for its growth is 25–30 °C, but is able to tolerate a wide range of water temperature from 0–38 °C. The Grass Carp can also tolerate changes in salinity and oxygen levels (Frimodt 1995).

Grass Carp are herbivorous fish, which consume both higher (vascular) aquatic plants and submerged terrestrial vegetation, and will also feed on filamentous algae. With its hard lips and large pharyngeal teeth, it can consume the hard basestems of reeds. If no plant material is available, it can feed on organic detritus and macroscopic invertebrates. Its feeding rate is exceptionally high, as it can only digest its food with low efficiency (Billard 1997).

The age of sexual maturity is heavily dependent on environmental factors and, in Hungary, usually takes place at 6–7 years. In its native range, spawning is timed to coincide with the monsoon. Grass Carp will migrate 50–100 kilometres to find appropriate spawning sites, such as fast-flowing river-sections with rocky or pebbled bottom. Its eggs are pelagic, they flow with the current. If the eggs precipitate, they perish. Hatched fry that are able to move independently migrate to the inundated areas adjacent to the shore (Shireman & Smith 1983).

The ecological requirements of the species in Hungary

In Hungary, the Grass Carp is a widespread and abundant species due to stockings and escaped individuals from fisheries. It occurs in all the lakes, rivers, canals and oxbow lakes, where there is enough plant material to feed on. In some of our rivers (Hármas-Körös, Tisza, Dráva) its breeding is documented and, as a consequence of global climate change, more and more waters will offer the Grass Carp appropriate conditions for spawning.

Ecological problems

Grass Carp populations affect both directly and indirectly the ecological condition of waters. They change the composition of aquatic plant communities through the selective consumption of plants. They might negatively affect native fish populations through the elimination of those habitats that serve as spawning, feeding or hiding sites (Shireman & Smith 1983). Disturbance in natural habitats usually cause the decline of species diversity, and the chance of invasion by alien species is increasing. Another direct effect on the habitats, arising from the fact that the digestion of the Grass carp is very fast and quite inefficient, is the production of excrement that is rich in easily obtainable nutrients for plants. This organic material is ready for uptake, and might change the trophic state of the water, and facilitates eutrophication (Hansson *at al.* 1987).

The extent of its effect on the environment is highly dependent on the intensity of stocking. But critical population size, or more the density, especially in natural waters, is very difficult to determine (Kovács & Urbányi 2019). A further problem associated with the spread of alien species is that they can potentially act as vectors of viruses and parasites. A tapeworm species was introduced to Hungary from the Far East with the Grass Carp transport, and this parasite, the Asian Tapeworm (*Bothriocephalus acheilognathi*), can spread in all native carp species (Kottelat & Whitten 1996).

Economic effects

The Grass Carp is most often bred as an auxiliary fish species in multi-species aquacultures (polycultures) in Hungary. This fish-culture composition is based on the idea that the Grass Carp can utilize the fodder (higher vascular aquatic plants) that is not consumed by the European Carp. As a consequence of its auxiliary role, the production yielded by the Grass Carp is negligible. Its importance in sport fishing can be outstanding in certain waters, as it is large and fights hard when hooked, but its feeding, and the consequent habitat transformation might pose a serious threat for the stocks of native fish species (Kovács & Urbányi 2019).

Methods of control

The Grass Carp is a large fish species, and hence highly valued by anglers. In most of the waters of Hungary it is not yet able to breed. With the ban on its introduction, stocking and release of caught specimens on the long run the number of Grass Carps can be reduced. There is an artificially bred triploid variety of the Grass Carp that is unable to breed, and it would be desirable to use this variety for fishery production.

References

Billard 1997, Bonar *et al.* 2002, Frimodt 1995, Froese & Pauly 2021a, Hansson *et al.* 1987, Harka & Sallai 2004, Kottelat & Freyhof 1996, 2007, Kovács & Urbanyi 2019, Nico *et al.* 2022c, Shireman & Smith 1983, Tölg 1970

Vera Lente, Ádám Staszny,
András Weiperth & Árpád Ferincz

Stone Moroko

Pseudorasbora parva (Temminck & Schlegel, 1846)

Original area of the species

The Stone Moroko is native to East Asia, including Japan, part of the Korean Peninsula, and China. It was accidentally introduced not only to Europe, but also to several Asian countries, such as Iran, Kazakhstan, Laos, Taiwan, Türkiye, Uzbekistan, Afghanistan and Armenia. It also occurs in Algeria, and on the Fijian Islands.

The introduction of the species to Europe and Hungary

In Europe, it was first reported from Romania at the beginning of the 1960's, where it was transported with a consignment of Bighead Carp and Grass Carp. In Hungary, it was first reported from the Paks Commercial Fishery in 1963 then, in 1967, its mass occurrence was reported from Biharugra. It probably got to the latter location by natural spread. From the 1970's, it spread very quickly throughout the whole country, and today it occurs in almost all the waters of Hungary (Pintér 2002). It had invaded practically all the countries of Europe by the 2000's (Copp *et al.* 2005), with its latest invasive spread being reported from the Iberian Peninsula (Caiola & de Sostoa 2002). The introduction of the species primarily takes place by infested fish transports, but its secondary, spontaneous spread is also documented.

Life history of the species

The Stone Moroko is a particularly small, elongated fish. Its body is silver-coloured, its dorsal surface is greyish, and laterally there is a dark stripe. It is a pronouncedly

© Árpád Ferincz

© Zoltán Sallai

short-lived species, very rarely living longer than 2-3 years. The largest specimens might grow to 10–15 cm.

It becomes sexually mature in its first year, and breeding occurs between March and June. The males first clean the appropriate surface on the bottom for spawning and, after the eggs are released, they guard the nest and later the hatched fry. The Stone Moroko reproduces several times a year.

An opportunistic feeder, it consumes planktonic crustaceans, insect larvae, worms, organic detritus, and fry. It also consumes carrion, or even gnaws the ill specimens of other fish.

The ecological requirements of the species in Hungary

The Stone Moroko is characterised by broad ecological tolerance, it is barely sensitive to water quality, it can adapt to extremely broad spectrum (Gozlan *et al.* 2002). It even tolerates a fish specific (piscidide) chemical: rotenone (Allen *et al.* 2006). However, it cannot tolerate high salt content, and hence does not occur in brackish water (Scott *el al.* 2007). Although it is categorised as a fish of flowing water bodies, in Hungary it also occurs in lentic waters, and can even becomes super-abundant in stagnant waters.

Ecological problems

Due to its high reproductive output, it can invade habitats in extremely high numbers. Also, as an opportunistic feeder, it is a competitor of all the native fish species. Moreover, it predates the eggs and fry of other fish species. The Stone Moroko transmits an intercellular parasite, *Sphaerothecum destruens*, which seriously threatens native carp (Cyprinidae), and particularly the protected Sunbleak (*Leucaspius delineatus*) (Gozlan *et al.* 2005).

Economic effects

Due to its exceptional invasive potential, it can radically influence the production of fisheries within a single year. It competes for food with all our native fish species. In fisheries where predatory fish are bred, the Stone Moroco might serve as a natural fodder, but the danger its presence pose far exceeds the benefit its presence constitutes.

Methods of control

The extirpation of settled populations is almost impossible, due to the exceptionally high reproduction rate of Stone Moroco, and its high tolerance against piscicide chemical agents. Just a handful of surviving individuals can begin a new invasion. In artificial lakes, the stocking of large amounts of carnivorous fish species might be an effective method for its control. In natural waters at present there is no method to control or limit its spread.

The Stone Moroko is included in the Commission Implementing Regulation (EU) 2016/1141, as an alien Invasive species of European Union concern.

References

Allen *et al.* 2006, Caiola & de Sostoa 2002, Copp *et al.* 2002, Gozlan *et al.* 2002, 2005, Pintér 2002, Scott *et al.* 2007

Ádám Staszny, Vera Lente,
András Weiperth & Árpád Ferincz

Black Bullhead Catfish

Ameiurus melas (Rafinesque, 1820)

Original area of the species

The Black Bullhead Catfish is native to North America, with the northern border of its distribution range in Southern Canada, and the southern border the Gulf of Mexico. Its range extends in the west to the Rocky Mountains, and to the Appalachian Mountains in the east (Page & Burr 1991). In its native range mainly occurs in shallow, muddy, silty water, and often it is found in extremely warm, muddy, oxygen-deficient waters. It primarily inhabits lakes, oxbow lakes, slowly-flowing tributaries, but also occurs in other secondary habitat types such as fish ponds, irrigation canals and water reservoirs (Etnier & Starnes 1993).

The introduction of the species to Europe and Hungary

It was probably introduced to Europe for the first time in 1871, when it was imported to France (Welcomme 1988). The initial phase of its spread and the early introductions are hard to reconstruct, as even the scientific reports did not differentiate the Black Bullhead Catfish from its close relative, the Brown Bullhead (*Ameiurus nebulosus*). By the end of the 1800s it spread to Germany, Belgium and the Netherlands (Wheeler 1978). Today, it has invaded almost the whole of Europe, and self-sustaining populations are reported from Norway to Portugal (Gante & Santos 2002). Besides its introduction to Europe, it also invaded South America (Chile), (Welcomme 1988).

Most of the scientific literature quotes its year of introduction in Hungary equivocally as 1980 (Pintér 1989, Harka & Sallai 2004), but it is possible that it arrived considerably earlier (around 1902) together with the Brown Bullhead Catfish. Its import in 1980 from Italy is precisely documented. Originally the plan was to import the Channel Catfish (*Ictalurus punctatus*), which grows considerably larger, but its fry were confused with the fry of the Black bullhead Catfish. Hence, 30,000 Black Bullhead Catfish fry was mistakenly introduced into the commercial fry fishery at Dinnyés, from where later it was transported to other commercial fisheries of Hungary (Pintér 2002). It now occurs throughout Hungary.

Life history of the species

The Black Bullhead Catfish likes eutrophic and hypertrophic waters, which are rich in nutrients, and have soft, organic matter-rich sediment. It tolerates various pollutants (both organic and inorganic) quite well (Ribiero *et al.* 2008), but it avoids habitats with strong currents and large waves.

It reaches sexual maturity at three years, but there is a difference between the invasive and resident (although alien, but stable, not-growing) populations. The former populations usually reach sexual maturity later, and the individuals are smaller, but the quantity of produced eggs (relative fecundity) is higher. Its spawning period is quite extended, and lasts from May to July. Spawning only begins when water temperature reaches 21 °C. For the mating, the male prepares a small depression into the bottom material, usually near to an object such as aquatic plants, stones or logs. After completing the characteristic nuptial dance, the female oviposits 1000-4500 eggs of 1.5-2 mm diameter into the small depression. The prepared nest with the eggs, and the later hatching fry, are guarded by both sexes, occasionally only by the male (Copp *et al.* 2016). The young fry move together in a group for some months, often near the water surface (these are called ‘fry-clouds’).

The Black Bullhead Catfish is omnivorous, and in its native range, the majority of its diet is composed of aquatic macroscopic invertebrates. In the absence of appropriate invertebrate food, it will consume plant material (threaded algae, fish fodder) (Leunda *et al.* 2008). As the Black Bullhead Catfish grows larger, the frequency of fish eating might increase, but it does not have to be exclusively living individuals. It

can consume considerably larger fish carcasses than its own size, usually beginning from the abdominal cavity; it tears off large chunks from the corpse (Preiszner *et al.* 2020).

The ecological requirements of the species in Hungary

The Black Bullhead Catfish can tolerate extreme environmental conditions (high water temperature up to 35 °C, low oxygen content down to 3 mg / l) for long periods (Ribiero *et al.* 2008). Consequently, the Black Bullhead Catfish occurs in almost every Hungarian water body. Especially large populations have formed in some Tisza River tributaries, and in oxbow lakes in the Transtisza region. It is abundant everywhere in the country around fishery infrastructures (Takács *et al.* 2017b).

It became super-abundant in Hungary in the second half of the 1980s. It is interesting to note that the Black Bullhead Catfish completely replaced the earlier introduced Brown Bullhead (*Ameiurus nebulosus*) that is also able to spread invasively everywhere in Hungary. This phenomenon was described all around Europe, but its reasons are still unknown, and some authors treat it as an accidental coincidence (Copp *et al.* 2016).

Ecological problems

The Black Bullhead Catfish often becomes super-abundant in artificial water bodies (commercial fisheries, fishing lakes, water reservoirs), and in the degraded near natural habitats. In such habitats, it can alter the food-web considerably, and larger specimens can pose a direct predation threat to smaller native protected species, and their young. In the spawning season they might also threaten native fishes with their nest-guarding, sometimes causing injuries to the trespassers.

Economic effects

The damage caused by the Black Bullhead Catfish is aggregated from several factors; it is a direct food competitor for most of the species kept in commercial fisheries, and reduces their yield, but its indirect effect is also very important. The fishing lakes invaded by large numbers of Black Bullhead Catfishes are not frequented by sport fishermen – the tiny and spiky fish are not really popular among them – hence the income potential of local and regional fishing tourism is decreasing. The Black Bullhead Catfish is a vector of several parasites and viruses, e.g. the European Catfish Virus (ECV), that can cause very high mortality in stocks of the European Catfish (*Silurus glanis*), which is a commercially important fish species in Hungary (Varju-Katona *et al.* 2021)

Methods of control

For the control of the Black Bullhead Catfish, local measures are recommended. In the last decades, the use of special Black Bullhead fish traps has become more widespread, and with these and diligent work its numbers can be kept under control. In smaller water bodies, the 'fry-clouds' could be eliminated with nets or electric fishing devices.

Also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

Copp *et al.* 2016, Etnier & Starnes 1993, Gante & Santos 2002, Leunda *et al.* 2008, Page & Burr 1991, Pintér 2002, Preiszner *et al.* 2020, Ribeiro *et al.* 2008, Takács *et al.* 2017b, Varju-Katona *et al.* 2021, Welcomme 1988, Wheeler 1978

Árpád Ferincz, Vera Lente, András Weiperth & Ádám Staszny

Rainbow Trout

Oncorhynchus mykiss (Walbaum, 1792)

Original area of the species

The Rainbow Trout was native to the western coast of North America, and occurred from Alaska to the northern border of Mexico, the Eastern part of Russia, and the northern coast of the Pacific Ocean. There are two forms within the species; one is adapted to living its full life cycle in freshwater, while the other; known as the 'Steelhead' is an anadromous, wandering fish. Except for Antarctica, the Rainbow Trout has been introduced to all the continents, and to at least 99 countries of the globe, either for sport fishing, or to breed in aquaculture. After it had invaded a country, it usually out-competed and displaced native trout species, probably aided by its outstanding competitive ability. In Europe, there are at least 130 self-sustaining Rainbow Trout populations in 16 countries.

The introduction of the species to Europe and Hungary

The exact date of its introduction to Hungary is unknown. Several authors agree that the first transport of Rainbow Trout arrived in Hungary between 1882 and 1884, from Hüningen (now in the territory of France), to the fish hatchery on the estate of Count Pállfy, situated North of Bratislava at Smolenic (then Szomolány) (Lever 1996). By the beginning of the 20th century Rainbow Trout became a popular fish species in Hungary, and was reared at least in 200 fisheries. The rise of the species was abruptly ended by WW1, when the hatcheries were abandoned, and most of the waters (mountain streams) that were appropriate for this species were annexed to other countries. Today in present-day Hungary there are only 3-4 locations, where the Rainbow Trout occur and live in a self-sustaining population (Garadna, Kecső and Jósva Creeks, Tengerszem Lake).

Life history of the species

Its body is elongated and torpedo-shaped. In its dorsal fin there are 3-4 hard, spiny rays and 10-12 soft rays. Between the dorsal and caudal fin there is a fat fin (pinna adiposa). Its colour can change from bluish to olive, and along the lateral line there is a reddish

© Árpád Ferincz

pink broad stripe. The belly is silvery grey, and its back, sides, head and fins are ornamented with tiny black spots, but there is no red among them.

It mainly occurs in the cool waters of mountain streams and creeks, and small running waters, where average water temperature does not exceed 12 °C, even in summer. Although the Rainbow Trout can tolerate higher temperatures than the River Trout's (*Salmo trutta*) maximum tolerated temperature, it gives the Rainbow Trout a competitive edge. For the Rainbow Trout ideal habitats are fast-flowing water bodies with ample pools, and where the waterside vegetation gives shade. Pebbled bottoms are of outstanding importance for the Rainbow Trout, where it can prepare the small depression in the bottom to lay its eggs. Depending on environmental factors, the Rainbow Trout reaches sexual maturity at 3-4 years. In its native range it prefers those waters, where in summer the water discharge decreases, and hence does not wash away the fry (Behnke 1992). The above mentioned two forms (the anadromous sea-run and non-wandering fresh water) differ significantly in their anatomy, and hence were formerly treated as two different species and later as very distinct subspecies (Allendorf & Utter 1979).

The Rainbow Trout is a more aggressive than the River Trout. Young individuals feed on aquatic invertebrates such as flatworms (Turbellaria), larvae of non-biting midges (Chironomidae), lower crustaceans, snails, insects fallen into the water, adults besides invertebrate prey, also consume small fishes.

The ecological requirements of the species in Hungary

In Hungary there are very few water bodies that are adequate for the Rainbow Trout, hence its number is negligible, and self-sustaining populations are only known from a handful of streams.

Ecological problems

As it competes for resources (such as food) and habitats, it can profoundly affect the populations of native salmonids (Scott & Irvine 2000, Van Zwol *et al.* 2012). These negative effects were documented in several habitats. The interactions of the Rainbow Trout and River Trout (*Salmo trutta*) were studied both in the field and in laboratories, and the results proved that the presence of the Rainbow Trout does significantly alter habitat choice and survival of the River Trout (Blanchet *et al.* 2007). It can cause severe damage in the stocks of smaller fish species through predation, and this was proven with the study of *Telestes metohiensis*, a cyprinid native fish species, in Croatia (Zupančič 2008). As the negative effects of the invasive Rainbow Trout are suffered by the native fauna world-wide, the Rainbow Trout is included in the list of the "100 of the World's Worst Invasive Species" (Lowe *et al.* 2000).

Economic effects

The Rainbow Trout is a very important species all over the world, both for sport and food, and this was probably the reason it was introduced to all the continents. Its success is based on several factors; its tolerance of comparatively high water temperature, its ease in it adapting to feed on fish fodder, its fast growth rate, and its tolerance to aquaculture keeping conditions (Crawford & Muir 2008, Halverson 2008, Woynarovich *et al.* 2011).

Methods of control

Hungary is lucky regarding the Rainbow Trout situation, as this species, which possesses outstanding competitive ability, does not find the necessary habitat characteristics in our country, and hence can become only locally invasive. According to the Hungarian legislation (Act No. LIII of 1996. on the protection of Environment and Nature) its release into natural waters is forbidden. If all the managers of waters comply with the law, there will be no serious harm posed by this species in Hungary.

References

Allendorf & Utter 1979, Behnke 1992, Blanchet *et al.* 2007, Crawford & Muir 2008, Halverson 2008, Lever 1996, Lowe *et al.* 2000, Scott & Irvine 2000, Stanković *et al.* 2015, Van Zwol *et al.* 2012, Woynarovich *et al.* 2011, Zupančič 2008

Ádám Staszny, András Weiperth,
Vera Lente & Árpád Ferincz

Western Tubnose Goby

Proterorhinus semilunaris (Heckel, 1837)

Original area of the species

The Western Tubnose Goby is a Ponto-Caspian faunal element, and is native to the basin of the Black Sea, the Sea of Azov and Aegean Sea. Earlier, the two taxa, the Western Tubnose Goby and Tubnose Goby (*Proterorhinus marmoratus*) were regarded as the same species (Dillon & Stepien 2001), hence the Western Tubnose Goby was treated as *P. marmoratus* in the Hungarian scientific works (Harka & Sallai 2004). But later molecular genetic studies proved that in fact there are two species; in fresh water, *P. semilunaris*, while the other, *P. marmoratus* is a marine fish (Stepien & Tumeo 2006). The salt-tolerant (euryhalin) species, *Proterorhinus marmoratus* occurs in the sea, on coastal areas, and in brackish water, while the Western Tubnose Goby *P. semilunaris*, (the species occurring in Hungary), lives only in fresh water, in the great rivers draining the seas (for example Danube, Dniester, Don, Kuban). It occurs in their permanently fresh lower, middle and upper reaches, and also in their tributaries.

The introduction of the species to Hungary

There is no data on its unintentional introduction with fish transport or any other way. It probably got to the Carpathian Basin directly from the lower reach of the Danube called Al-Duna, or from the Middle section of the Danube under Hungary (Ferincz *et al.* 2016b, Takács *et al.* 2017b, Weiperth *et al.* 2013). Most likely, its spread from the south was partly a natural area expansion, and also helped by introduction by the emptying of ballast water of ships (Ahnelt *et al.* 1998). After invading the water systems of the middle and upper reaches of the Danube, it infiltrated the water system of the Main and Rheine Rivers, the upper reaches of Dnieper River and the Vistula and Morava Rivers. It was also introduced with the ballast water of ships into North America, and colonised the Great Lakes and the rivers draining into them (Jude *et al.* 1992, Stepien & Tumeo 2006).

The Western Tubnose Goby was the first alien fish species described from Central Europe. It had probably already been present in the Lower Danube and the section under Hungary when its first specimens were found at Budapest in 1872 (Kriesch 1873). Today its population – due to the fast spread of the other goby species – has decreased in the main channel of the Danube, but it is still very abundant in the tributaries and smaller creeks (Bódis *et al.* 2012, Erős *et al.* 2005, Weiperth *et al.* 2013). Based on country-wide monitoring studies it is the most common goby species of Ponto-Caspian origin. It occurs on the whole Hungarian sections of Tisza and Danube Rivers, also in many tributaries, and has invaded artificial and natural stagnant water bodies (pit lakes, Lake Fertő, Lake Balaton), too (Takács *et al.* 2017b). Its spread is still ongoing in Hungary. It is regarded as the first alien invasive species of Lake Balaton (Ferincz *et al.* 2016a).

© Árpád Ferincz

Life history of the species

The Western Tubnose Goby is one of the smallest fish species in Hungary, the largest individuals rarely reaching 10 cm. Its body and head are flattened from the sides. It possesses two dorsal fins, its caudal fin is rounded and, at its base, there is a brown or black crescent-shaped dot (its latin name – *semilunaris* – refers to this characteristic). The ventral fins are fused into a suction cup, and on its nose there are two nostril tubes, and hence its common name. The lateral line (linea lateralis) is missing. Both the subadult and adult individuals are yellowish, rarely yellowish-brownish, and are ornamented with an irregular dark brown or black pattern. In the spawning period, males become considerably darker, sometimes they turn black. The fins are lighter, but in the spawning period they can become completely dark. Its lifespan is short, usually 2–3 years, 4 years at maximum. Both sexes reach sexual maturity at two years. Spawning lasts from April-July in several cycles. Eggs are laid under some object (rocks, stones, shells, roots, washed out vegetation, logs) on the bottom. It especially likes the holes in artificial rocky obstructions. A very fertile species, females can lay, depending on their size, 80–120 eggs. The male guards the nest till the eggs hatch. It feeds almost exclusively on benthic aquatic invertebrates, e.g. larvae of non-biting midges (Chironomidae), mosquitos (Culicidae), Mayflies (Ephemeroptera), Stoneflies (Plecoptera), they also feed on amphipods (Amphipoda) and water fleas (Cladocera). The larger specimens occasionally feed on fry and small fish.

It is a benthic species; in Hungary it prefers the shallow waters with diverse bottom material. In its habitat choice, seasonal pattern was not documented. In the recently colonised waters it prefers stretches with stony, rocky bottoms, and even artificial rock heaps, but as it is a comparatively small fish, larger gobies (Gobiidae) easily expel it from the optimal habitats. In the waters where it lives in large numbers it might occur in almost all the habitat types, but avoids marshlands and bogs (Erős 2007, Erős *et al.* 2005, 2008b, 2017, Szalóky *et al.* 2014, 2015).

The ecological requirements of the species in Hungary

In Hungary in different water bodies the Western Tubnose Goby does not exhibit significant differences in its habitat choice. In the Rivers Danube and Tisza and in their tributaries it likes natural or artificial rocky substrates, pebbled or stony bottoms, where it can find appropriate hiding places from predators (Erős *et al.* 2005, Szalóky *et al.* 2014, 2015). The larger, and sometimes more aggressive Ponto-Caspian goby species – e.g. the Round Goby (*Neogobius melanostomus*) and Bighead Goby (*Ponticola kessleri*) – that had invaded Hungarian waters later, and became superabundant and now in certain waters, displaced the Western Tubnose Goby from its preferred habitats, the natural and artificial rocky, stony and pebbled bottomed river sections. But it remained widespread and abundant in the tributaries and side branches with sandy or sometimes silty bottom (Bódis *et al.* 2012, Erős 2007, Takács *et al.* 2017b, Weiperth *et al.* 2020).

Ecological problems

It exerts an effect on the native fish fauna through competition for food and habitat. Where its density is high, it can transform the macroscopic water invertebrate communities. Because of its small size it is an ideal prey for several native predatory fishes and large omnivore fishes. It was listed in the diet of European Eel (*Anguilla anguilla*), Asp (*Leuciscus aspius*), Northern Pike (*Esox lucius*), Common Chub (*Sqalius cephalus*), European Catfish (*Silurus glanis*), Ide (*Leuciscus idus*), Volga Pikeperch (*Sander volgensis*), European Perch (*Perca fluviatailis*), Zander (*S. lucioperca*) and Burbot (*Lota lota*). The primarily piscivore Dice Snake (*Natrix tessellata*) also consumes the Western Tubnose Goby.

Economic effects

There is no information regarding its direct economic effects.

Methods of control

According to our present knowledge, it is impossible to extirpate this species from the waters where it has already settled. Its populations might be limited by stocking the waters with a high number of predatory fish.

In closed water systems, such as pit lakes, the application of piscicide chemicals is a theoretical option, but its later reinvasion cannot be prevented even with such a radical intervention

References

Adámek *et al.* 2007, Ahnelt *et al.* 1998, Bódis *et al.* 2012, Dillon & Stepien 2001, Erős 2007, Erős *et al.* 2005, 2008b, 2017, Ferincz *et al.* 2016b, Grabowska *et al.* 2021, Jude *et al.* 1992, Kriesch 1873, Stepien & Tumeo 2006, Szalóky *et al.* 2014, 2015, Takács *et al.* 2017b, Weiperth *et al.* 2013, 2020

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

Monkey Goby

Neogobius fluviatilis (Pallas, 1814)

Original area of the species

The Monkey Goby is native to the Caspian Sea, Black Sea, the Sea of Azov, and the Sea of Marmara (Ponto-Caspian species). It is an euryhaline species, which means it is able to adapt to a wide range of salinities. Therefore, it can inhabit sea shores, and both the brackish and fresh water sections of rivers (Danube, Dniester, Dnieper, Don, Kuban, Bug, Volga, Ural) feeding into the above mentioned seas (Pinchuk *et al.* 2003a). It is a benthic species, preferring shallow, sandy parts of the sea. There is a seasonal pattern in its habitat choice; in the summer it occurs at depths of 0.5–5 m, while in the autumn and winter it prefers deeper parts, and searches for sections 5–10 m deep. In rivers it primarily chooses sections with a sandy bottom, but also occurs on pebble and rock bottoms (Adámek *et al.* 2007, Jurajda *et al.* 2005).

The introduction of the species to Europe and Hungary

Its original area was situated from the Danube Delta to the Iron Gate Hydroelectric Power Plant, and its spread probably started when the construction of the water reservoirs of the Power Plant were completed (Roche *et al.* 2013). The exact date of its introduction to Hungary is unknown, but a large scale invasion was first reported from Lake Balaton in 1970 (Bíró 1971, 1972). As there is no data on its intentional or accidental introduction with fish transport, it probably spread in the Hungarian reach of the Danube even earlier. Probably its invasion from the South might have happened naturally or with ballast-water from ships (Ahnelt *et al.* 1998). It was first described from the Hungarian section of the Danube in 1984, and from the Tisza in 1993 (Pintér 2002). It has now spread into the water systems of the Rhine and Elba Rivers (Roche *et al.* 2015).

Life history of the species

The Monkey Goby is a small fish, in Hungary it only grows to 10–15 cm. It possesses two dorsal fins, and its caudal fin is rounded. Its body is brownish-grey, mottled with dark, merged spots. In the spawning period males become much darker, in some cases they are even black.

© Árpád Ferincz

The Monkey Goby is a short-lived species, with a life-span of only 3–4 years, exceptionally five–six years. It can reach sexual maturity in its second year. Spawning lasts from April to July in repeated cycles. Eggs are laid under objects such as rocks, stones, shells, logs on the bottom. The male guards the nest until the eggs hatch.

It feeds on benthic invertebrates, e.g. larvae of non-biting midges (Chironomidae) and water fleas (Cladocera), and the larger specimens occasionally feed on small fishes.

The ecological requirements of the species in Hungary

In different water types, the habitat choice of the Monkey Goby alters in Hungary, and it can probably be explained by competition. In Lake Balaton it chooses stony habitats offering adequate hiding places from predators. In the River Danube, where it co-occurs with the Bighead Goby (*Ponticola kessleri*) and Round Goby (*Neogobius melanostomus*), it is expelled by them from the stony sections, and more often observed on sandy-pebbled bottoms (Czeglédi *et al.* 2019, Erős *et al.* 2005). It is a species strongly associated with near-shore shallow waters. Its strongest populations are inhabiting River Danube, but also occurs in smaller rivers and canals. It was also found in Lake Balaton and other stagnant water bodies. Similarly to other gobies originating from the Caspian area, we are now witnessing the continuous spread of the Monkey Goby in Hungary.

Ecological problems

It affects the native fish fauna through competition for food and habitats and, where its density is high, it will alter the species composition of the macroscopic invertebrates that it consumes. Being a small fish, it is ideal prey for several native predatory fish species in Hungary such as, European Catfish (*Silurus glanis*), Northern Pike (*Esox lucius*), European Perch (*Perca fluviatilis*), Zander (*Sander lucioperca*), Burbot (*Lota lota*), and also some piscivorous birds (Pinchuk *et al.* 2003a).

Economic effects

There is no information on its direct economic effect. It might influence the choice of sport fishermen, as they avoid waters heavily infested by the Monkey Goby.

Methods of control

According to our present knowledge it is impossible to extirpate this species from the waters where it has already settled. Its populations might be limited by stocking the waters with a high number of predatory fish.

References

Adámek *et al.* 2007, Ahnelt *et al.* 1998, Bíró 1971, 1972, Czeglédi *et al.* 2019, Erős *et al.* 2005, Jurajda *et al.* 2005, Pinchuk *et al.* 2003a, Pintér 2015, Roche *et al.* 2013, 2015

Ádám Staszny, András Weiperth,
Vera Lente & Árpád Ferincz

Round Goby

Neogobius melanostomus (Pallas, 1814)

Original area of the species

The Round Goby (Gobiidae) has a Ponto-Caspian native range that includes the entire Marble and Black Seas and the northern parts of the Azov and Caspian Seas. As an euryhalin species, it can be found in coastal waters including the brackish and freshwater sections of river estuaries (e.g. of the Danube, the Dniester, the Dnieper, the Don, the Kuban, the Bug, the Volga and the Ural Rivers) (Pinchuk *et al.* 2003c).

The introduction of the species to Europe and Hungary

As there is no data either on deliberate or accidental introduction (e.g. by a fish consignment), the most likely is that it made its way from both the lower and upper sections of the Danube into the middle course. From the south, it could possibly travel spontaneously, but it was also aided by shipping (on the surface of the bottom, or with bilge (Ahnelt *et al.* 1998)). After colonising the water system of the Danube, it started spreading successfully in the watershed of the Baltic Sea and it was accidentally shipped to North America where it is also considered a nonindigenous invasive species (Charlebois *et al.* 2001). The exact date of its appearance in Hungary is unknown. Its first specimens were collected in 2001 in the Göd Danube section (1670 fkm) (Guti *et al.* 2003). Since then, it became the most frequent goby in the middle course of the Danube and has been reported from many tributaries (Weiperth *et al.* 2020). In 2017, it was observed in the River Tisza, from where it has explosively spread along the middle course of the river and the adjoining tributaries (Nyeste *et al.* 2017, 2018). From Lake Balaton, it was first reported in autumn 2017 (near Siófok and from the nearby section of the Sió Canal) (Weiperth 2018).

Life history of the species

The Round Goby is a small fish rarely reaching 15-20 cm in Hungarian waters. It has two dorsal fins, the caudal fin is rounded. The pelvic fins are modified


© Árpád Ferincz

into suction discs. Young individuals are slate grey, while mature ones are greyish brown with darker blotches and spots. The greenish front dorsal fin sports a dark brown or black spot. Sexually active males become much darker or even black. The edges of the fins are lighter, but these also darken during the spawning season.

It is a short-lived fish, rarely reaching the age of 6. Males reach maturity in the 2nd , females in the 3rd year of life. Spawning is intermittent, taking place from April to June. The eggs are deposited under rocks, stones, shells, roots or tree trunks in the water. It also prefers cavities created within riprap (artificial rock armour). Its highly fertile, females may lay 200-5200 eggs at a time (dependent on their body size). The male guards the nest until hatching.

The typical diet includes benthic invertebrates such as oligochaetes, he insect larvae (Chironomidae, Ephemeroptera and Plecoptera), and crustaceans (Cladocera, Amphipoda), while larger individuals may feed on the eggs and smolt of other fish. It's a benthic species preferring shallow, sandy marine habitats. Seasonal shifts have been observed in habitat preference. During the summer, it inhabits shallower (1-1.5 m deep) sites, while in autumn and winter it frequents deeper (5-20 m deep) parts. It finds ideal circumstances wherever larger rocks, pebbles or even riprap abounds both in seas and rivers, but where it occurs as an alien species, it also occurs in habitats with fine gravel or sand (Ádámek *et al.* 2007, Erős 2007, Erős *et al.* 2008b, 2017, Szalóky *et al.* 2014, 2015, Jurajda *et al.* 2005).

The ecological requirements of the species in Hungary

There are no tangible differences among different sites colonised by the Racer Goby in niche requirements. In the Danube, as well as in the Tisza and their tributaries, it prefers habitats with fine gravel, sand, less often naturally rocky or stony or pebbled riverbeds, where it finds shelter from predators (Erős *et al.* 2005). At the same time, it can often be found in high numbers in silty or sandy sections where tributaries join the Danube and the Tisza (Bódis *et al.* 2012, Nyeste *et al.* 2018, Weiperth *et al.* 2013, 2020). Wherever it finds optimal conditions, it abounds both in the shallows and in the deeper, inner parts of the riverbed (Szalóky *et al.* 2014, 2015). The largest populations are found in the Danube and its tributaries, but it also occurs in other rivers and canals and is on the rise. It has also been reported from deep, clear-watered excavation pits near the Balaton (Balog *et al.* 2021).

Ecological problems

Its main impact is exerted via competition for food and habitat with native fishes. As other Ponto-Caspian gobies, it is a significant competitor of the European Bullhead (*Cottus gobio*). Furthermore, wherever it reaches high abundances, it re-shapes the macroinvertebrate fauna contributing to its staple diet. Due to its small size, many native predatory fish feed on it. According to previous studies, the Eel (*Anguilla anguilla*), the Asp (*Leuciscus aspius*), the Northern Pike (*Esox lucius*), the European Catfish (*Silurus glanis*), the Volga Pikeperch (*Sander volgensis*), the European Perch (*Perca fluviatilis*), the Pikeperch (*Sander lucioperca*) and the Burbot (*Lota lota*), as well as fish-eating reptiles and birds regularly prey on it (Pinchuk *et al.* 2003c, Weiperth *et al.* 2014b).

Economic effects

There is no information available on direct effects. To a small extent, it may have a negative effect on angling tourism by diminishing interest in waters where it abounds.

Methods of control

Wherever it has established, there are no known methods of exclusion presently. In isolated water bodies, it may be controlled by the introduction of large predatory fish, or by the use of biocides, but none of these interventions can prevent recolonization.

References

Ádámek *et al.* 2007, Ahnelt *et al.* 1998, Balogh *et al.* 2021, Bódis *et al.* 2021, Charlebois *et al.* 2001, Erős 2007, Erős *et al.* 2005, 2008b, 2017, Guti *et al.* 2003, Jurajda *et al.* 2005, Nyeste *et al.* 2017, 2018, Pinchuk *et al.* 2003c, Szalóky *et al.* 2014, 2015, Weiperth 2018, Weiperth *et al.* 2013, 2014b, 2020

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

Racer Goby

Babka gymnotrachelus (Kessler, 1857)

Original area of the species

The Racer Goby (Gobiidae) has a Ponto-Caspian native range that includes the entire Marble and Black Seas and the northern parts of the Azov and Caspian Seas (Frejhof & Kottelat 2008). As an euryhalin species, it can be found in coastal waters including the brackish and freshwater sections of river estuaries (e.g. of the Danube, the Dniester, the Dnieper, the Don, the Kuban, the Bug, the Volga and the Ural Rivers) (Pinchuk *et al.* 2003b).

The introduction of the species to Europe and Hungary

As there is no data either on deliberate or accidental introduction (e.g. by a fish consignment), the most likely is that it made its way from both the lower and upper sections of the Danube into the middle course. From the south, it could possibly travel spontaneously, but it was also aided by shipping (on the surface of the bottom, or with bilge (Weiperth *et al.* 2013). Its first Hungarian record from the Szigetköz shows that invasive gobies transported by ships to the upper sections of the Danube may successfully colonise the lower sections from there on. After the Danube water system, the species appeared in the watershed of the Baltic Sea and is thus spreading (Jaroszewska *et al.* 2008). The exact date of its appearance in Hungary is unknown. The first two specimens were collected in the northern part of the Szigetköz (in the so-called Cikola watershed system) in 2004 (Guti 2005). Later on, it appeared from the direction of the lower Danube section and as of today, it is present across the entire Hungarian section as well as in a number of tributaries (Bódis *et al.* 2012, Takács *et al.* 2017b, Weiperth *et al.* 2010b, 2020). Also, it was reported to be spreading along the Tisza watershed system (Sallai *et al.* 2019, Sallai & Sallai 2020).

Life history of the species

The Racer Goby is a small fish rarely reaching 12-15 cm in length in Hungarian populations. It has two dorsal fins, the caudal fin is rounded. The pelvic fins

© Árpád Ferincz

are modified into suction discs. Its body is yellowish grey with darker spots. It can be distinguished from the Monkey Goby (*Neogobius fluviatilis*) by the oblique dark bands on the body. Another distinctive characteristic is that the front of the preoperculum is naked, as are the opercula, the bases of the pectoral fins and the throat in front of the pelvic fins. On each side of the head, there are 3 darks bands (Harka & Sallai 2004). The entire body becomes darker in the spawning season.

It is a short-lived fish, rarely reaching the age of 5. Maturity is reached in the 2nd year of life. Spawning is intermittent, taking place from April to July. The eggs are deposited under rocks, stones, shells, roots or tree trunks in the water. It also prefers cavities created within riprap (artificial rock armour). Its highly fertile, females may lay 100-2000 eggs at a time (dependent on their body size). The male guards the nest until hatching. The typical diet includes benthic invertebrates such as oligochaetes, insect larvae (Chironomidae, Ephemeroptera and Plecoptera), and crustaceans (Cladocera, Amphipoda), while larger individuals may feed on the eggs and smolt of other fish. It's a benthic species preferring shallow, sandy habitats both in salt- and in brackish water. It finds ideal circumstances wherever larger rocks, pebbles or even riprap abounds, but is often excluded from such microhabitats by the larger Bighead Goby (*Ponticola kessleri*) and the Round Goby (*Neogobius melanostomus).* It easily colonises riverbed sections with sand or gravel where it often co-exists with the Monkey Goby (Adámek *et al.* 2007, Erős 2007, Erős *et al.* 2008b, 2017, Szalóky *et al.* 2014, 2015).

The ecological requirements of the species in Hungary

There are no tangible differences among different sites colonised by the Racer Goby in niche requirements. In the Danube, as well as in the Tisza and their tributaries, it prefers habitats with fine gravel, sand, less often naturally rocky or stony or gravelled riverbeds (Bódis *et al.* 2012). It is most common in the shallows near riverbanks (Erős *et al.* 2017, Szalóky *et al.* 2014, 2015). Its largest populations can be found in the Danube and its tributaries, but it occurs in other rivers and canals, too, and is currently on the rise across the entire Hungarian water system (Bódis *et al.* 2012, Takács *et al.* 2017b).

Ecological problems

Its main impact is exerted via competition for food and habitat with native fishes. As other Ponto-Caspian gobies, it is a significant competitor of the European Bullhead (*Cottus gobio*). Furthermore, wherever it reaches high abundances, it re-shapes the macroinvertebrate fauna contributing to its staple diet. Due to its small size, many native predatory fish feed on it. According to previous studies, the Asp (*Leuciscus aspius*), the Northern Pike (*Esox lucius*), the European Catfish (*Silurus glanis*), the Volga Pikeperch (*Sander volgensis*), the European Perch (*Perca fluviatilis*), the Pikeperch (*Sander lucioperca*) and the Burbot (*Lota lota*), as well as the Dice Snake (*Natrix tessellata*) regularly prey on it.

Economic effects

There is no information available on direct effects.

Methods of control

Wherever it has established, there are no known methods of exclusion presently. In isolated water bodies, it may be controlled by the introduction of large predatory fish, or by the use of biocides, but none of these interventions can prevent recolonization.

References

Adámek *et al.* 2007, Bódis *et al.* 2012, Erős 2007, Erős *et al.* 2017, Freyhof & Kottelat 2008, Guti 2005, Harka & Sallai 2004, Jaroszewska *et al.* 2008, Jurajda *et al.* 2005, Pinchuk *et al.* 2003b, Sallai *et al.* 2019, Sallai & Sallai 2020, Szalóky *et al.* 2014, 2015, Takács *et al.* 2017b, Weiperth *et al.* 2010b, 2013, 2020

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

Bighead Goby

Ponticola kessleri (Günther, 1861)

Original area of the species

A Ponto-Caspian goby originating from the western coast of the Black Sea and its brackish estuaries, the Caspian Sea and in the Volga Delta. It was not known from the Azov Sea and its watershed. It typically inhabits the benthic habitats of the coastal zone, with rocky-stony surfaces overgrown with aquatic plants. It is rarely found in habitats with sand or shell sand (Vassilev *et al.* 2012).

The introduction of the species to Europe and Hungary

Originally it was a common species in the Danube Delta, dispersing upstream until about the Iron Gates Gorge. Until the 1960s, there were only a few records of it from upper sections (until about Banatska Palanka). Its spread started to intensify from the 1970s, and by 1986, it was present across the entire Yugoslavian section (Roche *et al.* 2013). In the first edition of the book *'Magyarország halai'* ('Fishes of Hungary') Károly Pintér assumes its presence based on catch data (Pintér 1989), but the first specimen identified with certainty was caught only in 1996 near Dömös (Erős & Guti 1997).

Life history of the species

Adults in their 3rd-5th year of life may reach 17 cm in length. The species inhabits the riverbank zone and smaller estuaries where the salt content does not exceed 3‰ (Erős *et al.* 2005, Vassilev *et al.* 2012). Individuals of invasive populations may reach maturity during their 1st year of life. The spawning season is extended from April to June, and the females lay eggs several times within the season, altogether usually 2,000-3,000. The eggs are most often deposited on rocks or shells. Like in other gobies, the eggs are guarded by the male until they hatch (Kováč *et al.* 2009).

Its diet mainly consists of crustaceans (Gammaridae), isopods (Asellidae) and to a lesser extent, other macroscopic invertebrates. This largely overlaps with the diet of other gobies. Larger individuals may consume significant amounts of fish (Borza *et al.* 2009). Its diet is most similar to that of

© Árpád Ferincz

© Zoltán Sallai

the Round Goby (*Neogobius melanostomus*). Larger bighead gobies prey on smolt more often than other invasive gobies (Borza *et al.* 2009, Brandner *et al.* 2013).

The ecological requirements of the species in Hungary

After it got established within the Hungarian Danube section, the Bighead Goby population sharply increased. However, as the Round Goby (*Neogobius melanostomus*) is a stronger competitor, it eventually ousted the bighead from its preferred rocky microhabitats (Borcherding *et al.* 2013). For this reason, the Bighead Goby population of the Danube eventually stabilized at a lower abundance than earlier (Szalóky *et al.* 2015). Apart from the entire Hungarian section of the Danube, it is also established in the Rába and the Ipoly Rivers, as well as in the estuarine zones of smaller tributaries.

Ecological problems

The Bighead Goby, like other Ponto-Caspian gobies, may significantly reshape the aquatic macroinvertebrate fauna by its predatory habits. This impacts those native and protected fish species the most, whose life strategies are similar, such as the European Mudminnow (*Cottus gobio*) and the Danube Ruffe (*Gymnocephalus baloni*), and the Striped Ruffe (*G. schraetser*) which have similar diets.

Economic effects

There is no information available on direct effects. Along with other gobies – especially the Round Goby (*Neogobius melanostomus*) –, it causes inconvenience for Danube anglers. It must be noted, however, that it is gastronomically excellent quality without fishbones and in its native range larger individuals are a preferred catch.

Methods of control

It spreads mostly spontaneously within the partial catchment areas and for this reason, the possibility of control is much constrained. It is also transported to larger distances (between catchment areas) by shipping (stuck to the hull or in the bilge). If at least this could be prevented, long-distance dispersal would be significantly reduced (Roche *et al.* 2013).

References

Borcherding *et al.* 2013, Borza *et al.* 2009, Brandner *et al.* 2013, Erős & Guti 1997, Erős *et al.* 2005, Kováč *et al.* 2009, Roche *et al.* 2013, Pintér 1989, Szalóky *et al.* 2015, Vassilev *et al.* 2012

Árpád Ferincz, Vera Lente,
András Weiperth & Ádám Staszny

Caucasian Dwarf Goby

Knipowitschia caucasica (Berg, 1916)

Original area of the species

The Caucasian Dwarf Goby has a Ponto-Caspian native range that includes the Black, the Azov, the Aegean and the Caspian Seas. Its westernmost distribution stretches over the western coast of Greece. As a euryhalin species, it can be found in coastal waters, brackish waters, lagoons and seaside ponds, and it also spreads into the lower course of estuaries.

The introduction of the species to Europe and Hungary

It is native in Ponto-Caspian and Mediterranean Europe. In its native range, it is relatively common (Berg 1949, Ahnelt *et al.* 1995). There is no data on deliberate introduction. It possibly spreads accidentally with fish consignments and spontaneous expansion from lower river sections. The first record from the Carpathian Basin is from 2009 from the River Szamos (Halasi-Kovács & Antal 2011, Halasi-Kovács *et al.* 2011). This first appearance raises a lot of questions, as the nearest known occurrence at the time was located almost 1940km away (the Danube Estuary at the Black Sea). In 2012, it was reported from the Tisza Lake (near Tiszafüred), providing evidence of its spread within the watershed (Harka *et al.* 2012). Subsequent monitoring detected it along the entire Hungarian section of the Tisza and within many tributaries (Halasi-Kovács *et al.* 2015, Takács *et al.* 2017b).

Life history of the species

The Caucasian Dwarf Goby is the tiniest fish in Hungary. On average, it hardly reaches 5 cm in length and males are smaller than females. The top of the head, the opercula and the bases of the pectoral fins are naked. Within the spawning season, males are light brown with 4-5 vivid vertical bars. A short-lived species, their lifespan is 1-2 years on average (rarely 3). Both sexes are mature within the first year of life. The reproductive season is intermittent, lasting from April to July, when water temperatures fall between 15–27 °C (Kevrekidis *et al.* 1990). The eggs are deposited under rocks, stones, shelves, shells, roots or tree trunks in the water. It also prefers cavities created within riprap

© Zoltán Sallai

(artificial rock armour). Its highly fertile, and despite their small size, females may lay 60-200 eggs at a time (on one occasion, 1389 eggs were counted (Gheorghiev 1964).). The male guards the nest until hatching. On account of its small size, its diet almost exclusively consists of benthic invertebrates (larvae of the groups Chironomidae, Culicidae, Ephemeroptera and Plecoptera), as well as crustaceans (Amphipoda, Cladocera) and benthic algae. The Caucasian dwarf goby is a benthic species itself, frequenting shallows with diverse substrates. There is a seasonal shift in its habitat preference. In newly colonised waters, it may occupy any microhabitat, but it prefers rocky, stony parts, including riprap. Due to its small size, it's a weak competitor, and easily gets excluded by larger invasive gobies. Wherever it is abundant, its occurrence may be expected in any habitat type (Harka *et al.* 2012).

The ecological requirements of the species in Hungary

There are no tangible differences among different sites colonised by the Racer Goby in niche requirements. In the Tisza and its tributaries, it prefers naturally rocky, stony or gravelled habitats, where it finds shelter from predators. Subsequently occurring, larger and generally more aggressive Ponto-Caspian gobies, such as the Racer Goby, the Round Goby (*Neogobius melanostomus*) and the Monkey Goby (*Neogobius fluviatilis*) often exclude it from its preferred sites, forcing it to suboptimal (sandy, silty) sections of tributaries and inlets.

Ecological problems

There is no information on its impact on the native fish fauna. Where it reaches high abundances, it may modify the aquatic macroinvertebrate fauna on which it preys. Due to its small size, it presents an ideal prey type to native predatory fishes and the young or mature individuals of larger, omnivorous fishes.

Economic effects

There is no information available on direct effects.

Methods of control

Wherever it has established, there are no known methods of exclusion presently. On account of its small size, it can easily hide from predators, but is preyed upon both adults of smaller predatory fish as well as the young of larger fish. In isolated water bodies, it may be controlled by the use of biocides, but such interventions cannot prevent recolonization.

References

Ahnelt *et al.* 1995, Berg 1949, Gheorghiev 1964, Halasi-Kovács & Antal 2011, Halasi-Kovács *et al.* 2011, 2015, Harka *et al.* 2012, Kevrekidis *et al.* 1990, Takács *et al.* 2017b

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

Chinese Sleeper

Perccottus glenii Dybowsky, 1877

Original area of the species

The Chinese Sleeper is native to East Russia, Northeast China and to the northeastern part of the Korean Peninsula (Reshetnikov 2010). The Hungarian name (meaning 'Amur Sleeper') signals the geographical origin of the species that is mostly contained by the watershed area of the middle course of the River Amur. The species was also originally distributed in the Rivers Sungari and Ussuri, as well as in the Lake Hanka and the River Tugur in Siberia (Courtenay 2006).

The introduction of the species to Europe and Hungary

An exact date can be put to the European introduction of the species. I. L. Zalivskiy transported specimens from the Southeast Siberian Zeya River to Saint Petersburg in 1912. In 1916, four specimens were translocated into a garden pond, from where the species soon spread to nearby water bodies (Makhlin 1990). Later on, specimens were repeatedly introduced to Europe, sometimes deliberately, on other occasions by accident, mixed in with transports of economically important fish stocks. The spread of the species may be very quick, as it can spread spontaneously within water systems, however, it requires human intervention to 'skip' from one system to another. In Eastern Europe, it was first recorded in Poland (1993), and then in Slovakia in 1998.

The first Hungarian record is from 1997, from the Tisza Lake (Harka 1998). During the past twentysome years, it has spread very quickly across the Tisza watershed. Presumably, it was transported with an Eastern Hungarian fish consignment to the watershed of Lake Balaton in the 2000s, and it also appeared both in the Danubian Plain and the

© Árpád Ferincz

Dráva watershed (Takács & Vitál 2012, Takács *et al.* 2015a), as well as the Dunamellék (Erős *et al.* 2008a).

Life history of the species

The Chinese Sleeper is a small, stocky fish, hardly reaching 25 cm in length. The fins are large and rounded. The two dorsal fins are separated. The semi-inferior mouth is large.

In its native habitat, spawning lasts from May to June, however, this period is much extended across the invaded areas, including Hungary: it may last from April until August, during which an individual may spawn more than once. It reaches maturity at the age of 1-3 years. Reproductively active males are darker, their forehead becomes swollen.

The Chinese Sleeper is a generalist, voracious predator feeding on microscopic crustaceans, insects, molluscs, fish and amphibians.

The ecological requirements of the species in Hungary

An opportunistic species with broad ecological tolerance, preferring stagnant waters and canals rich in waterweeds. However, as it is not really sensitive in terms of habitat characteristics, it may well proliferates in fishponds and mires. It tolerates well the lack of oxygen. Nowadays, it is regarded as the most aggressively spreading alien invasive fish in Hungary. It is extremely common in the Tisza watershed, but it was also observed in Transdanubian waters (primarily within the Balaton watershed) at an increasing frequency and abundance.

Ecological problems

Where it appears and is able to reach high abundances, it significantly reduces the diversity of native fauna. The negative impact is most dramatic for other fish species, newts and frogs. The Chinese sleeper feeds on the most abundant prey type, routinely switching from one prey species to another. It may well cause local extinction in several native fishes with a high nature conservation value, such as the European Mudminnow (*Umbra krameri*), the Sunbleak (*Leucaspius delineatus*), the Crucian Carp (*Carassius carassius*) and the European Bitterling (*Rhodeus amarus*). This is the consequence of direct predation combined with efficient competition for food (Košco *et al.* 2003). As its habitat requirements are generally overlapping with those of protected and strictly protected native species, it causes serious problems in oxbow lakes, excavation pits and canals, too. It is most harmful for European Mudminnow population viability.

Economic effects

There is no actual data available on economic effects in Hungary, it is presently regarded as a threat to nature conservation objectives. It is worth mentioning, however, that it was shown to cause significant damage in the stocks of two economically highly valuable fishes in the Selenga River (Lake Baikal watershed), namely the Siberian Roach (*Rutilus rutilus lacustris*) and the Siberian Dace (*Leuciscus leuciscus baicalensis*) (Litvinov & O'Gorman 1996).

Methods of control

There are no known methods that would have proved efficient. The only possibility is the prevention of introduction. To achieve this, strictly observed regulations are needed in the control of fish consignments. Furthermore, there should be no consignments from 'infested' water systems to those which are still free from the Chinese Sleeper. Also, raising awareness in fishing and angling communities is imperative, partly to enable them to identify the species, partly to inform them not to use it as live bait, and in general, to not support the spread of the species in any way (Ferincz *et al.* 2019).

The rapid spread of the Chinese Sleeper is a spectacular example of the threats imposed by the translocation of fish stocks, especially if we bear in mind that the subsequent extirpation of a fish species is impossible even from a smaller water body, such as the Marótvölgyi Canal.

The Chinese Sleeper is listed in the Implementing Regulation 2016/1141/EU as an invasive alien species of Union concern.

References

Courtenay 2006, Erős *et al.* 2008a, Ferincz *et al.* 2019, Harka 1998, Koščo *et al.* 2003, Litvinov & O'Gorman 1996, Makhlin 1990, Reshetnikov 2010, Takács & Vitál 2012, Takács *et al.* 2015a

Ádám Staszny, András Weiperth,
Vera Lente & Árpád Ferincz

Common Sunfish

Lepomis gibbosus (Linnaeus, 1758)

Original area of the species

The Common Sunfish is native to the eastern coast of North America, from St. Lawrence Bay to South Carolina and to the Great Lakes and the Hudson Bay area, as well as in the upper Mississippi Basin (Fuller & Cannster 2022). Today, it is also widespread in Europe, Africa, South and North America, outside its original range (Page & Burr 2011).

The introduction of the species to Europe and Hungary

The species was introduced to Europe at the end of the 1800s. As of today, it is present in at least 28 European and Asia Minor (Copp & Fox 2007). It has originally arrived at the continent as an ornamental fish, but later on it was also involved in fish farming. It was imported from Germany to Hungary (to the Iharos fish ponds) in 1905 and in 1909, the first individual was already caught from Lake Balaton (Vutskits 1912). Later on, it appeared in a range of natural water bodies, reservoirs and angling ponds (Harka & Sallai 2004). By now, it can be found in most water bodies across the country.

Life history of the species

The body is explicitly compressed laterally, and is characterized by a very high back. While it can reach the lengths of 40 cm in its native range, individuals rarely grow longer than 15 cm within Hungary. The eyes are relatively large, the snout is short. The dorsal fin has 10 sharp and 10-13 soft rays, the number of scales along the lateral line is between 37 and 41. The colour is generally bluish green with orange spots. Mature individuals are characterized by the black and red skin appendixes. It reaches maturity around the age of 2-3 years. In Hungary, the reproductive season starts in mid-May, but only if water temperatures exceed 20 °C. It may spawn twice within a season for which it creates a nest that is later guarded by the male (as are, of course, the offspring).

Immatures feed on zooplankton, but gradually switch to the consumption of aquatic invertebrates. Mature individuals feed on insect larvae, snails, shellfish, small fish and fry. Feeding on fish eggs has also been recorded.

The ecological requirements of the species in Hungary

The Common Sunfish prefers habitats with abundant submerged aquatic plants and other vegetation. It occurs both in flowing and stagnant waters, but it does prefer slow flows. At several locations, it has adapted to the native fauna and stabilized at a low abundance. Occasionally though, it reaches high abundances and local invasions. In freshly formed, small water bodies it often becomes dominant and overabundant. Still, following the introduction of other fish species, it retreats. A potential cause for its success lies in its territorial aggressivity.

Ecological problems

The Common Sunfish exerts most of it impact on native fish fauna by competition which is evident in several countries (www.cabi.org). Studies carried out in the UK provided evidence that both the Common Roach (*Rutilus rutilus)* and the Gudgeon (*Gobio gobio*) switched to more specific diets in the presence of the Sunfish. Furthermore, growth and condition parameters worsened in case of the gudgeon (Copp *et al.* 2017). Similar results were found in case of the European Perch (*Perca fluviatilis*): while Sunfish diet was dominated by chironomid larvae, perch diet shifted more towards zooplankton (Fobert *et al.* 2011). Observations also showed that Sunfish are extremely aggressive when feeding, fighting off other fishes from the food sources available (Almeida *et al.* 2014).

© Árpád Ferincz

Economic effects

Presently there is no known significant, direct impact on the economy. It used to be popular with aquarists and anglers used it as a live bait for predatory fish, but this is now forbidden. Its presence has no tangible impact on the profitability of fishpond management.

Methods of control

There is very little information about the possibilities of control. Based on currently available data, the Hungarian range of the Common Sunfish might extend with proceeding climate change (water temperatures shall get higher). The only method known to be efficient is the prevention of the species being introduced to presently Sunfish-free habitats. Native predatory fish, e.g. the northern pike (*Esox lucius*) and the Pikeperch (*Sander lucioperca*) may be efficient in stabilizing Common Sunfish populations, thus, their populations must be sustained. Some authors have suggested very low water levels to allow drying out or the application of selective biocides (e.g. rotenon) (van Kleef *et al.* 2008), but these methods are not only drastic for the Common Sunfish but likewise to our native fauna.

Also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

Almeida *et al.* 2014, Copp & Fox 2007, 2017, Fobert *et al.* 2011, Fuller & Cannster 2022, Harka & Sallai 2004, Page & Burr 2011, van Kleef *et al.* 2008, Vutskits 1912

Ádám Staszny, Vera Lente,
András Weiperth & Árpád Ferincz

Largemouth Black Bass

Micropterus salmoides (Lacepède, 1802)

Original area of the species

The Largemouth Black Bass is native to the Mississippi watershed, to the St. Lawrence River and to the water system of the Great Lakes (with the exception of the Upper Lake). The northern border of its range is between Quebec (Canada) and Minnesota (USA), while it stretches as south as the Gulf of Mexico. Towards the west, it stretches to the Midwest, the eastern border being the Atlantic Ocean (Page & Burr 2011). Nowadays, it is present across the entire territory of the USA, and in every continent (except the Antarctica), altogether in 50 countries (Brown & Grant 2009). In its native habitats, it prefers shallow, easily warming but very clear waters with emergent or submergent aquatic vegetation. It is also characterised by a daily dynamic: individuals spend the day in deeper (2.5-7m) parts and move to the shallows to feed during the night (Sammons & Maceina 2005).

The introduction of the species to Europe and Hungary

From the second half of the 1800s, it was widely introduced to Europe from the east coast of the USA. Its introduction to France and Belgium in 1877 was documented (Keith & Allardi 1998). Even though it was already introduced to Austria in 1883, the first documented Hungarian introduction originates only from 1909 (Vutskits 1910, Takács *et al.* 2017b). However, as it was recorded from the Danube, the Dráva and the Balaton in 1913, an earlier arrival can

© Zoltán Sallai

be presumed. It came from Germany to Hungary, first being imported to the Somogysárd fishery (Pintér 2002).

Life history of the species

Generally prefers warmer waters, the optimal temperature for growth is between 24–30 °C. However, it survives in colder waters, too, weathering out even half a year under ice. It tolerates well the lack of oxygen, but avoids sites with concentrations below 3 mg/l. For a short period, it may survive the concentration 1,5 mg/l, but dies promptly below 1 mg/l. An explicitly freshwater-dwelling species, but mature individuals were found occasionally in brackish waters. The Largemouth Black Bass is a visual predator, thus avoiding turbid waters with high concentrations of suspended material. Its optimum is in the range of 5–25 mg/l, as for total suspended material (Brown & Grant 2009).

The age of maturity is strongly dependent on the climate, happening later in cooler, earlier in warmer climates, but it generally falls between the 1st and 3rd year of life. Spawning takes place if the water is at least 15 °C, but in warmer regions it can reproduce at up to 25 °C. The male builds a nest in a sheltered part of the water with different underwater objects (e.g. close to submerged tree trunks), by clearing a large part of the bed (60-90 cm in diameter). The female deposits a very variable number of eggs. The male aggressively defends the nest until the young hatch. One female might mate with several males (Weyl & Hecht 1999, Brown & Grant 2009).

The Largemouth Black Bass is an opportunistic predator with a highly plastic diet. As it reaches the length of 7 cm, it already starts feeding on smaller fish, and when it exceeds the length of 10-12 cm, it starts feeding exclusively on fish and crayfish (Decapoda). This scheme is largely modified by food resources in a given habitat (Garcia-Berthou 2002).

The ecological requirements of the species in Hungary

A successful invasive across the world, the Largemouth Black Bass has very few viable populations in Hungary (e.g. in the Bokod Reservoir, the water system of the Ráckevei-Soroksári Danube, the Délegyháza Lakes). Despite the active establishment of large populations throughout the 20th century, it only occurs in certain reservoirs, clear-watered excavation pits and irrigation channels with lush vegetation cover. The size and stability of intentional populations is varied, and each one is under pressure from angling. This withdrawal is partly due to the evident climatic conditions, but mostly to the fact that Hungarian stagnant waters are characterized by higher concentrations of suspended material than is optimal for this species.

Ecological problems

The species presents an extremely high ecological risk causing serious losses to nature conservation assets across the globe (Pereira & Vitule 2019). It can exert significant predatory pressure at all levels of the food network, often causing the local extinction of native species (mostly fish and decapods). The Largemouth Black Bass is culpable for the extinction of the Atitlan Grebe (Podilymbus gigas), once endemic to a mountain lake in Guatemala (Jackson 1976). For the above reason, the Largemouth Black Bass is included in the list '100 of the World's Worst Invasive Alien Species' (Lowe *et al.* 2004).

Economic effects

It is difficult to estimate the direct economic damage it causes. According to the international literature, its main impact is exerted via the modification and decrease of natural fishing catches (Pereira & Vitule 2019). However, the species is very popular with anglers worldwide and thus may have a slight positive economic effect, too. This is notably much less than the damages caused to biodiversity.

Methods of control

As in Hungary it is only present in isolated populations unable to spread spontaneously, it can efficiently be controlled by prohibiting further introductions (Pereira & Vitule 2019). Even though it is a popular target of spinning fishing, this cannot justify its introduction to new habitats, due to the extreme ecological risk and the high invasive potential. As a consequence of global warming, the state of natural water bodies in Hungary shall change in unexpected ways. This in itself is advantageous for biological invasions and can easily bring about circumstances that trigger the spread of this species, too (Mungi *et al.* 2018).

References

Brown *et al.* 2009, García-Berthou 2002, Jackson 1976, Lowe *et al.* 2004, Mungi *et al.* 2018, Page & Burr 2011, Pereira & Vitule 2019, Pintér 2002, Sammons & Maceina 2005, Takács *et al.* 2017b, Vutskits 1910, Weyl & Hecht 1999

Árpád Ferincz, András Weiperth,
Vera Lente & Ádám Staszny

Jaguar Guapote

Parachromis managuensis (Günther, 1867)

Original area of the species

The Jaguar Guapote is native to Central America, where it is widespread in the water systems of Costa Rica, Honduras and Nicaragua. Originally, it inhabits estuarine marshlands, oxbows and the temporary or permanent channels connecting these (Bussing 1987, Nico *et al.* 2022c).

The introduction of the species to Europe and Hungary

Both in terms of Europe of Hungary, the exact circumstances are ambiguous. Based on the known data on the introduction of a closely related species, *Parachromis friedrichsthalii*, it is presumed that the first specimens of the Jaguar Guapote may have appeared in Europe during the 20th century (Novák *et al.* 2020). The species appeared in international pet trade during the second half of the 1980s, when it was imported to Cuba and North America. After it spread across the network of global pet trade, it was soon reported from the wild in an increasing number of tropical countries (Australia, Brazil, the Philippines, China, Singapore, Taiwan and several member states of the USA) (Barros *et al.* 2002,

© Árpád Ferincz

Holmes *et al.* 2020, Nico *et al.* 2022c, Shafland 1996). The first Hungarian record is from 2015 from the outlet of the Hévízi Lake (Takács *et al.* 2015b, 2017a, 2017b), where by now it has established a self-sustaining population. It is also widespread across the Kis-Balaton Water Protection System. Apart from the western watershed of the Balaton, single specimens were found in several thermal waters or lakes impacted by industrial hot water (e.g. the Városliget Lake in Budapest, a pond in Margaret Island), as well as one from the River Garam and from a Danube branch (near the Kopaszi-dam).

Life history of the species

The Jaguar Guapote is a relatively large cichlid: it may reach the length of 50-55 cm and the weight of 2.5 kg. The body is stocky, moderately flattened from the sides, slightly elongated. Its basic colour varies from silvery and light bluish green to light purplish bronze. The head is often yellowish or reddish. As its name signals, the pattern of the body and head resembles that of the jaguar, consisting of blotches and spots of various shapes and sizes. In older specimens, the pattern extends onto the fins, too. Young fish are significantly different from mature ones. Several dark, vertical stripes decorate their backs down to the lateral line, which, in case of females are more persistent. This camouflage is perfect for the dense underwater vegetation characterising both its aquatic or temporarily flooded habitats. Females often sport an almost continuous black stripe running horizontally along their lateral line. This black (or sometimes dark brown) stripe is always missing in males that are larger and more colourful than the females, while their dorsal and anal fins are pointed (as opposed to the rounded fins of the females).

Jaguar Guapotes are predatory fish, feeding almost exclusively on animals both in their native and in their colonized ranges. Young individuals feed on planktonic crustaceans first, then switch to larger aquatic invertebrates (invertivory). In an optimal habitat, their growth is quick, meaning when a few months old, their diet already includes smaller fish, fish eggs and large invertebrates such as the larvae of dragonflies (Odonata) and beetles (Coleoptera). Older individuals consume macroscopic aquatic invertebrates, terrestrial invertebrates falling into the water, as well as the offspring and mature individuals of fish and amphibians.

Due to its quick growth, the Jaguar Guapote reaches maturity before its 2nd year of life. At spawning, it deposits the orange-coloured eggs upon a thoroughly cleaned underwater object (a rock, a root, a piece of concrete). Its reproductive rate is extremely high: a larger female may lay 4,500-6,000 eggs at once. As soon as the eggs hatch, the parents carry their offspring into a cavity dug into the bed. Both parents aggressively defend the offspring, while the male also guards the perimeter (occasionally a total of 1-1.5 m^2).

The ecological requirements of the species in Hungary

The Jaguar Guapote quickly becomes dominant within an ideal, newly colonized ecosystem. As their population grows rapidly, they exert huge predation pressure on native populations (Bussing 1987, Gestring & Shafland 1997). According to Hungarian studies, within the two outlets of the Hévízi Lake and their adjoining channel networks, the re-organization of the entire aquatic macroinvertebrate and amphibian fauna can be observed. As a result, some native species go locally extinct with time, and are often substituted by various alien species. Both the aquarist literature as well as those works discussing invasives regard the Jaguar Guapote as a tropical fish with a thermal optimum between 22–30 °C (Kline *et al.* 2013, www.nas.er.usgs.gov). However, its extreme adaptability is shown by Hungarian studies in the Kis-Balaton watershed, which revealed that its populations do not withdraw to the warmer parts of the southern outlet of the Hévízi Lake even in winter. Instead, actively feeding individuals weather out the autumn and winter seasons in waters as cool as 12–15 °C.

Ecological problems

In an appropriate habitat, it's a quickly growing species with an extremely high reproductive rate. Besides its aggressive behaviour, it also exerts serious predatory pressure on its environment, gravely impacting certain native invertebrate (mostly insects) and vertebrate (fish and amphibian) populations co-existing with it (by preying on adults and offspring alike). In a study carried out on the single self-sustaining population of the species within the Kis-Balaton Water Protection System, it has been documented that guapotes preyed on strictly protected European Mudminnows (*Umbra krameri*) and Danube Crested Newts (*Triturus dobrogicus*).

Economic effects

As it is capable of eating up the entire macrofauna in a site, it imposes a significant threat to all colonized habitat types.

© Bence Bődör

The large, predatory Jaguar Guapote imposes a significant pressure on native fish populations

Methods of control

The Jaguar Guapote can be legally acquired from Hungarian pet shops. It can be easily kept in small aquariums, but it is highly fertile, reproducing more than once a year. Letting them loose in the wild must be avoided by any means. A campaign is essential to raise awareness about all exotic ornamental fishes that may get introduced into garden ponds or natural water bodies, even as a temporarily placement. The control of invasive fish is a difficult task (Patoka *et al.* 2018). In case of the Jaguar Guapote, international literature shows that it is highly tolerant to disturbance, and water management interventions or cutting the riverside vegetation do not have an effect on them. Also, intensive, targeted angling did not produce any results to control the populations. In smaller, isolated water bodies drying out and the use of biocides may be effective. Within larger, isolated stagnant water bodies under thermal pressure, the introduction of large, native predatory fish, such as the Northern Pike (*Esox lucius*), the European Catfish (*Silurus glanis*), and the Pike-perch (*Sander lucioperca*) may stabilize the Jaguar Guapote population, but empirical evidence is lacking.

References

Barros *et al.* 2012, Gestring & Shafland 1997, Holmes *et al.* 2020, Kline *et al.* 2013, Nico *et al.* 2022c, Novák *et al.* 2016, Patoka *et al.* 2018, Shafland 1996, Takács *et al.* 2015b, 2017a, 2017b, Welcomme 1988

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

Spotted Jewelfish

Hemichromis guttatus Günther, 1862

Original area of the species

The Spotted Jewelfish is native to Central Africa, where it inhabits freshwater, saltwater and brackish water habitats (lakes and oases as well as the connecting streams, canals and smaller river systems) within the savanna regions of Ivory Coast, Ghana, Cameroon, Nigeria, Sierra Leone and Togo (Loiselle 1979, 1992, www.cabi.org).

The introduction of the species to Europe and Hungary

The first individuals of the genus *Hemichromis* were imported to Europe (namely, to Germany) in 1905 (Reuter 1911–1915). However, experts disagree about which species (one or more) were introduced at the time (Welcome 1988, Novák *et al.* 2020). Likewise, the first Hungarian record is also ambiguous. The investigation of African cichlids and their aquarist trade gained new momentum in the 1950s, parallel with the widespread occurrence of the Spotted Jewelfish on the international pet market (Horn & Zsilinszky 2005). After entering the global pet trade, the species reached numerous countries. Reproductive populations of the Spotted Jewelfish can be found in natural environments across the southern states of the USA, in Australia, the Philippines and in Europe (Gherardi *et al.* 2009, Hanel *et al.* 2011, www.cabi.org, www.awe.gov.au). In Hungary, the first record is from the outlet of the Hévízi Lake from 2012 (Harka *et al.* 2014). Subsequently, several studies confirmed the existence of stable, self-sustaining populations within the Hévízi Lake and its outlets (Takács *et al.* 2015b, 2017a, 2017b). As of today, the species reached other habitats of the Kis-Balaton Water Protection System through the canals carrying thermal water. Apart from the one in the western watershed of the Balaton, there is a self-sustaining population in the Városliget Lake (Budapest), and occasional specimens are reported from other thermal lakes (Egerszalók, the Margaret Island, Miskolctapolca). Information about on self-sustaining populations is also available in aquarist communities.

Life history of the species

Spotted Jewelfish rarely reach the length of 10-13 cm (either in nature or in aquariums). In general, the body is 7-10 cm long, stocky, a bit torpedo-like, frontally cylindrical. As its Hungarian name suggests, there are conspicuous black spots on the body: one on the operculum, one in the middle of the body and one at the base of the caudal fin. Its main colour is reddish, but the belly of older individuals is of a yellowish-green tinge. The back is olive green. In smaller cichlids, such spots serve as a mimicry to mislead predators. The fins are pink or yellowish, with a reddish tinge at spawning. The entire body is scattered with bluish blotches, but females also sport red and green spots at spawning. Both in terms of 'courtship' colours of wild individuals as well as in terms of ornamental variations available in pet shops, the Spotted Jewelfish is among the most colourful fishes pet shops offer. Females are somewhat smaller, rounder and paler (especially at spawning). The distinction of the sexes is extremely difficult, but during the spawning period, males sport more purplish-blue spots on their dorsal and caudal fins than females.

In terms of their diet, Spotted Jewelfish are omnivores. Young individuals consume planktonic crustaceans and benthon. Older individuals feed on detritus, benthon, upper aquatic invertebrates, fish eggs, smolt and smaller fishes (Loftus *et al.* 2006).

Given appropriate habitat circumstances, it grows quickly and matures within a year. Dependent on its size, a female may lay 200-600 eggs at a time. It requires a solid base (rocks, roots, artificial surfaces) to lay eggs on. Parents create a smallish dent (a

so-called redd) near the spawning surface, and thoroughly clean both the surfaces and the surroundings. Eggs are deposited onto the cleaned, hard surface, and hatching smolt are transferred to the redds in their mouths. After spawning, both parents defend and care for the offspring, for up to a month.

The ecological requirements of the species in Hungary

The Spotted Jewelfish quickly becomes dominant within an optimal, colonized habitat. Based on Hungarian studies, it has become well-established in the Hévízi Lake and its two outlets, as well as in the adjoining canal network. Laboratory studies carried out abroad showed that their mortality significantly increased between 9.1–13.3 °C, while a field investigation carried out in the Florida shallow marshland, reported that all individuals died at 4 °C (Schofield *et al.* 2010). Within Hungary, its appearance can be expected in every aquatic habitat affected by thermal water or industrial hot water, and from there onwards, the species can spread to natural water bodies.

Ecological problems

The Spotted Jewelfish grows quickly and has a high reproductive potential in appropriate habitats. On account of its abundance, it imposes significant predatory pressure on certain invertebrates and lower vertebrates of the native communities (Loftus *et al.* 2006). By feeding on eggs and smolt, it causes losses to the populations of native fish species.

Economic effects

It imposes direct damage to those native fish species with an economic importance. By food competition and feeding on eggs and smolt, it causes losses to all co-existent fish species within a habitat. Between 2015 and 2017, such an abundant population dominated the Hévízi Lake that occasionally they even pecked at bathing people.

Methods of control

The Spotted Jewelfish can be legally acquired from Hungarian pet shops. It can be easily kept in small aquariums, but it is highly fertile, reproducing more than once a year. Letting them loose in the wild

The Spotted Jewelfish as well as other, thermophilous fishes find optimal conditions in the outlet of the Hévízi Lake

must be avoided by any means. A campaign is essential to raise awareness about all exotic ornamental fishes that may get introduced into garden ponds or natural water bodies, even as a temporarily placement (Novák *et al.* 2020, Patoka *et al.* 2018). The control of invasive fish is a difficult task. In case of the Spotted Jewelfish, international literature shows that it is highly tolerant to disturbance, the populations regenerate really quickly (www.cabi.org, www.awe.gov.au). This was also supported by the experiences from the habitat management intervention carried out between 2019–2021 in the Hévízi Lake outlets, after which the Spotted Jewelfish recolonized the site and quickly reached high abundances. As it is of no importance to anglers, in smaller, isolated water bodies drying out and the use of biocides may be effective, as well as the introduction of native predatory fish, such as the Northern Pike (*Esox lucius*), the European Catfish (*Silurus glanis*), the European Perch (*Perca fluviatilis*) and the Pike-perch (*Sander lucioperca*). Within larger, isolated stagnant water bodies under thermal pressure, Spotted Jewelfish populations may only be controlled by the termination of thermal impact, combined with predation by native fishes, fish-eating birds and the Otter (*Lutra lutra*).

References

Gherardi *et al.* 2009, Hanel *et al.* 2011, Harka *et al.* 2014, Horn & Zsilinszky 2005, Loftus *et al.* 2006, Loiselle 1979, 1992, Novák *et al.* 2020, Patoka *et al.* 2018, Reuter 1911–1915, Schofield *et al.* 2010, Takács *et al.* 2015b, 2017a, 2017b, Welcomme 1988

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

Three-spined Stickleback

Gasterosteus aculeatus Linnaeus, 1758

Original area of the species

Among all species of freshwater fish, the Three-spined Stickleback has the largest distribution range. Presently, it is widespread on the entire northern hemisphere, occurring in almost every type of temperate climate in freshwater, saltwater and brackish water. Its freshwater populations can be found in fast flowing streams, larger rivers, lakes of various sizes and, in some places with ample freshwater supply, even in bogs. As an invasive species, it spreads at different speeds within the inner, continental regions of Europe. Isolated populations appearing inside continents are often the result of intentional or, sometimes, accidental introduction. Even though there have been many attempts to describe different species of Three-spined Sticklebacks by morphological and, later on, by genetic methods, it eventually became evident that there is, in fact, only one single species (www.cabi.org).

The introduction of the species to Europe and Hungary

It is native to coastal and brackish waters, but is regarded as an invasive alien species in the inner, continental regions. At the end of the 19th century, it was widely kept as a pet in several European countries. Possibly, this is how it came to Hungary, too. The first feral specimens were reported from the Danube in 1956 (Sterbetz 1957, Berinkey 1960). Today, it is present in several tributaries and inlets, streams in Budapest and the agglomeration, as well as being abundant in many natural water bodies in the Szigetköz (Csipkés *et al.* 2012, Botta *et al.* 1984, Bódis *et al.* 2012, Weiperth *et al.* 2013, 2020, Takács *et al.* 2017a, 2017b).

Life history of the species

The body is elongated and laterally compressed, with the females (especially those bearing eggs) being stockier than males. A small fish, even larger females rarely exceed 9 cm in length. Individuals of saltwater and brackish water populations are typically larger than those permanently living in freshwater. The head and the eyes are relatively large, the snout is long. The mouth is superior or terminal (and, in the latter case, pointing slightly upwards). The lower jaw, that can be protruded to its maximum, is always longer than the maxilla. Both the upper and the lower teeth are small and conical. The pectoral fins are long and fan-shaped. It can be easily distinguished from native fishes on account of the characteristic, dorsal spikes (3, sometimes 4, located in front of the dorsal fin), likewise, one spike instead of each pelvic fin and one in front of the anal fin. The bases of these bony spikes are flat and wide to provide muscles with an insertion. They join the skeleton at the base with an articulation. The side of each spike is barbed. Due to this structure, the animal can deliberately move each spike independently.

© Árpád Ferincz

The spikes are usually covered with a skin membrane up to their two thirds. Another characteristic of the species is that it has scutes instead of scales (Cowen *et al.* 1991, www.cabi.org), the number of which is highly variable. There was a 'fully armoured' specimen collected in Hungary with 36 scutes down the flanks, while others are almost completely naked (Harka & Szepesi 2010). Independent of the number of scutes, the body is protected by bony ventral and base plates from below. The ventral plate covers the belly from the throat to the bases of the pectoral fins, while the base plate, starting from here, runs and narrows down to the end of the tail. The caudal fin is well-developed (Cowen *et al.* 1991, Frommen *et al.* 2011). The colour is highly variable. In Hungary, the top of the head, the back and the flanks are olive brown with or without blotches and bars. The belly is light (white or silvery). During the spawning season, the males sport reddish throats and bellies, and the lighter parts of the flanks are orange or golden coloured.

As for its diet, all age groups are omnivorous. The fries mainly feed on planktonic crustaceans and periphyton, while older individuals consume a wide range of plant an animal material from filamentous algae, aquatic plants, macroscopic invertebrates (e.g. insect larvae) to detritus, fish eggs and fries. The alimentary tract is relatively short and thus the stickleback needs to eat continuously. In an optimal habitat, both growth and sexual maturation is quick.

In its native range, as well as in captivity or in case of feral individuals, it reaches maturity within the 1st year of life. In Hungary, the spawning season lasts from April to June, but in thermally impacted waters it may lay eggs more than once. The reproductive behaviour is well studied. Males in their nuptial colouration defend territories, in the centre of which they build a cave-like nest from plant filaments stuck together by the so-called spiggin (a proteinaceous substance secreted from the kidneys). Spawning takes place within the nest. The nest is visited by several females, attracted by the courtship dance of the male. A large female can deposit hundreds of eggs in the nest. After she leaves, the male enters and fertilizes the eggs. After the courtship period is over, the male hides the two entrances from predators by adding more plant filaments and defends the offspring until shortly after hatching.

The ecological requirements of the species in Hungary

Within the optimal habitats, the Three-spined Stickleback quickly becomes the dominant species upon colonisation. The rapidly increasing populations create huge predation pressures mainly on certain macroscopic invertebrates. Based on studies carried out in Hungary, we know that it adapts skilfully to natural as well as to highly urbanized, disturbed habitats. Apart from semi-natural stream sections, it is often found in thermally polluted, sometimes even fully paved sections.

Ecological problems

In an appropriate habitat, it can quickly form abundant populations due to its high reproductive rate. Large populations impose a strong predation pressure both on native aquatic invertebrates that spend their entire life cycle in streams as well as those that only temporarily arrive from the Danube (invertebrates and smaller fish). Based on a study carried out in a small watercourse in Hungary, the Three-spined Stickleback may easily become the apex predator in a food network (Vesely *et al.* 2021).

Economic effects

There is no known direct impact.

Methods of control

The Three-spined Stickleback is an ambiguously viewed species. As an invasive alien species, it would have had ample time to spread across the entire Hungarian Danube section, however, it is only found in scattered locations upstream from Budapest and in other watercourses (Csipkés *et al.* 2012, Bódis *et al.* 2012, Weiperth *et al.* 2020). On the other hand, wherever it finds adequate circumstances, it reaches extremely high abundances (Harka & Szepesi 2010, Szendőfi *et al.* 2018). The Three-spined Stickleback became widespread in the 19th century due to its popularity with aquarists, but by today it has disappeared completely from pet shops. Even though it is small, it cannot be used as a live bait on account of its specific anatomy. As it spreads by natural dynamics within Hungary, it can be stopped by improving the ecological condition of ecosystems. Several native species, including fish, birds and the Dice (*Natrix tessellata*) and the Grass Snake (*Natrix natrix*), routinely prey on it.

References

Berinkey 1960, Botta *et al.* 1984, Bódis *et al.* 2012, Cowen *et al.* 1991, Csipkés *et al.* 2012, Frommen *et al.* 2011, Harka & Szepesi 2010, Leinonen *et al.* 2011, Sterbetz 1957, Takács *et al.* 2017a, 2017b, Veselý *et al.* 2021, Weiperth *et al.* 2013, 2020

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

Eastern Mosquitofish

Gambusia holbrooki (Baird & Girard, 1853)

Original area of the species

The Eastern Mosquitofish is native to the south-eastern USA from New Jersey to Mexico, and to the water systems south from Indiana and Illinois, from the Atlantic Ocean to the Gulf of Mexico (Welcomme 1988). It inhabits freshwater and brackish water habitats, with a preference for stagnant or slow flowing waters, marshes, lakes, oxbows and canals with lush vegetation (Báskay *et al.* 1998).

The introduction of the species to Europe and Hungary

The justification for the European introduction of the Eastern Mosquitofish was the biological control of culicid mosquitoes. In the 1920s, there were no synthetic insecticides available (such that are widely used today), so it seemed only logical to try and supress biting mosquito populations, as well as the diseases they spread by establishing populations of mosquito-eating fish (Báskay *et al.* 1998). In Europe, it was first introduced to Spain in 1922, then to Corsica in 1924. Later on, during the 1920s and the 1930s, many other countries, including the southern parts of the Soviet Union, Bulgaria, Italy, Greece and former Yugoslavia (Froese & Pauly 2021b) also initiated such programmes. In Hungary, it was first introduced deliberately in the Hévízi Outlet in 1939 from where it quickly spread and established an abundant population in the Hévízi Lake and its outlets. Later on, it was successfully introduced to other water bodies under thermal impact (e.g. the Városligeti Lake in Budapest, Miskolctapolca) (Wiesinger 1948). Wherever large predatory fish were absent, it became highly abundant (Wiesinger 1975).

Life history of the species

A small fish with a slightly compressed, elongated body. Females rarely reach 6-8 cm in length, while males are about 3-5 cm. Females are also stockier than the slender males. The head is of a moderate size, depressed from above, with big eyes and a superior mouth. The fins are rounded. A few rays of the male's anal fin forms a modified, spike-like gonopodium. The body is greyish brown, with the back darker than the belly. It has

© Árpád Ferincz

no lateral line (CABI 2021). This originally sub-tropical fish prefers warm waters with an optimum between 22–30 °C. However, for shorter periods, it can tolerate temperatures below 4°C or above 35 °C. A highly adaptable species that tolerates low oxygen levels, changes in salinity and pollutions (Froese & Pauly 2021b).

A carnivorous, surface feeding species (Howell *et al.* 2013), feeding on zooplankton and macroinvertebrates (including mosquito larvae), terrestrial insects and plant material falling onto the surface, detritus and the offspring of fishes, including their own. It constantly attacks larger fish by pecking at them (Báskay *et al.* 1998). There are significant differences in their food preference, both among habitats and ages, showing that the species follows an opportunistic strategy (Specziár 2004). It may reach maturity within the 1st year of life. Eastern Mosquitofish are ovoviviparous. Females are internally fertilized by means of a tube in the gonopodium (modified anal fin rays). The female stores the milt and thus 'gives birth' to several broods after a single mating event. Incubation takes place within the females body, lasting 5-8 weeks dependent on the external temperature. A brood usually consists of 10-50 fries that can swim right away. In the temperate zone, there may be 3-5 spawning events a year (Berinkey 1966, Pintér 2015).

The ecological requirements of the species in Hungary

The Eastern Mosquitofish can spread mostly in water bodies impacted by hot water (natural thermal springs or industrial hot water). However, it is not constrained to warm habitats. During the summer, it may reach faraway waters where it can overwinter. Increasing water temperatures with climate change may well trigger more intensive invasion by the Eastern Mosquitofish (Takács *et al.* 2017a). Presently, there are several self-sustaining populations in a number of thermal waters such as the Hévizi Lake and its outlet, the Csónakázó Lake in Miskolctapolca, the Városliget Lake in Budapest etc. Furthermore, there are several records from the canals of the Kis-Balaton Water Protection System as well as from other water bodies with no thermal impact (e.g. the River Zagyva, lakes in the vicinity of Budapest and small streams) (Harka & Szepesi 2016).

Ecological problems

The species did not meet the original expectations concerning the biocontrol of mosquitoes. On the other hand, from many habitats, it has excluded those native fish and macroinvertebrate species that were much more efficient in consuming mosquito larvae (Courtenay & Meffe 1989). Instead of positive effects, it exerts several negative ecological impacts. On account of its aggressive and carnivorous behaviour, it excludes small native fish species. Also, by consuming fish eggs, it competes with the young of larger native fishes for the same food source, also imposing a potential threat to amphibian larvae (Zeiber 2008). For the above reason, the Eastern Mosquitofish is included in the list '100 of the World's Worst Invasive Alien Species' (Lowe *et al.* 2004).

Economic effects

In terms of mosquito control, it has proven to be much less efficient than native species with similar diets. On account of its aggressive and carnivorous behaviour, its devastation of eggs and larvae, it may impose a significant negative effect on native fishes of economic or conservation interest (Courtenay & Meffe 1989).

Methods of control

As it easily adapts to different environments and has a high reproductive rate, it is extremely difficult to extirpate from habitats where it has already established itself (Willis & Ling 2000). The only efficient way of control is the prevention of it getting introduced into other water bodies. As with some other alien invasive species, thermal pollution of natural water bodies must be avoided (e.g. by sufficiently decreasing the temperature of cooling water before letting it out), especially during the winter season.

Also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

Báskay *et al.* 1998, Berinkey 1966, CABI 2021, Courtenay & Meffe 1989, Froese & Pauly 2021b, Harka & Szepesi 2016, Howell *et al.* 2013, Lowe *et al.* 2003, Pintér 2015, Specziár 2004, Takács *et al.* 2017a, Welcomme 1988, Wiesinger 1948, 1975, Willis & Ling 2000, Zeiber *et al.* 2006

Vera Lente, Ádám Staszny,
András Weiperth & Árpád Ferincz

Black Molly

Poecilia sphenops Valenciennes, 1846

Original area of the species

As its Hungarian name points out, the Black or Short-finned Molly is native to Central America. Its original range and habitats were the smaller lakes, clear streams, channels and brackish marshlands of Mexico and Guatemala (Miller 1983).

The introduction of the species to Europe and Hungary

The first specimens were brought to Europe (for German aquarists) in 1899 (Meyer 2015, Novák *et al.* 2020). Due to its easy care and breeding, it was popular in the pet trade from the 1920s onwards. At this time, it also appeared in Hungarian pet shops where it was marketed under its English name, 'molly'. In the international pet trade, it is still a significant ornamental fish. The first survey of feral populations was carried out in 2015 in the Hévízi Lake (Takács *et al.* 2015b). Despite the above, several records back up the fact that it was already present in 2010 in other thermal lakes (Egerszalók, Margaret Island, Miskolctapolca, Városligeti Lake), where it established self-sustaining populations. Its most significant feral population inhabits the Hévízi Lake and its outlets, as well as the water system of the Kis-Balaton Water Protection System. Besides, it can still be found in the above mentioned thermal lakes at variable abundances. Based on the above, the species may be considered a stable fauna element (Takács *et al.* 2015b, 2017a, 2017b).

Life history of the species

The body is elongated and somewhat compressed laterally. By size only, it is difficult to distinguish the sexes, but females tend to be stockier, especially so in case of a 'pregnant' female. Mature individuals are 6-8 cm long

© Árpád Ferincz

on average. The head is disproportionately small, while the snout and the eyes are relatively large. The nape as well as the head is covered by scales, the forehead is wide and, in case of older individuals, often domed. The superior mouth is relatively large and protrudable. The fins are rounded. The first rays of the anal fin of the male form a spike-like gonopodium, based on which it can be distinguished from the female. They have no lateral line. There are several ornamental colour variations, and for this reason both in pet shops as well as in feral populations, it occurs in various colours. The wild variations usually have a metallic sheen, and are dominated by the different hues of blue and grey. The back and the dorsal fin may be red or yellow, dependent on the lineage. Both in cultivated and feral variations, the edge of the caudal fin is fringed with a lighter, yellowish-orange fringe. Immatures are usually unicoloured: grey, green or brown. Their camouflage helps them hide (Brett & Turner 1983, Miller 1983).

Regarding its diet, the Black Molly is omnivorous. The fries are born in a very well developed state and start feeding on zooplankton and phytobenthos. Mature individuals eat larger proportions of plant material (e.g. algae, fresh shoots, detritus), and smaller proportions of animal material. In very dense Hungarian populations, researchers observed individuals constantly pecking at amphibian eggs and tadpoles. At extremely high densities, the frequency of cannibalism also increases.

In an optimal habitat, both growth and maturation is fast. In its natural habitats, in captivity and in feral populations in Hungary, it reaches maturity within its 1st year of life. Females are internally fertilized by means of a tube in the gonopodium (modified anal fin rays). The female stores the milt for several months after mating and thus 'gives birth' to several broods after a single mating event even if the male dies in the meantime. Incubation takes place within the females body, lasting 4-7 weeks, dependent on the external temperature. A brood usually consists of 20-150 well developed fries (ovovivipary). A sudden drop in the temperature may cause premature 'birth' that potentially leads to high mortality of the offspring. It easily hybridizes with other *Poecilia* species. Partly due to this, genetically or morphologically pure individuals are rare in feral populations, but most individuals available from pet stores are also hybrids.

The ecological requirements of the species in Hungary

Within the optimal habitats, the Black Molly quickly becomes the dominant species upon colonisation. The rapidly increasing populations create huge predation pressures on natural ecosystems. According to studies carried out in Hungary, it adapts easily. It finds adequate conditions not only in the Hévízi Lake and its outlets, as well as in the adjoining channel networks, but it thermal ponds of various sizes as well as in other artificial water bodies, such as concrete pools.

Ecological problems

In an appropriate habitat, it can form abundant populations due to its high reproductive rate. Large populations impose strong predation pressure on certain aquatic invertebrates and vertebrates (for example on newts (Caudata)). As much of its food is plant material and detritus, large populations may re-shape the entire food network of a colonised habitat.

Economic effects

There is no known direct impact, but both in Hungary and abroad it presents a significant ecological risk in every colonised habitat.

Methods of control

The Black Molly can be legally acquired from Hungarian pet shops. It can be easily kept in small aquariums, and is highly fertile, reproducing more than once a year. Letting the offspring loose in the wild must be avoided by any means. A campaign is essential to raise awareness about all exotic ornamental fishes that may get introduced into garden ponds or natural water bodies, even as a temporarily placement (Liziczai 2020). The control of invasive fish is usually a difficult task (Patoka *et al.* 2018, Pinter 1980, Takács *et al.* 2017a). In case of ovoviviparous poecilids, there are hardly any articles in the international literature relevant to efficient control methods. As a small and disturbance-tolerant species, its populations may be stabilized by its natural predators (fish, birds, reptiles and birds). In case of small and isolated water bodies, the termination of thermal input during the winter months, drying out the water as well as the application of biocides may be efficient.

References

Brett *et al.* 1983, Liziczai 2020, Meyer 2015, Miller 1983, Novák *et al.* 2020, Patoka *et al.* 2018, Pinter 1980, Takács *et al.* 2015b, 2017a, 2017b, Welcomme 1988

András Weiperth, Vera Lente,
Ádám Staszny & Árpád Ferincz

AMPHIBIANS

Amphibia

A short description of amphibians

African Clawed Frog

Xenopus laevis (Daudin, 1802)

As is shown by its name, this species occurs in many African countries in the Sub-Saharan region. On account of its importance in medical and other types of research, the species was introduced to many countries globally, where it is kept and bred for laboratory purposes (Kraus 2009). As an invasive species, it has already been recorded in Arizona, Florida, California and Texas in the USA, as well as in England, Belgium, Portugal, France, Germany, Italy, Spain and in China and Indonesia (www.amphibiaweb.org, www.gbif.org). As it is spreading in more than one country, further records are to be expected (Measey *et al.* 2012).

A relatively large frog with the males reaching 45–98 mm and females reaching 57–147 mm in length. The body is flat, the small, dark eyes are set on the top of the head. The strong legs are equal in length to the body. In the wild, the skin on the back is dark grey, grey or greyish brown with blotches and streaks. The underside is lighter, sometimes even creamy white. There are several colour variations, including albino (Trueb 2003).

Due to its extreme adaptability, it survives even in highly polluted brackish waters. As an alien species, it has been reported from warmer climates (Crayon 2005). During a 2016 survey of potential habitats, it was recorded from artificial ponds in Budapest urban parks (Városliget, the Japanese garden of Margaret Island), from a side arm of the Danube (Kopaszi Dam, also in Budapest) and a downtown artificial pond in Sárvár. Based on former risk evaluation, its appearance is possible across the entire Pannonian Biogeographical Region (wherever water bodies are under thermal impact from thermal waters or industrial warm water). As the species shows invasive tendencies in many European countries, further range expansion is to be expected.

The impact of the African Clawed Frog as an alien invasive species is complex. As a predator, it preys upon many native aquatic and terrestrial macroinvertebrates, fish (Pisces) and amphibians. In larger, closed populations, it's typically cannibalistic, too (www.iucngisd.org). It is also immune to the infection caused by the fungus *Batrachochytrium dendrobatidis.* As the original distribution of this fungus overlaps with the African regions which the clawed frog is native to, many researchers make a tentative connection between the spread of the African Clawed Frog and the collapse of frog populations across the globe (Weldon *et al.* 2004). The species can be legally obtained within Hungary, and for this reason, traders, breeders and pet owners must be notified that in order to protect native amphibian populations from *B. dendrobatidis* infections in future, nothing that comes from the aquariums used to keep African Clawed Frogs can make contact with nature, not even the water.

Bettina Szajbert & András Weiperth

© András Weiperth

African Dwarf Clawed Frog

Hymenochirus curtipes Noble, 1924

It is native to the lowland water bodies of the Democratic Republic of Congo, the Republic of Congo and the Central African Republic, inhabiting running waters, lakes, marshes and even temporary wetlands. It is also a popular pet that conquered many countries across the globe, but there have been no records yet of reproductive populations outside its native range (www.iucnredlist.org). The first Hungarian record is from February 2015, from the Városliget pond in Budapest (Weiperth *et al.* 2015). Since then, the species was also observed in the outflow of the Bük Spa, from the Békás pond within the settlement of Miskolctapolca, as well as from several locations in Budapest (the Alsórákos section of the Rákos stream and from the ornamental pond in front of the St. Lucas Thermal Spa)

© Imre Potyó

It is a small-bodied frog, mature individuals are rarely longer than 4 cm. Males are smaller, slimmer and darker in colour than females, with a tiny, light coloured (often pink or white) gland behind their forelimbs. Females are heavy-set with cloacas larger than those of males. Their body is flattened, the eyes are situated on top of the head. Their colour is usually brownish, with patches across the entire body.

Their diet is dominated by aquatic macroinvertebrates. This species is also immune to the infection caused by the fungus *Batrachochytrium dendrobatidis.* The highest ecological threat is imposed by the African dwarf frog as a potential vector to this pathogenic fungus, as the fungus can escape to the outside world directly or through the public utility network (when terrariums and aquariums are cleaned), and from then on, it is capable of infecting native amphibians (Kilpatrick *et al.* 2010, Murphy *et al.* 2015).

András Weiperth & Bettina Szajbert

Chinese Fire-bellied Newt

Cynops orientalis (David, 1873)

As its name signals, this species is native to China where it inhabits the slow flowing lowland sections of the Yangtze and its tributaries. In its native range, it has adapted to ricefield conditions and occurs in other artificial sites, too, such as canals and ponds. It has become widespread through the network of

© András Weiperth

international pet trade, but feral populations have only been reported so far from the USA and in Belgium (Fuller 2022, www.amphibiaweb.org). In Hungary, the first adult individuals were found in 2017 in Göd (in a small stream adjoining the Ilka stream) and then in 2019 further adult specimens were reported from an ornamental pond in front of the St. Lucas Spa and from the pond of cold spring in the Városliget.

The Chinese Fire-bellied Newt is a relatively small amphibian (Caudata). The body is sturdy, rarely reaching 8 cm in length (males are even smaller, not exceeding 6.5 cm) (Li *et al.* 2005).

The back and the flanks are black, brown or brownish grey, occasionally with light dots. The belly is a vivid orange or red with a black pattern. The colourful pattern extends onto the abdominal side of the tail, too (www.amphibiaweb.org). Skin glands excrete slightly irritant toxins (Brodie *et al.* 1975).

The diet consists of aquatic macroinvertebrates, primarily worms and insect larvae (Fuller 2022). In an optimal habitat, it easily gets established and starts spreading from there. It is an apt and skilful climber, thus furthering its active dispersal (Guo *et al.* 2021). Even though its impact on colonised habitats is yet to be revealed, it has been shown that it's a vector to the pathogenic fungus causing chitridiomycosis (*Batrachochytrium dendrobatidis*) (Kolby *et al.* 2014). Its trade and breeding is prohibited in the USA, but it is still legally available from China and some other Asian countries.

Bettina Szajbert & András Weiperth

Iberian Ribbed Newt

Pleurodeles waltl Michahelles, 1830

The species is native to the Iberian Peninsula and the northern part of Morocco, but it has already been reported from Belgium, France and Germany (www.amphibiaweb.org, www.gbif.org). In its native range, it inhabits small-sized, deep stagnant waters which it leaves only during rainy spells. In Morocco, specimens were found in 60-70 m deep caves (Schleich *et al.* 1996). Due to the loss, agrochemical pollution, urbanization of its native habitats as well as other threats (invasive species, illegal trapping and trade), it has been listed as *Near Threatened* since 2006 (Araújo *et al.* 2011, www.iucnredlist.org). Individuals bred in captivity may be obtained from pet stores, furthermore, it has been used for decades in laboratory experiments testing organ regeneration and zero gravity (Grigoryan *et al.* 2001). In Hungary, five larvae, two adult males and an adult female were collected from the larger pond of Városliget in May 2022.

© András Weiperth

Its total length is 15-19 cm on average, but in its native range, it can easily grow to 30 cm long. Males are larger than females. The back is usually dark grey, the belly is lighter with rusty spots (Griffiths 1996).

Its diet is dominated by aquatic macroinvertebrates, but it readily consumes tadpoles and small fish (Pisces), too. Data is only available so far from its native range, but it seems that the Iberian Ribbed Newt is a potential vector of the pathogenic fungus *Batrachochytrium salamandrivorans* (Baláž *et al.* 2015), and its introduction to natural water bodies, as well as any contact between the natural environment and the contained environment of the newt (emptying the aquarium outside) may pose a threat to our native amphibians.

András Weiperth & Bettina Szajbert

References

Araújo *et al.* 2011, Baláž *et al.* 2018, Brodie *et al.* 1974, Crayon 2005, Fuller 2022, Griffiths 1996, Grigoryan *et al.* 2002, Guo *et al.* 2021, Kilpatrick *et al.* 2010, Kolby *et al.* 2014, Kraus 2009, Li *et al.* 2005, Measey *et al.* 2012, Murphy *et al.* 2015, Schleich *et al.* 1996, Trueb 2003, Weiperth *et al.* 2015, Weldon *et al.* 2004

REPTILES

Reptilia

Pond Slider

Trachemys scripta (Schoepff, 1792)

Original area of the species

Within the Pond Slider species, three subspecies are described: Red-eared Slider (*Trachemys scripta elegans*), Yellow-bellied Slider (*T. scripta scripta*) and Cumberland Slider (*T. scripta troosti*), but, based on the latest results, Vamberger *et al.* (2020) suggested to erect more subspecies. The Red-eared Slider is native to the central and south-eastern part of the United States, around the Gulf of Mexico, and in the Mississippi Valley. Its distribution covers from south-western Virginia through Florida, Alabama, Mississippi, Louisiana, Texas and New Mexico to north-western Mexico (Bringsøe 2006, Ernst & Lovich 2009, Somma *et al.* 2022a). The Yellow-bellied Slider ranges from the south-eastern part of Virginia through the coastal plains of North and South Carolina, and Georgia to northern Florida and the eastern part of Alabama (Gibbons 1990, Gibbons & Semlitsch 1991, King 2000, Bringsøe 2006, Somma *et al.* 2022b). The Cumberland Slider has the smallest range from among the three subspecies: it is native on a relatively small area: in the eastern–north-eastern part of Tennessee and southernmost and south-western parts of Virginia (Somma *et al.* 2022c).

© Zsolt Újvári

The introduction of the species to Europe and Hungary

The Red-eared Slider is the most popular turtle among pet keepers; it is sold in the highest volume around the world (Somma *et al.* 2022a). In the 1970s, it was kept and bred in high numbers at turtle farms of the United States to provide the demanded amount by pet keepers. The international trade of the species in significant quantity started from the 1980s. Between 1989 and 1997 more than fifty-three million specimens were exported from the United States to different parts of the world (www.cabi.org). Back then, its impact as an invasive species on native reptile faunas and natural habitats was not known (Cadi *et al.* 2004). Beyond its native range, the species appeared in most states of the United States of America and the southern part of Canada (Somma *et al.* 2022a). At the beginning of the 21st century, its occurrence was reported from natural and near natural habitats from several Central and South American, African, Near Eastern and south-eastern Asian countries, and furthermore from Australia and New Zealand, too (Secretariat of the Convention on Biological Diversity 2014, www.cabi.org). Recognising the threat posed by the Red-eared Slider, the European Union banned its trade, but keeping them as a pet and its breeding for private enterprises was not restricted (Botta-Dukát 2016).

The first individuals of the Red-eared Slider entered Europe in the 1980s (Warwick 1991). Hungarian pet shops offered them from the 1990s in large quantity (Puky *et al.* 2005). There are no detailed data available on its import prior to this date, but, based on personal communication with pet shop owners, Pond Sliders appeared in Hungarian pet shops during the 1970s and 1980s. Before they appeared in legal pet shops, probably similarly to other young specimens of turtles they had been imported earlier by individual pet keepers. By now the Pond Slider occurs from England to Latvia, and from Sweden to Malta (Harrower *et al.* 2020, Global Invasive Species Database 2022, Standfuss *et al.* 2016, Vamberger *et al.* 2012). In Hungary, the Red-eared Slider is the most common alien reptile (Reptilia), and till today the most common turtle kept in captivity (Sóvágó 2019, herpterkep.mme.

hu). The occurrence of individuals of different age was reported form several hundred natural and man-made habitats. Besides city park lakes and garden ponds, it was reported from the side arms both inside and outside the dams of Rivers Tisza and Danube. Its occurrence was detected in larger mining lakes, from natural lakes, from slowly flowing canals and water bodies, and from the wetlands of Kis-Balaton and Lake Tisza (Szajbert 2019, herpterkep.mme.hu).

The Red-eared Slider is one of the aquatic turtle species bred in the highest quantity.

The Yellow-bellied Slider became a more prominent player in the field of the international pet trade after the ban had been declared on the trade of the Red-eared Slider. It was transported in the 1990–2000s to several countries in high volume from the turtle farms of the United States. Even today, it is exported to the Asian markets for human consumption (Williams 1999, Somma *et al.* 2022b). In its native range in the United States, its trade both as a pet and as food started as early as the middle of the 20th century. Its exact distribution outside North America becomes clearer in recent decades (Bringsøe 2006). Its free-living populations were not mentioned by the Hungarian or European reviews at the middle of the 2000s (Puky *et al.* 2005, Speybroeck *et al.* 2016). These books only dealt with the problems associated with the Red-eared Slider. After the European ban on the trade of Red-eared Slider had been declared, the Yellow-bellied Slider was imported in ever growing numbers to the European Union, and Hungary, too. Based on the experiences with the invasive nature of the Red-eared Slider, the Yellow-bellied Slider was also banned, as more and more individuals were found in natural and urban water bodies. Its adaptability is proven by the fact that its presence was confirmed in several states of the United States and many Central, South American and Asian countries. After the Red-eared Slider, the Yellow-bellied Slider is the most popular and numerous invasive alien reptile kept in Hungary. Occurrences of individuals belonging to different age classes were reported from around 50 Hungarian natural and man-made water bodies. Besides city park lakes and garden ponds, it was reported from the side arms both inside and outside the dams of primarily the River Danube, and from the River Tisza less frequently. Its occurrence was also recorded in the natural lakes, slowly flowing canals of the plains, and from some smaller flowing water bodies. It also invaded the Kis-Balaton wetland and the water catchment area of Lake Balaton.

Life history of the species

Both the Red-eared Slider and Yellow-bellied Slider are medium-sized, aquatic turtles. The carapace of the Red-eared Slider is relatively flat, olive green, but becomes darker as they get older. Its plastron remains light yellow even in mature specimens, and every plate is ornamented with a black patch. Their size, number and pattern give an individual appearance to every individual. The most striking – and for that matter the defining – feature of the Red-eared Slider – for which it was named – is the red or orange patch on the side of its head. It is the best identifying mark helping its recognition and differentiation from the other subspecies or closely related turtle species, as the corresponding area is either yellow (in the Yellow-bellied Slider), or the patch is missing (in the Cumberland Slider). The plastron of the male Red-eared Slider is concave, while that of the female is flat. Its legs, neck and head is greyish green, with lighter lines. Contrary to the above-mentioned other subspecies, the red stripes remain vivid in mature specimens, although they might become dull, orange coloured (Seidel 2002). The Yellow-bellied Slider is ornamented with wide yellow-coloured stripes on each side of its head. This yellow marking can be completely missing in some individuals, but even then the edges of the stripes are always visible. Its carapace is a bit more rounded than that of the Red-eared Slider, olive green, and in mature specimens it gets darker, becoming dark brown, and, in very old specimen, even black. The plastron is yellow in young and mature specimens alike, with black patches. Their size, number and pattern give an individual appearance to every individual. The plastron of the males is concave, while that of the female is flat. The legs, neck and head of young specimens is greyish green with lighter lines, in the older specimens these become darker, with a brownish tint. Opposed to the Red-eared Slider, the yellow stripes on the head of older individuals often fade out (Seidel 2002).

Pond Sliders (*Trachemys* spp.) – just like other turtles (Testudines) – do not possess outer ears; their middle and inner ear, the auditory organ, is protected by a cartilaginous shield (Christensen-Dalsgaard *et al.* 2012). All the Pond Slider subspecies can completely retract their head, tail and legs into their shell. The male and female sliders can be differentiated by the following features: size, shape of the plastron, the length of talons and tail. The plastron of males is concave, (while that of the females is flat), their talons are much longer, and their tail is longer and thicker. Their cloaca opens more distant from their shell. The longer talons help them to grab the females during mating, and they are presented to the females as a part of the courtship (Mohan-Gibbons & Norton 2010). The length of the shell in mature Pond Sliders is 12–20 centimetres. Males are considerably smaller than females: females can grow to 35 centimetres, while males grow only to 25 centimetres. Under ideal conditions, females in captivity might reach 40 centimetres. The Pond Slider is a long-lived species, some might live for 30-40 years.

All the Pond Slider subspecies are omnivorous. The young mainly feed on animals in order to obtain more protein for their growth: they eat insect larvae, snails (Gastropoda), eggs of fish and amphibians, juveniles fishes, tadpoles and metamorphs of amphibians, small toads (Anura), dead fish and other corpses (Gibbons 1990). The older specimens consume more plant material – the leaves and shoots of submerged aquatic plants – but they also consume animals (Bringsøe 2006, Gibbons 1990). As they are poikilothermic reptiles, their digestion is controlled by the temperature of their environment: the water.

In Hungary, the feral populations hibernate in natural or near natural habitats. As the water cools down in October or November, they migrate down to the silt layer of the bottom of the water, or occasionally they find a refuge near the water on land. The hibernating place can be a natural or artificial hole, or a depression on the sandy bottom. They wake up from hibernation in March or April. In thermal lakes or in the cooling lakes of industrial plants, they are active year-around. From spring through the summer till they start hibernating, they spend hours every day sunbathing. Often individuals of various species mix and flock at the sunbathing spots, for example on partially submerged tree trunks, or gently sloping shores.

Males become sexually mature at the age of two-five years old (when they are 9–15 centimetres long), and females at the age of four-seven years old (when they are 15–20 centimetres long). But escapees or intentionally released individuals might become sexually mature earlier as a consequence of better nutrition (Ernst & Lovich 2009). Mating takes place usually from March to June. Several weeks pass from mating till the female lays eggs. Females may lay eggs five or six time a year (Gibbons 1990). Females might venture 1 – 1.5 kilometres from their habitat to find an egg-laying site. They dig with

© Bálint Halpern

their hind legs a 12 – 15 centimetres deep hollow into the soil, and place on average 11 oval eggs into it, while larger individuals might lay up to 20–30 eggs (Gibbons 1990, Mohan-Gibbons & Norton 2010). Incubation time is dependent on environmental factors, especially temperature. At 30 degrees Celsius it is around 55–60 days, but at 22–25 degrees Celsius it might take twice as long (Perez-Santigosa *et al.* 2008). The shell of the freshly hatched Pond Sliders is green with black and yellow pattern. Their plastron is yellow, with varying number of greyish black or black markings, which might produce a fused pattern. In their native range, the young individuals grow as fast as food availability allows. By the next spring, they reach 6–9 centimetres body length. At the invaded habitats outside its native area, the survival of young Pond Sliders is dependent, in addition to the climate, on the availability of food resources and predation pressure. At several natural habitat in Hungary, young individuals suffered high mortality (Halpern B. *pers. comm.*), but, in urban habitats, a higher proportion of young survived the colder winter months (Szajbert B. *pers. comm.*).

The ecological requirements of the species in Hungary

Both the Red-eared Slider and Yellow-bellied Slider invaded natural waters and became an established alien species all over the world due to the illegal release of pets and escaping from garden ponds (Secretariat of the Convention on Biological Diversity 2010). The Hungarian distribution data confirms that they have successfully adapted to the climate of the Carpathian Basin. In their native area, they inhabit various water bodies. As a consequence of their illegal release, they colonised the side branches of rivers, canals, wetlands, and smaller and larger natural or artificial lakes. The overwintering specimens demonstrate that they can adapt to the new habitats successfully. They prefer larger water bodies overgrown with dense aquatic vegetation, where they can find appropriate sunbathing sites at the shore. Due to their adaptability, they can establish populations in the lakes of disturbed city parks (Botta-Dukát 2016, Weiperth *et al.* 2015).

The exact distribution of the Pond Slider is not known in Hungary. Puky *et al.* (2005) lists 13 areas as confirmed Red-eared Slider occurrences. Bódis *et al.* (2012) did not treat the two subspecies separately in their work on the invasive fauna element of the Danube, and they estimate that 6–20% of the Hungarian section of River Danube is invaded by them. Thanks to data collection carried out in recent years, Red-eared Sliders and Yellow-bellied Sliders were found in more than 100 water bodies in Hungary, mostly adult specimens. Their successful breeding was reported from several natural and urban habitats (Botta-Dukát 2016, Weiperth *et al.* 2015, herpterkep.mme.hu).

Although there is no exact data available on the population size of the Pond Slider in Hungary, the extent of the problem is shown by the fact that the Budapest Zoo adopted around 600 Pond Sliders. Still, the number of adopted specimens both at the Budapest Zoo and other animal recovery centres shows a growing trend, as both the captured escapees and the unwanted pets end up in these centres. There were several programmes dedicated to the reduction of Pond Slider numbers in invaded natural habitats. In the Naplás Lake, the Hungarian Ornithological and Nature Protection Society aided the personnel of the Rákosmenti Ranger Service who carried out the capture of escapees between 2015 and 2020. During the programme, 54 Red-eared Sliders and 47 Yellow-bellied Sliders were transported to the Budapest Zoo. At the Lake Feneketlen, the Főkert Limited Company, as the manager of the lake, asked the Hungarian Ornithological and Nature Protection Society to capture the Pond Sliders. Within this programme in 2016, 2017 and 2020, a total of 49 Red-eared Sliders and 48 Yellow-bellied Sliders were transported to the Budapest Zoo. The researchers of the Department of Freshwater Fish Ecology of the Institute of Aquaculture and Environmental Safety of the Hungarian University of Agriculture and Life Sciences led several research programmes on the invasion, occurrence and monitoring of Pond Sliders. In the framework of this researches, they captured between 2015–2021 from the Városligeti Lake 16 specimens, from the pond of the Japanese Garden at Margaret Island 47 mostly young individuals, and from the side branches of the Danube within the city limits of Budapest: at the Kopaszi Dam 71 individuals, from the Hárosi Bay 55 individuals, and at Népsziget 29 individuals (Weiperth *et al.* 2015, Szajbert B. *pers. comm.*).

Ecological problems

The effect of Pond Sliders (*Trachemys* spp.) on the colonised habitats is very complex. First of all, the invasion of Pond Sliders directly reduces the number of the native European Pond Turtle (*Emys orbicularis*), as the Pond Sliders are larger and more aggressive: they replace the European Pond Turtles at the sunbathing sites and chase them away from food sources (Avry &

Servan 1998, Cadi & Joly 2003, Valdeón *et al.* 2010). Besides their effect on the European Pond Turtle stocks, their consumption of water macro-vegetation exerts a profound effect on the populations on water macro-invertebrates, fish (Pisces), amphibians (Amphibia) and birds (Aves) (Kraus 2015, Krauss 2012). They can also transmit several parasites. The blood parasites (Polystomatidae) of North American Pond Sliders were found in the native European Spanish Pond Turtle (*Mauremys leprosa*), where they caused approximately 20–30% winter mortality (Meyer *at al.* 2015). They can also spread antibiotic-resistant Salmonella, which poses a serious hazard for human health (Secretariat of the Convention on Biological Diversity 2010, Somma *et al.* 2022a, 2022c). Because of the health hazard, their trade in the United States has been restricted since 1975.

Economic effects

Besides the severe ecological threats and conservation hazards, their large populations might affect water quality at the colonized habitats. As mature individuals mainly consume plant material, depending on the volume of the water bodies, the Pond Slider populations might seriously damage the submerged aquatic plants and even eradicate the protected White Waterlilly (*Nymphaea alba*) stocks. Besides altering the species composition of the habitat, they therefore facilitate the growth of floating algae, which quickly degrades water quality. Eventually, the uncontrolled algae growth might result in phytoplankton blooming. These processes were documented in the course of research carried out in Hungary in garden ponds and lakes in city parks located in and around Budapest (Szajbert B. *pers. comm.*).

Methods of control

The ban on its trade and keeping as a pet is extended to all the subspecies of the Pond Slider, but the import and hence the following invasion of closely related species such as the Cuban Slider (*Trachemys decussata*) and Meso-american Slider (*T. venusta*) should be prevented by all means. With the help of risk assessment studies, all the aquatic turtle species should be identified that can overwinter and possibly breed under the climatic conditions of Hungary (Botta-Dukát 2016, Vilizzi *et al.* 2021). But the studies should not be restricted to natural water bodies; all the possible waters of artificial habitats and urbanised areas should be analysed (Vilizzi *et al.* 2021). There should be a campaign targeting pet keepers to inform them about the hazards of releasing not only the Red-eared Slider, but any invasive alien aquatic turtle species into natural water bodies, and also into garden ponds and lakes of parks (Botta-Dukát *et al.* 2016). The control and reduction of the populations of alien and sometimes invasive turtles (Testudines) is usually quite a demanding task, and its legal background should be also brought to legislation and reinforced. The import and release of the Pond Slider is forbidden at the moment in the European Union, but the managers of waters are not interested in the eradication of feral populations. Based on the possible economic, ecological and human health hazards, this would be recommended. In man-made habitats (for example, city lakes), their populations can be decimated with intense collecting. In natural waters, the continuous monitoring of their populations would be necessary, and then passive and active trapping methods (for example, netted fish weirs, nets) should be applied to reduce the number. After the capturing of the individuals, monitoring should be continued at least for 1-2 years, and all of the invading or returning specimens should be eradicated (Alcayde *et al.* 2015, Sancho & Lacomba 2013).

In several countries it can be legally purchased, but, in the European Union, the *1143/2014/EU* decree of the European Parliament and Council strictly regulated the keeping of the species (including all the three described subspecies): it is strictly forbidden to import, keep, breed, commercially trade and transport even a single specimen into the European Union. Its release into natural habitats is also strictly forbidden. The Red-eared Slider is on the list of the most dangerous 100 invasive species of the IUCN (www.iucngisd.org).

References

Alcayde *et al.* 2015, Avry & Servan 1998, Botta-Dukát 2016, Bódis *et al.* 2012, Bringsøe 2006, Cadi & Joly 2003, Cadi *et al.* 2004, Christensen-Dalsgaard *et al.* 2012, Ernst & Lovich 2009, Gibbons 1990, Gibbons & Semlitsch 1991, Global Invasive Species Database 2022, Harrower *et al.* 2020, King 2000, Kraus 2015, Krauss 2012, Meyer *et al.* 2015, Mohan-Gibbons & Norton 2010, Perez-Santigosa *et al.* 2008, Puky *et al.* 2005, Sancho & Lacomba 2013, Secretariat of the Convention on Biological Diversity 2010, Seidel 2002, Somma *et al.* 2022a, 2022b, 2022c, Sóvágó 2019, Speybroeck *et al.* 2016, Standfuss *et al.* 2016, Szajbert 2019, Valdeón *et al.* 2010, Vamberger *et al.* 2012, 2020, Vilizzi *et al.* 2021, Warwick 1991, Weiperth *et al.* 2015, Williams 1999

András Weiperth

Chinese Softshell Turtle

Pelodiscus sinensis (Wiegmann, 1835)

Original area of the species

With the help of modern DNA-based taxonomic techniques, the native range of the Chinese Softshell Turtle can be determined with great precision. Formerly a very extensive range was hypothesized. Contrary to what its name suggests, its original range was thought not to be restricted to China, but included the eastern ranges of Russia, the catchment area of River Amur, the whole of China and most of the Korean Peninsula, the eastern part of Indochina, the northern part of Vietnam, and Japan, too. Nowadays its native range is thought to be considerably smaller: it is restricted to some provinces of eastern and southern China, and Taiwan (Rhodin *et al.* 2016, Kong *et al.* 2021). In several Asian countries (for example, Singapore, Vietnam), following its introduction the Chinese Softshell Turtle is bred in large numbers both for the pet trade and also as a delicacy (Smith 1931, Pritchard 1979, Bonin *et al.* 2006, Fritz *et al.* 2010, Gong *et al.* 2018). According to the data collected by IUCN, all of its natural populations are endangered due to overfishing, the transformation of habitats and pollution. A further problem is that various softshell turtle hybrids invade natural habitats, and hence genetic degradation starts in the affected populations (Asian Turtle Trade Working Group 2016, Gong *et al.* 2018).

The introduction of the species to Europe and Hungary

Specimens of the Chinese Softshell Turtle are traded in large numbers all over the world in the pet trade, and in Asian markets they are sold as food for human consumption, too (Bonin *et al.* 2006). It is only second to the Red-eared Slider (*Trachemys scripta elegans*) regarding the number of turtles bred and sold in the world. There are notes on its trade as a food item as early as from the 1800s, when they were imported in significant quantity for human consumption in the United States (Bonin *et al.* 2006, www.nas.er.usgs.gov, www.cabi.org). In the 1980s and 1990s, its import started from Asian turtle farms to the European markets, with many young individuals transported to European pet shops. By the end of the 2000s, its European and Hungarian trade diminished, but its worldwide export and trade is still going strong (Thanh *et al.* 2010). Although its trade in Europe is lagging behind, escapees were reported from natural and urban habitats alike from Hungary and many other European countries (Austria, Bosnia-Hercegovina, Lithuania, Romania, Serbia, Slovenia, France, Croatia, Germany and Spain) (Brejcha *et al.* 2014, García-Berthou *et al.* 2007).

© Márton Árvay

© Zsolt Brudnyák

In Hungary, up to now only adult Chinese Softshell Turtle individuals were captured from the Danube side arms around Budapest, from the Lázbérci Water Reservoir, Lake Naplás, Ráckevei-Soroksár Danube (RSD), and from two harbours of Lake Balaton. From its distribution pattern, we can predict that the occurrence of escapees and voluntarily released animals must be expected in Hungary. When Chinese Softshell Turtle individuals are captured or seen, sometimes it is not clear which species, or what sort of hybrids, were found. Research has shown that closely related species kept together at turtle farms can hybridise and even produce fertile offspring. The hybrids invading native natural habitats of the species can genetically degrade the native populations. The human induced gene mixing considerably reduces the genetic heterogeneity of different species (Gong *et al.* 2018). Furthermore, it makes the exact identification of individuals outside their native range more difficult.

Life history of the species

The length of mature Chinese Softshell Turtle's carapace is usually 25–33 centimetres, but it can reach 40 centimetres. Males are usually smaller than females, but their tail is longer. Their name reflects the fact that both their plastron and carapace lacks thickened horny scales, and hence their shell is leather-like. There is a massive bone shield under the middle section of the shell, but it is missing at the edges of the shell. Because of its light and flexible shell, the Chinese Softshell Turtle can move more agilely both in open water and on the muddy bottom of lakes. This also facilitates its hiding, as it can dig itself in the fine silt in very short time. Mature specimens living in the wild are usually olive grey, olive green or greenish-brown coloured, and ornamented with black spots. The plastron is orange red, and can be also marked with dark patches. The upper side of its head and legs are olive green, the front legs are lighter, the hind legs are orange red. There are dark patches on the head, and from the eyes a dark line starts towards the carapace. The throat is spotted, and the lips can also be ornamented with tiny dark stripes. There is a pair of dark dots in front of the tail, and a black stripe on both thighs. There are webs between the fingers, which covers almost completely the inner fingers on both the front and hind legs. There are well-developed claws on the outer three fingers of all legs; they are either light yellow or butter yellow. The carapace of younger individuals is usually lighter, and often more dotted, than that of older individuals. There are many colour variants in natural populations, but in the case of artificially bred individuals colour variability is even larger (for example, pure white or yellow individuals also exist among them).

It is a carnivorous turtle species: the young feed on water invertebrates, small fishes (Pisces) and the larvae of amphibians. The mature specimens consume water invertebrates – such as snails (Gastropoda) and crustaceans (Crustacea) and – fishes (Pisces), amphibians and small mammals, but stomach content studies have also revealed the consumption of water plants. It can swiftly and agilely move in the water, sediment and in shallow remnant waters after floods. It is an active hunter, but besides living prey it also consumes carcasses floating in or on the surface of the water (Ernst & Barbour 1989).

Its original habitats were larger rivers, lakes, wetlands, side branches of rivers, the main and side branches of slowly flowing rivers, and in the canals connecting them. But it can also utilise and inhabit man-made canal systems and temporarily inundated areas such as rice plantations. It is a very adaptable species (Bonin *et al.* 2006), but is strongly connected to water and wetland habitats. It rarely wanders far from its habitat, but goes to dry land to sunbath and to rest. Females leave water only for egg-laying and hibernation, and even then remain close to their habitat.

The Chinese Softshell Turtle becomes sexually mature at around 4–6 years of age. Females stay around their habitat even when they lay their eggs. They find suitable places in the muddy or sandy parts of the littoral zone. Sperm remain viable in the oviducts of the females for about six months. This might be part of the explanation why the ratio of males is lower in natural populations than that of females. Its breeding season starts at early spring and lasts till late autumn. Females lay large batches of eggs at a time, during intense storms and rains. They dig holes in the mud or sand measuring 4–5 centimetres across and s 10–15 centimetres deep, and lay their eggs in layers from the bottom of the hole to its top. Usually 8–30 eggs are placed into one hole. They can breed several times a year. The eggs conglutinate together in the nest, their shell is soft and leather-like. After the eggs are laid, females stay nearby and protect their nests (McKeown & Webb 1982, Bonin *et al.* 2006).

The ecological requirements of the species in Hungary

The climate of Hungary is just about ideal for the Chinese Softshell Turtle. For this species, the natural water bodies adjacent to our large rivers (such as the Danube) are ideal habitats, but some urbanised sites also offer ideal conditions. Based on the dynamics described in other countries the occurrence of new individuals should be expected in Hungary, but self-sustaining, established breeding populations have not yet been discovered in Hungary or any neighbouring country. As it is a very adaptable species, we can assume that it is capable of establishing self-sustaining populations both in natural and in urbanised habitats (Vilizzi *et al.* 2021). As it is a very secretive species, its abundance is hard to even estimate. Based on the studies conducted in recent years, less and less people keep them as pets. Nonetheless, the appearance of adult specimens in natural waters could be expected.

Ecological problems

As the Chinese Softshell Turtle is among the turtle species raised in the highest numbers commercially, its ecological role and effects are quite complex. There are reports on its hybridization with the native North American Smooth Softshell Turtle (*Apalone mutica*) (Kuzmin 2002), but most often the *Pelodiscus* species interbreed, which are kept together at turtle breeding farms (Gong *et al.* 2018). It might act as a vector for several parasites and illnesses, and these might threaten the native turtle and other animal species (Sinmuk *et al.* 1996, Liu *et al.* 2011, Thanh *et al.* 2010). Its direct effect on the habitats it invaded is less studied, but it feeds both on native and introduced reptiles. There are reports that the Chinese Softshell Turtle bite Pond Slider (*Trachemys* sp.) specimens, which hibernated in the mud (Halpern B. *pers. com.*).

Economic effects

It is an important species both as food, and also because it is a very popular pet and hence its global trade is significant. There is no known economic effect associated with this species.

Methods of control

The keeping of the Chinese Softshell Turtle as a pet is not forbidden in Hungary, and hence the occurrence of escapees and illegally introduced specimens can be expected in the future. A ban on its import and trade could significantly reduce the chance of its accidental introduction. But as the Chinese Softshell Turtle can be easily purchased in neighbouring countries, its illegal import will surely continue. It was demonstrated with risk assessment methods that this species established populations all over the Carpathian Basin, and is capable of reproducing here (Vilizzi *et al.* 2021). There should be a campaign targeting pet keepers to inform them about the hazards of releasing Chinese Softshell Turtles into natural water bodies and garden ponds and lakes of parks (Botta-Dukát *et al.* 2016). The control and reduction of the populations of alien and sometimes invasive turtles (Testudines) is usually quite a demanding task. It is especially true in the case of the Chinese Softshell Turtle, which spends most of its active time under the water, and very seldom ventures to the shore. Its populations can be eradicated in isolated artificial water bodies. In the case of natural waters, continuous monitoring should be carried out, and, because of its secretive lifestyle, environmental DNA screening would be the most effective and exact method for the detection of its presence (Kakuda *et al.* 2019). If its presence is confirmed, passive and active methods (for example, netted fish weirs, nets) should be applied to collect the specimens. After the capturing of the individuals, monitoring should be continued at least for 1–2 years, and all of the invading or returning specimens should be eradicated.

References

Asian Turtle Trade Working Group 2016, Bonin *et al.* 2006, Botta-Dukát 2016, Brejcha *et al.* 2014, Ernst & Barbour 1989, Fritz *et al.* 2010, García-Berthou *et al.* 2007, Gong *et al.* 2018, Kakuda *et al.* 2019, Kong *et al.* 2021, Kuzmin 2002, Liu *et al.* 2011, Pritchard 1979, Rhodin *et al.* 2016, Sinmuk *et al.* 1996, Smith 1931, Thanh *et al.* 2010, Vilizzi *et al.* 2021

Bettina Szajbert, András Weiperth

Common Snapping Turtle

Chelydra serpentina (Linnaeus, 1758)

Distribution

The Common Snapping Turtle is native to North America. It occurs from south-western Canada through the eastern two-thirds of the United States to Florida and the Gulf of Mexico (Fuller *et al.* 2022). Two populations formerly belonging to this species were elevated to the species level: the Central American Snapping Turtle (*Chelydra rossignonii*) occurring in Mexico, and the South American Snapping Turtle (*C. acutirostris*) which is found in Central America and north-western South America (www.reptile-database.org).

Introduction into Hungary

The species was on sale in Hungarian pet shops from the 1980s with newly hatched young being available for many years, although not in large numbers. As it does well in captivity, most generally survived, and even bred successfully (Roszkopf 2008). As the first annex of *41/2010. (II. 26.) Government decree* on keeping pets in Hungary categorised it as an ecological threat to the country's native flora and fauna, and then the first annex of the *85/2015. (XII. 17.) decree of the Ministry of Agriculture* categorised it as an especially 'dangerous' animal, commercial trade was subsequently banned. As a consequence, this species is now only allowed to be kept only in zoos and circuses. However, the legal situation for people who already owned specimens was unclear. It seems that some owners, as they could not legally keep their turtles, simply released them into the wild. Interestingly, observations in Japan revealed that Common Snapping Turtle populations began to increase in number after the keeping of them was outlawed in the country (Kobayashi *et al.* 2006). Although keeping this species in Hungary is illegal, they are still kept, as a specimen captured recently in Budapest's 2nd showed (herpterkep.mme.hu). Today, the number of illegally released specimens in Hungary is unknown.

Life history

The Hungarian name of the Common Snapping Turtle translates as 'Alligator Turtle'. However, this is a source of confusion, as it is a word-for-word translation of the German name *'Alligatorschildkröte'*. In addition, its American name 'Snapping Turtle' is sometimes used. The generally used English name Alligator Snapping Turtle, also refers to a similar, but considerably larger species *Macrochelys temminckii*. Hence, there is often a misunderstanding when the name 'Alligator Turtle' is used in Hungarian. The Alligator Snapping Turtle is seldom kept in captivity in Hungary, and its high commercial value probably discourages owners from releasing specimens into the wild. Moreover, the Alligator Snapping Turtle prefers a warmer climate than that which prevails in Hungary, and this, together with its scarcity as a pet, combine to prevent the establishment of a feral population.

An adult Common Snapping Turtle weighs up to 20 kg, and its carapace can reach 50 cm in length (Farkas & Sasvári 1999), although most often they are smaller. Adult males are larger than females (Galbraith *et al.* 1987). The colour of the carapace ranges from brown through reddish to blackish. Its plastron is light ochre. The plastron is rather small hence this turtle is unable to fully retract its head and limbs into it. The head is large, stout and the upper beak recurved. Its tail is almost as long as its carapace and the legs are strong and stout with pointed, strong claws (Farkas & Sasvári 1999).

The Common Snapping Turtle is a habitat generalist, inhabiting a wide range of aquatic ecosystems, although it prefers swamps and bogs (Paterson *et al.* 2012).

It is predominantly aquatic, rarely emerging to bask out of water. However, in a Canadian population some individuals regularly rested on partly submerged logs far from the shore but did not aggregate in groups


© Bálint Halpern

like other turtle species (Obbard & Brooks 1979, Galbraith *et al.* 1987). There are many photos on the internet of basking Common Snapping Turtles, including ones with other turtle species. Common Snapping Turtles are also highly vigilant, in most cases detecting humans before they themselves are noticed which makes it a difficult animal to observe. From a distance, small individuals are particularly difficult to recognise without experience. Like other aquatic turtle species, it commutes across dry land between water bodies. However, it spends most of its time hiding motionless in shallow water with vegetation, under submerged logs and branches, or burrowed into mud. Typically, only its eyes and nostrils break the surface of the water. Algae often grow on its carapace which enhances its camouflage as it blends perfectly into its surroundings. The Common Snapping Turtle is an excellent swimmer and can cover large distances (1–2 km) over a short period of time.

This reptile's home-range is on average some 3-4 hectares but varies between 0.5–8.0 hectares (Obbard & Brooks 1981). It shows a high site-fidelity and is even somewhat territorial. Aggression is only shown by males (Raney & Josephson 1954) but is most likely not related to territoriality (Keevil *et al.* 2017). This notion is supported by the fact that the home-ranges of individuals often overlap considerably (Galbraith *et al.* 1987). Population density varies from 1.5 individuals per hectare to as high as 30 individuals.

The Common Snapping Turtle is omnivorous, consuming large quantities of both plants and animals. It seizes prey with its beak and tears it apart with its strong front legs. As it is a quite a large turtle, it can consume a wide range of prey animals from aquatic invertebrates to smaller bird (Aves), and even feeds on carrion (Punzo 1975). Indeed, it is so strongly attracted to carrion that some American police forces use them to detect human corpses in wetland areas (Farkas & Sasvári 1999). It is a 'sit and wait' predator, ambushing its prey with a lightning quick strike, and helped by a vacuum in its oral cavity which sucks in water.

Under water, this species does not behave aggressively towards humans, on the contrary, it retreats when disturbed. On land, however, it becomes aggressive when cornered and under those circumstances may bite ferociously. With its long neck, it can reach to the rear end of its carapace, and hence is difficult to handle safely. Generally, it is the actions of people who irritate these reptiles, that results in conflict, rather than that of the turtle itself. If left alone, the Common Snapping Turtle is a harmless animal.

The Common Snapping Turtle is sexually mature at around twelve years, but in populations living at higher latitudes this may occur at 15-20 years (COSEWIC 2008). In natural habitats, females lay 15-55 eggs in June. Rounded and usually 3 cm in diameter, they hatch after 65–130 days (Farkas & Sasvári 1999). Most are thought to live to about 30 years, but some individuals tracked in long-term studies have been estimated to be 42-53 years old at their last capture. Others estimates state that they can live up to 100 years.

Ecological requirements in Hungary

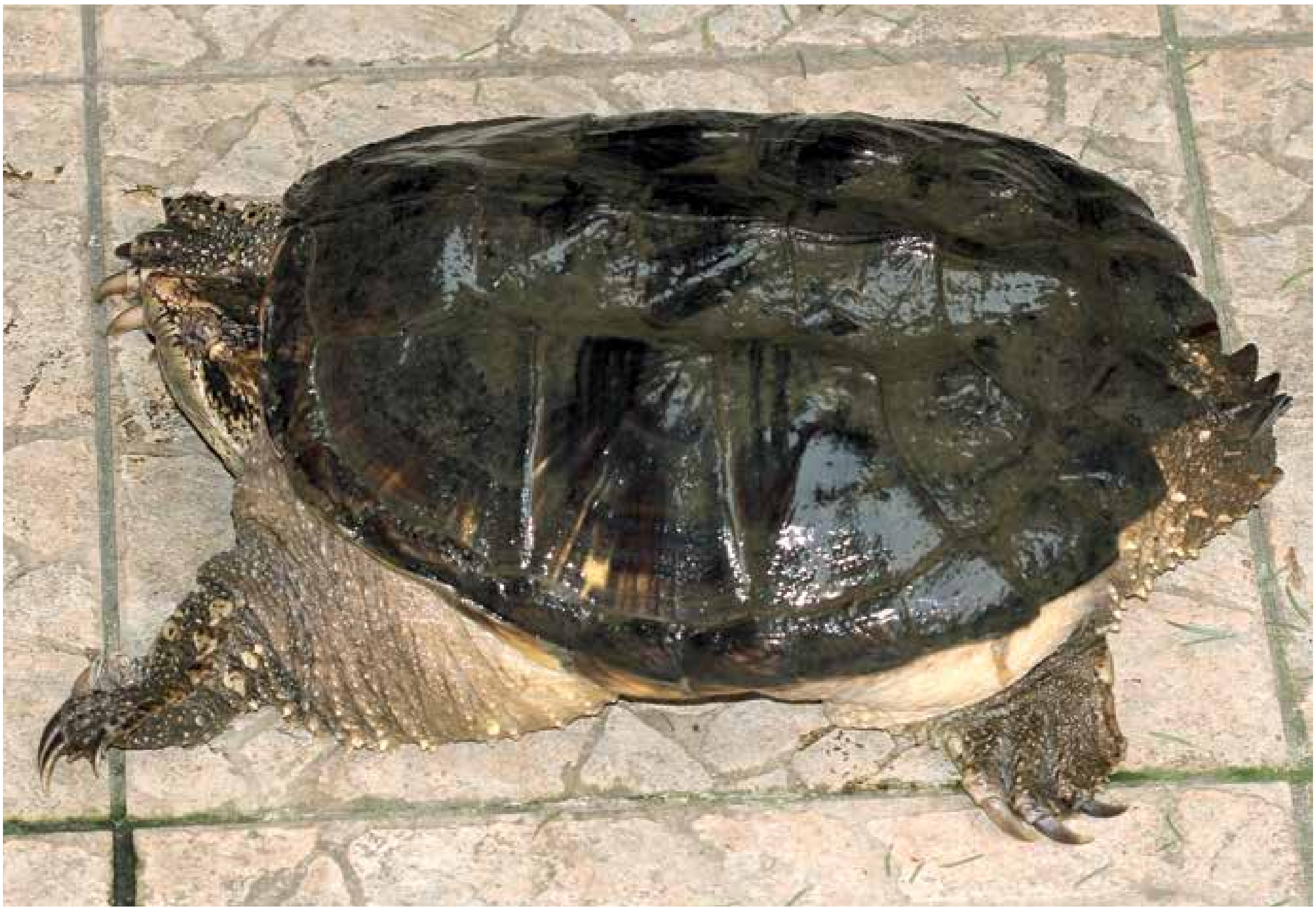
The hydrogeological regime and climate of Hungary are ideal for the Common Snapping Turtle. At the northern edge of its native range, it often thrives in colder areas than Hungary and it is believed that the formally commercially imported specimens did not come from southern populations. The stagnant ponds, lakes and slow-flowing rivers of the country provide ideal ecological conditions for this turtle and successful breeding in the wild has been documented, including cases of young over-wintering in the nest or eggs (Roszkopf 2008).

No self-sustaining population in Hungary is known, as only sporadic occurrences have been confirmed from various locations. Further anecdotal observations were known among specialists. Captured specimens were usually taken to zoos. Besides, in recent years, the tabloid press reported on several captured specimens, but the credibility of these reports is questionable. Most probably concern deliberately released and recaptured turtles. At the same time, the fate of captive Common Snapping Turtles (which might have been kept in significant numbers), and their offspring is unknown as the hasty ban on the keeping of this species most likely resulted in keepers failing to declare them. As the ecological conditions in Hungary are ideal for the Common Snapping Turtle, it is possible that many individuals survive in the wild unnoticed. A key question is whether the density of released individuals has locally reached the threshold where they can reproduce and thus start to spread. In the case of an elusive invasive species, the latency of their presence might be considerable, and hence any spread could go unnoticed. Therefore, the immediate capture and reporting of any Common Snapping Turtle is crucial. The current platform to report observations of this 'alien' species is as follows: herpterkep.mme.hu.

Ecological problems

As it is a large carnivorous reptile that can quickly reproduce and form substantial populations when

© Bálint Halpern



conditions are favourable, the Common Snapping Turtle can have a significant effect on its potential prey species. It can cause severe reductions in the populations of protected native species of fish (Pisces), amphibians (Amphibia) and other reptiles (Reptilia), and even insects (Insecta). As it is a voracious feeder the quantity of biomass it consumes can be considerable, which may impact the ecological processes of the habitats it invades.

Economic effects

The potential economic effects of the spread of the Common Snapping Turtle are hard to predict. In some areas of the United States, this turtle is caught in high numbers for consumption. Consequently, some Hungarian turtle keepers in the 1980s proposed that this was a good reason to introduce the species into the country. But this 'theoretical advantage' is heavily outweighed by the negative effects of its presence in our waters. Their appearance in high numbers might heavily affect the waterfowl stocks, and, to a lesser extent, the stocks of fish species caught by sport anglers, too. The real economic disadvantages caused by predation are far outweighed by the negative psychological effects it my have on potential visitors to nature, and hence might influence the tourism industry locally. The fear of attacks by Common Snapping Turtles might deter people from bathing and fishing and eventually visiting areas where this turtle actually - or supposedly, for that matter - occurs.

Methods of control

The immediate removal of all individuals of this invasive species from Hungary's wetlands is of paramount importance. Captured animals should be deposited in zoos. In order to verify whether any other individuals survive, it would be important to use traps at known sites of occurrence and conduct a screening of waters for Common Snapping Turtle DNA. The Common Snapping Turtle can be most effectively trapped by using nets at weirs baited with meat or fish (Lagler 1943).

References

COSEWIC 2008, Farkas & Sasvári 1999, Fuller *et al.* 2022, Galbraith *et al.* 1987, Keevil *et al.* 2017, Kobayashi *et al.* 2006, Lagler 1943, Obbard & Brooks 1979, 1981, Paterson *et al.* 2012, Punzo 1975, Raney &. Josephson 1954, Roszkopf 2008

Gergely Babocsay

Kotschy's Gecko

Mediodactylus kotschyi (Steindachner, 1870)

Native range

The Kotschy's Gecko occurs in the Eastern Mediterranean from the South-eastern Apennine Peninsula across the south of the Balkan Peninsula (Albania, southern North Macedonia, Greece including the Aegean Islands). At least ten subspecies are recognised (www.reptile-database.org) to date. The populations towards the east – formerly treated as subspecies of the Kotschy's Gecko – have been elevated to the species level (Kotsakiozi *et al.* 2018): *Mediodactylus orientalis* (Ikaria, Samos, south of Asia Minor, Western Syria, Lebanon, Israel, Cyprus), *M. danilewskii* (Crimea, Southeast Bulgaria, Thrakia, Southwest Asia Minor), *M. bartoni* (Crete and the surrounding smaller islands), *M. oertzeni* (Dodekanisos). As the exact origin of the specimens introduced into Hungary is mostly unknown, it is possible that some population belong to the latter species.

Introduction to Hungary

Till now six occurrences have been reported in Hungary, from among these four are known from Budapest. Its first occurrence was reported from an old apartment block on the Budaörs Road at Dayka Gábor Street (Farkas *et al.* 1999). The building has been demolished since. There is no evidence that the population invaded the surrounding, still standing buildings. In 2020, a young individual was found in the Tűzoltó Street in the 9th district. Further two specimens were reported from around 33 Ferenc Körút, and one from the vicinity of the Népliget Park in 2007 (Babocsay 2021). These specimens found in close proximity indicate a self-sustaining feral population inhabiting possibly several blocks of apartment houses. At this point, it is unclear what the distribution and density of this colony are within the area delimited by the three observation points. Another population is known from Balatonszéplak, established by a pet owner on his own weekend house (Farkas *et al.* 1999). The founding individuals on the Budaörsi Road and Balatonszéplak were brought from Southwest Bulgaria in the early 1980s. At the time, Bulgaria was a popular destination for herpetoculturists, from where a number of specimens were imported as pets. The geckos in the 9th district escaped from a keeper in the early 1980s, and were too collected in Southwest Bulgaria. They escaped from a house in Ferenc Körút at Tompa Street which locale coincides with locales of two of the observations listed above. There is a further photo-documented population on a family house in Gyula (Babocsay 2021) whose origin is unknown. The discovery of further colonies cannot be ruled out. These may come from sources abroad or from established Hungarian populations.

Life history

Kotschy's Gecko is a small gecko, growing up to 8-10 centimetres in total length. Its ground colour is grey, yellowish or brownish grey. An array of V-shaped (pointing towards the tail) dark marks with a lighter edge runs along the back. On the tail, this pattern becomes a series of bands. The pattern may occasionally be missing entirely. The ventral side is yellowish or greyish white. Eyes are large, greyish, sometimes with golden speckles. Pupil is vertical, in bright light narrows down to a serrated slit. Tubercles present on the back and the tail. On the back, they are arranged in longitudinal rows. Toes lack adhesive pads, equipped only with claws. Despite this, Kotschy's Gecko is an apt wall climber and can cling upside down. Males often vocalize; their call is reminiscent of tiny iron balls knocked against each other. Rarely, females too vocalise. It is often active during the day, especially in the morning or late afternoon.

It feeds on small arthropods, often ambushing them around lights attracting insects. Its habitat varies along its distribution range. The populations in

© Gergely Babocsay

encountering very few natural predators or competitors (e.g. Common Wall Lizards (*Podarcis muralis*)). It often passes unnoticed by people too.

There is no any information regarding the size of the Hungarian populations. Long-term survival of the isolated population at the Budaörsi Road is quite improbable, if it still exists at all. The population at Balatonszéplak still survives. The exact range and density of the 9th district's population is also unknown, but the repeated reoccurrences of specimens indicate a well-established population. The population in Gyula has been known since 2008, and involves five houses and their immediate neighbourhood. The size of this population is unknown, but probably does not exceed a few dozen individuals. The discovery of further populations cannot be ruled out, and they might be founded either by escapees of imported specimens or by the further spread of the established Hungarian populations.

Bulgaria mostly inhabit buildings, but elsewhere in the Balkans they live on rocky hillsides, boulder fences around farms or on walls of terraces. In these populations they seldom inhabit buildings as those are usually occupied by the Mediterranean House Gecko (*Hemidactylus turcicus*) or the Common Wall Gecko (*Tarentola mauritanica*). The Mediterranean Thin-toed Gecko (*Mediodactylus orientalis*), formerly regarded as a subspecies of Kotschy's Gecko, is mainly a tree-trunk dweller (Werner 1993), but in Greece Kotschy's Geckos too have been observed on tree trunks (Schwarz *et al.* 2016). As this species lives in the immediate surroundings of humans, it can be accidentally introduced to new locations with the transport of building materials, furniture or other goods. Females lay their eggs (usually one or two at a time) into crevices of walls or debris, but do not glue them to the surface (Werner 1993). They can lay eggs several times a year. The four-centimetre-long young hatch after two and a half months (Valakos 2008).

Ecological requirements in Hungary

Being a Mediterranean species, its behavioural arsenal probably lacks the strategies that would help it to search for frost-free hibernacula outside human settlements in Hungary. At the same time, the temperate conditions of buildings provide suitable places to hibernate (Koynova *et al.* 2017). Especially suitable are the old apartment blocks with cracks in the walls or with well compartmentalised staircases providing an ample number of frost-free hibernacula. In urban settings, this species can easily spread from house to house while

Ecological problems

As this species' lifestyle is quite different from that of the native lizards (Sauria) and being a partially nocturnal animal, it does not compete significantly with them. However, it may carry parasites to which native species may be vulnerable and the partially urbanised Common Wall Lizard (*Podarcis muralis*) may transmit those to other native reptiles.

Economic effects

There is no foreseeable economic impact of the presence of Kotschy's Geckos in Hungary. However, as this species is a building dweller, reaction of people to their presence depends on their personal feelings and attitudes towards these animals.

Methods of control

There is no known method to effectively remove these geckos from buildings, but any captured individuals should be transferred to a zoo or a responsible keeper rather than released.

References

Babocsay 2021, Farkas *et al.* 1999, Kotsakiozi *et al.* 2018, Koynova *et al.* 2017, Schwarz *et al.* 2016, Valakos *et al.* 2008, Werner 1993

Gergely Babocsay

Common House Gecko, also known as Asian House Gecko

Hemidactylus frenatus Schlegel, 1836

Original area of the species

As it name implies, the Asian or Common House Gecko is native to south-eastern Asia, and ranges from Pakistan to Japan. It also occurs in Indonesia, New Guinea, on the Philippine Islands, and in the northern part of Australia (www.reptile-database.org, Wogan *et al.* 2021).

The introduction of the species to Europe and Hungary

The Common House Gecko is the most common gecko kept as a pet, and hence it is bred, sold and kept in the highest number among all gecko species. Outside its native range, individuals were observed and reported occurring in the wild from 87 countries (Carranza & Arnold 2006, Lei & Booth 2014, www.iucngisd.org, www.cabi.org). It was reported outside of its native range from several countries of Africa, Asia, Central and South-America, From Florida and Texas of the United States. The appearance of the Common House Gecko in Europe coincides with the growing popularity of keeping reptiles and fishes as pets. This species soon become a popular reptile among hobby pet owners, and soon escapees founded self-sustaining populations in Portugal, France and Italy (Weterings & Vetter 2018, www.iucngisd.org, www.cabi.org). It is imported in high volume as a pet and also as living fodder for other larger reptiles till today.

The exact date of its first appearance in Hungary is unknown, as several reptile species were imported in a single lot at the beginning of the pet trade industry. Unfortunately, this is still practiced till today. The first feral individuals were collected in the densely populated districts of Budapest in the spring of 2020. Since then further occurrences were detected in other inner districts of the Hungarian capital (Vilizzi *et al.* 2022).

Life history of the species

The Common House Gecko is a reptile species with less decoration. Its ground colour is greyish yellow, sometimes greenish or brownish, speckled with light or rarely darker brown spots. Its ventral side is lighter, usually butter yellow, or, for that of the darker individuals, darker filthy yellow. Thanks to its camouflage, for the untrained eye they are difficult to spot. Its fingers are equipped both with suction discs and claws, and hence can climb even on smooth vertical walls easily. Its body length is 9–15 centimetres, and most of it is made up by its tail. Males are considerably larger than females, and the form of their head is more varied. Its scales – especially on its belly – are

© Tibor Hadarics

smooth; while on its back and tail they possess a finely serrated edge. The tail of the males is a bit wider than that of females. On the lateral sides of the tail there is a lighter stripe, which is the same width from the base of the tail to about its middle section, and then tapers out till the distal end of the tail. On both sides of the body there is a darker stripe from the tip of the nose to the hind legs (Köhler 2003, Powell *et al.* 2016).

The males are territorial, while females freely move between the territories of males. Both the freshly hatched young and the adults exclusively feed on insects and their larvae. The Common House Gecko is a nocturnal reptile, i.e. it is active at night, and spends the day hiding in the crevices of walls, rocks or tree bark (Meshaka *et al.* 2004, Punzo 2005). As it is a poikilothermic animal, the individuals seek refuge in houses during cold periods in some invaded areas. Also, being a tropical species, the Common House Gecko can survive and thrive in habitats offering a warm microclimate, as its feeding stops at 17 ^{0}C (Lei & Booth 2014).

Both sexes become sexually mature at the age of 1-2 years, and under optimal conditions it might reproduce several times a year. The females lay 1-2 eggs in crevices of dry microclimate. Under the right condition new eggs can be produces after 21–28 days. The eggs must be kept at 28-29°C in order to hatch, and the process lasts 48–90 days (Krysko *et al.* 2003).

The ecological requirements of the species in Hungary

Based on fieldwork and modelling studies, the Common House Gecko, as a tropical species, can only survive (and hence form colonies) in urban environments in Hungary. Based on observations, the species is active from April to October depending on minimum night temperatures. Right now, self-sustaining populations were only reported from the inner districts of Budapest, such as the 8th, 9th and 13th district in the Pest side of the city. In Hungary, the occurrence of Kotschy's Gecko (*Mediodactylus kotschy*) was detected from the end of the 1990s in a single site in Budapest, and from several other locations in Hungary (Babocsay 2021). Based on the studies conducted lately, the areas of the two species overlap in Budapest. The exact size of the population of either species is unknown.

Ecological problems

In tropical countries, this species might on the one hand harm the local native insect fauna, and on the other hand can spread dangerous diseases to the native gecko species. Often the drastic decrease of native gecko faunas is blamed on the spread of the Common House Gecko (www.iucngisd.org). In Hungary there is no data on its ecological role and effect on the native fauna.

Economic effects

There is no known direct economic effect associated with the occurrence of this species. It certainly captures and consumes various insects (Insecta) – for example heteropterans (Heteroptera), flies (Brachycera) – and spiders living in houses. In some pet shops, the owners set the individuals free in the shops in order to consume the escaped insects kept as pet food. The Common House Gecko is kept in zoos and by pet owners as a diet for other reptile species.

Methods of control

This is a species that can be easily bought at pet shops, and even pet fairs. There should be a research project dedicated to the study and risk assessment of the impact of the Common House Gecko and its closely related sister gecko species (Gekkonidae), and what sort of ecological and nature protection risk they pose. The studies completed so far indicate that viable populations were only formed in urbanised environments of countries outside the tropical region. Its further spread in Hungary is inhibited by the climatic attributes of our country. The Common House Gecko can get into Hungary as a stowaway with various imported commodities, but a more realistic way of its introduction is as escapees from pet shops, and from the flats of owners. These individuals might have successfully started self-sustaining populations. Therefore the public should be informed about the responsible pet keeping of gecko species, and also the threats associated with setting free individuals in the towns. Based on the experiences of other countries, the control or reduction of alien and sometimes even invasive gecko species is a very difficult task, especially in urban settings. At the same time, the climatic attributes of Hungary makes the prolonged invasion and uncontrolled spread of the Common House Gecko unlikely.

References

Babocsay 2021, Carranza & Arnold 2006, Köhler 2003, Krysko *et al.* 2003, Lei & Booth 2014, Meshaka *et al.* 2004, Powell *et al.* 2016, Punzo 2005, Vilizzi *et al.* 2022, Weterings & Vetter 2018, Wogan *et al.* 2021

Bettina Szajbert, András Weiperth

BIRDS

Aves

Ruddy Duck

Oxyura jamaicensis (J. F. Gmelin, 1789)

Original area of the species

The native area of the Ruddy Duck is located in North America. It is closely related to the White-headed Duck (*Oxyura leococephala*), which is native in Europe and Asia. Its geographical range is enormous: this includes the Southern and Central part of Canada, the Central and Western part of the United States and the Western part of Mexico, but there is a large isolated population on the East coast of North America, too. Formerly the populations breeding in the North-Western part of South America (ssp. *ferruginea*), and the one breeding on the Eastern coast in the Andes and Tierra Fuego (ssp. *andina*) were treated as subspecies of the Ruddy Duck, but recently they are regarded and treated as an independent species: the Andean Duck (*Oxyura ferruginea*) (Brua 2020).

The introduction of the species to Europe and Hungary

The first individuals were imported the United Kingdom in the 1940s to waterbird breeding facilities (Hughes 2000). It proved to be a species that is very easy to breed, and the first flight capable birds escaped from the Slimbridge facility of the Wildfowl and Wetland Trust in 1952, where the Ruddy duck first bred successfully in 1950. In Great Britain the first breeding pair in the wild was recorded in 1960. In the 1950s and 1960s an additional 90 individuals escaped from captivity, but from 1973 only a few individuals escaped. Though it is important to note that at the same time the Ruddy Duck was a quite popular and common species kept in the aviaries of animal traders and ornamental bird breeders (Clement & Gantlett 1993). The population of the Ruddy Duck grew steadily and very rapidly, and the process was enthusiastically welcomed and witnessed by British society. By the beginning of the 1990s the English population grew to 600 pairs, and the number of wintering birds was estimated to be around 3500 individuals. The population grew by 10% yearly (Gantlett 1993). At the end of the 1990s the British population was estimated to be around 900 breeding pairs and around 4000 individuals, moreover yearly population growth was 15% (Hughes 2000). From the growing population that mostly occupied the South-Eastern part of England, some individuals flew over to the European continent. It was first recorded in Sweden in 1965, and till 1993 more than 600 sightings were recorded from 19 countries located mainly in the Western Palaearctic areas of Europe. The first successful breeding was observed in Europe in 1973 in the Netherlands. In the following years the Ruddy Duck continuously bred in the Netherlands, and became a breeding bird from 1988 in France, and from 1991 in Belgium, Ireland and Spain (Lever 2005). The species became a regular breeder in Iceland (Hughes 1997), and in 2001- it successfully bred in Germany (Niehaus 2001). The birds spreading all over Europe mainly originate from the growing feral English population, but in Germany some ringed aviary escapees were also observed (Gantlett 1993).

The occurrence and spread of the Ruddy Duck is of great importance. The first record dates to 1983 in Spain, and in 1986 this species was breeding in Andalucía, which happens to be the main breeding area for the White-headed duck (*Oxyura leucocephala*). Both its occurrence and breeding was mainly reported from the same lakes, where the White-headed Duck bred. This is reasonable, as the habitat requirements of the two closely related species are very similar. The spread of invasive species is a threat to the native fauna as the two species might interbreed. In Spain the first hybrid of the two species was discovered in 1990 (Urdiales & Pereira 1993). If the hybridization had been frequent, the westernmost population of the White-headed Duck would have

© Balázs Pintér

become extinct, and the aggressively invading Ruddy Duck could reach the Asian breeding populations of the White-headed Duck.

Luckily, specialists recognised this threat in time. In order to protect the White-headed Duck population of Spain, in 1992 the extirpation by culling of hybrids were mandated in Spain. In 1993 at a conference on this invasive species (International Ruddy Duck Workshop, Arundel), the Spanish delegates asked the participants to join forces to stop the spread of the Ruddy Duck (Gantlett 1993). Based on simulations by intense hunting in the breeding season, the then 4000 strong British population could have been reduced to around 50 individuals within ten years (Henderson 2010). But the culling of the British population of the Ruddy Duck was only started in 2005, when the population was estimated to be 6000 individuals. By 2015 – after 7200 specimens had been shot – only 40 Ruddy Ducks remained in the UK, and they were extirpated in the following years. By 2015 with similar measures implemented in other countries, the total number of Ruddy Ducks decreased to around a total of 300 individuals in France, Belgium and the Netherlands combined (Robertson *et al.* 2015).

Eastward spread of the species resulted in the occurrence of some individuals in the Carpathian Basin. In Hungary until 2020, 16 observations were reported. Only a single report mentioned two individuals, all the other sightings were of lone birds. Number of mature and subadult males was three times higher than that of identified females. The occurrences were evenly spread among the three large geographical regions of Hungary: west of the Danube, between the Danube and Tisza Rivers, and East of River Tisza (Gál 2021a).

The Ruddy Duck – with two other bird species – is listed among the 100 most dangerous invasive species of the World.

Life history of the species

The Ruddy Duck is perfectly adapted to aquatic habitats. As a typical diving duck, its legs are in the hind third of its body, enabling the bird to swim and dive perfectly. But it makes the bird very ungainly on land, and hence the bird spends most of its time on the water. It prefers lakes and stagnant water bodies with adjacent vegetation where it can build and hide its nest. Its clutch size is 6–10 eggs, which are incubated by the females for 24–26 days. The hatched ducklings are led by the female, but feed independently.

The Ruddy Duck feeds on aquatic plants and small invertebrates.


© Zoltán Orbán

The ecological requirements of the species in Hungary

Based on the few occurrences during autumn migration in Hungary, we have limited information on the ecological requirements. It is clear that the Ruddy Duck frequented our shallow lakes with non-freezing water. The Ruddy Duck did not succeed to establish a breeding population in Hungary and, as the Western European populations were eradicated, it will hopefully not happen in the future.

Ecological problems associated with the species

The Ruddy Duck is closely related to the White-headed Duck (*Oxyura leucocephala*), and the westernmost edge of the distribution area of this species extends to the Iberian Peninsula. The White-headed Duck (*Oxyura leucocephala*) is categorised as an "Endangered species" by the IUCN, there are only 120-130 pairs in Spain, and 82–186 pairs breed in Turkiye (BirdLife International 2015). Half a century ago the White-headed Duck bred in Hungary, Romania and then Yugoslavia, but became extinct in this region. The growing population of the Ruddy Duck dispersed to the South and reached Spain, where Ruddy Duck males aggressively harassed White-headed Duck females. In the small remaining populations of the endangered White-headed Duck, even the pairing of a few females with Ruddy Duck males and the resulting hybridization poses a serious threat. Hence not a single Ruddy Duck should be left in the Iberian Peninsula.

Economic effects

Direct economic damage cannot be contributed to the appearance and invasion of the species in Western Europe, as this duck only feeds in the water. At the same time the great ecological risk associated with the spread of the Ruddy Duck prompted the implementation of an eradication programme in Europe that costed 10-12 million Euros. It is important to note that the Ruddy Duck is a very conspicuous species aggregating in high numbers on the open waterbodies during the autumn, which considerably simplified the eradication of the species. In the case of a less conspicuous and more cautious bird species, the same results could only be achieved by investing considerably more effort and time and hence would be much more expensive.

Possible methods of control

The populations of the Ruddy Duck can be controlled and finally eradicated by the diligent culling by shooting of individuals. Animal right advocates might protest against this method, but we should emphasize that sealing the eggs by a lacquer layer, although considered more humane, is much more difficult and less effective. Luckily nowadays the chances that its populations get established and increase are lower and lower. It is partly due to the strict control measures against the spread of the species. But also as the spread of an invasive species becomes a major problem, and hence more attention is paid to it, more intense research is conducted on this topic. Our knowledge and understanding of the mechanisms are more comprehensive, and control measures are more intense, than 25-30 years ago.

This species is also listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to the wild is strictly forbidden in all the EU member states.

References

BirdLife International 2015, Brua 2020, Clement & Gantlett 1993, Eaton 2020, Gál 2021a, Gantlett 1993, Henderson 2010, Hughes 1997, Lever 2005, Niehaus 2001, Robertson *et al.* 2015, Urdiales & Pereira 1993

Tibor Hadarics & László Haraszthy

Canada Goose

Branta canadensis (Linnaeus, 1758)

Original area of the species

The native area of the Canada Goose is North America: it breeds in Alaska, Canada (with the exception of the northern arctic part), in the Northern and Central part of the United States, and in small numbers on the Western coastal part of Greenland. Seven subspecies are recognised in its enormous geographical range (ssp. *moffitti*, ssp. *maxima*, ssp. *occidentalis*, ssp. *fulva*, ssp. *parvipes*, ssp. *canadensis*, ssp. *interior*) (Mowbray *et al.* 2020b). The smaller forms living in the Northern arctic areas of Alaska and Canada were formerly also regarded as subspecies and included in *B. canadensis* (ssp. *leucopareia*, ssp. *minima*, ssp. *taverneri*, ssp. *hutchinsii*) but from 2004 they are treated as an independent species: Cackling Goose (*Branta hutchinsii*) (Mowbray *et al.* 2020a). The Canada Goose is a migrating species: the ones living further North migrate larger distances, while those living in the South take shorter routes, moreover, some individuals stay in the breeding habitat year around. Their wintering grounds are located in the United States (Mowbray *et al.* 2020b).

The introduction of the species to Europe and Hungary

The first individuals were shipped to Europe more than 200 years ago, and they and those introduced later formed the breeding population of our continent. From the middle of the 20th century, the number of individuals continuously increased everywhere in Europe. Nowadays the Canada Goose breeds in at least ten European countries.

The first Canada Geese were shipped to Great Britain around 1650. At the beginning, they were kept in parks, gardens and zoos. They started to appear as nesting feral birds around natural water bodies only in the 20th century (Lever 2005). In Great Britain the population was estimated to be around 19000 in 1976 (Ogilvie 1977), but by 1991 the population number rose more than three-fold to more than 63000 individuals. This was achieved mainly through the increase of the density of the populations, but the size of the breeding area of Canada Geese also increased by 37% (Delany 1993a, 1993b). By the end of the 20th century, the Canada Goose became a wide-spread and regular breeder in the British Isles, but was still only breeding at a handful of places in Scotland and in the Irish islands (Kirby & Sjöberg 1997). The population was estimated to be about 30000 breeding pairs at the middle of the 1990s (Kirby & Sjöberg 1997).At the end of the 1990s they were estimating at 20000 pairs, which means that after the breeding season the population could be around 80000 individuals, with the fledged young. In 2000 the whole British population was about 55000 individuals (Lever 2005). Nowadays in Great Britain, 62000 pairs breed (Musgrove *et al.* 2006).

In Scandinavia, some individuals where introduced around the end of the 1920s and beginning of the 1930s. More precisely two pairs – probably of European origin – and one male straight from North America were introduced to Sweden. Most of the Scandinavian population can be traced back to these five individuals (Heggberget 1991). The birds became feral individuals, and started to breed in the wild. The southern Swedish population was growing slowly at the beginning, but later its growth accelerated considerably: from the 150 pairs in 1960, it grew to 2000 pairs in 1970, and the whole population was estimated to be almost 10000 individuals. At the beginning of the 1980s, the number of breeding pairs was estimated to be 5000, and the whole population was estimated to be around 50000 individuals (Lever 2005). At the middle of the 1990s, the population was estimated 5000 – 10000 breeding pairs, and with the non-breeding individuals and the young birds at autumn was probably 50000 individuals (Kirby & Sjöberg 1997). In Norway, the first Canada Geese were introduced at the end of the 1930s from Sweden. In the 1960s, more individuals were introduced from Sweden, and by 1984 the population in Norway had grown to around 700–900 breeding pairs (Heggberget 1991). By the end of the 1990s, the figure increased to around 1000 pairs. They mainly bred in the southern and central parts of Norway (Kirby & Sjöberg 1997). In Finland, the first introduction was in 1964, and the Canada Goose bred for the first time in 1966. At the end of the 1990s, the number of nesting pairs reached about 1000. The breeding area is situated mainly in the southern and southwestern parts of Finland, but the spread towards the central parts of the country continues (Kirby & Sjöberg 1997). At the beginning of the 2020s, 7000–8000 pairs breed in Finland (Noble 2020a).

© László Haraszthy

The breeding populations of Canada Goose in France, Belgium, the Netherlands and Germany were initiated by individuals arriving from Scandinavia to winter, and to a lesser extent the descendants of birds that were introduced to these countries earlier. In Denmark, the Canada Goose has nested since 1962. In Germany, vagrant individuals first occurred in the 1950s, and first nested in 1978 (Rutschke 1987). The German population was estimated at around 1000 pairs at the middle of the 1990s; in addition to the coastal areas, it breeds at some locations in the central and southern parts of Germany, too (Kirby & Sjöberg 1997). In the Netherlands, it has been breeding since 1951, and a stable population was established by 1970s. At around the same time (1973), the species started to breed in Belgium. At the beginning of 2020s, in the Netherlands 9000 – 12000 pairs breed, while in Belgium 1400–1600 pairs breed (Noble 2020a). At the end of the 1990s, the nesting of this species was reported from the Baltic states and Russia (Kirby & Sjöberg 1997). Lately in the past decades the Canada Goose succeeded to establish smaller or larger breeding populations even in Poland, Italy and Austria.

The massive majority of Canada Geese breeding Europe belongs to the nominating North American subspecies (ssp. *canadensis*) that occurred in the Eastern part of North America. Specimens belonging to other subspecies are observed very seldom. These are either escaped captive birds, or hybrids of other subspecies (Rutschke 1987, Madge & Burn 1988). Very seldom do wild North American individuals reach Europe. The possibility of crossing the Atlantic Ocean was proven by the recapture of a Canada Goose in North America that was ringed in Great Britain, and also by the observation of individuals in Western Europe that wore North American rings (Oates 1999, Batty & Lowe 2001, www.migrationatlas.org).

The Canada Geese occurring in Central Europe are escapees either from breeding facilities or zoos, or might arrive from the Scandinavian populations, which join the migrating Greylag Goose (*Anser anser*) in the autumn and travel with them to the inner parts of the continent. The first Canada Goose individuals were observed in Hungary at Lake Fertő in 1997 (Hadarics & Neuwirth 1998), and in 1998–1999 at the Kis-Balaton wetland area (Faragó & Lelkes 1999). Since then rarely, but more or less every year, some individuals turn up in Hungary arriving with the migrating masses of flocks of geese.

Although between 2015 and 2018 two individuals were regularly observed around Pusztaszer, they did not show any inclination to nest (Gál 2021c).

Life history of the species

As the European population was founded by a few individuals, the genetic variance of their populations is very low. Nevertheless, no signs of decreased viability were detected (Kirby & Sjöberg 1997), on the contrary: the stable increase of population size and area expansion proves the extreme adaptability of this species.

Under natural condition, the Canada Goose becomes sexually mature at the age of two or three years. In the European populations some individuals start breeding even earlier. Its clutch size is 4–7 eggs. Incubation is done by the females only, and nestlings hatch after 28–30 days. The fledged young become able to fly around 10 weeks (Mowbray *et al.* 2020b).

The Swedish and Finnish populations are migratory. They spend the winter in the western part of the Baltic Sea (the coastal areas of southern Sweden, Denmark and Germany), and the South-eastern part of the North Sea: the coastal areas of the Netherlands, Germany and Denmark. The rest of the European stock does not migrate, they might just move a bit to the South for the winter, or fly to their moulting sites (Rutschke 1987, Kirby & Sjöberg 1997).

The ecological requirements of the species in Hungary

In Europe, the Canada Goose is associated with aquatic habitats such as fresh water lakes and sea shores, but becomes more and more widespread in city parks and around lakes in cities. In Hungary, the occurring specimens turn up with the migrating flocks of geese in the autumn, and hence can be observed at the well-known gathering places of geese. In the morning, they go to feed with other wild native geese from the night roosts to adjacent feeding areas (cut sweet corn fields, oilseed rape plantations, grasslands), and then return in the afternoon to the aquatic habitats to spend the night at them.

Ecological problems associated with the species

In the United Kingdom for a long while, the Canada Goose would breed without any control. The first census of this species was carried out in the moulting period in 1953, and 2000–4000 individuals were counted. Between 1967–1969, 10500 individuals and in 1976, 19400 individuals, were counted, while their number rocketed to 63580 in 1991 (Allan *et al.* 1995).

In Hungary, the Canada Goose could only establish breeding populations where the native Greylag Goose (*Anser anser*) nests, and hence could compete only with that species.

The Canada Goose interbreeds with Greylag Goose, the Greater White-fronted Goose (*Anser albifrons*) and the Barnacle Goose (*Branta leucopsis*). Such hybrids have been already observed in Hungary several times. Randler (2008) collected 2395 records of hybridization occurring among different species of Anseriform birds (Anseriformes) in Central Europe. From among these, in 600 instances the native geese species interbred with invasive alien species. In 283 instances, the Canada Goose paired and bred with Greylag goose, and in 45 cases the Canada Goose interbred with the Barnacle Goose. Interestingly the invasive Canada Goose might interbreed with the also invasive Bar-headed Goose (*Anser indicus*) at those locations, where the two species co-occur, and 28 such cases were recorded.

Economic effects

In Hungary the seldom and singly occurring specimens of Canada Goose do not have any economic effect whatsoever.

In Western Europe, its urbanising populations also have no, or negligible, economic effects, though some pathogens (such as the *Influenza virus A*) might be transmitted by them. But as virus hosts and potential agents, the Canada Goose is not more dangerous than any other water bird. The ones nesting in city parks might damage the vegetation of parks, especially by grazing the grass. Also, their faeces might spoil the footpaths. The birds coming to shore might accelerate the erosion of the shoreline with trampling. In a London park, the price of cleaning and shore restoration is estimated to be 40 GBP per bird per year. Around airports larger flocks of Canada Geese might pose a serious hazard for air traffic; several cases of collisions of Canada Geese with aircrafts have been reported (Allen *et al.* 1995).

In natural habitats, the large masses of wintering Canada Geese affect the environment the same way as other large migrating and wintering flocks of wild geese (*Anser* spp., *Branta* spp.). In agricultural lands, especially in freshly planted crops, they might damage through grazing.

Possible methods of control

The Canada Goose slowly progresses towards the interior of our continent. As it is a very large and easily recognisable bird, its occurrence – especially in the nesting season – would not be unnoticed by ornithologists and conservation specialists. Although not too much is done in Western Europe to control and reduce the number of this species, its presence in the Carpathian Basin is not desired. As it is on the list of game birds, if a breeding population was established it would be easy to extirpate by various water bird hunting methods.

References

Allan *et al.* 1995, Batty & Lowe 2001, Delany 1993a, 1993b, Faragó & Lelkes 1999, Gál 2021c, Hadarics & Neuwirth 1998, Heggberget 1991, Kirby & Sjöberg 1997, Lever 2005, Madge & Burn 1988, Mowbray *et al.* 2020a, 2020b, Musgrove *et al.* 2006, Noble 2020a, Oates 1999, Ogilvie 1977, Randler 2008, Rutschke 1987

Tibor Hadarics & László Haraszthy

Bar-Headed Goose

Anser indicus (Latham, 1790)

Original area of the species

The native area of the Bar-headed Goose is located in the high elevation parts of Central Asia. Its enormous breeding range is divided into four separated areas. From among these the largest is in Central and Western Mongolia, but also includes a bit of Southern Siberia and Eastern Kazakhstan. The second largest breeding are is in Western China, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan and Pakistan. There are two further small breeding areas in China, one of them in Tibet, while the other is in the central part of China. The breeding areas are usually at high elevations, between 4000-5000 meters above sea level, and are situated in and around various wetland habitats. It migrates to India to winter, where usually tens of thousands of individuals stay for the cold period. Smaller wintering groups occur in Pakistan, Nepal, Bangladesh and Burma. This species flies over the mountain ranges of the Himalaya to its wintering grounds (Carboneras & Kirwan 2020). In its breeding area, its population size decreased slightly during the last two decades. IUCN categorise this species as *Least Concern* (BirdLife International 2022).

The introduction of the species to Europe and Hungary

The Bar-headed Goose was intentionally introduced to Europe, but individuals also surely escaped from zoos, wildlife parks and breeders. In Europe, and especially in Western Europe, free-living individuals and breeding attempts are known from the 1950s

© Tibor Hadarics

and 1960s. This species attempted to breed at several places in Western Europe, but self-sustaining breeding populations only formed at a handful of locations. The Bar-headed Goose has been observed to nest in France, Great-Britain, Spain, Belgium, the Netherlands, Germany and Finland. In the British Isles in 1991 its population was approximately 80 individuals (Delany 1993a, 1993b), but successful breeding was reported only from a single location. It bred at several places between 1996 and 2000 in Great Britain. At the beginning of the 2000s more than a hundred individuals lived freely at 30 different locations, and at least 5 pairs bred successfully (Lever 2005). Its strongest population is found in the Netherlands in Europe, where in the middle of the 1970s only a single pair bred, but by the mid-1990s six to ten pairs bred (Lever 2005). By the beginning of the 2000s the population grew to 125–200 pairs (Bauer 2020b). The Dutch population has decreased since 2005, and from 2010 the local authorities have exerted strong control over them, and hence the number of breeding pairs declined (Bauer 2020b). The Bar-headed Goose has been breeding in German regularly since the 1980s, and its population was estimated to be around 100-200 individuals at the beginning of the 2000s, but only 5-10 pairs bred successfully (Lever 2005). The smaller population breeding in Southern Germany became self-sufficient in 2005 (Bauer *et al.* 2016). In other countries (France, Spain, Finland) it only nests sporadically, often the nesting attempts fail, and real breeding populations have not yet been formed (Bauer 2020b). The breeding pairs are often escaped birds from zoos or aviaries.

The first records of the Bar-headed Goose dates back to the 1930s (Vasvári 1942, Boross 1943), but at those times there were no free-ranging populations in Europe. Hence these birds probably escaped from breeders, just like the two subadult individuals captured in the summer of 1992 at the resort are of Fertőrákos (Hadarics 2006). Most of the individuals observed from 1997 in Hungary surely originate from Western European stocks. (Category C), but it is also possible that they escaped from nearby zoos or from the aviaries of breeders (Category E). In Hungary, Bar-headed Geese usually show up in the masses of migrating geese arriving from the North during the autumn migration. Most often they are observed among the migrating or overwintering geese between November and January, but seldom also during the spring migration. These individuals integrate into the flocks of Greylag goose (*Anser anser*) and Greater White-fronted Geese (*A. albifrons*). They also behave similarly, and hence we can assume they originate from Western European populations. The sporadically occurring very tame individuals from May to August are most often escaped birds from captivity. As the species is characterised by a strong inclination to migrate, its appearance and even breeding attempt can be expected any time. It mainly depends on how successful the control of the Western European population is. If the Western populations disappeared, it is highly improbable that the Bar-headed Goose will become a nesting species in Hungary, forming a breeding self-sustaining population.

Life history of the species

With its 2000–3000 grammes bodyweight, the Bar-headed Goose is a bit smaller than the Grey-lag Goose (*Anser anser*). Regarding its weight and size, it is most similar to the Greater White-fronted Goose (*A. albifrons*). It is a herbivore species, mainly feeding on leaves and seeds of different grass species (Poaceae), but sometimes even consumes their roots also (Carboneras & Kirwan 2020).

The Bar-headed Goose forms loose colonies during nesting. It builds its nest among the vegetation around water bodies, or sometimes on the dry ground or trees. Its clutch size is 4–6 eggs. The parents take turns during incubation, which lasts for about 27–30 days. The young start to fly from the age of 52–54 days (Carboneras & Kirwan 2020).

The ecological requirements of the species in Hungary

In Hungary, the Bar-headed Goose has only appeared occasionally. Till today, only a single individual appeared every now and then in larger flocks of mixed species geese. These were observed either on the feeding grounds (wet meadows, on seedings, or cut corn fields), or at the water bodies used as night roosting sites. From its first appearance in Hungary in 1997 (Hadarics 2006) till today, it is mostly present between October and November, when mixed geese flocks arrive to the Carpathian Basin in great masses. But single individuals were observed during almost any period of the year (Gál 2021d) (but the individuals observed in the summer are almost surely escaped birds). If it would form a breeding population in Hungary, the same habitats would be used for nesting as that of the breeding areas of the Grey-lag Goose (*Anser anser*).

Ecological problems

More than 10.000 kms away from its original mountain breeding range, the Bar-headed Goose found optimal breeding conditions at sea level. If intervention is not immediate and appropriate, this species can quickly form large breeding populations. It can only nest in areas where the indigenous Greylag Goose (*Anser anser*) breeds, and therefore the two species are direct competitors. The two species might even hybridise. Randler (2008) collected evidences on 2395 cases when anseriform birds interbred in Central Europe. From among these, in 600 attempts individuals belonging to introduced species tried to pair with indigenous geese. 35 cases of Greylag and Bar-headed goose pair-bonding and breeding were recorded. Interestingly, the Bar-headed Goose also can hybridise with the introduced Canada Goose (*Branta canadensis*) at those places where these species co-occur (28 such cases were reported).

Economic effects

Its sparse occurrence does not have any economic significance. If it had started a stable breeding population, its effect would be probably the same as that of the indigenous Greylag goose (*Anser anser*).

Possible methods of control

As long as this species occurs in Hungary as part of the large migrating or wintering mixed-species flocks of geese, and disappears with them as they leave, there is no need for any control measure. However, its breeding and forming a stable population should not be tolerated. The individuals that show a tendency should be captured, and if these trials fail, all the specimens should be shot.

References

BirdLife International 2022, Bauer 2020b, Bauer *et al.* 2016, Boross 1943, Carboneras & Kirwan 2020, Delany 1993a, 1993b, Gál 2021d, Hadarics 2006, Lever 2005, Randler 2006, Vasvári 1942

Tibor Hadarics & László Haraszthy

Egyptian Goose

Alopochen aegyptiaca (Linnaeus, 1766)

Original area of the species

The native area of the Egyptian Goose is located in Sub-Saharan Africa, where, with the exception of the Central and Western African rain forests, it breeds practically everywhere (Callaghan *et al.* 2020). It usually breeds on the plains, but, for example in Ethiopia, it breeds at 4000 metres above sea level. Long ago, it occurred in the Nile valley, the Eastern part of the Mediterranean, and probably even in Southwest Europe. Although the existence of the European native population is questionable, it is difficult to judge whether it was a wild breeding population, or at that time the Egyptian Goose was already kept as an ornamental species in parks and gardens. In Africa the species is associated with wetlands, occurs around lakes, water reservoirs, slowly flowing rivers, but also breeds in moors.

The introduction of the species to Europe and Hungary

The Egyptian Goose was introduced to the United Kingdom in the 17th century, and from the escaped birds a small, but stable self-sustaining breeding population formed by the 19th century (Venema 1997). From the 1970s the species started to grow in number and enlarge its breeding area. In 1988 approximately 400 individuals were recorded in the UK, mainly in Norfolk county (Sutherland & Allport 1991), but by 1991 the population number grew threefold to around 900, and most of them (around 90%) still lived in Norfolk (Delany 1993a, 1993b). The breeding population in England was estimated to be 85 pairs in 1999, 127 pairs in 2000, 147 pairs in 2001. However other estimates suggest it numbered even around 300 pairs (Lever 2005). Its first breeding attempt in the Netherlands was recorded in 1967. The Dutch population originated from escaped birds. At the beginning it grew slowly in numbers, but later the growth accelerated, in 1994 reaching 1300 pairs, and its breeding area also enlarged (Venema 1997). At the beginning of the 2000s its population was estimated to be 1400 pairs, and with the nestlings by the autumn it gives around 6000 individuals. In 1977 the Egyptian Goose appeared in Brussels as a breeding species, and by the mid-1990s the Belgian population grew to 50–100 pairs (Venema 1997). By the beginning of the 2000s its number might have grown to 150 pairs (Lever 2005). Around the same time, it also started to breed in Germany and Luxemburg. In France it appeared in 1985–1986, breeding pairs were reported from the Northern part of the country (Venema 1997), but fast spread was only reported after 2000. In Germany the number of nesting pairs at the beginning of the 2000s was around 200–400, and the full population number was estimated to be around 1000 to 3000 individuals (Lever 2005). In 2003 the species was reported from Switzerland. Nowadays it became a breeding species in Denmark, South Sweden and Northern part of Poland. It bred for the first time in the Czech Republic in 2011 (Ondra & Klejdus 2013). The species also enlarged its breeding range towards the South: at present it also breeds in Spain and Portugal. Its population is estimated to around 30000 pairs in North-western Europe (Gyimesi & Lensik 2012).

At the beginning of the 2000s, interesting predictions surfaced regarding the European spread of the species. These envisioned that the area of the species will be extended to the South and Southeast in France and Germany, and that by 2015 the European population would grow to around 20000 individuals. By 2010 stable populations would have been established in Switzerland, Austria and Hungary, which would further spread to the South and South East along the Danube valley, and will soon reach Serbia (Lever 2005). By today the European population has reached and even surpassed the predicted size, but stable populations have not yet been established in the Carpathian Basin, though several breeding attempt was reported from this area.

In Hungary it was first observed around the city of Paks in 1993 (Zörényi 1993). Until the beginning of the 2000s it occurred only sporadically, only being seen eight times in Hungary until 2008 (MME Nomenclator Bizottság 2008). From the end of the decade till the middle 2010s it became more and more frequent. And while formerly only single individuals were seen, in 2012 and 2013 closely associated pairs were observed. In 2015 a pair settled in a stork nest on a factory building's chimney in Tolna county in Szakály, but the returning storks chased them away (Kalotás 2020). The first successful Hungarian breeding attempt was recorded in 2016, in Zsennye, Vas county, and the pair fledged 10 offspring (Tóth 2016). They nested again at the same place in 2017, and fledged again 10 young (Gyurácz & Kóta 2020). These nestlings were captured.

Life history of the species

The Egyptian Goose is an extremely aggressive species. In South Africa, where it is a native breeding bird, it was observed to chase away an African Hawk-eagle (*Aquila spilogaster*) from its nest, and bred in the occupied nest. Also in South Africa it was observed to breed in the empty alternate nests of the Secretary Bird (*Sagittarius serpentarius*) (Ernst *et al.* 2015). In Germany it occupied a nest hole in a stone wall that was formerly used by a Peregrine Falcon pair (*Falco peregrinus*) and then by Eagle Owls (*Bubo bubo*) for nesting, and also occupied an artificial nest box placed on a high chimney for Peregrines (Brauneis 2012).

Usually pairs occupy the breeding areas. It builds its nest on the ground from reeds and leaves. Sometimes it occupies nests of other species built from twigs on trees. Often it uses holes in the walls of high buildings. Clutch size is 5–12 eggs, and they are incubated for 28–30 days. The nestlings can fly at the age of 60–75 days and become sexually mature in their second year (Callaghan *et al.* 2020).

It mainly feeds on plants, and can only settle at water bodies located near open grasslands, where it can graze. Besides grass, it consumes other plant material such as leaves, seeds, but also collects orthopterans (Orthoptera) and earth worms (Lumbricidae).

The ecological requirements of the species in Hungary

Its ecological requirements seems to be the same as those of the Greylag Goose (*Anser* anser) It usually settles around lakes and water reservoirs and feeds as other geese on grass lands and cereal crops. Till 2022 it could not establish a breeding population in Hungary, and although its repeated appearance should be expected, the establishment of breeding populations should be blocked by all means.

© Roland Döbrösi

Ecological problems

As a consequence of its ingrained aggressiveness, it might behave very antagonistically against any other goose or duck species during incubation and especially when it rears its nestlings. It would use the same breeding areas for nesting as the native Hungarian geese and duck species, especially the Greylag Goose (*Anser anser*).

Based on the trends in other European countries, after a certain number of breeding pairs settle, its populations grow very quickly and the species invades new habitats. If the Egyptian Goose breeds in high number, it will compete with the native breeding ducks and geese of Hungary.

Economic effects

If it appears in large numbers, it can have the same effect as any other native European geese species. Significant damage can only arise when frozen seeded areas suddenly thaw, and are trampled by them. With its grazing in the autumn and winter, it initiates growth of cereal crops, resulting in higher productivity.

Possible methods of control

The Egyptian Goose is a very cautious bird, and hence it is difficult to capture with traps. At the same time, it is easy to shoot with modern firearms, especially if the location of its nest is known. Its year-round hunting should be permanently practiced and mandated, and even a prize should be offered to hunters if the species would appear in large numbers in Hungary.

The Egyptian Goose is listed in the List of invasive alien species of Union concern, and hence its keeping, breeding and introduction to the wild is strictly forbidden in every member state of the European Union.

References

Brauneis 2013, Callaghan *et al.* 2020, Delany 1993a, 1993b, Gyimesi & Lensik 2012, Gyurácz & Kóta 2020, Kalotás 2020, Lever 2005, MME Nomenclator Bizottság 2008, Retief *et al.* 2015, Ondra & Klejdus 2013, Sutherland & Allport 1991, Tóth 2016, Venema 1997, Zörényi 1993

László Haraszthy

Feral Pigeon

Columba livia f. domestica Linnaeus, 1758

Original area of the species

The Feral Pigeon is the descendant of the Domesticated Pigeon (*Columba livia* f. *domestica*) that descends from the wild Rock Pigeons (*Columba livia*), originally occurring in southern Europe, North Africa, and the south-western part of Asia. When domestic pigeons escape from captivity and form self-sustaining breeding populations, these feral birds are called Feral Pigeons. But it is important to note that the Feral Pigeons we can observe now in different habitats are from the several hundredth generation of feral birds, so these are not fresh escapees, but a bird whose ancestors have already lived independently from mankind for many generations.

The introduction of the species to Europe and Hungary

The Rock Dove (*Columba livia*) is native to Europe. The Domestic Pigeon is the oldest domesticated bird, and is mentioned in Mesopotamian Cuneiform tablets and Egyptian hieroglyphs alike. Its domestication started 4,000–6,000 years or, according to some new research, even 10,000 years ago. It is impossible to date the first event when Domestic Pigeons escaped from captivity and started to establish wild breeding populations. The Feral Pigeon occurs in the whole of Europe at present, with the exception of some parts of Scandinavia (Sattler 2020).

© János Bagyura

The so-called blue-banded variety, especially in flight, is almost impossible to tell apart from the Rock Dove. All the other colour varieties are easily recognised as Feral Pigeons.

Life history of the species

Similarly to its wild relatives, the doves (*Streptopelia* spp.) and pigeons (*Columba* spp.), the Feral Pigeon lays only 2 eggs. Nevertheless, its yearly reproductive output is very high. The number of individuals can increase very quickly. This is due to its capability to lay 5-6, or even more, clutches a year. The females become sexually mature and start to reproduce at 5-6 months of age.

The feral pigeon is granivorous bird, and is not too picky in terms of food, from sweet corn to the tiny seed of weeds: it eats everything. But in human settlements besides grain and seeds it also feeds on food remains, especially on leftover pieces of bread. It also regularly feeds on different berries and fruits, such as the berries of the Common Hackberry (*Celtis occidentalis*).

The survival of urban populations is aided to a small extent by the habit of feeding birds and pigeons, in particular at parks.

The ecological requirements of the species in Hungary

It is an extremely adaptable species regarding climate, diet and nest site use.

In Hungary, the Feral Pigeon is widespread and can be found in a smaller or larger number everywhere in the country. It can settle in the large cities just as easily as in small villages, everywhere it can nest. The preferred nest sites are the attics of large buildings, both in cities and in agricultural areas, towers of churches, but even an abandoned or even partly ruined house can be a preferred nest site in villages. Oftentimes it settles in uninhabited agricultural farmhouses, but also is at home in inhabited buildings. If the Feral Pigeon cannot infiltrate into the building, it starts nesting on the outer facade of buildings. It regularly breeds in barns, cowsheds and various other agricultural buildings.

Till the 1990s, enormous populations of Feral Pigeons lived in the larger cities and around the grain processing plants, which offered stable nutrition. In the middle of the 1970s, the number of Feral Pigeons was estimated to be around 150,000 – 200,000 individuals (Csernavölgyi 1976). At the beginning of the 1980s, in the large attics of Budapest often more than 1,000 individuals nested or used the attic as a night-time roosting site. After the political changes in the 1990s, the large apartment blocks were privatised, and during the rebuilding of the buildings these entrances were blocked, and hence the attics could not be used as nesting sites any longer. At around the same time, its feeding opportunities were also considerably reduced. As a result of these factors, nowadays only one-tenth of the former number of Feral Pigeons breeds in Budapest. As the privatizations of apartment blocks was a common practice all over the country, probably the situation is similar to that in Budapest in other cities, and probably a similar decline in its number took place.

Ecological problems

The Feral Pigeon is in every aspect a typical invasive species, which can easily and quickly adapt to the changes of the environment. Because of its high number, the Feral Pigeon is a food competitor for all the native granivorous bird species. There were no studies conducted on the effects of the collapse of Feral Pigeon populations on other bird species. But the successful spread of Collared Doves (*Columba palumbus*) in city parks and their increasing number in cities probably has to do something with the occupation of the spaces left vacant by the Feral Pigeon, and also the fact of better food availability.

The Feral Pigeon is an important food source for many raptors, for example, the Northern Goshawk (*Accipiter gentilis*), Saker Falcon (*Falco cherrug*) and Peregrine Falcon (*Falco peregrinus*). It is an important host and vector of many avian diseases, such as the Avian pox caused by *Avipovirus*. Unfortunately, this disease can spread to these rare and protected raptor species, and might cause their death.

Economic effects

Feral Pigeons exert various economic effects. The most well-known is the pollution of buildings and statues with their droppings. This is not only an aesthetic problem since the acid droppings might cause structural problems, too (Csernavölgyi 1976). A completely pigeon-free state of building facades is not easy to maintain, even if very expensive protective methods are implemented. The guano accumulating through decades in attics and towers under the nest of pigeons might be half a meter thick. The removal of this excrement can also be very expensive.

It is very difficult to exactly price the costs which arise when we discuss the diseases transmitted by Feral Pigeons. Some of these diseases might be transmitted to humans, and can cause serious illnesses.

On agricultural lands, the large Feral Pigeon can cause considerable damage, for example by taking seeds from sunflowers.

Methods of control

The entering of Feral Pigeons into towers and attics is easy to inhibit by blocking the entrances of such spaces.

Several methods are available for the mechanical protection of the exterior of buildings against Feral Pigeons. However, we have to mention that pigeons often do not care for these devices, and use their nesting or day-time roosting sites just the same as before the installation of the protective devices. The protection of buildings with nets is effective, but the nets are disturbing for viewers. This solution is cumbersome, especially in the case of historic buildings, and their use is limited or omitted. There are various electric devices or even systems, both solar-powered and traditional, using ultrasonic or other frequencies, against Feral Pigeons, too. Sometimes these electric devices emit alarming light impulses, and there are also some bird deterrent pastes. Nowadays, plastic Eagle Owl dummies, sometimes giving calls, are also used to deter Feral Pigeons.

Firearms are not applicable in residential areas to control Feral Pigeons, as their use for hunting within residential areas is prohibited. The capture and relocation of Feral Pigeons is usually a futile effort, as they can easily navigate back to their home range.

There were trials to use chemical agents such as mestranol to cause infertility in Feral Pigeons. With these agents, which must be added to the food of pigeons, their populations were successfully reduced at some locations (but the chemical treatment must be regularly repeated for a long-lasting effect) (Csernavölgyi 1976).

The other possibility is to employ falconers to protect a building from Feral Pigeons, but it is a very time-consuming and hence expensive method, as it requires the regular appearance of the falconer and its bird at the site.

It is impossible to significantly reduce the stock of Feral Pigeons by banning their feeding. Its only outcome might be that large flocks of pigeons do not stay all the time at a given site.

The number of Feral Pigeons consumed by Beach Martens (*Martes foina*) in urban areas can be quite considerable, but as usual, predators cannot completely kill off a prey species.

References

Csernavölgyi 1976, Sattler 2020, Szép *et al.* 2012.

László Haraszthy

African Sacred Ibis

Threskiornis aethiopicus (Latham, 1790)

Original area of the species

The African Sacred Ibis is a breeding bird of Sub-Saharan Africa, but it is not present in the arid desert areas of Southwestern Africa (Matheu *et al.* 2020). It breeds in wetland habitats, and nests either inside these wetlands or in the adjacent areas, in reed-beds, marshlands, but also might build its nest in trees. It can adapt to drier habitats too, and therefore might occur everywhere in its geographical range. It often forms colonies far away from wetlands. It also breeds in the vicinity of large cities and busy motorways.

The introduction of the species to Europe and Hungary

On the European continent, the African Sacred Ibis is often kept in zoos, and even smaller bird parks. They are often kept as semi-wild birds, i.e. they nest in aviaries, but after the fledglings hatch, they are released from the aviary and hence they can fetch their own food. At other places, the mature specimens are not able to fly at all, or only for limited distances, but their offspring are able to fly perfectly. These birds regularly escape from captivity. Such birds formed breeding populations first in Spain (1970), then in France (1990). As the population, formed on the shoreline of Western France, grew continuously, first several new colonies were founded on the Atlantic coast of France, then several breeding colonies appeared around the French part of the Mediterranean Sea (Yésou & Clergeau 2005). In the second half of the 2010s the number of individuals in the French populations grew to several thousands. The species spread to Italy, first in the floodplain of the River Po, then also in the adjacent counties around the Po in Italy. Smaller breeding colonies were formed in Germany and the Netherlands.

The African Sacred Ibis was not introduced to Hungary, and not a single pair appeared as escapes from the breeding populations, which come closer and closer to our borders. But after its first appearance in 2008, lone individuals were seen several times, and these were all ringed individuals with the exception of one bird. Therefore all the vagrants probably came from breeding centres, zoos or from semi-natural colonies.

Natural history of the species

The African Sacred Ibis is a colonial breeder. The colonies may consist of several dozens to some thousand pairs. It predominantly builds its nest in trees standing in extensive reed beds, and most often breeds in mixed-species colonies formed with other large wading birds such as herons and other ibises. In wetlands it mainly feeds in flocks during the day on insects, larvae of amphibians, snails, fish, reptiles etc. In Africa, the African Sacred Ibis is a common sight almost anywhere as it searches for food. On the arid pastures and in similar habitats, it mainly hunts for locusts, crickets and grasshoppers. It even catches smaller lizards, small mammals, crustaceans, and steals the eggs of birds and crocodiles. Nowadays it is often observed feeding at waste disposal plants. Usually it feeds in smaller flocks, but sometimes several hundred feeding birds aggregate.

Its clutch consists of 2-3 eggs, and they are incubated for 28-29 days. The chicks fledge at the age of 35-40 days (Matheu *et al.* 2020).

The ecological requirements of the species in Hungary

When observed, this species has always occurred in wetland habitats in Hungary. One individual first observed on the 22nd May 2008 near Pusztaszer was still around this location in December, and it proves that the African Sacred Ibis can survive even in the colder and more food-restricted periods in Hungary. If snow cover were high and long periods of cold temperature prevailed, not a single individual would be able to persist in Hungary. But as winters get milder we cannot base all our protective measures on this assumption.


© Norbert Papirnyik

This species occurred only on a few occasions in Hungary in the last 20 years. In each of 2008, 2009 and 2010, a single individual was observed. All of them had closed rings, so they were captive birds which had escaped from aviaries. But the individual observed in 2012 had no ring, and hence we can assume that it arrived from a free-living population. In the summer of 2019 again a ringed specimen was reported from Hungary.

The African Sacred Ibis never nested in Hungary; the species did not succeed to found a stable population.

Ecological problems

In the native area of the species, the African Sacred Ibis was observed to consume the eggs of colonially breeding water birds such as herons and terns (Williams & Ward 2006). In France, its growing populations became a serious threat to ground-nesting bird species (Vaslin 2005).

In Hungary, the African Sacred Ibis was not observed to prey on bird eggs. But if it had shown up even in small groups around the tern colonies in the marshlands or around the soda lakes, it would pose a threat both for the clutches and the freshly hatched nestlings.

The most highly prioritised nature conservation values of the Hungarian avifauna would be endangered just like the Western European tern colonies. And hence its presence should not be tolerated in the breeding season in Hungary, and its nesting should be prevented by all and every means.

Economic effects

We do not know of any significant economic damage caused by the African Sacred Ibis, although the trees supporting the nests at their colonies will die sooner or later because of the accumulation of concentrated excrement.

Methods of control

As it is a very conspicuous bird, feeding and aggregating in open areas, its presence is easily discovered. Its identification is also very easy, as in the Hungarian avifauna there is no similar bird with similar stature, size and colouration.

If any sign of nest predation is discovered, the African Sacred Ibis should be removed from the area immediately. It is not extremely difficult to capture them, but if it is impossible, all the individuals should be shot. The latter method proved to be very effective in France and other countries to reduce their growing and harmful populations (Yésou *et al.* 2017).

It is very important to keep in mind that not a grain of tolerance should be exhibited towards such an invasive species. We should not let any individuals settle in Hungary, as the situation quickly can change, and the species would breed out of control and invade the wetland habitats of the country.

The species is listed in the Invasive Species List of the European Union, posing a threat to the indigenous fauna, and therefore its breeding, keeping and the release of individuals to the wild is strictly forbidden.

References

Matheu *et al.* 2020, Vaslin 2005, Williams & Ward 2006, Yésou & Clergeau 2005, Yésou *et al.* 2017

László Haraszthy

Western Cattle Egret

Bubulcus ibis (Linnaeus, 1758)

Original area of the species

The native area of the nominate subspecies of the Western Cattle Egret (ssp. *ibis*) was located in the tropic and subtropical areas of equatorial Africa, but invaded other areas from the end of the 19th and beginning of the 20th centuries. As a consequence of the enlargement of areas used by pastoral tribes, the Western Cattle Egret found more feeding opportunities, and started to expand its area first in Africa, where it is abundant almost everywhere except the dry desert areas of the Sahara. Its expansion did not stop in the African continent. Although there were earlier reports from the 19th century and the beginning of the 20th century, the first voucher specimen was shot on the American continent in Guyana on the 27th May 1937, 2,850 km from its nearest African nesting site (Blake 1939). Afterwards the species quickly invaded the American continent. In 1943, it occurred in Venezuela, in 1946, in Suriname and in the 1950s it invaded Colombia and Peru (Blaker 1971). In 1956, its breeding was recorded and proven in Florida. In 1964, it was a widespread bird species in Mexico, and in the same year appeared on the western shores of the United States (Malin 1968, Crosby 1972). Nowadays the Western Cattle Egret is breeding all over North-, Central-, and South America, where it finds suitable habitats. It bred for the first time in Canada in 1962 (Maddock & Geering 1994).

The introduction of the species to Europe and Hungary

From north-western Africa it spread into south-western Europe. In its colonies on the Iberian Peninsula, the number of breeding individuals is still increasing. At the middle of the 2010s, its breeding population was estimated in Spain to be around 28,200 – 32,200 pairs and in Portugal around 14,900 – 18,000 pairs (these together constitute around 57% of the European population). From the Iberian Peninsula it spread first to southern France. In the Camargue, the first individuals bred in 1967, and by the end of the 1990s its number rose to 3,000 pairs. In France nowadays 11,700 – 11,800 pairs nest. In Italy the first nesting was recorded in 1985, and now its number is estimated to be around 9,000 – 15,400 pairs (BirdLife International 2021).

The Western Cattle Egret at the same time is continuously advancing from south-eastern Europe. In the Near East it breeds almost everywhere. The number of breeding pairs is only between 330–500 in Türkiye, but in Azerbaijan the number of breeding pairs is estimated to be between 8,000 – 12,000 (BirdLife International 2021). In the Romanian part of the Danube delta, a single pair settled in 1996. In 1997 two, in 1998 six, and in 1999 eight pairs nested in a mixed species heron colony (Kiss & Szabó 2000). In 2016 it's first breeding attempt was recorded in the Czech Republic, but it has not been observed breeding there since.

The first Hungarian records date back to the first years of the 1930s. It was observed in 1931 at Dinnyés (Nagy 1935), and in 1934 around Mohács (Porgányi 1935). At both of the locations three individuals were seen. At the end of the 1950s and beginning of 1960s Western Cattle Egrets were seen several times at a small creek called Sasér near Hódmezővásárhely, but its breeding was not proven (Schmidt & Sterbetz 1962, Sterbetz 1964, 1974). In the 1970s, ringed Western Cattle Egret escapees were observed at several locations – at Fertőrákos (Kárpáti 1983), and Dáka. In Bajánsenye, an individual was captured that originated from a Viennese bird collection (Schmidt 1978). Both in 1976 and 1989 in the Hortobágy a single bird was observed, both of which appeared to be wild (Ecsedi & Szondi 1990, 1993). Afterwards, sporadic occurrences were observed: 1996 in the Hortobágy (Kovács *et al.* 1998), in 1997 in the Kiskunság (Pigniczki 1999) and at Fertő in 1998

© Tibor Hadarics

(Hadarics 1999). Then in the following years, the Western Cattle Egret appeared regularly every year in Hungary, and from the 2000s it occurred at more and more locations and more often on the wetland habitats and around the heron colonies of Hungary.

In 2011 it probably bred in the Hortobágy (Zalai & Oláh 2017), but its first confirmed nesting was observed in 2013 in Dévaványa (although the nesting attempt failed) (MME Nomenclator Bizottság 2016). In 2016 two pairs successfully bred at the fish ponds in Soponya (Haraszthy 2019, MME Nomenclator Bizottság 2019). In the same year, 2-3 pairs were observed nesting in the fish pond at Ohat in the Hortobagy. The fish pond was heavily overgrown with reed and willow bushes. Both Western Cattle Egrets and Squacco Herons (*Ardeola ralloides*) landed on their nests only a few meters from the observers standing in the dense reed bed in the water (Haraszthy L.). In 2017 one pair bred at Lake Fehér near Szeged, but the species was probably also breeding in the reed beds of Kis-Balaton (Gál 2017), and at the Kendersziget and Polgári fish ponds (Pigniczki 2021). Since its first breeding at Soponya in 2016, every year 1-5 pairs has bred. For example, in 2018 three nests were found with eggs (Haraszthy 2019). The number of breeding pairs was estimated to be 8–10 in 2017, 14–15 in 2018, 12–13 in 2019 (Pigniczki 2021). In 2022 two pairs settled at Lake Földvári near Dávod.

As the number of nesting attempts rose, more and more Western Cattle Egrets were observed; several individuals were regularly seen around the breeding sites, and single individuals or small groups consisting of a few individuals showed up at other wetlands of Hungary. From the second half of the 2010s at some sites, for example at the Lake Fehér and in the Kis-Balaton area, aggregations consisting of 50-100 individuals were formed at the end of the summer (www.birding.hu). The appearance of such groups suggests that, besides the found nests, several other pairs bred successfully in Hungary.

Life history of the species

It is a colonial bird. The number of breeding pairs at the colonies might vary between some dozens and several thousands. Primarily it builds its nest in reed-beds and on trees, and forms mixed species colonies with other egrets and herons (Ardeidae) and ibises (Threskiornithidae).

The Western Cattle Egret utilises human-induced environmental changes, and can consequently adapt to habitats that are unsuitable for other closely related egret species. For instance, they frequent waste disposal sites, where they can find food scraps. They also follow ploughing agricultural machines just like White Storks (*Ciconia ciconia*), Black-headed gulls (*Chroicocephalus ridibundus*) and Mediterranean Gulls (*Ichthyaetus melanocephalus*). In southern areas, the Western Cattle Egret visits rice fields in enormous groups, although these profitable feeding sites are frequented by other herons and egrets, too.

The nest building, which usually takes 5-6 days, is carried out by the male and female together. The male carries the building material to the nest site, and the female builds it into the nest. The Western Cattle Egret breeds once a year, but a replacement clutch is laid if the first breeding attempt fails in its early – egg laying or incubation – phase. Its clutch size is 1–6 eggs, most often 3–5 eggs are laid. Incubation lasts for 22–26 days. Both parents take turns in incubation and feeding. The chicks leave the nests around 20 days (they wait for their parents on the branches around the nest), and they return into the nest when their parents arrive. They are able to fly at around 30 days, and become independent 15 days later (Cramp & Simmons 1977).

The ecological requirements of the species in Hungary

The species most often forms breeding colonies on trees and bushes standing in in wetlands, and can also nest in breed-beds. In the Hortobágy, a Western Cattle Egret built a nest in a mixed heron colony which was located in a Common Sallow (*Salix cinerea*) stand in the old reed-bed of an abandoned fish-pond. Probably the site was also used for nesting by this species prior to this attempt in 2014 and 2015. In Soponya, a Western Cattle Egret pair also bred in a mixed heron colony that was formed in a small forest standing on an island of a fish-pond. In Lake Fehér near the city of Szeged, it nested in a heron colony built in the reed-bed of the lake (Haraszthy 2019).

The Western Cattle Egret can be observed usually in wetland habitats (fish-ponds, bogs, wet-meadows etc.) in the breeding season and afterwards, but also appears frequently on dry areas, too, catching insects around grazing livestock.

Ecological problems

Interestingly the Western Cattle Egret does not exhibit such explosive population growth in Hungary, Romania and The Czech Republic as in many locations in the Mediterranean region, where its populations has skyrocketed at many locations. For example, in Algeria in 1999 there were 12,135 pairs, while in 2007 an estimated 31,600 pairs nested (Si Bachir *et al.* 2011). In Hungary, since its first successful breeding attempt in 2016 its population has not increased significantly, the total number of nesting pairs probably remained under 25 in 2022.

In the Camargue in France, studies showed that the breeding success of Little Egrets (*Egretta garzetta*) has declined since the Western Cattle Egret invaded the area. Consequently, at the heron breeding colonies the proportion of Western Cattle Egrets increases at the expense of the Little Egrets. The reason is that the Western Cattle Egret, being a more aggressive species, succeeds in occupying the best breeding sites, and the Little Egrets are forced to build their nests in lower quality nest sites (Dami *et al.* 2006). Since the Western Cattle Egret utilises the feeding opportunities offered by rice plantations extremely well, they successfully replace Little Egrets, which need to be content with the natural, less profitable feeding sites (Lombardini *et al.* 2001).

Economic effects

There is no any sign of any economic effect associated with the occurrence of the Western Cattle Egret.

Possible methods of control

As the species did not exhibit significant spread or population growth in Hungary in a decade, hopefully the Western Cattle Egret will not ever reach such a population size where control measures should be considered necessary.

References

BirdLife International 2021, Blake 1939, Blaker 1971, Cramp & Simmons 1977, Crosby 1972, Dami *et al.* 2006, Ecsedi & Szondi 1990, 1993, Gál 2017, Hadarics 1999, Haraszthy 2019, Kárpáti 1983, Kiss & Szabó 2000, Kovács *et al.* 1998, Lombardini *et al.* 2001, Maddock & Geering 1994, Malin 1968, MME Nomenclator Bizottság 2016, 2019, Nagy 1935, Pigniczki 1999, 2021, Porgányi 1935, Schmidt 1978, Schmidt & Sterbetz 1962, Sterbetz 1964, 1974, Si Bachir *et al.* 2011, Zalai & Oláh 2017

László Haraszthy & Tibor Hadarics

Monk Parakeet

Myiopsitta monachus (Boddaert, 1783)

Original area of the species

The Monk Parakeet is a South American bird species. Its native range mainly lies in Argentina, but it also occurs in Southern Bolivia, Paraguay, Uruguay and Southern Brazil (Burgio *et al.* 2020). Unlike most of the Southern American parrots, the Monk Parakeet is not a rain forest species. It prefers the more varied landscape types: open areas with sparse tree cover, savannah-like tree-covered grasslands, various plantations (including palm stands), gallery forests along rivers, orchards, the environs of human settlements, urban parks and suburban areas.

The introduction of the species to Europe and Hungary

From the 1960s, the Monk Parakeet was imported to Europe in large quantities. Escaped birds first formed a colony in Barcelona at the middle of the 1970s, and ever since they can be observed in the city in high numbers. At the beginning of the first decade of the 2000s, at least 1300 pairs bred in Barcelona, and the population drew by about 20% every year. From Barcelona the species invaded almost the whole of Spain, and then appeared in Italy, too. Smaller populations were established in Belgium, the Netherlands, United Kingdom and Greece (Lever 2005). The invasive populations originate from Uruguay. Invasive colonies are found not only in Europe, but also in America. In Great Britain the eradication of the monk parakeet started in 2009, and in 5 years approximately 250000 Pounds were spent on the programme. In 2014 only 24 pairs were recorded by the authorities (Holling & Rare Breeding Birds Panel 2017).

Monk Parakeets live in 179 settlements in eight European countries. It was also shown that its populations grow and spread faster in the Mediterranean countries than in the Western countries with more Atlantic climate (Postigo *et al.* 2019). Its populations

© Tibor Hadarics

were thoroughly studied in Spain in 2015 and 2016, and the number of individuals was estimated to be 18900 – 21455. Most of them bred in Barcelona and Madrid (Molina *et al.* 2016).

In Hungary there are three recorded cases of escaped or intentionally released birds starting nest building or breeding. At the end of the 1970s and beginning of 1980s, several individuals escaped from the aviary of a breeder in Bóly, and the escaped birds started to build nests on pine trees in a park, but a Goshawk (*Accipiter gentilis*) started to hunt them and soon eliminated the colony (Gálos I. *pers. comm.*). In 2005, in Abaújszántó a pair started build a nest in an eavesdrop, but after a month the birds disappeared. In Budafok in 2006, Monk Parakeets started to build a nest on a concrete electric pylon. Based on information from local residents, the pair has been around for years, and even built nests in previous years (Éles *et al.* 2006). There is no doubt all of the above-mentioned birds escaped from aviaries.

Life history of the species

The Monk Parakeet is the only parrot that builds a nest from twigs. It often breeds in colonies. In such cases, the nest of pairs are not separate units, but are fused. The nest is built from thin twigs and used for several years. It is often renovated and rebuilt. The leaf cusps of palms (Arecaceae), wide-spread and frequent in all Mediterranean countries, offer ideal nest sites for the Monk Parakeet. In Spain, 99% of pairs build their nests on trees, and the remaining 1% is built on electric pylons (Molina *et al.* 2016).

The majority of the European populations live in cities, but more and more it appears in agricultural lands, too, where it causes severe damage. As it builds its own nest, neither the availability of nest-holes nor other nesting factors limit its spread and settling new areas. As there are no natural specialised enemies of Monk Parakeets, its populations grow very fast. In Spain every three year, while in Italy every three and a half years the number of breeding pairs doubles. Individuals from invasive populations do not exhibit higher survival than those from natural populations, but their reproductive potential and success are higher. The number of fledged young is twice higher in invasive populations compared to natural populations, and second clutches are three times more often produced. 55% of individuals of invasive populations breed in their first year, but it never happens in the South American populations (Senar *et al.* 2019).

It predominantly feeds on seeds and, as with other parrots, the Monk Parakeet also consumes not fully ripe seeds. Seeds with high oil content and those containing more starch are equally liked by this species. Seeds of Common Sunflower (*Helianthus annuus*), Sweet Corn (*Zea mays*), Hemp (*Cannabis sativa*), cereals, and fruits are consumed by the Monk Parakeet, but green parts of Chick Weed (*Stellaria media*), Spinach (*Spinacia oleracea*), and Salad (*Lactuca sativa*) are also taken.

The ecological requirements of the species in Hungary

The Monk Parakeet has not established a breeding population in Hungary yet, but some individuals tried to build a nest. As in the Mediterranean countries where almost exclusively urban populations were established, in Hungary the same could be expected if the species establishes a breeding population. It is important to note that surviving severe winters is not a problem for Monk Parakeets and for many related parrot species. The milder and milder winters experienced lately in Europe would not hinder its survival at all.

Ecological problems

In the countries of the Mediterranean region, there are no ecological problems associated with the Monk Parakeet. As it is not a hole-nester, even competition with native hole-nesting bird species is out of the question.

Economic effects

Where larger populations of Monk Parakeets are formed, birds cause considerable damage to crops they feed on. This phenomenon is well known in South America as well. The damage to sweet corn (*Zea mays*) and other cereals and various fruits is not limited to the amount consumed since they also damage the plants by pecking the fruits and seeds.

Possible methods of control

Its spread in Hungary should be stopped by capturing the escaped individuals that start nest building. As it frequents bird feeders filled up with oily seeds of the sunflower, it is not difficult to capture. But capturing parrots with mist nets is almost impossible, as they walk out from the nets using their strong beaks and legs.

References

Burgio *et al.* 2020, Éles *et al.* 2006, Holling & Rare Breeding Birds Panel 2017, Lever 2005, Senar *et al.* 2019, Molina *et al.* 2016, Postigo *et al.* 2019

László Haraszthy

Rose-Ringed Parakeet

Psittacula krameri (Scopoli, 1769)

Original area of the species

Ring-necked parrots (*Psittacula* spp.) are native to the Hindustan Peninsula, south-east Asia and the islands of the Indian Ocean, and some parts of Africa. The Rose-ringed Parakeet has disjunct native ranges: similarly to its relatives in the genus some of its populations live in India, but the species also have a separate African breeding range, located south of the Sahara in the Sahel region. There are four subspecies: the nominate one (ssp. *krameri*) living in the western and central parts of the Sahel, and *parvirostrtis* in the eastern part of the Sahel. The *manillensis* is found in the Southern part of India and in Sri Lanka, while in Northern India the *borealis* subspecies occurs (Collar *et al.* 2020).

This species is always associated with trees, as it nests in hollows of trees. It prefers open forests, but is also well adapted to urbanization and occurs and nests in cities in high numbers.

The introduction of the species to Europe and Hungary

The Rose-ringed Parakeet is kept as a pet all over the world in high numbers. No wonder that both in the past and at present they regularly escape from captivity, especially since these individuals can fly very well. Moreover, the species was intentionally introduced to several locations, and these trials were most of the time successful. There are free-ranging feral populations at least in 35 countries all over the world. The Rose-ringed Parakeet started to occur in the large European cities in the 1960s. Nowadays in Europe it has large breeding populations in ten countries. In 2015 in Europe there were at least 85,120 feral individuals. The largest population is found in Great Britain, where at least 31,000 feral Rose-ringed Parakeets live. According to census studies its number is 10,800 in Belgium, 10,100 in the Netherlands, 10,960 in Germany. In Italy, its number is estimated to be 7,740 – 10,600, and in France

© Csaba Barkóczi

7,000 – 7,500. Smaller but growing populations were established in Spain (3,000 individuals) and Portugal (700–900 individuals), and in Türkiye and Greece around 1,000 individuals are estimated (Pârâu *et al.* 2016). In Europe, the feral populations can be traced back both to the African and Asian forms, and also their hybrids are present. Representatives of the Indian *manillensis* and *borealis* subspecies are the most common. This is partly due to the fact that pet shops sold birds mainly arriving from India. The other factor is that the subspecies of Indian origin are more cold-tolerant than the African ones (Noble 2020b).

In Hungary, there is no free-ranging feral nesting population of the Rose-ringed Parakeet. Several cases of escapes from aviaries were reported, but these sporadic events fortunately have not resulted in the formation of a nesting colony, yet. There were several cases when single individuals escaped from captivity, but these solitaire birds could not form nesting pairs. However, as this species becomes a more and more popular pet, and is kept in large numbers, and the natural green colour variety becomes cheaper – compared to the other colour variants (blue, yellow, cinnamon) – more individuals will be set free that are not interesting or profitable for their owners or breeders. Sooner or later these birds might settle into a larger park of a Hungarian city.

Life history of the species

The Rose-ringed Parakeet nests in holes. In Western Europe, it occupies almost exclusively city parks, where they establish loose breeding colonies. The members of these colonies aggregate into large flocks outside the breeding season. It largely finds the seeds and fruits it consumes in bird feeders.

In Germany, the nesting behaviour of the Common Starling (*Strunus vulgaris*) and Rose-ringed Parakeet was studied in large parks (Czajka *et al.* 2011). The Starling preferred trees with the diameter of 75 cm on average, while the Rose-ringed Parakeet preferred larger trees, with a diameter of 116 cm on average. The Rose-ringed Parakeet prefers to breed in the hollows of Hybrid Plane (*Platanus* × *hybrida*) trees, 57% of their nesting attempts were recorded in this tree species, while hollows of the Sycamore (*Acer pseudoplatanus*) were never occupied by them. The Common Starling preferred Pendunculate Oak hollows, 25% of their nests were built in this tree species. The highest number of occupied hollows by Rose-ringed Parakeets in one tree was nine, while the highest number of occupied hollows in a single tree by starlings was five. During the study, two instances were recorded when Starlings took over Rose-ringed Parakeet nests, while a single case of Rose-ringed Parakeet pair replacing a Starling pair was recorded. These observations do not support the assumption that the Rose-ringed Parakeet is a strong competitor for nesting sites for birds breeding in similarly-sized nests.

The ecological requirements of the species in Hungary

As the Rose-ringed Parakeet does not nest in Hungary, we do not know much on either its habitat or ecological requirements. But we should keep in mind that some parrot breeders keep their Ring-necked Parakeets in open air aviaries through the winter, which shows that cold weather in winter would not be a limiting factor on the invading populations.

Ecological problems

As it is a hole-nesting species, its large colonies might be competitors with native species for nesting sites. Consequently, just like other invasive species, it might exert a negative effect on the native hole-nesting species of the avifauna.

Economic effects

Although the Rose-ringed Parakeet nests in high numbers in several European cities, there is no data on any economic damage associated with the presence of this alien species. This is mainly due to the fact that these populations live almost exclusively within urban limits, and they seek for food in these human habitats, and hence no agricultural damage is linked to the Rose-ringed Parakeet.

Methods of control

As there are no severe ecological problems or any economic adverse effects associated with this species, although it invades more and more European cities forming large nesting colonies, there are no control measures implemented against the Rose-ringed Parakeet anywhere in Europe. Moreover, the presence of this exotic bird is considered as a vivid, interesting phenomenon by the public.

Based on the study of Hancock & Martin (2015) carried out in London, the Rose-ringed Parakeet is hunted by several urbanised raptor species such as the Tawny Owl (*Strix aluco*), Eurasian Sparrowhawk (*Accipiter nisus*), Eurasian Hobby (*Falco subbuteo*) and Peregrine Falcon (*Falco peregrinus*).

References

Collar *et al.* 2020, Czajka *et al.* 2011, Hancock & Martin 2015, Noble 2020b, Pârâu *et al.* 2016

László Haraszthy & Tibor Hadarics

Common Myna

Acridotheres tristis (Linnaeus, 1766)

Original area of the species

The Common Myna is originally native to Asia. The native populations live in Indochina, the Malay Peninsula, Hindustan, Pakistan, Afghanistan, Turkmenistan, south Kazakhstan and the southern part of Iran. There are two recognised subspecies: (ssp. *tristis*) living in almost the entire range of the species, and the population breeding in Sri Lanka forms the other subspecies (ssp. *melanosternus*) (Kannan & James 2020).

The nominate subspecies of the Common Myna was introduced to many locations around the world (Lever 2005). Today South America is the only continent where it does not occur in the wild.

It was introduced to several places – for example to Hawaii and Queensland – in order to control insects that were regarded agricultural pests. In Australia, between 1862 and 1872 around 120 were released to the wild around Melbourne, and around the same time some individuals were introduced to the environs of Sydney. At the beginning of the 1880s, some birds from the Melbourne population were transported to Northern Queensland in order to control the grasshoppers (Acridoidea) and beetles (*Lepidiota frenchi*, *Lepidoderma albohirtum*) that were damaging the sugarcane plantations. Since the farmers did not succeed to decrease the number of pests to the desired density, in 1935 the Cane Toad (*Rhinella marina*) was introduced from South America. Unfortunately, the Cane Toad also failed to effectively control the insects, but it succeeded to form self-sustaining populations spreading and increasing at an alarming rate. Consequently, instead of facilitating biological control of agricultural pests, Australia received an another invasive species, which still spreads very quickly and causes enormous damage to the native fauna of Australia (Lever 2005). The Common Myna breeds in a wide coastal stripe in Eastern Australia, but also invaded the islands east of Australia to the North Island of New Zealand.

The Common Myna occurs in separated patches throughout the Arab Peninsula, and nests in Florida. Its introduced populations grow at an alarming rate at several places of the world.

As the species extended its area, it invaded the islands between India and Africa, successfully established a population in Madagascar, and nowadays breeds in high numbers at an enormous range in South Africa. It became one of the most widespread birds in the cities of South Africa between the Indian Ocean and Johannesburg. It also inhabits large farms and any area where human facilities of any kind were built.

The introduction of the species to Europe

In Europe, Common Myna individuals either escaped from pet shops or breeders, or were sometimes intentionally introduced. These individuals successfully settled. As of today, its successful temporary breeding has been reported from Spain, Portugal and Southern France. Temporary settlement was also reported from several locations from Türkyie, but a significant population only settled in Istanbul, where less than 100 pairs have bred. In the Crimea, it also settled around Sochi, but there is no agreement whether these are escaped birds that started to breed, or they are part of a naturally spreading feral population (Lever 2005).

Life history of the species

The Common Myna is a bit larger than a Common Starling (*Sturnus vulgaris*). Its body length is 23–26 centimetres; its weight is 80–140 grams. The body is covered with brown feathers, its head is dark grey. Its belly and under-tail coverts are white. Its legs, the bare skin surfaces behind its eyes and beak are yellow. In flight, its white wing panels are visible, and also its white under-wing coverts (Feare & Craig 1998).

It mostly feeds on the ground on insects (Insecta), but also consumes quite a large quantity of fruits. It nests in hollows. In human settlements, it uses any crevices under the roof, and other hollows of buildings, to nest. This species can increase its numbers very quickly, and hence wherever it was introduced, its breeding range has enlarged very quickly. Its further spread seems to be unstoppable.

The species originally adapted to open natural areas and agricultural lands, but can inhabit the edges of open forests and even plantations. It especially likes urban areas, where it inhabits parks and more rural outskirts.

The Common Myna is listed among the "100 of the World's Worst Invasive Species" and is one of only three birds that made it to the top 100 (Lowe *et al.* 2004)

The ecological requirements of the species in Hungary

In Hungary the Common Myna has not appeared yet, and luckily its feral populations live very far from Hungary. In August 2016, a Common Myna

© Tibor Hadarics


© György Cserép

was photographed right beside the Hungarian border in Horgos (Horgoš) in Serbia (source: www.birding.hu), but the origin of the bird has remained unclear.

Ecological problems

Due to its ability to reproduce at a fast rate, it became a competitor of native species wherever it established a breeding population, either as an introduced species or as an invading species. The large Common Myna populations successfully compete for food against the smaller bird species, and they also win in competition for nesting sites against native species. It can even consume the eggs and young nestlings of smaller birds. The Common Myna might act as a host and vector of contagious diseases and parasites.

Economic effects

Where the Common Myna breeds in high number, it can become an agricultural pest. It can damage most seriously the orchards.

Methods of control

If it appears anywhere, the observed individuals should be captured immediately. Where it successfully forms self-sustaining populations, and usually these are quite large, the only real aim can be to inhibit its further spread. Theoretically, the full population could be shot, but in inhabited areas this is impossible.

With well-organised control actions, its populations can be eradicated. Recently the Common Myna has been eradicated both from the Canary and Balearic Islands (Bauer 2020a).

This species is also added to the List of Invasive Alien Species of Union concern in the EU, and hence its keeping, breeding, and release to the wild is strictly forbidden in all the EU member states.

References

Bauer 2020a, Feare & Craig 1998, Kannan & James 2020, Lever 2005, Lowe *et al.* 2004

László Haraszthy

MAMMALS
Mammalia

European Rabbit

Oryctolagus cuniculus (Linnaeus, 1758)

Original area of the species

After the last Glacial Period, the native area of the European Rabbit included the Iberian Peninsula (Spain and Portugal), south-western France, and possibly north-western Africa. In the late Pleistocene, besides the Iberian Peninsula the European Rabbit probably occurred in most of Central Europe, too, but during the Glacial Period the area of the species became smaller. In its original native area, the European Rabbit population suffered drastic decrease, due to first of all several contagious diseases (for example, myxomatosis, Rabbit haemorrhagic disease) and the loss of natural habitats. Due to the extent of its recent decline, in 2019 the IUCN reclassified it as an *Endangered* species (Villafuerte & Delibes-Mateos 2019).

The introduction of the species to Europe and Hungary

In the Middle Ages, the European Rabbit was voluntarily introduced to Southern Europe (including several islands in the Mediterranean Sea), and also to Great Britain, Western and Central Europe. In Western Europe, the European Rabbit is a common and abundant species, only missing from the larger part of Scandinavia and from the Baltic States and the Balkan Peninsula, while only present on some Greek islands. Its eastern distributional limit is the Black Sea (Katona & Altbäcker 2007).

Its introduction to Hungary started in the Middle Ages. Feudalist landlords used to passionately hunt. They created stone-walled rabbit enclosures, where they kept and bred semi-wild European Rabbits in order to hunt for them. It was very practical to breed rabbits on small islands, as they did not require stone walls to keep the populations inside. This method of rabbit keeping was exercised from, and became widespread in, the times of the Árpád dynasty. This was the reason Margaret Island (then called the Island of Rabbits) was stocked with European Rabbits (Stohl 1981). From the middle of the 19th century, European Rabbits were introduced to hunting grounds in high quantities by landlords of large estates. These introductions were often not documented in a detailed manner (Szunyoghy 1959).

Life history of the species

Female European Rabbits produce young 3–5 times a year after a gestation period of 31-32 days. Usually 3–8 offsprings are born. The does give birth in a side chamber called a 'stab' of the warren they dig for this purpose. Offsprings are born naked and blind, in a nest lined with dry grass and the fine insulating fur of their mother. The entrance of the chamber is closed with earth in order to protect them from predators, and is opened only for about three minutes per day for the time to nurse the young. The juveniles will leave the nest after three weeks of age, and change from milk to plant material when they are four weeks old. The reproductive success and life expectancy of dominant females is higher than that of subordinate ones. When the density of the population is too high, dominant females might ruin the nest chambers of unrelated subordinate females and kill their offsprings. Sexual maturity is attained at six months, although usually they start reproducing only next spring. Life expectancy is 5–6 years at most, but most of the young die much earlier (Katona & Altbäcker 2007).

The ecological requirements of the species in Hungary

In its native range, the European Rabbit lives in a mosaic of landscapes composed of short grasslands mixed with Holm oak stands, or in more open grasslands where at least 40% is covered by bushy vegetation offering hiding place to create their warrens (Villafuerte & Delibes-Mateos 2019). In these areas, they consume grass shoots and seeds, while the roots of the woody vegetation offer structural rigidity of the soil necessary to dig their warrens. In Hungary, the European Rabbit lives in underground burrows, its home range is 2–10 hectares. In its habitat of choice, the structure of the vegetation and the soil suitable for digging are the most fundamental necessities. Its typical habitats are bushy open forests, where the vegetation offers ample protection against predators, and the roots of trees and bushes support the warrens in the soil. Its occurrence in Hungary is mostly associated with juniper-poplar stands and young pine plantations, both on sandy soil. In Western Europe, the European Rabbit often occurs near human settlements, for example, around airports and in city parks.

In Hungary, the European Rabbit was a very widespread and common animal. It was associated predominantly with areas of sandy soils, for example in the sand dune areas of the Kiskunság (such as the Bugaci juniper stand), around the sand mines in Pest county (such as Ócsa), and in the Gödöllő Hillside. At the beginning of the 1990s, its populations started to drastically dwindle, and today its occurrence is only sporadic in our country. The drastic decline is clearly shown by the change of number of shot rabbits. While in 1990–1992, in Hungary 5500–6000 rabbits were shot a year, this figure diminished to 100–130 rabbits per year in 2001–2003. Probably the catastrophic decline is due to the same reasons here as in its native area, two contagious and lethal diseases: myxomatosis and Rabbit haemorrhagic disease (RHD) decimated its populations. The situation was worsened by the severe and lasting snow cover in the winter of 1994. After this period, only small, isolated colonies survived in Bács-Kiskun, Pest and Tolna counties (Katona & Altbäcker 2007). The catastrophic decline of its populations prompted some owners to restock the habitats, and sometimes European Rabbit – Domesticated Rabbit hybrids were released (Varga 2019). This practice of releasing individuals of mixed genetics instead of pure European Rabbits adapted to wild circumstances for centuries should be avoided. As the reintroduction trials were not documented properly, their magnitude, success and effect on the habitats are unknown.

Ecological problems

Although its populations declined considerably in Hungary, and its distribution is restricted to small areas, the strong effect it asserts on vegetation makes the European Rabbit an environment engineer species. Consequently its effect might be profound locally (key species). As their diet partially overlap, it was supposed that the decline of native European Hare (*Lepus europaeus*) populations, lasting for several decades, is linked with the introduction and spread of the European Rabbit. But this theory was disproven when the collapse of European Rabbit populations did not have a positive effect on the European Hare populations (Katona *et al.* 2004). At the same time, it was confirmed that light grazing of European Rabbits has a positive effect on the composition of the flora, which furthermore reduced the capability of fires to spread in the grass patches (Markó *et al.* 2011, Ónodi *et al.* 2008). In Hungary, the negative effect of the European Rabbit on biodiversity was not confirmed in a species assemblage that functioned in association with the European Rabbit for centuries. Taking into account its alarming decline in its native area and the restricted distribution in Hungary, we have to consider carefully the possibility whether the Hungarian populations should have a role in the restoration and sustaining of its native populations. The restoration efforts should be concentrated to areas with similar biological assets and near to that of the original native area of the species. It is important to note that the classification of the European Rabbit as an alien invasive species is unquestionable, but still, it is possible that under the present climatic conditions – similar to the age prior the last glaciation – the European Rabbit could spontaneously, without human help, recolonise some of its range occupied before the glacial period. If the answer is yes, than human introduction (or reintroduction for that matter) only accelerated the natural process.

In several locations where the European Rabbit was introduced (for example, in Australia), because of its fast reproduction and high adaptability it asserts a significant negative effect on native herbivores. The European Rabbit is listed as one of the 100 most dangerous alien invasive species (Lowe *et al.* 2004).

Economic effects

The European Rabbit was the ancestor of the Domestic Rabbit (*Oryctolagus cuniculus* var. *domesticus*) – which is the only mammal species domesticated in Europe. Romans, known for their culinary excellence, kept and bred captured young European Hares (*Lepus europaeus*) and Mountain Hares (*L. timidus*) in stone-walled enormous parks called 'leporarium'. The animals were consumed. After the Iberian Peninsula had been conquered, the Romans brought delicious European Rabbits to their rabbit gardens, where they were successfully bred. Hence the Romans started to not only keep but to breed

© Zsolt Kalotás

this species. However, its domestication was carried out not in Rome, but in its native are: in the Iberian Peninsula. The European Rabbit was kept and bred in Iberia in stone-walled yards and stables. Most of all, monks engaged in breeding rabbits in their monasteries for two reasons. First, the very fertile and not too picky and undemanding rabbits provided badly needed protein to the diet of the monks, and second, new-born rabbits (and even their foetus) were considered to be consumable during fasting periods. The habit of breeding rabbits spread from the Iberian Peninsula to monasteries in France, and subsequently to other areas of Europe (Stohl 1981).

Later, wild European Rabbits were introduced to several locations in Europe in order to provide a new game species for hunting. In former times, damages caused by rabbits in forestry industry were reported. For example, Aurél Bartal Junior wrote the following in December 1900: *"I believe very few fortunate hunting areas can be considered rabbit free in Hungary. Even if it did not show up for a while, the nightmare of foresters will appear, and it will multiply so fast and so unnoticed, that in a few months the soil will be littered with rabbit warrens all around that are connected by underground tunnels. Forest plantations damaged, and the small saplings chewed… … these are all the unmistakably signs of the invasion of the rabbits."* But following the drastic decline of rabbit populations, similar damage can never happen (Faragó 2002).

It is worth mentioning that around 1100 B.C. the Phoenicians called the shores of the Iberian Peninsula *I-Shpania* (=Rabbit Shore Üreginyúl-*part*) because of the high number of rabbits they saw. Later the Roman name '*Hispania'* might have originated from the Phoenician one, which was then transformed into *España* (Faragó 2002).

Methods of control

The populations of the European Rabbit went through drastic decline both in Hungary and in its native area due to the spread of two contagious and lethal diseases: myxomatosis and Rabbit haemorrhagic disease (RHD). The virus of myxomatosis (*Leporipoxvirus*) is spread by the Rabbit Flea (*Spilopsyllus cuniculi*) or mosquitoes (Culicidae); in Hungary the main vectors are mosquitoes. Rabbit haemorrhagic disease is caused by Calicivirus (RHDV), which was introduced from China. RHDV was discovered in Europe and in Hungary in 1988. Its transmission might be facilitated by dipterans (Brachycera) drinking from the fluid produced by the lacrimal apparatus. Both diseases might spread to the Domesticated Rabbit (*Oryctolagus cuniculus* var. *domesticus*), and probably the Domesticated Rabbit played an important role as a vector in the spread of microorganisms causing the contagious diseases that killed off most of the Hungarian European Rabbit stock at the beginning of the 1990s.

In Hungary, the European Rabbit became so rare that no effect can be associated with it. Before the 1990s, when it was an abundant game species, their populations could be effectively controlled by hunting. At other locations (for example, in Australia and New Zealand), because of the strong negative effect of the introduced rabbit populations, various control methods were tried. Experimental introduction of myxomatosis and RHD was among the methods under trial, quite successfully in Australia, but only mild success was achieved in New Zealand (Katona & Altbäcker 2007).

References

Faragó 2002, Katona & Altbäcker 2007, Katona *et al.* 2004, Lowe *et al.* 2004, Markó *et al.* 2011, Ónodi 2008, Stohl1981, Szunyoghy 1959, Varga 2019, Villafuerte & Delibes-Mateos 2019

Olivér Váczi

Nutria

Myocastor coypus (Molina, 1782)

Original area of the species

The Nutria is native to the subtropical and tropical areas of South America. It is a littoral fauna element, and prefers those sections where short vegetation is available near the edge of the water (Zalba *et al.* 2001). It does not usually distance itself more than 100 metres from water, but at the same time might move several kilometres along water courses (Bertolino *et al.* 2012). It prefers high banks where it can dig its underground tunnels, but, in the absence of banks, it will readily build a nest on the surface in the vegetation (Redford & Eisenberg 1992). It does not require pristine natural habitats and can survive in heavily transformed habitats (Zalba *et al.* 2001). Its diet consists almost exclusively of plants, but regarding plants it is not too picky. Under natural conditions, its populations are restricted by food availability and the size of available appropriate habitats. In its native range, the Nutria is consumed as food by the human inhabitants, and its fur is also used and often exported. Due to overharvesting, its native stocks are significantly reduced, and the situation is further deteriorated by the loss and overbuilding of its natural habitats (Guichón *et al.* 2003c). Still, in its large native distribution, its survival is not threatened. Consequently IUCN categorise it as 'Least Concern'.

The introduction of the species to Europe and Hungary

From the 1900s, Nutria were kept in ever increasing numbers in fur farms in Europe, North America and Central and East Asia (including Japan and Korea), Kenya and the Near East (Carter & Leonard 2002). The introduction trials in the 1970s in Canada failed due to severe winter cold (Bertolino *et al.* 2012). As the fur trade lost impetus, these fur farms became unprofitable, and the animals were released when the farms were closed down. The adaptable and prolific rodent quickly spread along water courses if the climatic and environmental factors were favourable (Schertler *et al.* 2020).

Nutria infiltrated Hungary by individuals spreading naturally from their established feral populations – that originally escaped or were released from the closed-down fur farms in neighbouring countries. We believe large stocks were kept in Romania. Probably some individuals arrived from Austria and Slovakia, too. Its further spread in Hungary is limited by severe winters. Below zero temperatures might kill both adult and subadult individuals, and through the deteriorating body condition their breeding output is also reduced (Gosling 1981). Till the second half of 2010s, there was no evidence of offspring surviving the winter in Hungary. However, in 2017 cubs running around in snow were photographed along the River Ipoly (Juhász Lilla *pers. comm.*). Since then reports on successfully breeding populations have arrived from the waterbodies which do not freeze. At present, according to available information there might be several self-sustaining breeding Nutria populations in Hungary, mainly spreading along the Danube and its tributaries (Nagy *et al.* 2020). Its spread is helped by the reduction of snow cover and shortened cold periods in winter, but the adaptations to our colder climate cannot be ruled out either. This might be proven by the observation that Nutria living in a temperate continental climate grow to larger average weight (Bertolino *et al.* 2012). The pace of its spread is difficult to forecast, but we can assume its invasion-type spread has just begun in Hungary (Schertler *et al.* 2020).

The Nutria also listed among the 100 most dangerous invasive animals (Lowe *et al.* 2004).

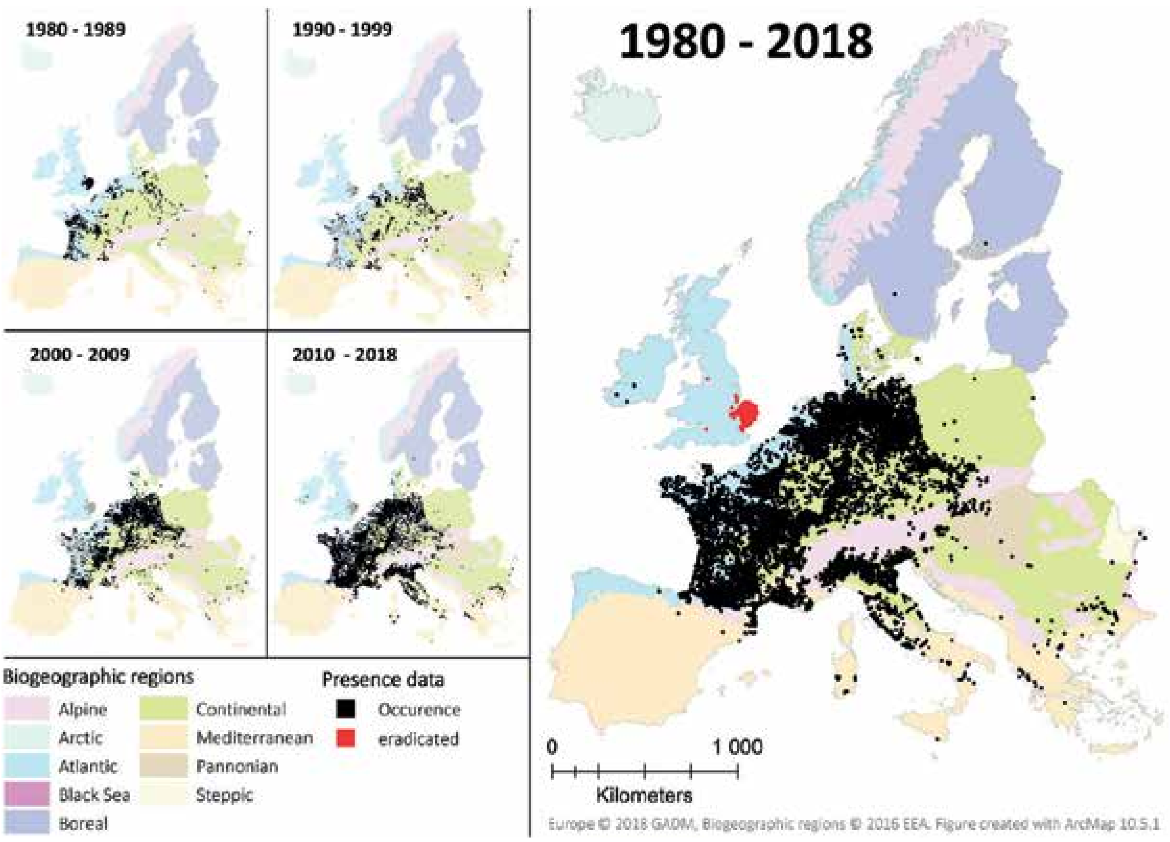
Life history of the species

Females reach sexual maturity before 1 year of age. Nutria can reproduce the whole year around, and

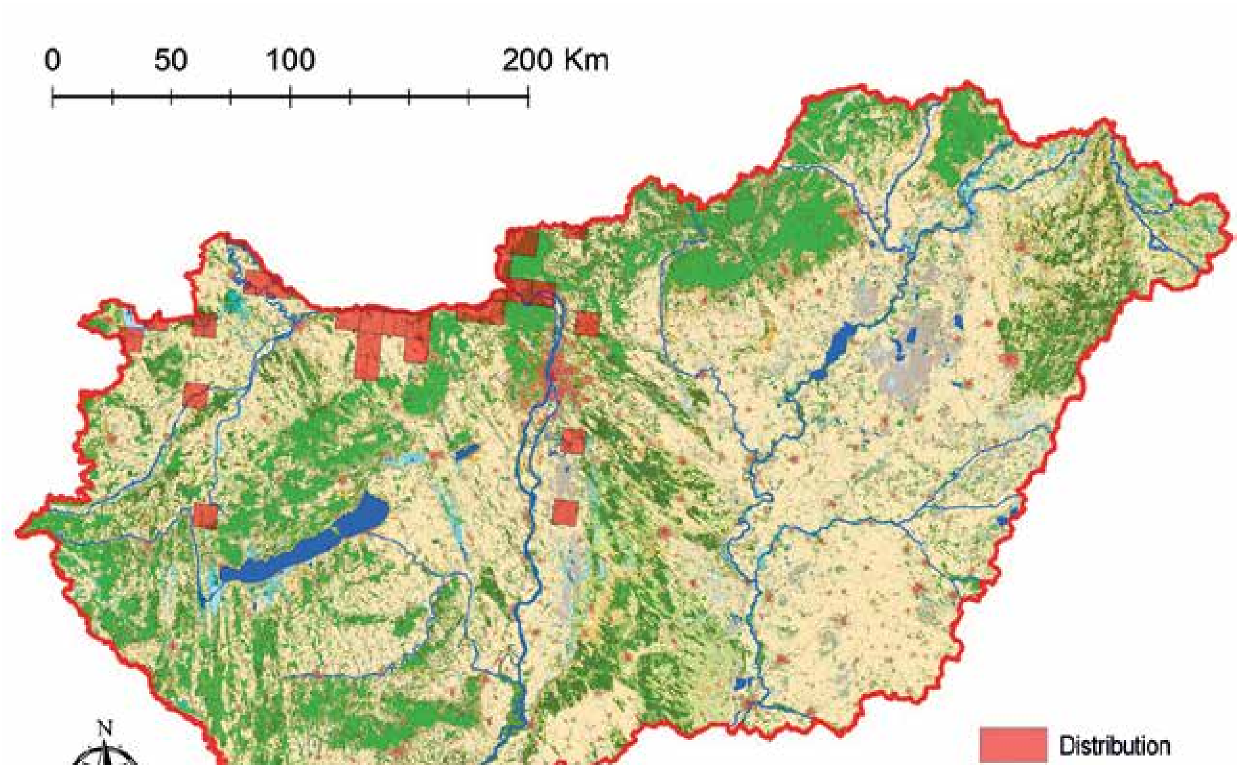
© Dávid Czabán

the litter is 4–6 offsprings (but exceptionally as many as 12). In the growing populations, at most 2.7 litters per year are produced and hence 8–15 pups can be reared. In its native area, Nutria live in groups composed of about 10 young and adults and led by a dominant male (Guichón 2003b). Along flowing waters, the groups are more separated and also genetically more distinct than along stagnant water bodies. Their home range varies according to habitat type, sex, social rank and availability of resources. The home range of females and solitary individuals is usually smaller than that of males or individuals integrated into family groups. Because of better food availability, individuals living in urban populations have smaller home ranges than the ones living in natural habitats. On its native range, the main consumers of Nutria are caimans (Caimaninae), although cats (Felidae), and dogs (Canidae) and other medium-sized carnivorous mammals and birds of prey (Accipitridae) also hunt them (Bertolino *et al.* 2012).

In its introduced populations, the general trend is that the individuals develop faster, mature sooner, and can live in higher densities than in natural populations. In Europe, higher density and lower survival was observed. This is probably due to harsh winters. Frosty periods are survived easier by larger specimens, which might explain the advantage of faster weight-gain (Bertolino *et al.* 2012). In its natural habitat, native population density is 6–8 individuals per hectares, and in temperate zones only a few individuals per hectares. Under subtropical



The spread of Nutria in Europe (Schertler *et al.* 2020)



Distribution of nutria in Hungary according to the 2020 EU Country Report on the routes of its spread (Nagy *et al.* 2020) conditions, 20–40 individuals per hectares were recorded. Besides hunting pressure, the density is controlled by food availability, climatic conditions and predation pressure. In Europe, and for that matter in Hungary, too, its most effective hunters are coming from increasing Stray Dog (*Canis familiaris*) and European Fox (*Vulpes vulpes*) populations. The daily activity pattern of Nutria is controlled by hunting and predation: in undisturbed habitats Nutria are active by day, while in heavily disturbed populations they become nocturnal (Mori *et al.* 2020). Nutria might act as a vector and host of pathogens affecting human health (for example, Psittacosis). Consuming its meat without proper heat-treatment, or feeding it to livestock, its bite, or being in direct contact with water where numerous Nutrias live, all might cause leptospirosis. It might also act as a vector for the virus of foot-and-mouth disease (Capel-Edwards 1967). It is a host of *Toxoplasma gondii* unicellular organism and *Chlamydia psittaci* bacterium (Howerth *et al.* 1994).

The ecological requirements of the species in Hungary

The Nutria is a generalist herbivore, not picky regarding its food. It choses aquatic plants or vegetation nearest to the water (Guichón *et al.* 2003a). It prefers the more nutritious species and often digs out their roots, too. While feeding, it remains near the water's edge, and prefers to stay within a few tens of metres from it. Occasionally, if forced it might venture out to about 100 metres. Sometimes it also feeds on crabs (Crustacea) and snails (Gastropoda), but this was not observed in all populations, only in some of them. At high densities, due to the thinning of vegetation it might exert a negative effect on ground nesting water birds, but disturbance of nest and trampling of clutches were also recorded. Consuming of eggs has not been observed yet (Bertolino *et al.* 2011). At high densities, invasive populations can damage components of water ecosystems and water edge vegetation composition as well.

Its occurrence in Hungary is patchy and isolated, and there are no confirmed high-density populations. The most well-known occurrence in Hungary is that in the lake system around Tata, where the somewhat warmer water and the stability of food offered by the urban environment is more favourable for the Nutria than the natural water bodies.

Ecological problems

In Hungary, its direct negative effect has not yet been proven: neither the degradation of wetland habitats, nor the exclusion of other species could be associated with its appearance. Nutria might spread pathogens (for example, toxoplasma unicellular organisms), which might pose a threat for the native fauna.

Economic effects

The economic problems arising in other countries, and the damage in water management apparatus such as dams, have not yet been a serious issue in Hungary.

Methods of control

Nutria is at present in a state when its transition into an invasive species could still be stopped. Reduction of its number can be achieved by selective hunting methods. Shooting and selective trapping proved to be very effective at several locations all over the world. At the same time, we have to mention a negative example from Italy: after 220,688 individuals had been removed in a 6 year-long programme (1995–2000), their damage remained very severe (Bertolino *et al.* 2012). The effective control and reduction of its number in Hungary is more difficult as feral Nutrias continuously arrive from neighbouring countries. A further problem is the pro Nutria approach of the public in settlements, as many feed the Nutrias showing up in their neighbourhood, without knowing of the problems the spread of the species can cause. In these instances, the control efforts of the Nutria populations should be started with a communication campaign on its ecological and nature conservation role.

The Nutria is included in the List of invasive alien species of Union concern, and hence its keeping, breeding and release to natural habitats is forbidden in all EU countries (there are very few exceptions limited to licensed strictly enclosed breeding facilities). According to the EU regulation, all member states should inhibit its spread, and the changes of its populations should be monitored (Regulation No 1143/2014/EU of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species).

References

Bertolino *et al.* 2011, 2012, Capel-Edwards 1967, Carter & Leonard 2002, Gosling 1981, Guichón 2003a, 2003b, 2003c, Howerth *et al.* 1994, Lowe *et al.* 2004, Mor *et al.* 2020, Nagy *et al.* 2020, Redford & Eisenberg 1992, Schertler *et al.* 2020, Zalba *et al.* 2001

Olivér Váczi

Muskrat

Ondatra zibethicus (Linnaeus, 1766)

Original area of the species

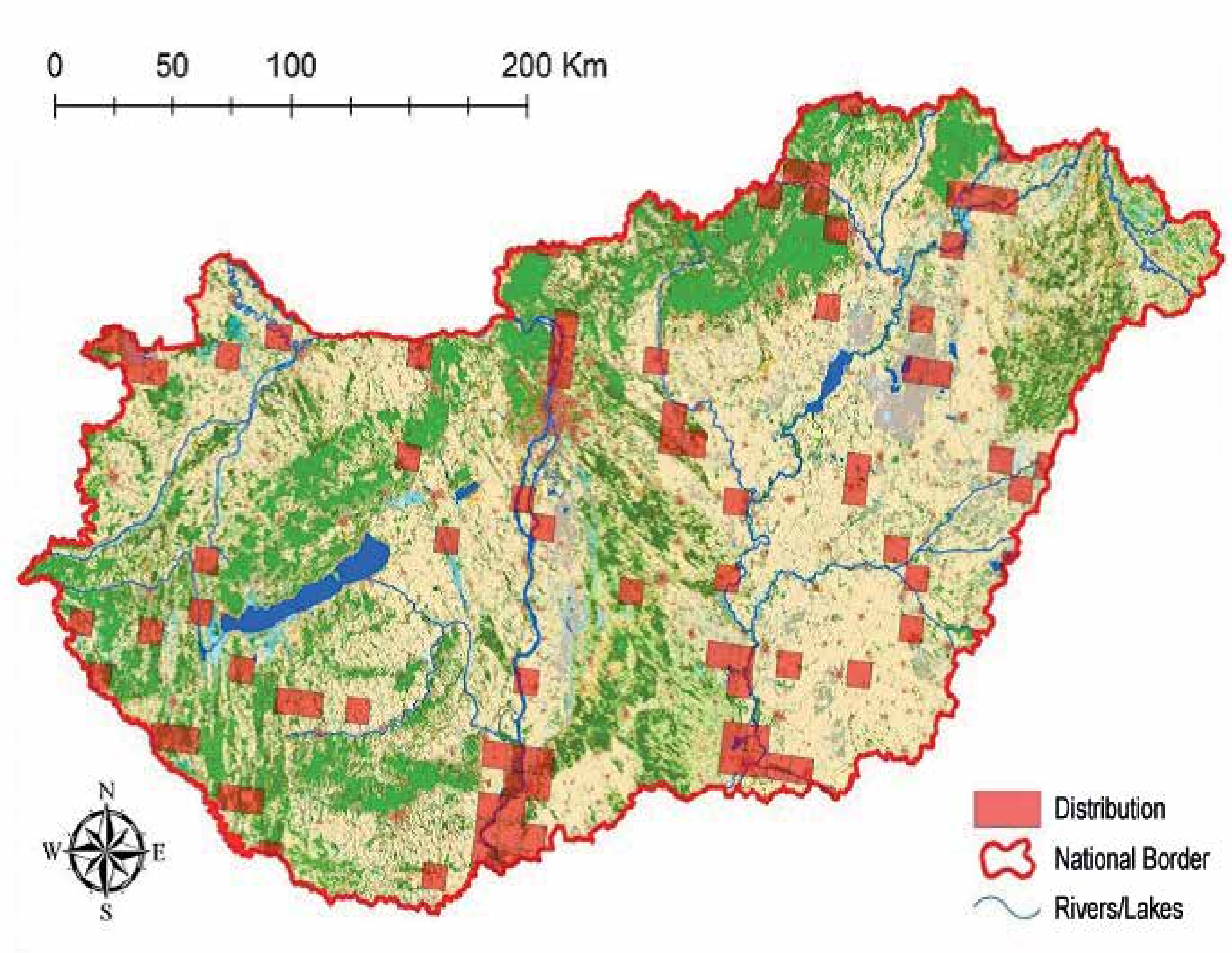
The Muskrat is native to North America, where it occurs from Florida to Alaska. In its native range, its populations suffered significant (even over 90%) decline in recent times, for reasons which are unclear. Probably the deterioration of water quality in wetland habitats played an important role in this process (Sadowski & Bowman 2021).

The introduction of the species to Europe and Hungary

In Europe, the Muskrat was bred because its valuable fur. The first fur farms were implemented in the Czech Republic in 1905, in Finland in 1922, in the Soviet Union in 1927. In the former Soviet Union, in the appropriate habitats tens of thousands of individuals were voluntarily released to the wild. These created feral populations were further strengthened by the massive number of escapees in other parts of Europe, for example, in France, Belgium and Poland. In Great Britain, between 1927 and 1932 escapees established feral populations, but these were eradicated with systematic hunting by 1939 (Gosling & Baker 1989). The European populations can be traced back according to some sources to Canada, while others believe they came from Ohio. At present, the Muskrat occurs in most of Europe from France to the Ural Mountains, from Finland to Bulgaria, but in several countries recently its populations are decreasing spontaneously (Mitchell-Jones *et al.* 1999, Zhang *et al.* 2020, Schuster *et al.* 2021).

The Hungarian Muskrat populations could possibly have originated from Czech stocks, where two males and three females were introduced to Moravia as

© Csaba Forrásy



The distribution of the Muskrat in Hungary (Nagy *et al.* 2020)

game species for hunters (Schuster 2021). The first individuals were observed in 1915 in what used to be Hungary then, and in present day Hungarian territory the first specimens were captured in Budapest in 1921. By that time, in the Szigetköz stable, self-sustaining populations were probably established, although its presence was only confirmed in 1925 by Jablonowsky J. (1927). Around 1934, about 1,000 specimens were shot, and in 1945 they occurred everywhere in Hungary. At present, the Muskrat inhabits all the larger water bodies of our country (Bihari 2003, 2007).

Life history of the species

The mating season lasts from April to October, during the whole vegetation period. Mating takes place in the water, and the gestation period lasts for 28–30 days. Females can have 3–4 litter a year of 5–9 (3–15) offsprings each. In its native range, only 2–3 litter per year is mentioned in the literature, and on average 6.5 offsprings per litter are born. Offsprings are born blind and naked, and their weight is only 20–22 grams at birth. Their eyes open at the age of 10–14 days, and from this age they are also able to swim. The female nurses the young for three weeks, and the juveniles start to take green plant material from the age of 21 days. They are weaned at 30 days. Females become sexually mature at the age of 5 months, but in Europe they usually mate and produce young only next spring. In America, they might give birth in the same year when they were born. Parents overwinter with the last litter, and the young disperse next spring. If a food shortage takes place, the adults chase away their young earlier (Bihari 2007, Sadowksi & Bowman 2021).

The ecological requirements of the species in Hungary

The Muskrat is an aquatic rodent. Stagnant and flowing water bodies, fish ponds and wetland areas are suitable for it. When they are looking for new habitats – especially the dispersing young – they might venture far from the shore. Its occurrence could be expected only on those dams which have an underwater base (for example, fish ponds, and water reservoirs). They only settle temporarily on water management dams during floods. As it prefers and usually does not leave the edge of the water, it will be found in the rush and sedge associations at the terrestrial edge of the water, in littoral vegetation along the shore, and in the submerged rooted and unrooted floating aquatic plant communities. It is not sensitive regarding the composition of the vegetation. It swims very efficiently using its hind legs and tail, and can spend up to 8–12 minutes underwater (Antonova *et al.* 2020). Depending whether the shore is steep or gently sloping, it builds simple underground burrows, or a complex chamber system with underwater entrances, or above-ground warrens. The latter is rounded or hemisphere shaped and, as it is created on an accumulated mud shelf, it is elevated above the water level. The warren contains a single chamber with a diameter of 40–60 centimetres; its entrance opens above the water level. For the winter, the warren is insulated with reed, grass and the leaves of aquatic and shore plants. The Muskrat often builds in marshes push ups from mud and vegetation, which it uses for rest and sunbathing. Both the push up and the warren are composed of rushes (*Typha* sp.), Reed (*Phragmites australis*) and aquatic plants. The Muskrat prefers water bodies with rich vegetation and a constant water level or minimal water level changes. It tramples a 20–30 centimetres-wide path on the shore, which is easy to find. Although it moves relatively slowly on land, still it is difficult to observe, as the Muskrat is very cautious, and dives under the water at any alarming sign. It will only surface far from the danger. It is most active at dusk, at sunset and sunrise. The territory of a family is 0.5–1.3 hectares, and its feeding area is 0.4–1.0 hectares. The Muskrat signs the boundaries of its territory with secreted musk (Bihari 2007).

From among climatic factors, ice-cover in winter and floods threaten it most. Thick unbroken ice-cover hinders both its movement and feeding. Floods are a major threat when they rear their young, and the family will disintegrate if they have to leave their burrows. Drying out of waters is also a threat (Bihari 2003).

The Hungarian populations were not surveyed comprehensively, but the Muskrat can be regarded as a widely distributed species in our country. In the last decades, its populations spontaneously declined, which might result in the disappearance of this species in certain areas. The confirmed occurrences are shown on the map below (Nagy *et al.* 2020).

© Viktor Schneidler

Ecological problems

The Muskrat usually does not leave the water-edge vegetation. It moves around in the rush and sedge associations at the terrestrial edge of the water and in the submerged rooted and unrooted floating aquatic plant communities. Hence these plant associations are damaged by its feeding, and this is where ecological problems are caused. The Muskrat is a herbivorous rodent whose food spectrum is wide. It is not specialised on a single plant species, instead choosing the most abundant plant. In Hungary, as a consequence of the presence of invasive plants in the littoral and water edge zones, it often feeds on alien plants such as: Carolina Fanwort (*Cabomba caroliniana*), Himalayan Balsam (*Impatiens glandulifera*) and so on. It might occasionally cause damage to protected valuable native plants such as Fringed Water Lilly (*Nymphoides peltata*), (*Carex bohemica*), Waterwheel Plant (*Aldrovanda vesiculosa*), but it is not a general problem at all. At times its presence can even be regarded advantageous, as it removes plant material and hence reduces the organic matter in eutrophic waters. In winter months it also consumes the roots of plants and hence the plant cover will be less dense (Bihari 2003).

It could be a competitor of the native and protected Eurasian Beaver (*Castor fiber*), but based on the very successful spread of the Eurasian Beaver in Hungary, this competitive exclusion must be very weak. There might be a competition for food with other rodent species, such as the European Water Vole (*Arvicola amphibius*), or possibly with the Tundra Vole (*Microtus oeconomus*), but there are no scientific studies on this topic.

Another source of problems could be the occasional or regular animal diet of Muskrats. Some studies found that the Muskrat eats large quantities of mussels (Bivalvia), and if these are collected from a small patch, the abundance of shells might seriously decline. Some species, such as the Thick-shelled River Mussel (*Unio crassus*), might even be wiped out by the Muskrat. On the other hand, consuming the aggressively spreading invasive Zebra Mussel (*Dreissena polymorpha*) can be advantageous. Its predation of birds' clutches is also documented, and it might negatively affect birds nesting in the littoral zone (Bihari 2003).

An additional possible threat to native rodents is that the Muskrat is susceptible to various contagious diseases of rodents (for example, leptospirosis, tularaemia, paratyphoid, *Yersinia pestis*, pseudotuberculosis), and therefore can act as their vector (Ayral *et al.* 2020). In North America, more than 100 endoparasites of the Muskrat were described (Sey 1966). As there is no data on its active role in the transmission of these diseases, we can assume it is not as an important vector for them in Hungary.

Its main natural protagonist is the Eurasian Otter (*Lutra lutra*). It is also hunted by Red Fox (*Vulpes vulpes*), White-tailed Eagle (*Haliaeetus albicilla*), harriers (*Circus* spp.), Northern Goshawk (*Accipiter gentilis*) and larger owls (Strigiformes). The Stoat (*Mustela erminea*) – being a small and lean carnivore – can chase Muskrats in their tunnels, and kills not only the young but also mature individuals. Vagrant specimens can be killed by dogs (*Canis familiaris*), too (Bihari 2007).

Economic effects

If it is present in a high number, the Muskrat can damage occasionally agricultural crops along the water courses. Water control structures such as dams can be damaged by their burrows, therefore it is trapped along such dams.

Methods of control

The Muskrat is not protected and can be hunted during the whole year. It is listed on the List of invasive alien species of Union concern, and hence its keeping, breeding and release to natural habitats is forbidden in all the EU countries (there are very few exceptions limited to licensed strictly enclosed breeding facilities). According to the accepted EU regulation, all member states should inhibit its spread, and the changes of its populations should be monitored (Regulation *No 1143/2014/EU* of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species).

Their local hunting and trapping is justified around the nest sites of rare or colonially nesting water birds, at the habitats of valuable native plants that might be a food source of Muskrats, and in protected sanctuary-like dead arms when Muskrat populations increase out of control (Bos *et al.* 2019). As they might endanger other species – such as Eurasian Otter (*Lutra lutra*), Stoat (*Mustela erminea*) and so on – the use of killing traps should be not practiced. Its local total eradication is possible.

References

Antonova *et al.* 2020, Ayral *et al.* 2020, Bihari 2003, 2007, Bos *et al.* 2019, Gosling & Baker 1989, Jablonowsky 1927, Mitchell-Jones *et al.* 1999, Nagy *et al.* 2020, Sadowski & Bowman 2021, Schuster *et al.* 2021, Sey 1966, Zhang *et al.* 2020

Olivér Váczi

House Mouse

Mus musculus Linnaeus, 1758

Original area of the species

The House Mouse was native to the area from Iran to northern India (Suzuki *et al.* 2013). Genetic studies show that genetic variability in the species was remarkably high before its anthropogenic spread started, and that this was the foundation for its ability to enlarge its distribution (Suzuki 2020).

The introduction of the species to Europe and Hungary

The House Mouse is the first small mammal species that was proven to be introduced and spread by mankind in Europe. In the Eastern part of the Mediterranean 15,000 years ago, that is, well before the advent of agriculture, anthropogenic landscape transformations created the commensalistic type of the House Mouse, which ever after accompanied settled and nomadic human tribes (Weissbrod *et al.* 2017). The House Mouse first occurred 7,000-8,000 years ago (Neolithic period) north of the Black Sea, in Eastern Europe, from where it spread along with the activities of mankind to the Balkan Peninsula in the Copper Age (4,800-6,500 years ago /Chalcolithic period). The Balkans could be the starting point of its westerly spread. Based on bone remains, it reached Hungary 3,700-3,500 years ago (Kovács 2014). The spread of the House Mouse was significantly facilitated by the advent of crop production, and also the storing of grain and other foods in early human societies. The House Mouse was adapted to living in underground tunnels that it dug and consuming seeds of weeds and insects (Shiels & Pitt 2014). This predisposition proved to be ideal to utilise human structures to survive unfavourable climatic conditions, especially harsh winters. Furthermore, buildings provided food sources, too.

Life history of the species

Although the House Mouse is adapted to eating seeds and berries, it can survive by eating any organic material it can access.

The House Mouse can mate and breed the whole year round under the man-made (though involuntarily) conditions, where it is not dependent on the climate anymore. Its gestation period is 20–21 days, and can produce four to eight litters a year (Csanády *et al.* 2021), but in extreme cases it might be as much as 12 a year. The young are sexually mature at the age of two months, and can live up to three years under natural conditions (Bihari 2007). The mating system of the House Mouse is polygamous, and

© Csaba Forrásy

male dominance is based on their ability to monopolise females (Groó *et al.* 2013).

The ecological requirements of the species in Hungary

While the House Mouse was originally associated with dry subtropical grasslands and bushy vegetation, and used underground tunnels to hide, in Hungary they are strongly associated with human settlements and especially buildings. It can live from the cellar to the attic anywhere in a house. In granaries and stables, they can live in masses, and can venture as far as 1-2 kms from buildings into agricultural lands and natural habitats. It avoids particularly wet areas.

It is mainly active during the night, but in less disturbed places the House Mouse might be also active by day. It digs its long, meandering tunnels under timber stacks, haystacks and even the wooden floors of rooms. In compacted earth-wall or cob buildings, it will dig tunnels in the walls. In other houses, it can build its nest in soft insulation material. Its tunnels open with a hole of 2 centimetres diameter to the surface. The tunnel system forms a wider part of the nest, which is lined with paper, pieces of cloth and other soft torn material. It can jump very well and climb vertical walls, so it can infiltrate any building. Its smell is very distinctive, and can be told apart from that of other mouse species, which also gives away its presence (Bihari 2007).

It is found basically in and around all human settlements: it is a very common rodent. Its population size is hard to even estimate, as it will significantly decrease when and where humans apply protective measures, but will rise again as soon as the House Mouse families move to undisturbed locations. The dynamic movement from disturbed to undisturbed areas and the oscillations in its population size sustain a very significant House Mouse stock in Hungary.

Ecological problems

As the House Mouse is closely associated with human settlements its ecological effect is minimal in natural habitats, even though its number is very high. The disappearance of native rodents in human settlements is more linked to human activities and presence than to competition with the House Mouse. But the House Mouse might transmit diseases both to humans and livestock, and therefore they pose a real threat (Manabella Salcedo *et al.* 2021). Also, they might act as vectors transmitting diseases to natural fauna elements. Therefore, it is listed among the 100 of the World's Worst Invasive Alien Species (Lowe *et al.* 2004).

Besides the negative effects, it should be mentioned that the House Mouse is a food source for several carnivores, such as owls (Strigiformes), diurnal birds of prey (Accipitriformes, Falconiformes), several mustelid small carnivores (Mustelidae), Red Fox (*Vulpes vulpes*) and the House Cat (*Felis catus*) (Bihari 2007

Economic effects

The House Mouse is a pest organism, and can cause significant damage in food (by consuming and also contaminating it), animal fodder, and anything that it can gnaw (for example, the plastic insulation of electric wires).

Methods of control

Its control within buildings – first of all to safeguard stored food – is achieved with mechanical and chemical methods. To maintain the mouse-free condition of an important building, continuous control measures must be applied, which should be more intense during autumn when the House Mouse seeks refuge from cold in buildings. Fortunately, in the human environment the selectivity of control measures is easier to achieve than in natural habitats. Therefore, its control within buildings is less dangerous for wild animals. But it is only true if both the pesticides and the traps are used according to the rules. Adhesive traps might kill protected rodent species and other small animals if they are placed out improperly (small protected animals such as birds can be stuck in them). But its application is also questionable on the grounds of animal welfare, as the trapped animals suffer for a long time before they die. Parallel with the appearance of the House Mouse, the House Cat (*Felis catus*) was domesticated, and it might be as effective agent to control the House Mouse populations nowadays, as it was in historic times. (However, being a watchful and effective hunter, keeping a House Cat is a very good measure against pests, but its selectivity is far from ideal. The House Cat will chase and kill song birds, small mammals and reptiles around the house.) It is quite easy to catch the House Mouse with traps, and, if applied in time properly, the first invading specimens can be successfully eradicated from houses.

References

Bihari 2007, Csanády *et al.* 2022, Groó *et al.* 2014, Kovács 2014, Lowe *et al.* 2004, Manabella Salcedo *et al.* 2021, Shiels & Pitt 2014, Suzuki 2020, Suzuki *et al.* 2013, Weissbrod *et al.* 2017

Olivér Váczi

Brown Rat

Rattus norvegicus (Berkenhout, 1769)

Original area of the species

The human-assisted spread of the Brown Rat started so long ago that its exact place of origin and its native range cannot be precisely pinpointed with the scientific tools at our disposal. Most of the sources place its native area to the northern part of East Asia: northern China, Mongolia, or/and to south-eastern Siberia. These locations are hypothesized as a suitable refuge based on the climatic conditions during the last Glacial (Hulme-Beaman *et al.* 2021). Based on genetic studies, the species branched off from the related Eurasian rats 0.9–2.9 million years ago. In the Pleistocene, rats belonging to the *Rattus* genus lived in the eastern part of the Mediterranean, too, but their relatedness to the Brown Rat is not known.

The introduction of the species to Europe and Hungary

The invasive spread of the Brown Rat probably started from East Asia, principally with the aid of naval trade. Its European occurrence and rapid spread might have started in the 1700s, although the species had sporadically occurred in Polish cities in the 11th century. Its spread was further intensified with its repeated reintroduction. We can firmly state that the Brown Rat became a cosmopolitan species, and occurs on all continents. Its success is partly due to the fact that it can survive periods of unfavourable climatic conditions in man-made artificial habitats. Hence it could colonise such locations where the natural conditions were not appropriate for this species (Hulme-Beaman *et al.* 2021). By today it has colonised all the European countries, including Iceland, but its occurrence along the coast of the Mediterranean Sea is more sporadic (Horváth 2003, 2007).

Life history of the species

The Brown Rat is the archetypal invasive rodent, capable of gradation: explosive population increase. It can breed throughout the year. Larger females can produce 6–8 litter a year, the gestation period is 21 days. Depending on the condition of the female, the litter can number 7–11 pups that are weaned at the age of three weeks. Brown Rats reach sexual maturity at three months. Explosive breeding is coupled with considerably high mortality: half of the young do not reach maturity due to food shortage, illnesses (Rothenburger 2015), and possibly predation pressure. In stable populations, 95% of individuals die before the age of 1 year. In captivity, they can live for several years. Brown Rat families are well-organized, rigid, hierarchical communities, but increasing density ruins the strict hierarchy step-by-step (Horváth 2003, 2007).

The ecological requirements of the species in Hungary

In its presumed native range, the Brown Rat occurs far from human settlements, where it can find food and shelter and can sustain the social structure of its communities. Its dentition shows that its diet originally consisted of seeds and other plant material, but it was not especially choosy. It successfully invaded human settlements and their surroundings, and self-sustaining populations are mostly found in this habitat type in the settled areas till today. Its diet is very varied: it eats plants, animals dead and alive, and even decomposing carrion. This extremely wide food spectrum is one of the reasons the Brown Rat occurs in large masses in many parts of the world. Its diet also explains why the Brown Rat became one of the most dangerous vectors of diseases of other vertebrates, including man (Horváth 2007).

The Brown Rat occurs everywhere in Hungary where it can find some food. Its primary man-made habitat is the sewage canal systems, cellars and the littoral zones of water bodies. The Brown Rat is a good swimmer, so it is a frequent inhabitant of fish ponds and inundation areas. It digs burrows and an extensive connecting multilevel tunnel system, but in buildings it uses any appropriate hiding places. It lines its burrows with leaves, paper, plant fibres and wool. Its extensive tunnel systems also contain food chambers (Horváth 2003).

It's very difficult to estimate its population size in Hungary (and also in Europe) as it can reach extremely high densities in most towns and large cities, even though more or less intense control measures (usually dispensing poisoned baits) are everywhere implemented.

© Csaba Forrásy

Ecological problems

The magnitude of ecological, health and economic damage caused by the Brown Rat is mainly due to its wide distribution, the immense number and size of its populations and its adeptness of invasion. Its ecological effect is also profound, and mainly exerted in wetland habitats, where it predates everything it can cope with. The eggs and young of birds nesting near the water level and on the ground and amphibians are especially threatened. It competes with the European Water Vole (*Arvicola amphibius*). Brown Rats are vectors of various pathogens which harm wild animals, livestock or humans. Due to the immense damages listed above, the Brown Rat is listed among the 100 of the World's Worst Invasive Alien Species (Lowe *et al.* 2004).

Economic effects

Brown Rats cause immeasurable economic damage by transmitting diseases, by digging tunnels in buildings, under roads, in dams and other water management constructions, also by consuming and fouling food and fodder in granaries and warehouses, and by their predation on poultry farms.

Methods of control

The brown rat can be eradicated with selective methods all year round without a licence, and in most of the settlements its organised control is performed. Most often, chemical defence is applied (by the use of poisoned baits containing rodenticides), but at local level the combined use of Tamed Ferrets (*Mustela putorius furo*) and Dogs (*Canis familiaris*) can very effectively eradicate Brown Rats.

Thanks to the co-ordinated control measures, Budapest – rather uniquely among cosmopolises of the world – was basically rat-free till the end of the 2010s. Based on the statistics of the experts carrying out the control, only some 1,000 Brown Rats lived in the Hungarian capitol. The first eradication programme that targeted the entire city was so effective that at the beginning of the 1970s, Budapest was almost completely rat-free. But the situation had some drawbacks. In the absence of Brown Rats, other animals started to proliferate, and the accumulation of sludge and debris that was formerly consumed by the rats caused stoppages. These problems were solved with the release of neutered individuals, according to some theories (Bodnár 2019).

In the near-natural parts of settlements and outside cities, biological control of the Brown Rat can be assisted through the protection of native mustelids (Mustelidae) and larger owls (Strigidae). The increasing Red Fox (*Vulpes vulpes*) – partly as a consequence of their immunisation against rabies with special baits – and spontaneously spreading Golden Jackal (*Canis aureus*) also helps in the biological control of the Brown Rat.

References

Bodnár 2019, Horváth 2003, 2007, Hulme-Beaman *et al.* 2021, Lowe *et al.* 2004, Mitchell-Jones *et al.* 1999, Rothenburger *et al.* 2015

Olivér Váczi

Black Rat

Rattus rattus (Linnaeus, 1758)

Original area of the species

Its native range is the southern part of the Indian Subcontinent. The natural western spread of the species probably started before the Holocene, and probably reached the Near East then, but its exact time is not known. Although rat (*Rattus* sp.) bones can be identified in the subfossil paleontological finds from the Holocene of Central and Eastern Europe, the presence of the Black Rat cannot be proven (Kovács 2014).

The introduction of the species to Europe and Hungary

The Black Rat was surely introduced in the Classical Era to Europe with maritime trade, and later it was reintroduced during the age of Crusades. Till the 11–13th centuries, probably only small, sporadic populations were present in our continent. Its invasive spread probably started and strengthened with the formation and growth of large human settlements from the 14th century. Based on bone remains, the Black Rat was introduced to Hungary in the Roman Period in the 3rd–4th centuries. The first remains were unearthed from along the Danube and Tisza Rivers, which points to the importance of trade in its spread. Based on bone remains from archaeological sites, we can assume that in the 16–17th centuries (Turkish Period) a strong population of Black Rats was established (Kovács 2014). The Black Rat occurs nowadays all over the world, but its populations are only a small fraction of what it used to be. In Hungary, the decline of its populations was fairly fast, and started from the second half of the 19th century. The main reason of its decline probably was the intense spread of the Brown Rat (*Rattus norvegicus*), which proved to be more successful than its smaller relative in competition. Its decline was further accelerated by the disappearance of wooden houses, which were more suitable for the Black Rat as a habitat than modern buildings (Jabir *et al.* 1985). Its decline brought a significant change in human health, as many pandemics were initiated and maintained for a long period by the Black Rat as a vector of pathogens. The Black Rat occurs in the western part of Europe and in the Mediterranean today, but is missing from the Scandinavian countries. In Great Britain, only sporadic occurrences are recorded nowadays, and the Black Rat is a rare species in Poland, Slovakia and Romania (Horváth 2007).

Life history of the species

The Black Rat is a crepuscular rodent, most active at dawn and sunset. Before noon and around midnight very few individuals are active. Originally, its diet was composed of seeds and other plant materials, but also consumed food items of animal origin. Not choosy at all regarding food, in the course of becoming an invasive pest it has adapted to consuming anthropogenic food sources: agricultural products, goods and produce in warehouses and granaries, and even organic items from human waste.

In buildings, the Black Rat occurs in groups of 20–60 individuals, within these groups there are neither rigid hierarchy, nor long lasting pair bonding. It builds a den or nest in its building or territory and uses various materials available in the house to line it: paper, textile, plastic bags etc. (Horváth 2007). Its breeding output is almost as high as its infamous relative: the Brown Rat (*Rattus norvegicus*). The Black Rat breeds almost year round and in a continuous manner. Its gestation period is 21–23 days. Average number of offspring in the litter is around seven, and the young rats start breeding at the age of three – four months. With increasing density, aggression intensifies, which leads to lower reproductive output (Horváth 2007).

© Balázs Buzás

The ecological requirements of the species in Hungary

In its native range, the climate is subtropical, and hence the Black Rat prefers warm and shady habitats. Black Rats living in natural habitats build their nests in hollows of trees or in areas with dense shrub cover. In areas with continental climate, it actively seeks man-made structures, because they provide a more protected tempered climate, and usually also offer more food year-round (Kovács 2012). Unlike a Brown Rat (*Rattus norvegicus*), a Black Rat rather prefers the attics of buildings, and does not choose the cellar or sewage canals.

Till the middle of the 19th century, the Black Rat probably occurred at every human settlement. Its invaded range was as big, or possibly even bigger, than that of the Brown Rat. In Hungary nowadays it is a rare species. Although the two rat species' bones found in owl pellets can be differentiated, we have very few confirmed data on its present distribution. There are only two stable Black Rat populations in Hungary: in the southern part of the Trans-Danube region and in the Port of Csepel. From other parts of Hungary, there are only sporadic occurrence data (Jabir *et al.* 1985, Horváth 2007).

Ecological problems

At the present density and occurrence of the Black Rat, its ecological, economic and health damages are negligible. At the peak of its invasion, it caused serious concern because of its large distribution and immense number, just like the Brown Rat (*Rattus norvegicus*) nowadays. In the close vicinity of human settlements, it might have caused serious ecological damage in natural and near-natural habitats with their seed predation. Black Rats used to be vectors of various pathogens, affecting wild animals, domesticated livestock and even humans. A well-known example is their role in spreading plague (Black Death): the bacterium causing plague – *Yersinia pestis* – lives in the fleas (Siphonaptera) of rats, and by sucking their blood they transmit the disease to the rats, which consequently die. When their host dies, the fleas search for new hosts, and, in the lack of enough rats, they might choose humans, who will be infested too.

Economic effects

At its present low density, it does not cause considerable economic damage, though in the past when it was a pest it caused serious damage in food depots and in the granaries of animal husbandries.

Methods of control

Although it is rare, the Black Rat is not protected, and, as it is an invasive alien species, that would not be justified. If its local population multiplies out of control, it can be eradicated with selective methods all year round without a licence, with the same method as in the case of the Brown Rat (*Rattus norvegicus*). But its present distribution and density does not justify organised control, with the exception of a very important exception: in the Free Port of Csepel its continuous and targeted control is necessary.

References

Horváth 2007, Jabir *et al.* 1985, Kovács 2012, 2014, Rothenburger *et al.* 2015

Olivér Váczi

Domestic Cat

Felis catus Linnaeus, 1758

Original area of the species

The Domestic or House Cat is the domesticated descendant of the Near Eastern subspecies of the African Wildcat (*Felis lybica*), which is native to Africa and the Near East (Driscoll *et al.* 2007, Burgin *et al.* 2020). Therefore, the European Wildcat (*Felis silvestris*) is not a direct ancestor of the Domestic Cat, but since they are closely related, they can hybridise. As a consequence of natural processes and partly as the result of its domestication, the Domestic Cat has lived with humans for millennia (Fitzgerald 1988, Randi & Ragni 1991). However, even today, the Domestic Cat is only regarded as a half-tame companion animal (Lorenz 1983), which successfully spread and inhabited, with the help of humans, the vast majority of the globe. Approximately 97% of the approximately one billion Domestic Cats kept in houses are breeding haphazardly (Dryscoll *et al.* 2009). Feral Domestic Cats cause immense ecological problems, and are responsible for the extinction of several animal species (Fitzgerald 1988, Doherty *et al.* 2014, 2016b). Therefore the Domestic Cat is listed among the 100 of the World's Worst Invasive Alien Species (Lowe *et al.* 2004).

© Zsolt Kalotás

Tengelicet (*Carduelis carduelis*) zsákmányoló házi macska

The Domestic Cat probably joined humans about ten thousand years ago somewhere in the Near East in the area called the Fertile Crescent (Driscoll *et al.* 2009, Ottoni *et al.* 2017). Its deliberate domestication only started four thousand years ago in Ancient Egypt. Contrary to other cases, the domestication of the African Wildcat did not cause significant changes in its anatomy (Hu *et al.* 2014). This fact is proven by comparing of Domestic Cats living today to several thousand-year-old mummified cats, and the Stone Age remains of cats unearthed in Cyprus. These 9,500-year-old archaeological finds were excavated from a site where cats and humans were buried together (Ottoni *et al.* 2017).

The introduction of the species to Europe and Hungary

The Domestic Cat was very highly regarded not only by ancient Egyptians but also by Greeks and Romans (Anghi 1990). Although there were Domestic Cats in the Iberian Peninsula in the 5th century BC, their significant introduction started in the 1st century BC by Romans with individuals from North Africa and the Near East. The Domestic Cat was introduced to Britannia and Pannonia (the provinces of Great Britain and Hungary) similarly by Romans. By the Middle Ages, the Domestic Cat became widespread in the whole of Europe as a specialised rodent hunter and a pest control agent. A source from 10th century Wales contains a collection of laws regulating the legal punishment of those who killed or maimed a Domestic Cat. Also, it gave instructions on the pricing of cats: a cat that had already caught a mouse was twice as expensive as the one that had not caught a mouse yet (

Zimmermann & Zimmermann 1944). Sailors thought cats were animals bringing good luck, and in the 15-18th century, they introduced them all over the world. Today, the Domestic Cat has become the most popular companion animal kept in the highest number among our pets. In 2020, its European stock was estimated to be 110 million individuals; in Hungary its number is estimated to be around 2.33 million (www.fediaf.org).

Life history of the species

The Domestic Cat occurs all over the world. Since it can tolerate extreme climatic conditions, it can appear not only in man-transformed habitats and near human settlements but anywhere on the invaded continents. It can live solitarily or in groups.

In sharp contrast with the European Wildcat (*Felis silvestris*), which only breeds in the appropriate season once a year, the females of Domestic Cats are polyestrous: they have several estrus cycles within a year. The Domestic Cat is seasonal polyestrous (Ortega-Pacheco *et al.* 2012). In temperate climates, one of its main breeding periods lasts from the end of winter till the beginning of summer, while the other lasts from the middle of summer till the middle of autumn. It can go through an oestrus cycle several times in each of these periods. Cat species living around the Equator can breed all year round, while the European Wildcat only breeds again in a year, if its first litter is lost. It will not rear two litters in a year. Heat may last from 4–7 days to 20 days. The average gestation time is 63 days, the average litter size is four (1–8), and the kittens are fed with milk till 8–9 weeks. Females reach sexual maturity at 10 (4–12) months (Turner & Bateson 1988, Kitchener 1991). The average lifespan of Domestic Cats can be longer than 20 years. A single female can produce more than 100 offspring within its lifetime.

Radio-tracking studies in Hungary showed that the home range of feral Domestic Cat females is 80 hectares, while that of males is 170 hectares (Biró *et al.* 2004).

Depending on the strength of association with humans, a Domestic Cat can be a room cat, a cat living in and around a house or farm, which strays away from the house for shorter or longer periods of time, or completely feral (Liberg 1984, Liberg & Sandell 1988, Pearre & Maass 1998). A Domestic Cat living around a house is highly dependent on its owner for food and is not forced to hunt to get enough prey to survive. The Domestic Cat becomes feral quickly and easily: it can quickly transform from a tame creature living around a house to a free-living wild animal (Liberg & Sandell 1986, Fitzgerald 1988). The feral Domestic Cat, an agile and very successful hunter (Turner & Meister 1988), can survive without food provided by its owner, or occasionally consumes cat food (Liberg 1984, Biró *et al.* 2005, Doherty *et al.* 2015).

Although providing enough food decreases its drive for hunting (Turner & Meister 1988), some “around the house” Domestic Cats kill many prey animals, as they will hunt even when they are not hungry. Besides food provided by their owners, Domestic Cats mainly hunt for small mammals, primarily rodents (Rodentia) (Fitzgerald 1988). Still they often kill and consume smaller songbirds (Passeriformes) and arthropods, mainly insects (Insecta) (Széles *et al.* 2018). Feral Domestic Cats also mostly hunt for small mammals (among them, there might be both pests and protected species). Still they also hunt massive amounts of birds (Liberg 1984, Pearre &

Maass 1998). Even European Rabbits (*Oryctolagus cuniculus*) (Corbett 1979, Liberg 1984, Ozella *et al.* 2016) and reptiles (Reptilia) are also frequently killed (Dickman 1996a, 1996b, Doherty *et al.* 2015, Lanszki *et al.* 2016). They are obligate carnivores: they eat fresh meat almost exclusively: and rarely consume plants or carrion (Fitzgerald 1988).

When hunting, they either hide using foliage as cover, apply the 'sit and wait for' approach, or stalk their prey. They are opportunistic regarding prey choice, take prey items according to their availability, and utilize domestic waste as a food source (Turner & Meister 1988). The Domestic Cat will "crawl" on all fours with its neck retracted between its shoulders, stalk using cover, and tries to remain unseen till the last moment (Morris 1986, Turner & Meister 1988). It will only jump on its prey when it succeeds in approaching it within paws ' reach. When stalking, faster crawling and even running are integrated into the approach of its prey. Then it stops and waits and jumps at last. The Domestic Cat often plays with its captured prey before it kills it. The prey usually dies of fear as a consequence of stress. The Domestic Cat rearing its kittens often fetches live prey to the nest, motivating and teaching its offspring to kill prey. Often the Domestic Cat will take its freshly caught live prey to its owner and behaves with its owner as if they would be its kitten (Morris 1986, Turner & Meister 1988).

Ecological problems

The strong negative effect asserted by the Domestic Cat on biodiversity should not be underestimated. In Great Britain, a questionnaire survey was carried out among cat owners to collect data for a model to estimate the species composition and amount of prey brought home by Domestic Cats (Woods *et al.* 2003). In Great Britain, the number of Domestic Cats is estimated to be 9 million individuals (to put it in perspective, this figure is 38 times higher than the number of Red Foxes). Data pulled for approximately 1,000 cats from April to August showed that 69% of prey brought home were mammals (Mammalia), 24% birds (Aves), 4% amphibians (Amphibia), 1-1% each reptiles (Reptilia) and insects (Insecta), rarely fishes (Pisces) and leftovers. If we calculate from the number of cats and their predation figures the amount of killed animals, the results are shocking: in a single late spring-summer period, the estimated number of prey items taken is 92 million (85–100 million), and from these there might have been 27 million birds. A similar study was conducted in Poland based on prey items brought home and diet composition in agricultural areas (Krauze-Gryz *et al.* 2019). The estimated numbers of prey items are: 48 million mammals taken home, and about 583 million are killed and consumed. For birds, the figures are the following: 9 million are fetched and about 136 are killed and consumed. In Switzerland, the estimated loss is 0.1–0.3 million birds in spring (Tschanz *et al.* 2011). In the United States of America, the estimated yearly loss caused by freely roaming Domestic Cats is 1–4 billion birds, and 6–22 billion mammals (Loss *et al.* 2013). In Canada, the estimated yearly loss caused by Domestic Cats is 150–250 million birds, which amounts to 2–7% of the total population of birds. Of the 461 bird species occurring in Canada, 115 species were found among the prey taken by the Domestic Cat (Blancher 2013). On oceanic islands, millions of birds are killed by Domestic Cats (Pascal 1980, Chapuis *et al.* 1994). In Australia, the yearly estimated number of birds killed by pets and Domestic Cats combined is 377 million (i.e., at least 1 million per day) (Woinarski *et al.* 2017). But the actual figures are probably much worse. Loyd *et al.* (2013) attached small camcorders to the collar of cats to record the hunting of those cats that venture out from the house. Based on the data collected within a year from 55 cats, they found that 44% hunted outside the house. These cats carried home only 23 % of the prey they killed, and ate only 28% of it, and left about half of the killed prey (49%) at the site where they captured them. Without the records of the cameras, a significant proportion of the prey killed by the Domestic Cat would be invisible. Based on the data from studies carried out at 53 European sites, the results showed that the prey composition of different groups of cats (cats living around houses, feral Domestic Cats, European Wildcat) is not as diverse as it was presumed formerly. Based on the prey taken back to their house, the diet of the Domestic Cat is very similar to that of the European Wildcat. Furthermore, it is also very similar to the diet of feral Domestic Cats, which, in turn, is similar to that of the European Wildcat (Széles *et al.* 2018).

Besides the loss of habitat and bird collectors, Domestic Cats played an essential role in the extinction of the Stephens Island wren in 1895, which happened just a single year after the Domestic Cat had been introduced to the island (Galbreath & Brown 2004). The situation is just as bad today as it used to be: feral Domestic Cats threaten the avifauna of islands, for example the endemic sea birds in Hawaii (Lohr *et al.* 2013). The review published by Doherty *et al.* (2016b) showed that the Domestic Cat is responsible for the extinction of 63 vertebrate species (40 birds, 21 mammals and two reptiles).

Rodents (especially introduced rats (*Rattus* sp.)) took an even higher tool: they extirpated 75 species (52 birds, 21 mammals, and two reptiles). If we sum the number of extinct and threatened species, the figures for the different invasive introduced taxa are the following: Domestic Cat: 420; Rodents: 430; Domestic Dog (*Canis familiaris*): 156; Feral Hogs (*Sus scrofa*): 140; Javan Mongoose (*Herpestes javanicus*): 83; Red Fox (*Vulpes vulpes*): 48; and Stoat (*Mustela erminea*): 30 (Doherty *et al.* 2016b). The eradication of the Domestic Cat from a given habitat proved to be advantageous in stopping the extinction process and safeguarding biodiversity (Nogales *et al.* 2004, Bonnaud *et al.* 2007). However, in some cases, the extraction of the top predator may result in population growth of the smaller, medium-sized predators (mezopredator species) (Courchamp *et al.* 1999, Crooks & Soulé 1999, Russsell *et al.* 2009).

As an example, the case study below shows how a predator's introduction or population size change can affect the whole ecosystem through a trophic cascade effect. Macquarie Island, with an area of 128 km^2, lies south-east of Tasmania and serves as a nesting ground for an immense number of sea birds. In the 1860s, European Rabbits were introduced to the island as a game species to hunt and for humans as a food source. Their numbers by the 1960s grew to an intolerable level (Bergstrom *et al.* 2009), and, to protect the vegetation from their gnawing, eradicating the rabbit population became an urgent task. To control the European Rabbit population, the virus myxomatosis (*Leporipoxvirus*) was introduced. By the 1980s, the number of European Rabbits decreased considerably, and the vegetation started regenerating. But as the number of European Rabbits decreased, the prey search image of feral Domestic Cats – also introduced voluntarily by man to the island earlier – shifted from the European Rabbit to sea birds. To prevent the loss of clutches of sea birds in a habitat restoration programme initiated in 1985, the total eradication of feral Domestic Cats was decided. By 2000, all the feral Domestic Cats were shot on the island, and as a consequence European Rabbits were not preyed by them anymore. As the European Rabbits became immune to myxomatosis and the predation pressure also ceased, their number grew again to such an extent that they completely degraded the flora of the island. So, when the effects of the applied measures are not planned carefully enough, the introduced invasive species might cause profound changes; in extreme cases, it can result in species extinction, or even the collapse of ecosystems (Bergstrom *et al.* 2009). It is important remember that interventions should always be full-scale and must perform risk assessments to prepare for their indirect effects.

In Hungary, a questionnaire survey was circulated among nature protection personnel managing Natura 2000 areas. They believe the Domestic Cat is the most dangerous among all invasive species (Kézdy *et al.* 2018). According to the Hungarian official national hunting bag statistics (www.ova.info.hu), in the 2020/2021 hunting season 4.186 feral Domestic Cats were shot. This figure is only one-tenth of the number shot and trapped in the 1997/1998 hunting season. But the feral Domestic Cat problem is very complex and sensitive.

According to a radio tracking study carried out in Hungary (Biró *et al.* 2004), feral Domestic Cats have integrated into the social system of European Wildcats (*Felis silvestris*). The study showed that European Wildcats avoided the territories of feral Domestic Cats. This means that feral Domestic Cats occupy valuable European Wildcat habitats and proves the two species compete for territories.

A former study compared the diet composition of feral Domestic Cats and European Wild cats and their hybrids (Biró *et al.* 2005). Rodents – most of all vole species (Arvicolinae) – were dominant in the diet of the three groups. Feral Domestic Cats (n=264), besides small mammals (73%), occasionally consumed European Hares (*Lepus europaeus*) (1%), too. Besides common rodents, the following more valuable protected species were also hunted: European Ground Squirrel (*Spermophilus citellus*), European Hamster (*Cricetus cricetus*) and Dormouses (Gliridae). Among the birds (6%) taken, mainly smaller passerines were hunted, but occasionally Pheasant (*Phasianus colchicus*) was also killed. Occasionally and in small proportion, other animals were also consumed: reptiles – snakes (Colubridae) and lizards (Sauria) – (0,8%), Arthropods (Arthropoda) (2%), and other food sources such as fish, domestic animals, cat food, plant material. Feral Domestic Cats occasionally consumed food remains of anthropogenic origin, which was not recorded in the diet of European Wildcats. In critical periods – such as food shortages – it might give a competitive edge to feral Domestic Cats, as they can move nearer to settlements and utilise the food sources there. Stray Domestic Cats were constantly present at those sites, where Domestic Cats were removed yearly to protect breeding bird colonies, (Biró *et al.* 2005). Domestic Cats kept around houses form an almost inexhaustible reserve to repopulate formerly cleaned areas. Based on the results of diet composition studies and the large number of feral or stray Domestic Cats, the damage in the native fauna caused by the Domestic Cat is probably immense.

The Domestic Cat is one of the most dangerous factors threatening the populations of the European Wildcat (*Felis sylvestris*) (Hubbard *et al.* 1992, Yamaguchi *et al.* 2015, Kilshaw *et al.* 2016). The high number of Domestic Cats present in natural habitats and the low density of European Wildcats results in a high probability of European Wildcats encountering Domestic Cats, and these encounters lead to hybridization. According to a study carried out 20 years ago in Hungary, hybridization is quite prominent (Pierpaoli *et al.* 2003). The frequent encounters lead to integrative hybridization, and due to its lower number European Wildcats will be the losers. Domestic Cats can be encountered in any natural habitat in Hungary, even far from human settlements. This is proven by both the photographic records of 50-60 camera traps and also genetic analysis of samples from fur traps, both of which operated in the Hungarian European Wildcat research project carried out since 2018 (Lanszki & Gruber 2021a). Although identification of the two species by morphological characters has its limitations (French *et al.* 1988), photographic trap results are still valuable, and they, plus the autopsy of European Wildcats found dead, suggest that at least one-third of the Hungarian European Wildcats are hybrids (Lanszki & Gruber 2021a, 2021b). The situation of the European Wildcats is further deteriorated by the contagious diseases spread among them by Domestic Cats, such as feline leukemia (caused by the FeLV virus), Feline AIDS (caused by FIV virus) and panleukopenia (caused by cat parvovirus, FPV) (Duarte *et al.* 2012).

Methods of control

From the 19th century, sporadic, and from the 1970s, very pronounced trials and even control programs has been carried out worldwide to eradicate Domestic Cats from natural habitats, especially islands. Nogales *et al.* (2004) analysed and summarised the results of 48 eradication programs on islands. Three-quarters of the islands were smaller than 5 km^2, while the largest island's (Marion Island) area is 290 km^2. On islands larger than 10 km^2, the complete removal of Domestic Cats was achieved only on 21% of islands. Trapping and hunting with firearms and dogs were often successful (91% of 43 islands). Trapping was often combined with hunting, and other methods were also applied (Doherty *et al.* 2016a).

Domestic Cats at houses hunt less frequently to gain enough food if their needs are catered for (Rochlitz 2005). To prevent the drastic negative effects, Domestic Cats exert on fauna, the best method is to keep them inside the house and not let them roam free in the neighbourhood. If the Domestic Cat can venture out of the flat or house, it is imperative to castrate or neuter them to prevent the birth of unwanted kittens. Constraining the time Domestic Cats can spend outside the house (keeping it inside the house by day), feeding them in the morning, constant surveillance of their activity, attaching small bells to their collar (Ruxton *et al.* 2002), or equipping them with a collar containing flashing LED lights together might decrease their hunting success. When placing new bird feeders, they should be positioned far enough from bushes that offer hiding places for Domestic Cats. Otherwise, bird feeders placed with good intentions to help birds will instead function as cat feeders! For further advice on the protection of birds against Domestic Cats, the Hungarian Ornithological Society has sound advice (https://www.mme.hu/madarak_es_macskak_a_kertben). Responsible Domestic Cat keeping should be a priority for every cat owner.

To protect potential prey animals, and keep the genetics of European Wildcats intact, it would be essential to practice higher standards of keeping pets as companion animals. Also, there should be stricter legislative control on keeping pets in Hungary.

References

Anghi 1990, Bergman 2005, Bergstrom *et al.* 2009, Biró *et al.* 2004, 2005, Blancher 2013, Bonnaud *et al.* 2011, Burgin *et al.* 2020, Chapuis *et al.* 1994, Corbett 1979, Courchamp *et al.* 1999, Crooks & Soulé 1999, Dickman 1996b, Doherty *et al.* 2014, 2015, 2016a, 2016b , Driscol *et al.* 2007, 2009, Duarte *et al.* 2012, Fitzgerald 1988, French *et al.* 1988, Galbreath & Brown 2004, Hu *et al.* 2014, Hubbard *et al.* 1992, Kézdy *et al.* 2018, Kilshaw *et al.* 2016, Kitchener 1991, Krauze-Gryz *et al.* 2019, Lanszki & Gruber 2021a, 2021b, Lanszki *et al.* 2016, Letnic & Koch 2010, Liberg 1984, Liberg & Sandell 1988, Lohr *et al.* 2013, Lorenz 1983, Loss *et al.* 2013, Lowe *et al.* 2004, Loyd *et al.* 2013, Morris 1986, Nogales *et al.* 2004, Ortega-Pacheco *et al.* 2012, Ottoni *et al.* 2017, Ozella *et al.* 2016, Pascal 1980, Pearre & Maass 1998, Pierpaoli *et al.* 2003, Randi & Ragni 1991, Rochlitz 2005, Russell *et al.* 2009, Ruxton *et al.* 2002, Széles *et al.* 2018, Tschanz *et al.* 2011, Turner & Bateson 1988, Turner & Meister 1988, Woinarski *et al.* 2017, Woods *et al.* 2003, Yamaguchi *et al.* 2015, Zimmermann & Zimmermann 1944

József Lanszki & Gabriella Lanszki-Széles

Golden Jackal

Canis aureus Linnaeus, 1758

Original area of the species

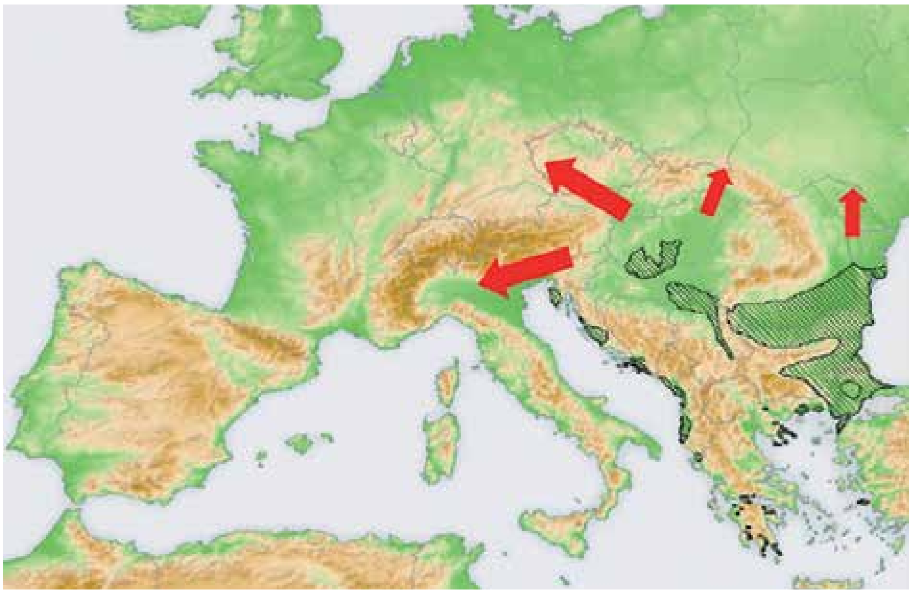
The Golden Jackal is one of the most successful mammal carnivore species in Europe; its spread is very fast (Rutkowski *et al.* 2015). Its native area extends from South-eastern and Central Asia through the Middle East and the Arab Peninsula to Eastern Europe and also the Eastern part of Central Europe (Macdonald & Zubiri 2004). The African sister species was separated from the Golden Jackal based on genetic studies as the African Wolf (*Canis lupaster*) (Rueness *et al.* 2011, Koepfli *et al.* 2015), but formerly was regarded as a subspecies of the Golden Jackal.

The adaptability and plasticity of the Golden Jackal are exceptional. Regarding habitat selection, it is a generalist: within its enormous Eurasian home range, it lives in temperate, sub-Mediterranean, Mediterranean and subtropical regions. It occurs in grasslands, wetlands, and broad-leaved forests, from pristine natural habitats to heavily transformed human-affected habitats, and even in the vicinity of large cities (Aiyadurai & Jhala 2006, Trouwborst *et al.* 2015).

The introduction of the species to Hungary

The Golden Jackal has native reproducing populations in Albania, Austria, Bosnia-Hercegovina, Bulgaria, Croatia, Greece, Hungary, Serbia, Romania, Slovakia, Slovenia, Turkey, Ukraine and Russia (Hoffmann *et al.* 2008). The causes and mechanisms enabling its fast spread have not yet been fully discovered. Its European area was restricted to the South-Eastern part of Europe in former centuries (Kryštufek *et al.* 1997, Arnold *et al.* 2012). The disappearance of the species from the Eastern part of Central Europe at the beginning of the 20th century was driven by the transformation of habitats and hunting pressure (Giannatos 2004, Giannatos *et al.* 2005). By the middle of the 20th century, its reproducing populations were isolated island-like fragments, limited to the coastal areas of the Mediterranean and Black Sea (Krofel *et al.* 2017). In Bulgaria, the species was declared protected in 1962. The Golden Jackal in the 1970s and 1980s exhibited a fast spread from the Balkan Peninsula to the West and North, except for the mountain areas populated by the Grey Wolf (*Canis lupus*), its direct competitor (Kryštufek *et al.* 1997, Arnold *et al.* 2012). Its spread is not restricted by geographical barriers (Rutkowski *et al.* 2015). There might be many reasons causing or enabling its spread, such as the change in land use and climate (Šálek *et al.* 2014, Kleijn *et al.* 2009, Trouwborst *et al.* 2015). Its spread was surely strongly enhanced by the limitless availability of food resources provided by humans (Cirovic *et al.* 2016, Lanszki *et al.* 2018a), or/and the local extirpation of the Grey Wolf, which is a significantly stronger predator and, at the same time, a competitor of the Golden Jackal (Krofel *et al.* 2017, Newsome *et al.* 2017). Its area expansion and population number growth were further helped by the pronounced plasticity of its dispersion pattern (Kapota *et al.* 2016, Lanszki *et al.* 2018b, Stronen *et al.* 2021), habitat use (Fenton *et al.* 2021) and social system (Macdonald 1979, 1983, Moehlman 1987, Jhala & Moehlman 2004). Vagrant individuals or even young reproducing families were reported from Germany, Poland, Denmark, Switzerland, Belarus, France, Estonia, Latvia, Lithuania and Finland (Hoffmann *et al.* 2008, Trouwborst *et al.* 2015). In February 2021 it occurred in Norway north of the Arctic Circle (Linnell *et al.* 2021).

Its estimated European population number was around 70,000 (Cirovic *et al.* 2016), but recently its number is probably closer to 97,000 – 117,000 (LCIE 2021).



The area of the Golden Jackal till the beginning of the 2000s and its routes in Europe (modified from Arnold *et al.* 2012). Shaded areas show the reproducing population.

The recent new occurrences of the Golden Jackal in Europe (Trouwborst et al. 2015). Orange colour shows the reproducing populations, while red dots represent sporadic occurrences.

The Golden Jackal is a native predator of Hungary (Rakonczay 1989, Hoffmann *et al.* 2008, Tóth *et al.* 2009). Since the Middle Ages, it has been continuously present in our country, although in low density. The Jackal and Golden Jackal are recent names for the species. Formerly, it was known as Reed Wolf, Meadow Wolf, Turkish Fox or Toportyán. This name variability makes identifying of the species difficult in old written accounts. In the 1940s, this species became extinct in Hungary, although sporadic occurrences were reported for the following 50 years. These were young male specimens and never formed reproducing populations in this period (Demeter & Spassov 1993, Rakonczay 1989). Its spontaneous spread was started at the beginning of the 1990s from the Balkan Peninsula, as a result of the population growth in Bulgaria. From then on, both the population growth and the area expansion happened in an invasive manner (Heltai *et al.* 2010, 2013).

IUCN categorises the Golden Jackal as a *Least Concern* species. Its population is growing both in Hungary and Europe. The species can be hunted year-round in Hungary.

Life history / Biology of the species

The Golden Jackal is a secretive species. It occurs in many habitats and likes the dense scrublands where it can hide its den easily. It also likes fragmented forests rich in game species, agricultural areas rich in rodents, grasslands, set-aside areas and gallery forests, but also occurs in wetlands and moors. The Golden Jackal usually avoids large closed forest areas and open, intensely managed agricultural lands. It also frequents communal waste disposal plants (Giannatos 2004, Jhala & Moehlman 2004). It shows a tendency to inhabit wetlands, sparsely populated agricultural areas managed less intensely, and areas characterised by mild winters (Ranc *et al.* 2018).

The Golden Jackal is a medium-sized predator, and its body mass is around 10–15 kgs. Its diet is quite well-known due to intense research, with more than 40 diet studies carried out in its geographical range. Based on these studies, we can claim that its food spectrum is especially varied compared to other predators (Lanszki *et al.* 2018). Climate and other environmental factors strongly influence its diet composition and feeding habits. As an opportunist hunter, it utilises the most profitable prey with the highest energy intake available in a given area in a given period. Hence this species can very quickly adapt to the constantly changing environment. Its hunting strategy is very adaptable, and it helps the spread of the species considerably. The Golden Jackal can quickly adapt its hunting technique to the size of available prey and utilise new opportunities. Although the Golden Jackal primarily is a lone hunter, it can change to hunting in a pair, or for that matter, in packs during the period of teaching pups how to hunt (Macdonald 1979, 1983, Moehlman 1987, Demeter & Spassov 1993, Yom-Tov *et al.* 1995). In accordance with its build – compared to the Grey Wolf (*Canis lupus*), the legs of the Golden Jackal are shorter – the Golden Jackal is a searcher predator, not a pursuer (Aliev 1969, Taryannikov 1974, Lanszki *et al.* 2006). It prefers prey lighter than 4 kgs (Hayward *et al.* 2017). Individuals usually kill small-sized prey, but the Golden Jackal can kill injured larger animals in groups. It cannot fill in the role of large predators; we do not know whether it has a top-down effect on prey populations. The Golden Jackal plays typical medium-sized predator roles: feeding on carrion and controlling small predators that negatively affect biodiversity, for example, the Red Fox (*Vulpes vulpes*) (Crooks & Soulé 1999, Glen *et al.* 2007, Beschta & Ripple 2009).

It is an omnivorous and opportunistic predator. In Eurasia, it mainly preys on small mammals but also consumes plants and the carrion of domestic animals. And it can utilise several other sources, the following prey items were listed in its diet: 78 mammals (Mammalia), 31 birds (Aves) and also eggs, 11 reptiles (Reptilia) and amphibians (Amphibia), five fishes (Pisces), 53 invertebrates and 81 species of plants (Lanszki 2012, Hayward *et al.* 2017, Lanszki *et al.* 2018). The Golden Jackal is especially adapted to feeding on the carrion of domestic animals and game species, on the innards of large game species, and the leftovers from the prey of other carnivores. Some studies report the following prey items from the diet of Golden Jackals: hare, Pheasant (*Phasianus colchicus*), water birds and their eggs, eggs of turtles, and newborn specimens of large game species (Demeter & Spassov 1993, Brown & Macdonald 1995, Lanszki *et al.* 2009, 2018). It also feeds on ripe fruits and ripe corn (*Zea mays*). The Golden Jackal can utilise such resources as food remains found at communal waste disposal plants (Macdonald 1979, Kapota *et al.* 2016, Cirovic *et al.* 2016).

The structure of the Golden Jackal family is similar to that of the Grey Wolf (Macdonald 1979, 1983, Moehlman 1987). The pack is led by the alpha pair: a dominant female and male, which usually pair for life and are equal in the dominant rank. The mating season lasts from January to March. The gestation period lasts 60-63 days, and afterward, usually, 3-5 (maximum is 8) pups are born from April to May. The dominance rank in the pack strictly controls the reproductive behaviour of the individuals: only the dominant pair reproduces. If the prey availability is high in the area, the pups from the previous year might remain with their parents. These “helpers” do not breed themselves. Instead, they help to rear their brothers and sisters (Macdonald 1983). The pups spend the first two weeks after birth in the den with their mother and are fed only with milk. Meanwhile, the nursing mother is provided by her pair and the helpers. From the third week, the milk is augmented with pre-digested regurgitated food brought by their parents and their helpers. The training of the young jackals can last for six to eight months, as it involves teaching the young how to hunt for dangerous prey, for example, injured large game species. The females become sexually mature in the year following their birth, while males become sexually active in the second year. Their lifespan can be 16 years. In Bulgaria, only 10% of the studied individuals were older than three years (Stoyanov 2012). The rapid adaptation to new habitats is facilitated by the parents and helpers feeding the pups with a very varied diet and teaching them different hunting techniques over a long period.

The dispersing young (first year) and older helpers migrate large distances to find a territory and form a family. These vagrants also replace the disappearing alpha individuals and hence occupy vacant territories. A continent-wide molecular genetic study (Rutkowski *et al.* 2015) confirmed that populations living far from each other (for example, those in the Caucasus and Baltic areas) might show a high degree of relatedness, even though the distances among the sampling points were hundreds of kilometres (Rutkowski *et al.* 2015, Trouwborst *et al.* 2015).

A GPS-collared Golden Jackal searching for a territory moved 220 kilometres within two weeks

(Lanszki *et al.* 2018). Several migrant individuals fall victim to traffic, hunting, and predating larger carnivores. In Israel, of 39 collared Golden Jackal, ten left their natal territories, and among these, 8 perished (Kapota *et al.* 2016).

Based on radio telemetry studies, the average home range size in Greece is 2–15 km^2 (Giannatos *et al.* 2005). Based on bioacoustics studies, its density is 8-50 packs (groups) per 100 km^2 in Greece, 6–11 packs per 100 km^2 in Croatia, 14–70 packs per 100 km^2 in Bulgaria, in Hungary, 14–32 packs per 100 km^2 in agricultural areas and 15–32 packs per 100 km^2 in forested areas (Giannatos *et al.* 2005, Heltai *et al.* 2010, Stoyanov 2012, Sálek *et al.* 2014, Lanszki J.).

The Golden Jackal is receptive to some well-known Canid diseases such as rabies and canine distemper, and might spread several parasites. Some parasites of the Golden Jackal might pose a danger to humans, too, for example, the dog heartworm (*Dirofilaria immitis*), the Trichinella Nematode (*Trichinella spiralis*) and some cestodes (*Echinococcus* spp.) (Széll *et al.* 2013, Takács *et al.* 2014, Balog *et al.* 2021).

The ecological requirements of the species in Hungary

The Golden Jackal first reoccurred in the Southern part of Hungary at the beginning of the 1990s. This part of the country is rich in mammal carnivores. According to the Hungarian National Game Management Database (www.ova.info.hu), at the beginning of the legal hunting of the Golden Jackal in 1997, 11 individuals were shot. In the 2020/2021 hunting season, this figure grew to more than 12,000 individuals. Nowadays, the Golden Jackal is present in the whole country of Hungary, with the highest densities reported in Somogy, Baranya and Bács-Kiskun counties, while the lowest densities are recorded in Nógrád and Győr-Moson-Sopron counties. The exponential growth of shot specimens in Hungary stopped in 2020 (Csányi 2021).

The climatic features and biological assets of Hungary, the high productivity of the natural plant associations and hence the high number of herbivores – both game species and rodents (Rodentia) – offer ideal circumstances for the Golden Jackal. The innards of large game species harvested by hunters are left out in the hunting areas, and their quantity is estimated to be 3,000 tonnes per year. Moreover, this source is concentrated in ideal jackal habitats: in the forested counties, characterised by a high density of large game species (Lanszki *et al.* 2015). No wonder the highest densities of the Golden Jackal is detected in the high ungulate-density areas. As the forested area of our country grows, it will probably be followed by the increase in the population size of large game species. The fenced-off forest plantations – created to reduce damage by large herbivores – are ideal habitats for the Golden Jackal to hide its den. Anthropogenic food sources such as the viscera of shot ungulates, the corpses of large game species, and the illegally dumped corpses of domestic animals around farms and animal husbandries, the waste products of slaughters, and also legally or illegally dumped communal waste offers an unlimited food source for the Golden Jackal and other carnivores year around (Rotem *et al.* 2011, Lanszki *et al.* 2018).

Ecological problems

There are several unanswered questions regarding the Golden Jackal. Its adaptation techniques to the ever-changing environment might be different in different geographical regions and at different population densities. These differences might also manifest in its habitat use, feeding, and reproduction, and therefore these characteristics are very unpredictable. Intense hunting conducted during the winter might cause the disintegration of Golden Jackal family units. As the dominant female is removed from the pack, the formerly subdominant and, therefore, not reproducing daughters might pair with vagrant males and hence begin producing offspring. It might lead to a situation when instead of a single female, many female jackals start producing offspring. It might even happen without pair or family formation, and the lone female looks for the most easily accessible food resources. The effect of the Golden Jackal on game species, extensively raised livestock, and the management of protected species is very hard to judge, the situation is contradictory at best.

The Golden Jackal can reduce the population size of the Red Fox (*Vulpes vulpes*) locally, as they are direct competitors for food. Several observations provide evidence of the competition between the two species. Moreover, the remains of Red Foxes have been discovered in the stomach content or faeces of Golden Jackals. The exclusion of some small predators might have a positive effect through a cascade effect for some species characterised by high nature conservation importance (for example, some bird species) (Crooks & Soulé 1999). Until today there is no evidence that the Golden Jackal would exclude competitors or threaten any populations of rare species. In the moorland of the Kis-Balaton area, where Golden Jackal density is estimated at 2–12 groups per 100 km^2, there was no evidence of Golden Jackal consumption of eggs in bird clutch predation tests over 11 years (Lanszki J.).


© József Lanszki

Economic effects

Detailed studies on the effects of offspring predation and the population trends of game species are missing. The effects of the spread of Golden Jackals on the populations of Roe Deer (*Capreolus capreolus*) in Hungary are especially interesting. The ability of Golden Jackals to seriously affect and reduce the populations of large game species, especially such as the Red Deer (*Cervus elaphus*) and Wild Boar (*Sus scrofa*), is questionable, especially in the light of the increasing number of these species harvested every year (www.ova.info.hu). Under special circumstances, for example, in harsh winters with reduced food availability, Golden Jackals at several locations tend to hunt for Wild Boar piglets (Lanszki & Heltai 2010, Szabó *et al.* 2010). In extensive husbandry, when human surveillance is inadequate, Golden Jackals may successfully prey on calves and lambs (Yom-Tov *et al.* 1995, Szabó *et al.* 2010).

Possible methods of control

The Golden Jackal is categorised as a species that can be hunted all year round with legal hunting methods to control their populations. In extensive animal husbandry, some measures should be taken in sensitive periods to avoid severe damage to livestock. For example, herders, watchdogs, and indoor keeping might be necessary when offspring are born and in the following weeks when the young individuals are vulnerable. The higher the number of Golden Jackals culled in their offspring rearing period, the better the chance to reduce loss to predation of game species (Heltai *et al.* 2010).

References

Aiyadurai & Jhala 2006, Aliev 1969, Arnold *et al.* 2011, Balog *et al.* 2021, Beschta & Ripple 2009, Ćirović *et al.* 2016, Crooks & Soulé 1999, Csányi 2021, Demeter & Spassov 1993, Fenton *et al.* 2021, Giannatos 2004, Giannatos *et al.* 2004, Glen *et al.* 2007, Hayward *et al.* 2017, Heltai *et al.* 2010, 2013, Hoffmann *et al.* 2018, Jhala & Moehlman 2004, Kapota *et al.* 2016, Kleijn *et al.* 2009, Koepfli *et al.* 2015, Krofel *et al.* 2017, Krystufek *et al.* 1997, Lanszki 2012, Lanszki & Heltai 2010, Lanszki *et al.* 2006, 2009, 2015, 2016, 2018a, 2018b, LCIE 2021, Linnell *et al.* 2021, Macdonald 1979, 1983, Macdonald & Sillero-Zubiri 2004, Moehlman 1987, Newsome *et al.* 2017, Rakonczay 1990, Ranc *et al.* 2018, Rotem *et al.* 2011, Rueness *et al.* 2011, Rutkowski *et al.* 2015, Šálek *et al.* 2014, Stoyanov 2012, Stronen *et al.* 2021, Szabó *et al.* 2010, Széll *et al.* 2013, Takács *et al.* 2014, Taryannikov 1974, Tóth *et al.* 2009, Trouwborst *et al.* 2015, Yom-Tov *et al.* 1995

József Lanszki

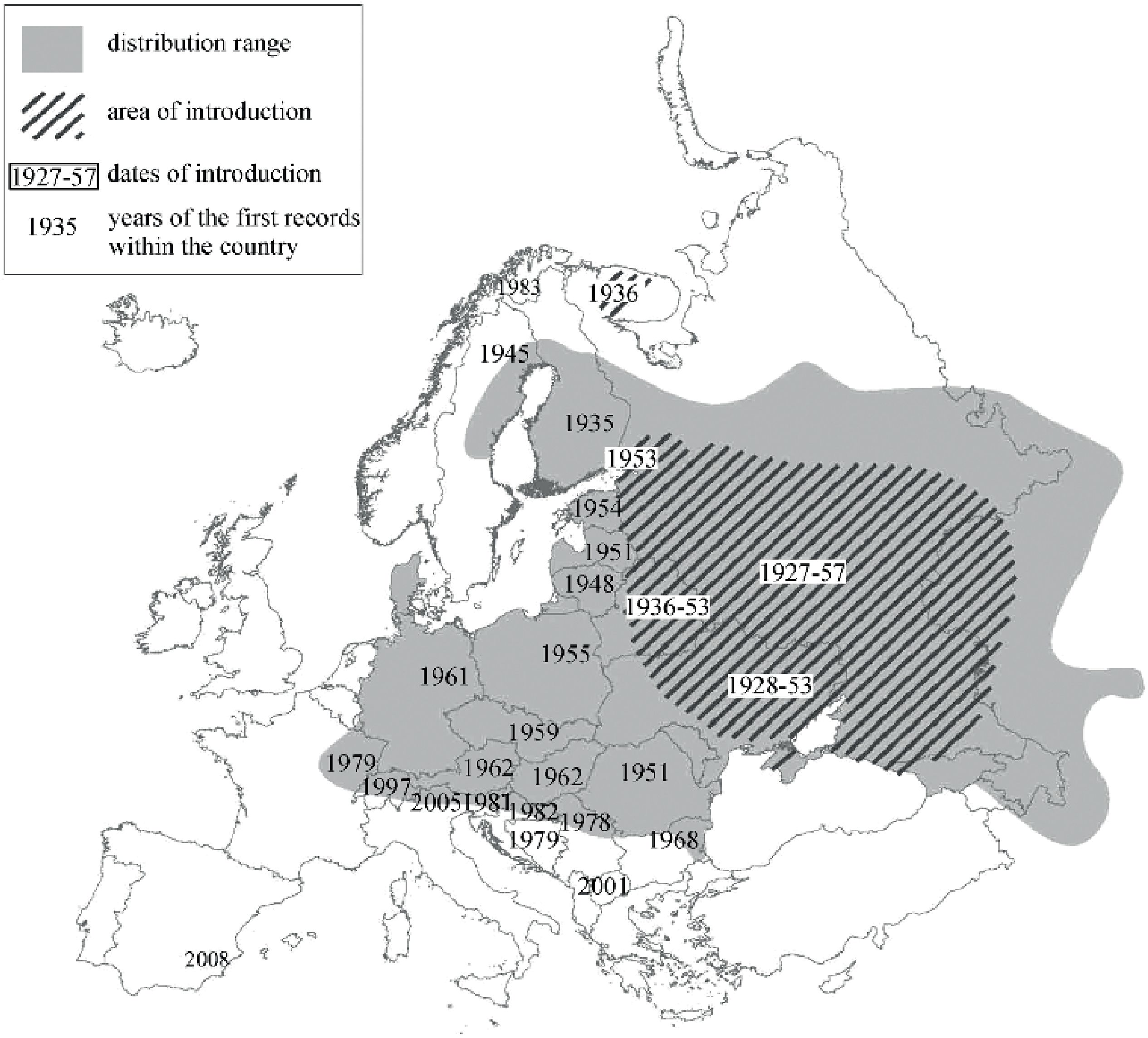
Common Raccoon Dog

Nyctereutes procyonoides (Gray, 1834)

Original area of the species

The Common Raccoon Dog belongs to the family of canids (Canidae, including dogs, foxes, wolves) and originally it was native to Far East Asia. Its six subspecies populate the vast area from the subtropical parts of North Vietnam to the south-eastern part of Siberia and Hokkaido Island, areas characterized by continental climate and harsh winters. Its wide geographic distribution is due to its great adaptability, expressed by different feeding strategies, body size, fat reserves, fur density and behaviour under different climatic conditions (Kauhala & Saeki 2004). The south-eastern Siberian subspecies (ssp. *ussurensis*) introduced to Europe originally lived in an area where winter is harsh and snow cover lasts long. Hence this Common Raccoon Dog's fur is dense; it builds up fat reserves in the fall and hibernates in the winter (Kauhala & Kowalczyk 2011). These characteristics set the evolutionary background for its spread in Europe.

© János Oláh

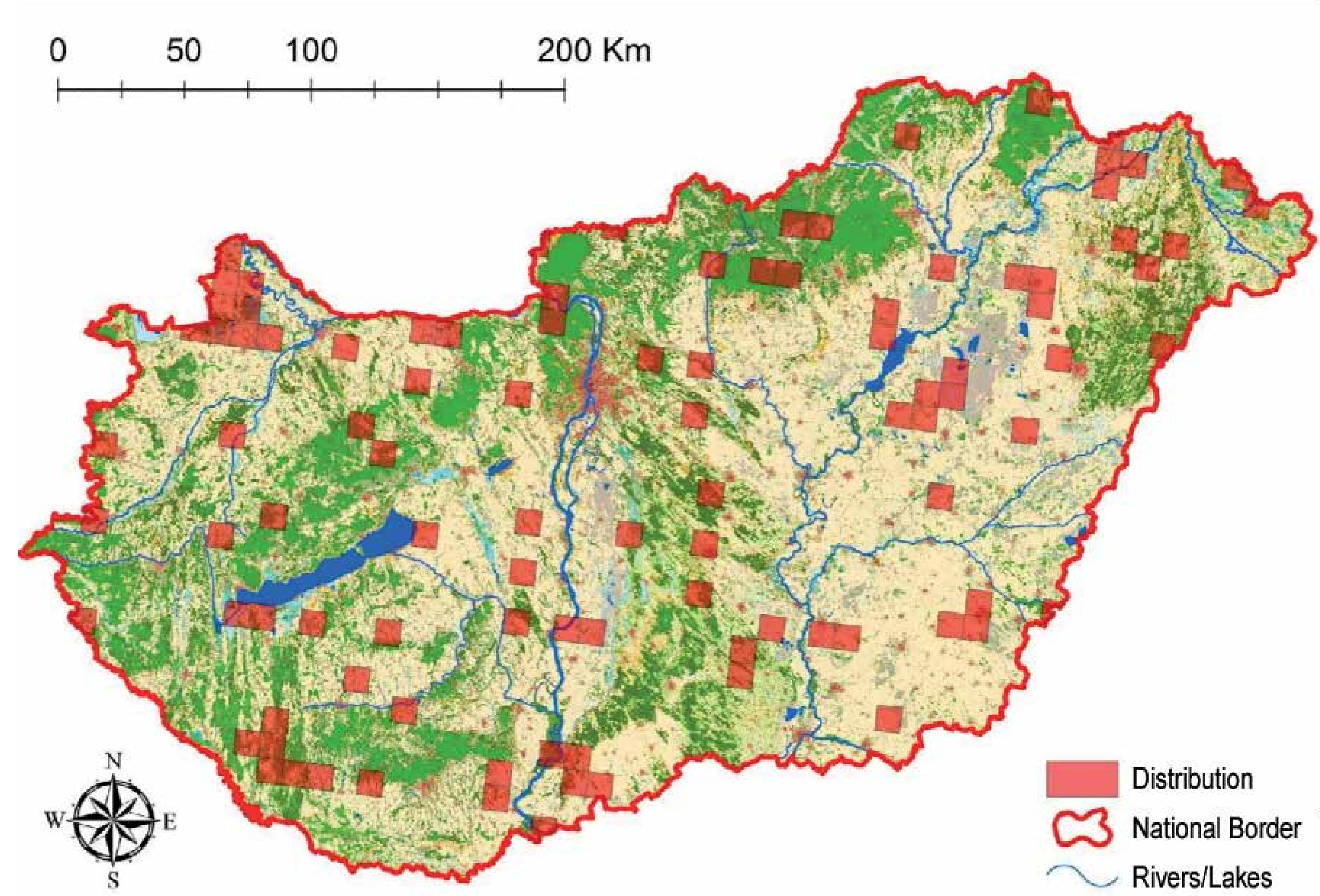


The European areas where the Common Raccoon Dog was introduced (obliquely lined pattern), and the first record and area by countries (Kauhala & Kowalczyk 2011)

The introduction of the species to Europe and Hungary

9,100 individuals were introduced to the European part of the Soviet Union between 1929 and 1955 for hunting (Lever 1985). The stock introduced to the Caucasus did not grow. Later it started to decline and then finally disappeared. But the European introduction trial proved to be successful. The area expansion of the species reached or surpassed 40 kilometres per year, and in exceptional years it spread 120 kilometres (Lavrov 1971). The first Common Raccoon Dog individuals searching for new territories appeared in Finland in the 1930s and 1940s, and the colonization took place in the middle of the1950s. The explosive growth of its population started ten years later. The other example of its fast spread is Poland, where the first individuals were observed in 1955, and by the end of the 1960s the species had invaded the whole of the country (Pielowski *et al.* 1993). In the northern countries of Europe, its populations reached their maximum number of individuals in the middle of the 1980s. Then after a short decline, it stabilised. The further westward spread of the species went on as expected, and it appeared in Spain in the last years. Now the Common Raccoon Dog occurs in many European countries.

In Hungary, the first Common Raccoon Dog was shot at the beginning of the 1960s, and ever since, its occurrence has been sporadic. Probably there are small, self-sustaining populations in eastern Hungary (Heltai *et al.* 2010), but there were no targeted field studies of this species. In Hungary, it is a species occurring in the wild but with very limited distribution (Nagy *et al.* 2020).



The distribution of the Common Raccoon Dog in Hungary (Nagy *et al.* 2020)

Life history of the species

The Ussuri Raccoon Dog subspecies (ssp. *ussurensis*) introduced to Europe originates from an area with a continental climate, where it lives in deciduous forests. In Europe, besides forests, it likes densely vegetated wetlands and marshes, reed beds and gallery forests. Watercourses play an important role in its spread. It also occurs in agricultural areas and the vicinity of human settlements (Kauhala & Kowalczyk 2011, Mulder 2012).

In the autumn, it builds up subcutaneous fat reserves and internal reserves around the visceral organs in the abdomen. Besides being an energy reserve, they also play an important role in insulation. It might take an aestival period in the winter to avoid unfavourable climatic conditions and food shortages, but it does not really hibernate (Kauhala *et al.* 2007). This might give it a competitive edge against some predators such as the Red Fox (*Vulpes vulpes*). The hibernation might be omitted completely in Hungary and the warmer parts of the Balkan Peninsula.

The diet of the Common Raccoon Dog is very diverse. It practically eats what it can get. It is a real omnivore (Sutor *et al.* 2010). Depending on the season and location, its diet composition might change considerably (Jedrzejewska & Jedrzejewski 1998, Rotenko & Sidorovich 2017). It mainly hunts for small mammals (Mammalia). However, in cold winter periods, it consumes the carrion of large mammals, and additionally frogs (Anura), lizards (Sauria), invertebrates and very often birds (Aves) (Sutor *et al.* 2010). To complement its meat diet, it regularly eats fruits and grain. Due to its omnivore feeding and the wide variety of food taken, the limited availability of a single food source does not influence its occurrence.

Average litter size is 8–10 pups, which is approximately twice as much as its competitors. It is a monogamous species, living in established pairs, which also helps its successful rearing of its young. The young become independent at 4-5 months, although most of them will perish before they reach the age of one year. For example, in the southern part of Finland, 88% of the young die. Mortality in the 2-4 years age class is only 43%. The offspring reach sexual maturity at the age of 10 months. The maximum life span is eight years, but only 1% of individuals live for five years (Helle & Kauhala 1993, 1995).

Young usually disperse to an average of 13.5 km in Germany (Drygala *et al.* 2010), but they can wander very far from their parents' territory. In Germany, a 91 km movement was recorded, while in Finland within four months a 145 km movement was recorded (Kauhala *et al.* 2006).

Its population density is dependent on the characteristics of its habitat. In Finland, in a habitat mosaic, the maximum density was two adults /km^2 (with a home range of approximately 100 hectares). In comparison, in a very inferior habitat (spruce forest), its density was only 0.8 adults /km^2 (with a home range of approximately 260 hectares) (Kauhala *et al.* 2010).

The ecological requirements of the species in Hungary

In Hungary, the Common Raccoon Dog appeared in communities characterised by numerous carnivore mammal species. There are very few data available on this species. The most informative source is the statistics on hunting (www.ova.info.hu). The number of specimens shot per year shows an increasing trend, which suggests that the Common Raccoon Dog has settled permanently in Hungary (Csányi 2021). As there is an abundance of food sources in its habitats, there is no indication of competitive exclusion between the Common Raccoon Dog and any native carnivore. Also, as the number of Common Raccoon Dogs is very low, and its occurrence is sporadic, its negative effect on prey populations is not documented. The reasons are unknown why the population of the Common Raccoon Dog did not increase considerably in the past decades.

Ecological problems

Without research carried out on the Common Raccoon Dog in Hungary, there are only foreign experiences regarding the ecological problems it causes. In Europe, there are very few research studies on the effect of the Common Raccoon Dog on the native fauna. It threatens bird species (Aves), avian communities of wetland habitats, and the populations of amphibians (Amphibia). It especially might exert a profound negative effect on ground-nesting birds. As a consequence of the Common Raccoon Dog' preference of wetland habitat, the loss of clutches in waterbird populations might reach 85% (Ivanova 1962). Still, it can also considerably damage bird game species and songbirds (Passeriformes) (Sutor *et al.* 2010, Kauhala & Kowalczyk 2011). It consumes more birds when the population size of small mammals is declining. The Common Raccoon Dog mainly consumes frogs (Anura) and newts (Caudata) in the spring and summer. In times of limited availability of different sources, it might be a competitor of native carnivore mammals (Rotenko & Sidorovich 2017). Based on the results of studies carried out abroad, the Common Raccoon Dog might act as a vector of contagious virus diseases threatening other animals and even humans, such as rabies, SARS coronavirus, influenza (H5N1) and canine distemper. It also might transmit parasites such as Tapeworms (and Notably *Echinococcus multilocularis*) and Nematodes (*Trichinella* spp.) (Kauhala & Kowalczyk 2011).

Methods of control

The scarce observations might be the result of the secretive nature and nocturnal activity of the Common Raccoon Dog, but the more and more widespread application of game cameras might help in registering its presence. As an invasive alien species, the Common Raccoon Dog can be hunted all year round in Hungary. To prevent its spread, all the settled Common Raccoon Dog populations should be discovered, and all the individuals of all age cohorts should be eradicated systematically with legal hunting methods (firearms, live-catching traps). If and when this species spreads to more habitats in higher numbers, its control will be impossible. All the collected specimens should go through detailed molecular genetic, dietary and parasitological examinations.

The Common Raccoon Dog is included in the List of invasive alien species of Union concern; and hence its keeping, breeding and release to natural habitats is forbidden in all the EU countries. Member States are required to take action on pathways of introduction and to take measures for the early detection and rapid eradication of these species (Regulation *No 1143/2014/EU* of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species).

References

Csányi 2021, Drygala *et al.* 2010, Helle & Kauhala 1993, Heltai *et al.* 2010, Ivanova 1962, Jędrzejewska & Jędrzejewski 1998, Kauhala & Helle 1995, Kauhala *et al.* 2004, 2006, 2007, 2010, 2011, Lavrov 1971, Lever 1985, Mulder 2012, Nagy *et al.* 2020, Pielowski *et al.* 1993, Rotenko & Sidorovich 2017, Sutor *et al.* 2010

József Lanszki

American Mink

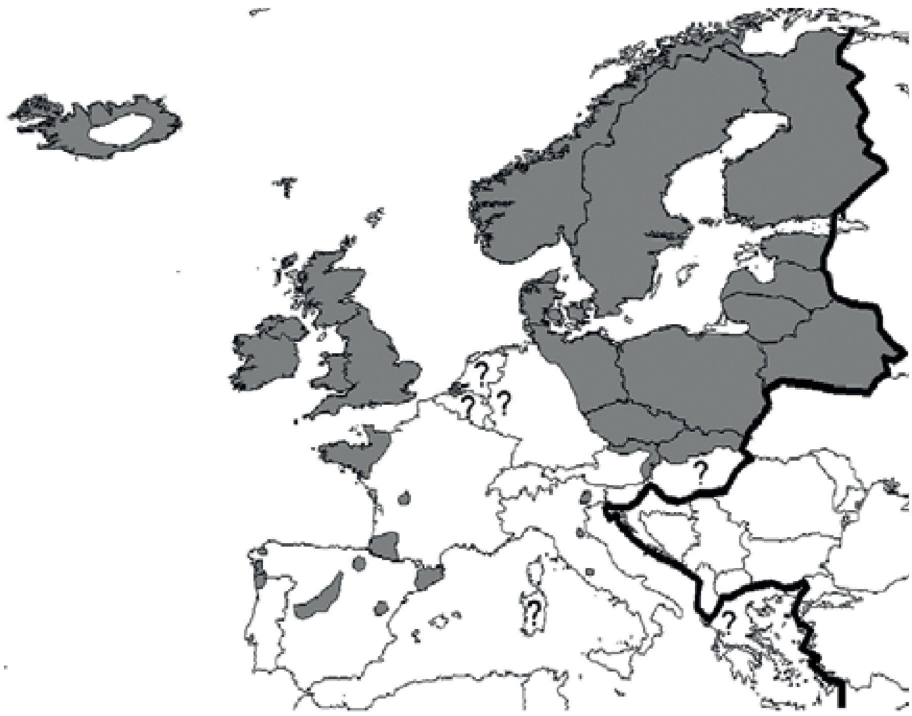
Mustela vison (Schreber, 1777)

Original area of the species

The American Mink is native to North America and occurs – except the dry southwestern areas – from Alaska to the southern States of the USA. It is a semiaquatic mustelid and, as such, likes densely vegetated shores of lakes, wetlands, creeks and rocky sea coasts (Reid *et al.* 2016). It has been bred for its valuable fur for 150 years. The escapees from fur farms are larger than wild specimens due to artificial selection, and they cause nature conservation issues in their native area. Two-thirds of the American Minks shot in its native range are either escapees from fur farms or hybrids. Although its primary food source is fish, its population size changes in synchronously with Muskrat (*Ondatra zibethicus*) numbers, one of its preferred mammal prey items (Shier & Boyce 2009). Water pollution, especially mercury (Hg) and PCBs, induce abnormalities in its breeding and higher pup mortality. It might even lead to its local extinction (Osowski *et al.* 1995, Basu *et al.* 2007). The American Mink is an alien invasive species in its introduced range in the southern part of South America, Europe and Asia.

The introduction of the species to Europe and Hungary

The first American Minks were introduced to Europe in 1920 to fur farms. Although the first specimens escaped in the 1920s from Scandinavian fur farms, until the 1950s its explosive population growth was not observed anywhere. In Finland and Norway in the 1950s, the American Mink had limited distribution, but 30 years later, it became a widespread species in both countries. In Belarus, its number grew from about 900 specimens in the 1950s to 56,000 by the end of the 1980s. It mainly spreads from Scandinavia to the south and Russia to the west. Now, it is widespread in the northern parts of Europe: Scandinavia, Great Britain, Iceland, Germany and Poland. Island-like, isolated populations are found in the Benelux countries, western France, the Iberian Peninsula and Italy. It occurs in the neighbouring countries around Hungary; it has a stable population in Slovakia (Bonezi & Palazón



The distribution of the American Mink in Europe (Bonezi & Palazón 2007) (question marks stand for data deficient countries)


© István Kerekes

2007, Zalewski & Brzezinski 2014). In Hungary, it was first bred by István Vásárhelyi in the middle of the 1950s. The first feral specimen was collected in Biharugra in 1988 (database of the Mammal Collection of the Hungarian Natural History Museum). Nowadays, its sporadic occurrence is reported from the Szigetköz and from around the intersection of the Hungarian-Austrian-Slovenian border (Őrség National Park) (Lanszki 2020.).

Life history of the species

It can occur in any wetland habitat type. It especially likes slowly flowing and stagnant water bodies, but can also settle in areas far from water (Macdonald *et al.* 2017). It also occurs on the shores and coastal islands of northern countries. It inhabits similar habitats to the Muskrat (*Ondatra zibethicus*) and likes to live close to beavers (*Castor* spp.). It prefers ice-free water bodies. It is a semiaquatic carnivore, so its den is often situated on the shores. It can take over the abandoned nests and tunnels of larger rodents but can also build its nest among the roots of trees, and under or besides large rocks and stones.

It is a nocturnal animal. It does not form pair bonds. It will eat everything that it can get: muskrats, catches rabbits (Leporidae) even in their dens and tunnels, small mammals (Mammalia), fish (Pisces), decapods (Decapoda), amphibians (Amphibia), birds (Aves), and their eggs, and aquatic insects (Macdonald *et al.* 2017, Zalewski & Brzezinski 2014, Mezzetto *et al.* 2021). From among fishes, it eats the smaller ones. Although it is primarily a semiaquatic mammal, it can adapt to land habitats, too. It is more territorial during autumn and winter. Its fur protects it less from soaking through than the Otter's (*Lutra lutra*), and hence in the winter, instead of fish, it mainly feeds on frogs (Anura) and rodents (Rodentia). In contrast during the spring and summer, fish and birds dominate its diet (Zalewski & Bartoszewicz 2012). Compared to its own size, it can kill considerably larger birds: for example, gulls (Laridae), cormorants (Phalacrocoracidae) and poultry.

The home range of males is two to three times larger than females'. Around water bodies, its home range is 1-9 km of shore or coastal section, while in its original wetland habitats are 2.3–6.9 km^2

(Macdonald *et al.* 2017). If food is abundant, it will only patrol a 200-300 metre-long section on the shore, but males searching for a new territory might move as much as seven kilometres in a single day.

It is a promiscuous species. Offspring are cared for by the female only. The mating season lasts from February to the end of March (in northern locations till April). Ovulation is triggered by copulation. There is a short delay before fertilised ova go through implantation (embryonic diapause); hence the gestation period can vary between 40–75 days. It cannot hybridise with the closely related European mustelids (Mustelidae), as in the European Mink (*Mustela lutreola*) and the European Polecat (*M. putorius*); there is no delayed implantation. Due to its flexibility with the start of implantation, the kits (on average, the number of offspring is four, but rarely can exceed ten) will be born in the optimal period of food abundance (Feldhamer *et al.* 2003). The kits will start to hunt at the age of eight weeks, but will remain with their mother till autumn. They will reach sexual maturity at the age of ten months, which means they can breed the year after they are born. Its lifespan can be as long as 10-12 years, but specimens older than three years are rare.

The ecological requirements of the species in Hungary

Mink farming ended in the 1990s in Hungary, and there were only sporadic observations of escapees. For decades, there was no confirmed occurrence of the American Mink in Hungary. As its populations spreading in neighbouring countries, and there were sporadic observations in Hungary in former years, we can expect new occurrences. From banks of smaller flowing water bodies with appropriate den sites, side branches, bogs and marshes to fish ponds, all are potential habitats for the American Mink. It is difficult to detect its presence. In Hungary, in the Szigetköz area, it was photographed by a wildlife photographer, and from around the intersection of the Hungarian-Austrian-Slovenian border (Őrség National Park), a camera trap recorded images of the American Mink.

Ecological problems

Invasive American Mink populations cause several severe ecological problems, but there is no such experience in Hungary yet. The American Mink especially threatens bird (Aves) populations, breeding around and in wetland habitats. For example, ducks (Anatidae), Common Moorhen (*Gallinula chloropus*), Eurasian Coot (*Fulica atra*), gulls (Laridae), and their clutches are the most targeted (Macdonald *et al.* 1999, Ibarra *et al.* 2009, Zalewski & Brzezinski 2014). The ecological plasticity of this species is proven by the fact that its average body weight can change through some generations, adapting to the local environmental endowments (Zalewski & Bartoszewicz 2012). The hunting behaviour of the American Mink is especially flexible. The larger American Mink can out-compete and replace the smaller but ecologically similar European Mink (*Mustela lutreola*). Presumably, competition between the two species is the driving force causing a drastic decrease in the populations of the native and threatened European Mink (Maran & Henttonen 1995). The diet of the American Mink considerably overlaps with that of the European Polecat (*Mustela putorius*). The diet of the two species only differs in the size of the consumed frogs (Anura): the American Mink hunts for smaller prey (Zalewski *et al.* 2021). When the Eurasian Otter (*Lutra lutra*) and the American Mink co-occur, the Eurasian Otter will consume even more fish (Pisces), while the American Mink will hunt more frogs and mammals (Mammalia) (Bonesi *et al.* 2004).

Methods of control

The American Mink is intensely hunted in several European countries because of the damage it creates in wetland habitats. Several field studies demonstrated the positive effect of eradicating the American Mink on the breeding of bird fauna (Nordström *et al.* 2003, Bonesi & Palazon 2007, Harrington *et al.* 2009). In the field, it is easy to confound it with other closely related mustelids (Mustelidae), especially with the European Polecat (*Mustela putorius*). Its role and damage are judged similarly to that of the Common Raccoon Dog (*Nyctereutes procyonoides*) and Raccoon (*Procyon lotor*). Immediate eradication of all occurring specimens is the only possibility to inhibit its invasion.

References

Basu *et al.* 2007, Bonesi & Palazon 2007, Bonesi *et al.* 2004, Feldhamer *et al.* 2003, Harrington *et al.* 2009, Ibarra *et al.* 2009, Lanszki 2020, Macdonald *et al.* 1999, 2017, Maran & Henttonen 1995, Mezzetto *et al.* 2021, Nordström *et al.* 2003, Osowski *et al.* 1995, Reid *et al.* 2016, Shier & Boyce 2009, Zalewski & Bartoszewicz 2012, Zalewski & Brzeziński 2014, Zalewski *et al.* 2021

József Lanszki

Raccoon

Procyon lotor (Linnaeus, 1758)

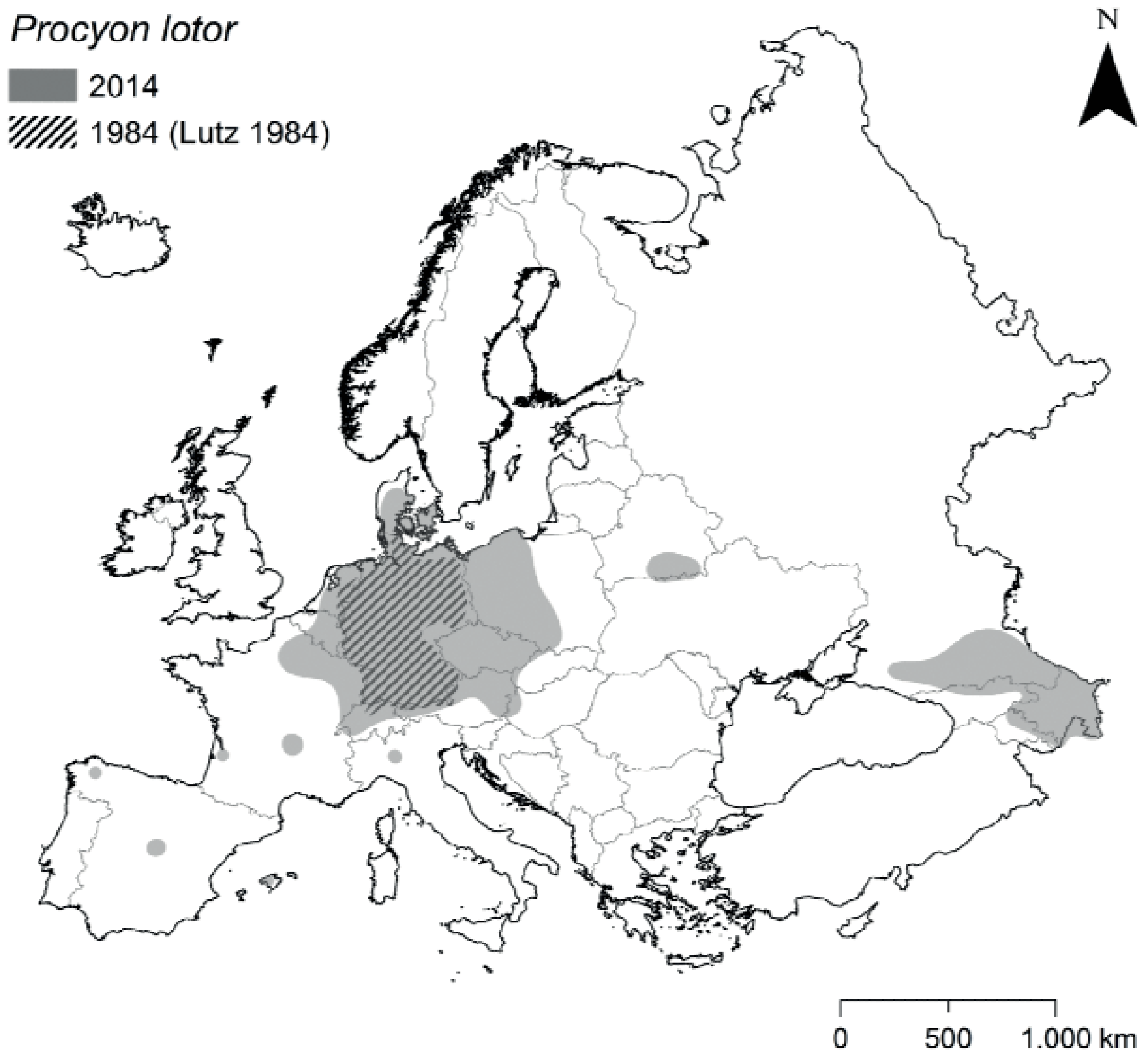
Original area of the species

The Raccoon is native to North America and occurs from the southern part of Canada to Central America (Gehrt 2003). In its native range, it occupies diverse habitat types from open areas through wetlands to river sides. In the last 100 years, it has also inhabited human settlements (among them large cities). Its native range is still enlarged nowadays due to the irrigation of agricultural lands and urbanization (Kamler *et al.* 2003). Because its fur is very valuable, it was introduced intentionally for fur hunting and trade to several locations around the globe: for example, to Alaska, Antilles, Europe and Asia (www.cabi.org).

The introduction of the species to Europe and Hungary

In Europe, the first two pairs were released in 1934 in Hessen Province, Germany, and in the same year, some further specimens were set free around Berlin. During the Second World War, even more Raccoons were released from fur farms, and some individuals escaped from captivity around Berlin. By the mid-1970s, its number had reached 20,000 in Hessen Province. Then its number decreased; in the 1980s, it started to increase again (Kauhala 1996). The Raccoon became a common animal in German settlements. There were introductions in the 1950s in the former Soviet

© Zsolt Kalotás



The distribution of the Raccoon in Europe (Lutz 1984, Jerdzejewska *et al.* 2014, Salgado 2018)

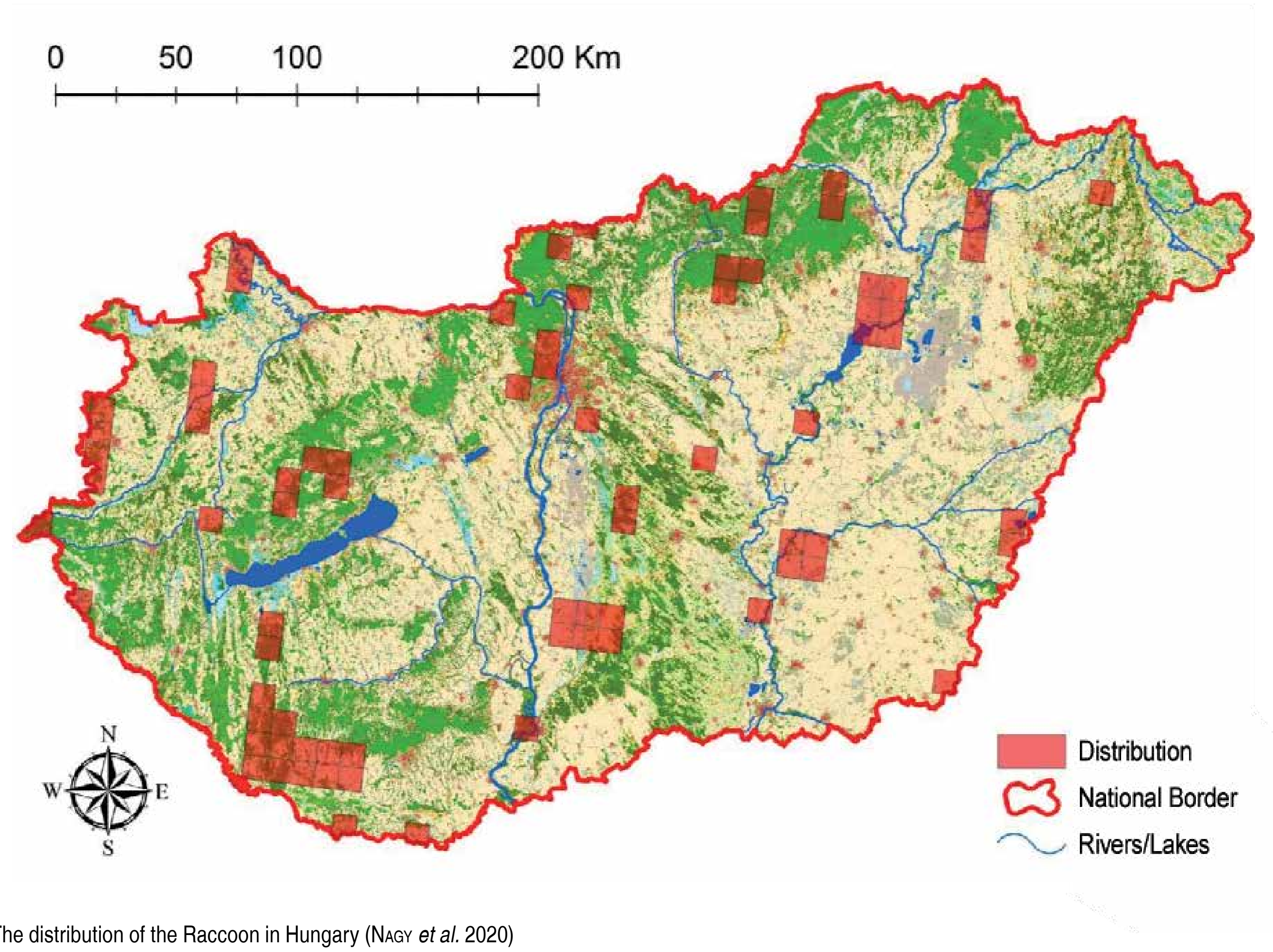
Union, too. The first representatives of this species appeared in France in 1934, in the Netherlands in 1960, in Luxembourg in 1979, in Austria in 1974, and in Switzerland in 1975 (Stubbe 1993). Nowadays, it also occurs in several other European countries. Its spread is limited by such natural barriers as high mountain ranges and larger rivers (Lutz 1984).

The species first occurred in Hungary in 1982. Its sporadic occurrence in Hungary originates from the following sources: immigrants from the populations of neighbouring countries, and escapees from fur farms, and also the release of unwanted pet Raccoons. The Raccoon is also kept in zoos and wildlife parks. The Raccoon can be hunted year around.

Life history of the species

The Raccoon occupies diverse habitat types in its native and invaded European range. It mainly occurs around and in the vicinity of water, prefers old forest stands with dense vegetation and lots of potential hiding places, marshlands and dense scrublands, but also lives in less dry areas, grasslands and pine forests (Kaufmann 1982, Macdonald & Barrett 1993, Lutz 1996, Gehrt 2003). It has perfectly adapted to human environments and occurs in agricultural lands, suburbs, city parks and gardens (Kauhala 1996, Gehrt 2004).

Based on radio tracking studies carried out in Germany, its average density in urban environments is one individual per hectare (Hohmann *et al.* 2000). In forests, its home range is significantly larger: it might be even 200–700 hectares (Hohmann 2000). Another study found that its home range in cities is up to five hectares, and in forests is approximately 100 hectares (Kaufmann 1982). During the day, it prefers to stay in the foliage of trees and in uninhabited buildings. Its preferred den sites are often underground burrows around water, cracks in rock walls,



The distribution of the Raccoon in Hungary (Nagy *et al.* 2020)

and heaps of logs. It mainly hunts on the ground but is agile in climbing trees and also is able to swim well. The Raccoon picks up food with its front paws and usually rubs them with a 'washing' movement. It will douse its food even if water is missing or polluted. This characteristic behaviour is reflected in its scientific name, as "lotor" means "washer" in Latin.

The females and young form small groups at the resting places, while males live separately and are polygamous. Its expected life span is five years, but in captivity may live for 10–14 years.

Its fat reserves, accumulated during the autumn, and thick fur protect it from cold, it does not leave its den for days or even weeks during extended cold periods. The climate of its habitat dictates the length of the inactive period. For example, in the southern parts of the United States, it is only one or two days, while in the north, it might last for weeks (Bogges 1994).

The Raccoon is omnivorous, and its diet is very varied (Bartoszewicz *et al.* 2008). It feeds on birds (Aves), small mammals (Mammalia), reptiles (Reptilia), amphibians (Amphibia), decapods (Crustacea), insects (Insecta), forest and garden fruits, grain, vegetables and kitchen leftovers (Kaufmann 1982, Gehrt 2003). Like the Beech Marten (*Martes foina*), the Raccoon also eats the pellet food placed out for dogs and cats. It expertly climbs trees and uses its long fingers to feel and grab objects. It can to reach the eggs and young of hole-nesting birds in their hollows. Therefore it threatens bird populations to a greater extent and on more 'levels' of vegetation layers of a given habitat than the Common Raccoon Dog (*Nyctereutes procyonoides*) and the American Mink (*Mustela vison*) do (Lutz 1996, Macdonald & Barrett 1993).

Its breeding period lasts from January to March, and its gestation period is 63–65 days. The female gives birth in a secluded hole to3–4 kits (rarely up to 10) (Fritzell *et al.* 1985, Stubbe 1993). Its reproduction is highly flexible, and if its litter is destroyed, a replacement second litter will be produced (Gehrt & Fritzell 1998). Most of the cubs remain with their mother till the next spring. The different generations often live in close vicinity and will form a new family in the immediate neighbourhood. Females become sexually mature at 8–12 months, while the males will mature only at 24 months (Faragó 2002, Heltai *et al.* 2010).

The survival rate of yearlings from their birth to September is 65%, and from September to the spring is 30–50% (Stubbe 1993). During cold winters, up to 60% of yearlings can perish (Faragó 2002). In Europe, harsh winters limit the northerly expansion of the Raccoon (Kauhala 1996), although, in North America, the species is extending its range to the north (Macdonald 1989).

The ecological requirements of the species in Hungary

In Hungary, its distribution data partly comes from natural habitats and also from human settlements. In many cases, the specimens caught were surely kept at houses formerly (Heltai *et al.* 2010). Between 1996/1997 and 2020/2021, the number of shot specimens slightly increased: even 20 individuals were achieved (www.ova.info.hu).

Ecological problems

The Raccoon is a medium-sized mammal (body weight 4–9 kg, rarely up to 15 kg), and its behavioural and ecological plasticity enables it to invade and populate new areas quickly. Only foreign results are known on the ecological problems caused by the Raccoon. Based on these studies, when its population density is high, it can seriously threaten the populations of sea birds (Hartman *et al.* 1997), birds associated with freshwater habitats (Urban 1970, Greenwood 1981), songbirds (Passeriformes) (Robinson *et al.* 1995), reptiles (Reptilia) (Christiansen & Gallaway 1984) and the wildlife fauna of parks (Robinson *et al.* 1995). The populations of turtles might also suffer profound loss as their nests are robbed of their eggs by Raccoons (Davis & Whiting 1977, Christiansen & Gallaway 1984, Ratnaswamy & Warren 1998). It not only hunts on the ground but can also find prey in the foliage of trees and wetland habitats. Its damage to crops, for example, corn, is also documented (Bartoszewicz *et al.* 2008).

It can act as a vector for viruses such as rabies and canine distemper. The Raccoon might pose a health hazard in human settlements by stealing food remains from waste disposal depots and bins. According to Finnish studies (Mikkonen *et al.* 1995), a high proportion of Raccoons, especially adult specimens, are infected with trichinosis (72% of males, 53% of females). The infection with this parasite is probably due to frequent encounters with Raccoons and Brown Rats (*Rattus norvegicus*).

The Raccoon is a potential competitor of some native carnivores as it occupies the same habitat and/or consumes the same prey. The competing species are the protected European Wildcat (*Felis silvestris*), some mustelids – Beech Marten (*Martes foina*), European Pine Marten (*M. martes*), European Badger (*Meles meles*) –, Red Fox (*Vulpes vulpes*) and the also alien invasive Common Raccoon Dog (*Nyctereutes procyonoides*) (Kauhala *et al.* 1998, Hohmann & Hupe 1999, Jerdzejewska *et al.* 2014). Its natural enemies such as eagles (*Aquila* spp.), Grey Wolf (*Canis lupus*), Eurasian Lynx (*Lynx lynx*) and Brown Bear (*Ursus arctos*) (Gehrt 2003) are usually not present in the areas that the Raccoon invades.

Due to its very low number in Hungary, its ecological and economic damage cannot be evaluated. Where it has been established for a long time as an invasive species, it can significantly negatively affect the fauna (Michler *et al.* 2014, Jerdzejewska *et al.* 2014).

Methods of control

The Raccoon can be hunted year-round, and the control measures are similar to those described for the Common Raccoon Dog. Strict control measures should be implemented against it until its number is low and its occurrence is limited and isolated, because it will be impossible to eradicate the Raccoon when its distribution is wider in Hungary.

The Raccoon is included in the list of Invasive Alien Species of Union concern; hence its keeping, breeding, importing, selling and releasing into the wild is forbidden. Member States are required to take action on pathways of unintentional introduction and to monitor its changes (The decree of the European Council and Parliament 1143/2014/EU on the prevention and management of the introduction and spread of invasive alien species).

References

Bartoszewicz *et al.* 2008, Boggess 1994, Christiansen & Gallaway 1984, Davis & Whiting 1977, Faragó 2002, Fritzell *et al.* 1985, Gehrt 2003, 2004, Gehrt & Fritzell 1998, Greenwood 1981, Hartman *et al.* 1977, Heltai *et al.* 2010, Hohmann 2000, Hohmann & Hupe 1999, Hohmann *et al.* 2000, Jerdzejewska *et al.* 2014, Kamler *et al.* 2003, Kaufmann 1982, Kauhala 1996, Kauhala *et al.* 1998, Lutz 1984, 1986 Macdonald ed. 1989, Macdonald & Barrett 1993, Michler *et al.* 2014, Mikkonen *et al.* 1995, Nagy *et al.* 2020, Ratnaswamy & Warren 1998, Robinson *et al.* 1995, Salgado 2018, Stubbe 1993, Urban 1970

József Lanszki

European Fallow Deer

Dama dama (Linnaeus, 1758)

Original area of the species

According to some researchers, the European Fallow Deer bones and remains unearthed from the Neolithic and Bronze Age of Macedonia, Bulgaria and Greek Islands are evidence of human introductions. It means that Greeks and other people probably helped the spread of this species along the central and eastern shores of the Mediterranean Sea (Mattioli 2011). Bone remains suggest that, until the Bronze Age, a significantly larger Fallow Deer lived in Europe than the present form, and then its remains disappeared from the palaeontological records. Then, in the Roman Age, the Fallow Deer appeared again on the European continent, but these were considerably smaller than the earlier remains. They were about the same size as the present European Fallow Deer. Probably both the change in body size and the present colour varieties are characteristics created by the deliberate breeding efforts and directional selection of the Romans, who kept and bred, besides other game species, European Fallow Deer in walled game enclosures. The Romans probably introduced the Fallow Deer to many provinces of their Empire, among them the British Isles, as it is well-known that Romans voluntarily introduced various species to their conquered territories (Németh *et al.* 2016).

© Zsolt Kalotás

The introduction of the species to Europe and Hungary

The European Fallow Deer occurred at several locations in Europe after the fall of the Roman Empire, but several populations – among them several isolated island populations – slowly disappeared in the coming centuries. For example, the European Fallow Deer lived in large numbers on the island of Sardinia in the 18th century, but it was extirpated from the island in the 19th century. In the 14th century the Order of Saint John introduced the species to Rhodes, where it later became extinct. During Italian rule (1912–1945), the species was again reintroduced to Rhodes (Heidemann 1986). In the last decades, the species was introduced to several new locations, for example to North and South America, South Africa, Australia, Tasmania, New Zealand and Fiji Islands. Most of these populations have successfully survived (Faragó 1994, 2002). Similar voluntary introductions were carried out also in Europe, and consequently, with the exception of Iceland and Greece, the European Fallow Deer occurs in almost all European countries. In the mid-1970s the European stock was estimated to be about 120,000 individuals (Heidemann 1986). By the turn of the 20th century, the European stock had increased to 530,000 individuals (Mattioli 2011).

After the Roman Age, the European Fallow Deer disappeared from the Carpathian Basin, then, either in the period of Anjou kings' rule or during the reign of King Mathias Corvinus, it was reintroduced into game enclosures. It is questionable how the introduced stocks could survive the following chaotic, often warfare-stricken, centuries, if they were able to survive at all. After a long period of data deficient centuries, from the 18th century there are data again on European Fallow Deer occurrences from natural areas in Hungary. In the 19th century, the aristocrats of our country imported and introduced European Fallow Deer to their estates. At the beginning of the 19th century, its largest stock (more than 3,000 individuals) lived in the areas around Gyulaj. Between the Great War and the Second World War, four large isolated populations were known from Hungary: around Gyulaj, Tamási from around the upper reaches of River Tisza, and two more in Békés and Somogy counties (Antli 2001). The fast increase and expansion of its populations started in 1969, when, in the framework of the introduction programme of the Association of Hungarian Hunters, its voluntary release started. Between 1970–1987 European Fallow Deer stocks were released at 81 locations in Hungary. Consequently, today the European Fallow Deer occurs almost everywhere in our country with the exception of continuous closed stands of forest in the mountain ranges (Faragó 1994, 2002).

Life history of the species

The males of the species (called bucks) have characteristic broad, shovel-shaped, palmate antlers. The main beams of the antlers are usually 55–65 cm long, but exceptionally they might be 80–86 cm, and the weight of the antler might exceed 5 kilograms. The bucks grow a new antler every year, and clean their velvety antlers by August, and shed them in April–May (Mattioli 2011).

The European Fallow Deer prefers to feed on the foliage and buds of forest trees and shrubs, the leaves, stalks and flowers of herbs. It also likes cultivated plants such as vegetables, Tobacco (*Nicotiana tabacum*), pumpkin (*Cucurbita* sp.), Melon (*Cucumis melo*), grape (*Vitis* sp.) and various fruits (Corbet & Ovenden 1982, Görner & Hackethal 1987, Faragó 1994, 2002).

Before the mating season, the growth and cleaning of antlers is finished by August-September, and the bucks accumulate large reserves for the mating season, which is called the rut. Not much later, bucks occupy their leks or rut sites, where the more mature individuals scrape shallow lekking depressions. In good habitats, as much as fifty lekking depressions can be located. Old bucks urinate into the depressions and spray them with their sperm. Then they lay into the depressions and emit low frequency

© Viktor Schneider

mating vocalizations called groans. Does visit the rut sites and search for the best bucks. Bucks try to herd a group of does, their harem, around their lekking depression, and fight vigorously with other competing males trying to rob their harem. Usually the young bucks wait around the best lekking sites to intercept and fertilise some does. After copulation, the does leave the lekking site and disperse in the surrounding area (Faragó 1994, 2002).

Gestation lasts for 230 days, and then the does drop their single fawn in a secure part of the forest. The fawns start to follow their mother from the age of three weeks. The fawn is fed with milk usually for five months, but it might be considerably longer. The young reach sexual maturity at the age of 17 month, but rarely doe fawns might be receptive at the age of 5 months (Corbet & Ovenden 1982, Görner & Hackethal 1987, Faragó 1994, 2002).

In the wild, life expectancy of the European Fallow Deer is 15–20 years, but in captivity it might exceed 30 years (Faragó 1994, 2002). In Europe, the most important predators of the European Fallow Deer are: the Brown Bear (*Ursus arctos*), Grey Wolf (*Canis lupus*) and stray Dogs (*C. familiaris*), but the young ones might be also threatened by the Wild Boar (*Sus scrofa*) and Golden Jackal (*C. aureus*) (Corbet & Ovenden 1982, Görner & Hackethal 1987).

The ecological requirements of the species in Hungary

The European Fallow Deer mainly occurs in areas characterised by loess, sand or other less coarse soil. It prefers open broad-leaved or mixed forests. It prefers more open forests with rich understory, interspersed with meadows and agricultural lands. For the European Fallow Deer, not-too-deep snow-cover and short periods of snow-cover are also important. The strongest stocks of European Fallow Deer in Hungary are located around Gyulaj (Tolna county), in the Duna–Tisza Interfluve, around Gúth (in the Nyírség area) and around the city of Gyula (Békés county) (Faragó 1994, 2002).

Due to the successful introduction programmes and the adaptability of the species, nowadays the European Fallow Deer is present with higher or lower density all around the country except for the large, continuous closed forest stands. The European Fallow Deer is characterised by high site-fidelity, and it only wanders away if its local density is too high, or when it is introduced to an unsuitable area (Faragó 1994, 2002). The number of European Fallow Deer in Hungary was estimated to be 40,035 individuals in the spring of 2021 (Csányi *et al.* 2021).

Ecological problems

Those populations that are kept at artificially increased densities might cause agricultural and forestry wildlife damage, but it is only a fraction of the damage caused by the Wild Boar (*Sus scrofa*) and Red Deer (*Cervus elaphus*). In forests, European Fallow Deer cause the following species characteristic damages: they bite off the apex shoot, debarking, and the digging out of planted oak acorns. In those forests where its large number and high density exceeds the carrying capacity of the habitat, it might completely chew off the undergrowth and bush layer (Faragó 1994, 2002).

Economic effects

As a consequence of introduction programmes, local environmental characteristics and deliberate wildlife management, the Hungarian European Fallow Deer stock became world famous: from the first 20 trophies of the world record list, 10 were shot in Hungary (Csányi *et al.* 2010). In the 2020/2021 hunting season, according to national hunting bag statistics 16,940 individuals were shot in our country (Csányi *et al.* 2021), and therefore no wonder this species constitutes the firm (economic) foundation of wildlife management in some hunting areas, while in others the European Fallow Deer only produces auxiliary marginal incomes (Faragó 1994, 2002). Regarding its rank as a large game species, it is the fourth most important game in Hungary, as its significance is far higher than that of the European Mouflon (*Ovis aries*), but less important than the Roe Deer (*Capreolus capreolus*), Red Deer (*Cervus elaphus*) and Wild Boar (*Sus scrofa*) kisebb (Faragó 1994, 2002).

Methods of control

At the moment, the Hungarian populations do not cause so much damage that would require special control measures. If it proliferates intensely and its local density is too high, population management hunting might be the appropriate solution. Alternatively the translocation of individuals to game enclosures can be a good solution to decrease the number of free ranging European Fallow Deer. In the latter case, there is a hazard that the increased game population will completely degrade the vegetation of the reserve (Faragó 1994, 2002).

References

Antli 2001, Csányi *et al.* 2010, Faragó 1994, Görner & Hackethal 1987, Heidemann 1986, Mattioli 2011, Németh *et al.* 2016, Oswald 2012

Tamás Tóth

European Mouflon

Ovis aries Linnaeus, 1758

Original area of the species

The origin, taxonomy and nomenclature of this species are quite complex, and was not settled for a long time (Groves *et al.* 2011, Castello 2016). Based on molecular biological studies, the ancestor of the domestic goat is the Mouflon (*Ovis gmelini*), and the European Mouflon is a feral subspecies (or form) of the primitive domestic goat (Burgin *et al.* 2020). The survival of this form (and the special situation that we can witness the early stage and study the ancient form of domesticated species at present) is due to the fact that the early domesticated form was introduced to the islands of Sardinia and Corsica, and became feral there. Luckily, these feral populations survived to the present day. As we regard them the same species, the domestic sheep and the European Mouflon has the same scientific name: *Ovis aries*.

The introduction of the species to Europe and Hungary

Although there is no information on exactly when and how the European Mouflon was introduced to Corsica and Sardinia, this might have happened at the beginning of the Neolithic, at the earliest, as there are no earlier Mouflon remains either from the above mentioned islands, or from the European continent. Based on our present knowledge, the Romans might have introduced it from those islands to other parts of continental Europe.

There were trials to introduce the European Mouflon to the European continent from the 18th century, but these actions (for example, in Switzerland, Belgium and the Netherlands) failed. By the beginning of the 20th century, its populations in Sardinia and Corsica started to deteriorate, as hunting, and the spread of forest management and agriculture, decimated its stocks. Around 1980, in Europe the stock of the European Mouflon was estimated to be around 53,000 individuals, while in Corsica only approximately 300 individuals survived, and in Sardinia only around 300-500 individuals remained (Röhrs 1986). In Corsica and Sardinia, and probably on the continent too, it is a problem that the European Mouflon have long and probably still does hybridise with the domestic goat. In this way, continuously changing and locally different populations formed. Even the stocks on Corsica and Sardinia are different, as 60% of females (called ewes) has horns on Corsica, while on Sardinia only a fraction of females has horns (Röhrs 1986).

The European Mouflon was introduced lately to several locations around the world, for example to the United States of America (to the states of California, Texas and Hawai'i), Argentina and to the Kerguelen Islands lying in the southern part of the Indian Ocean.

The history of the European Mouflon in Hungary started in 1868, when Count Károly Forgách introduced it to Nyitra County (now in Slovakia). By 1871, ten individuals had been released in a game enclosure he built on his estate at a Ghymes. The new habitat was so appropriate for the animals, and they were breeding so successfully, that in 1883 100 individuals were set free from the descendants of the original stock in new areas. This was the first successful release on the European continent since the Roman Age. The introduction programme was such a success that on the Ghymes estate (which was about approximately 8,100 hectares) the stock was estimated to be around 2,000 individuals before the Great War, though more than 800 individuals were shot during the hunts. According to the national hunting bag statistics, in the period of 1904-1905 the most European Mouflon was shot not surprisingly in Nyitra County in Hungary: 54 individuals per year. The yearly national hunting bag statistics were the highest in 1907, when the number of specimens shot was 83 (Faragó 1994, 2002).

The European Mouflon was first introduced to the territory of present-day Hungary in 1901 or 1902 to Füzérradvány. Some sources claimed the stock was brought from Ghymes, while others claimed they were originated from Nagyappony. Until 1942, European Mouflons were released in 19 further locations. Due to good environmental conditions and expert wildlife management, the Hungarian stock increased to about 2,000 individuals by the beginning of the 1940s. During the Second World War, as a consequence of the fighting and poaching, the number of European Mouflons fell to 80-100 individuals by 1946. Due to the success of the European Mouflon introduction programme, which started in the 1970s, the Hungarian stock started to grow, and by 1990 increased to more than 10,000 individuals (Faragó 1994, 2002).

Life history of the species

The mouflon is basically a grazing animal, and consumes grasses (Poaceae). It only turns to other food sources when grass is scarce. In such cases, they mainly gnaw the shoots of trees and bushes, and also eat herbs. In suboptimal habitats, the proportion of burclover (such as alfalfa) (*Medicago* sp.) and European Elderberry (*Sambucus nigra*) can be also high. From among the wild ruminants (Ruminantia) living in Hungary, the European Mouflon has the smallest rumen compared to their body weight, and hence it probably ruminates more than deer (Cervidae) (Faragó 1994, 2002).

The rutting season lasts from the middle of October to the end of December but exceptionally might start as early as the end of August and might last till January. At the beginning of the rutting season, the ram groups disintegrate, and solitary rams try to isolate as many ewes from the herd as they can. The rams often fight for the receptive ewes by ramming each other with their curved horns. They run towards each other from the distance of 10-20 metres before they clash, and repeat this several times. At the end of the fight, the loser leaves the territory of

© Tibor Hadarics

The European Mouflon was native to the Island of Corsica, from where it has been introduced to many regions of the world. The photograph shows a Corsican individual.


© Gábor Leskó

the winner. The receptive females are chased around a bit by the rams, and copulate with them away from the herd. Gestation period is 21-22 weeks, and lambs are born between the end of March and beginning of May, in a quiet, secure place. Usually one or seldom two lambs are born. The lambs and ewes soon re-join the herd, where lambs are fed with milk for about for 5 months, and then they leave their mothers and become independent. The young become sexually mature at the age of one-and-a-half years, but it might take longer for rams, and ewes can be receptive at the age of 8-9 months (Corvet & Ovenden 1982, Görner & Hackethal 1987, Faragó 1994, 2002).

Their natural predators are the Brown Bear (*Ursus arctos*), Grey Wolf (*Canis lupus*), European Lynx (*Lynx lynx*) and Golden Jackal (*C. aureus*), but stray Domestic Dogs (*C. familiaris*) might also kill some individuals. Moreover, sometimes Wild Boars (*Sus scrofa*) might also eat their lambs (Corvet & Ovenden 1982, Görner & Hackethal 1987). Besides predation, long lasting and deep snow cover is also a threat to their survival (Faragó 1994, 2002).

The ecological requirements of the species in Hungary

In Europe, under optimal conditions the European Mouflon occurs from sea level up to 1,000 meter above sea level, but its distribution is also shaped by terrain, soil characteristics and climate. Yearly precipitation is the key to its habitat choice, as the European Mouflon prefers those areas where yearly average rainfall is less than 800 millimetres. It is also important that the period of snow-cover should be shorter than 50 days, and the thickness of the snow-cover should be less than 30 centimetres. As a consequence, mouflons usually

© Gábor Leskó

stay in higher altitudes during the summer, and move down to lower elevations during the winter (Faragó 1994, 2002).

The European Mouflon occurs in all our mountain ranges, but its distribution is usually isolated. Outside the mountain ranges, significant stocks populate Somogy county, which is dominated by a lower-lying hilly landscape (Faragó 1994, 2002).

The Hungarian population of the European Mouflon in the last decades stabilised around 10,000 individuals. In the spring of 2021, the national estimate was 11,717 individuals (Csányi *et al.* 2021).

Ecological problems

In Hungary, in the locally overpopulated areas wildlife damage in forestry plantations can be significant, but it is only a diminutive fraction of the total wildlife damage (Erdei Vadkárfelvételi és Értékelési Útmutató 2018). On southerly facing warm mountain sides, in the especially valuable rocky grasslands, the European Mouflon can cause immense damage. Several rare and endemic plant species are threatened by it with its grazing, gnawing and trampling. Moreover, European Mouflons aggregate in larger herds during winter, and their home range is very small. The concentrated stocks can locally damage considerably the vegetation (Faragó 1994, 2002).

Economic effects

The European Mouflon in Hungary is the last among our large game species regarding its number and importance (Faragó 1994, 2002). Still, its hunting is very popular in certain areas of Hungary. In the 2020/2021 hunting season, its annual national hunting bag statistics was 3,559 individuals, from among these 995 trophies were evaluated, and 419 were awarded with medals (Csányi *et al.* 2021).

Methods of control

On those areas where the superabundant European Mouflon stocks cause excessive wildlife damage, control hunting is the best method to alleviate their damage. From those areas, where they threaten protected natural assets the Mouflon has to be extirpated. In such areas, with increased hunting pressure a European Mouflon-free state can be achieved and maintained.

References

Burgin *et al.* 2020, Castello 2016, Corbet & Ovenden 1982, Csányi *et al.* 2021, Faragó 1994, 2002, Görner & Hackethal 1987, Groves *et al.* 2011, Erdei Vadkárfelvételi és Értékelési Útmutató 2018, Röhrs 1986

Tamás Tóth

REFERENCES

FLATWORMS – Platyhelminthes

Bassi R. (1875): Sulla cachessia ittero-verminosa, o marciaia dei carvi, causata dal *Distomum magnum*. *Il Medico Veterinario (Torino)* S. 4. **4**(11–12): 497–515.

Bazsalovicsová E., Králová-Hromadová I., Štefka J., Minárik G., Bokorová S. & Pybus M. (2015): Genetic interrelationships of North American populations of Giant Liver Fluke *Fascioloides magna*. *Parasites & Vectors* **8**: 288.

Demiaszkiewicz A. W., Kowalczyk R., Filip K. J. & Pyziel A. M. (2018): *Fascioloides magna* (Bassi, 1875) pasożytem sarny w Borach Zielonogórskich. *Medycyna Weterynaryjna* **74**(4): 257–260.

Dunkel A. M., Rognlie M. C., Johnson G. R. & Knapp S. E. (1996): Distribution of potencial intermediate hosts for *Fasciola hepatica* and *Fascioloides magna* in Montana, USA. *Veterinary Parasitology* **62**(1–2): 63–70.

Erhardová-Kotrlá B. (1971): *The occurence of Fascioloides magna (Bassi, 1875) in Czechoslovakia*. Academia, Prague.

Esteban J. G., Bargues M. D. & Mas-Coma S. (1998): Geographical distribution, diagnosis and treatment of human fascioliasis: a review. *Research and Reviews in Parasitology* **58**(1): 13–42.

Florijančić T., Ozimec S., Opačak A., Bošković I., Jelkić D., Marinculić A. & Janicki Z. (2010): Importance of the Danube River in spreading the infection of Red Deer with *Fascioloides magna* in eastern Croatia. *In: 38th IAD Conference, June 2010, Dresden, Germany. Extended abstracts.* – www.danube-iad.eu

Foreyt W. J. & Todd A. C. (1976): Development of the Large American Liver Fluke, *Fascioloides magna*, in White-tailed Deer, Cattle, and Sheep. *Journal of Parasitology* **62**(1): 26–32.

Haider M., Hörweg C., Liesinger K., Sattmann H. & Walochnik J. (2012): Recovery of *Fascioloides magna* (Digenea) population in spite of treatment programme? Screening of *Galba truncatula* (Gastropoda, Lymnaeidae) from Lower Austria. *Veterinary Parasitology* **187**(3–4): 445–451.

Loker E. S. & Hofkin B. V. (2015): *Parasitology. A conceptual approach*. Garland Science, New York – London.

Majoros G. & Sztojkov V. (1994): Appearance of the Large American Liver Fluke *Fascioloides magna* (Bassi, 1875) (Trematoda: Fasciolata) in Hungary. *Parasitologica Hungarica* **27**: 27–38.

Malcicka M. (2015): Life history and biology of *Fascioloides magna* (Trematoda) and its native and exotic hosts. *Ecology and Evolution* **5**(7): 1381–1397.

Mas-Coma M. S., Esteban J. G. & Bargues M. D. (1999): Epidemiology of human fascioliasis: a review and proposed new classification. *Bulletin of the World Health Organization* **77**(4): 340–346.

Ménard A., Agoulon A., L'Hostis M., Rondelaud D., Collard S. & Chauvin A. (2001): *Myocastor coypus* as a reservoir host of *Fasciola hepatica* in France. *Veterinary Research* **32**(5): 499–508.

Nagy E., Jócsák I., Csivincsik Á., Zsolnai A., Halász T., Nyúl A., Plucsinszki Zs., Simon T., Szabó Sz., Turbók J., Nemes Cs., Sugár L. & Nagy G. (2018): Establishment of *Fascioloides magna* in a new region of Hungary: case report. *Parasitology Research* **117**(11): 3683–3687.

Pfeiffer H. (1983): *Fascioloides magna*: Erster Fund in Österreich. *Wiener Tierarztliche Monatsschrift* **70**(5): 168–170.

Pybus M. J. (2001): Liver flukes. *In:* Samuel W. M., Pybus M. J., Kocan A. A. (eds.): *Parasitic diseases in wild mammals*. 2nd edition. Iowa State University Press, Ames: 121–149.

Qureshi T., Lynn Drawe D., Davis D. S. & Craig T. M. (1994): Use of bait containing triclabendazole to treat *Fascioloides magna* infections in free ranging White-tailed Deer. *Journal of Wildlife Diseases* **30**(3): 346–350.

Rajský D., Patus A. & Bukovjan K. (1994): Prvý nález *Fascioloides magna* Bassi, 1875 na Slovensku. *Slovenský Veterinárske Časopis* **19**: 29–30.

Rondelaud D., Novobilský A., Vignoles P., Treuil P., Koudela B. & Dreyfuss G. (2005): First studies on the susceptibility of *Omphiscola glabra* (Gastropoda: Lymnaeidae) from central France to *Fascioloides magna*. *Parasitology Research* **98**(4): 299–303.

Salomon S. (1932): *Fasciola magna* bei deutschem Rotwild. *Abhandlungen der Naturforschenden Gesellschaft Görlitz* **31**(3): 139–142.

Slavica A., Florijančić T., Janicki Z., Konjević D., Severin K., Marinculić A. & Pintur K. (2006): Treatment of fascioloidosis (*Fascioloides magna*, Bassi, 1875) in free ranging and captive Red Deer (*Cervus elaphus* L.) at eastern Croatia. *Veterinarski Arhiv* **76** (Suppl.): 9–18.

Ullrich K. (1930): Über das Vorkommen von seltenen oder wenig bekannten Parasiten der Säugetiere und Vögel in Böhmen und Mähren. *Prager Archiv für Tiermedizin und Vergleichende Pathologie* **10**: 19–43.

Ursprung J., Joachim A. & Prosl H. (2006): Vorkommen und Bekämpfung des Amerikanischen Riesenleberegels, *Fascioloides magna*, in einer Schalenwildpopulation in den Donauauen östlich von Wien. *Berliner und Münchener Tierarztliche Wochenschrift* **119**(7–8): 316–323.

GASTROPODS – Mollusca

Aldridge D., Madhyastha A. & Van Damme D. (2012): *Corbicula fluminea*. *In: The IUCN Red List of Threatened Species 2012*: e.T155736A735697. – www.iucnredlist.org

Alonso A. (2013): *Potamopyrgus antipodarum* (New Zealand Mudsnail). *In: CABI Invasive Species Compendium*. – www.cabi.org

Alonso A. & Castro-Díez P. (2008): What explains the invading success of the aquatic mud snail *Potamopyrgus antipodarum* (Hydrobiidae, Mollusca)? *Hydrobiologia* **614**(1): 107–116.

Anistratenko V. V. (2013): On the taxonomic status of the highly endangered Ponto-Caspian gastropod genus *Caspia* (Gastropoda: Hydrobiidae: Caspiinae). *Journal of Natural History* **47**(1–2): 51–64.

Anistratenko V. V., Neubauer T. A., Anistratenko O. Yu., Kijashko P. V. & Wesselingh F. P. (2021): A revision of the Pontocaspian gastropods of the subfamily Caspiinae (Caenogastropoda: Hydrobiidae). *Zootaxa* **4933**(2): 151–197.

Ansart A., Vernon P. & Daguzan J. (2001): Freezing tolerance versus freezing susceptibility in the land snail *Helix aspersa* (Gastropoda: Helicidae). *CryoLetters* **22**(3): 183–190.

Ayad N., Mousa A. H., Ishak M. M., Yousif F. & Zaghloul S. (1970): A preliminary study on biological control of the snail intermediate hosts of schistosomiasis in U.A.R. by *Helisoma duryi* snails. *Hydrobiologia* **35**(2): 196–202.

Bába K. & Varga A. (1980): A *Boettgerilla pallens* Simroth újabb lelőhelye. *Folia Historico-naturalia Musei Matraensis* **6**: 205–206.

Bachó Z. (1952): A meztelen csigák kártételének jelentősége. *Növényvédelem* 1952 (4): 11–14.

Balashov I. A., Kramarenko S. S., Zhukov A. V., Shklyaruk A. N., Baidashnikov A. A. & Vasyliuk A. V. (2013a): Contribution to the knowledge of terrestrial molluscs in southeastern Ukraine. *Malacologica Bohemoslovaca* **12**: 62–69.

Balashov I. A., Son M. O., Coadă V. & Welter-Schultes F. (2013b): An updated annotated checklist of the molluscs of the Republic of Moldova. *Folia Malacologica* **21**(3): 175–181.

Báldi T. (1973): *Mollusc fauna of the Hungarian Upper Oligocene (Egerian). Studies in Stratigraphy, Palaeoecology, Palaeogeography, and Systematics* Akadémiai Kiadó, Budapest.

Balogh Cs. (2008): *A vándorkagyló (Dreissena polymorpha) megtelepedése, mennyiségi viszonyai, anyagforgalomban betöltött szerepe, filtrációja, valamint baktériumközösségre gyakorolt hatása.* Doktori értekezés. MTA Balatoni Limnológiai Kutatóintézet, Tihany.

Balogh Cs., Muskó I. B., G.-Tóth L. & Nagy L. (2008): Quantitative trends of Zebra Mussels in Lake Balaton (Hungary) in 2003–2005 at different water levels. *Hydrobiologia* **613**(1): 57–69.

Banha F., Marques M. & Anastácio P. M. (2014): Dispersal of two freshwater invasive macroinvertebrates, *Procambarus clarkii* and *Physella acuta*, by off-road vehicles. *Aquatic Conservation (Marine and Freshwater Ecosystems)* **24**(5): 582–591.

Barker G. M & Efford M. G. (2004): Predatory gastropods as natural enemies of terrestrial gastropods and other invertebrates. *In:* Barker G. M. (ed.): *Natural enemies of terrestrial molluscs.* CAB International, Wallingford: 279–403.

Barker G. M. & Watts C. (2002): *Management of the invasive alien snail Cantareus aspersus on conservation land.* New Zealand Department of Conservation, Wellington. /DOC Science Internal Series 31/

Bartha F. (1971): A magyarországi pannon biosztratigráfiai vizsgálata. *In:* Góczán F. & Benkő J. (szerk.): *A magyarországi pannonkori képződmények kutatásai.* Akadémiai Kiadó, Budapest: 13–163.

Basinger A. J. (1931): *The European Brown Snail in California.* University of California, College of Agriculture, Agricultural Experimental Station, Berkeley (California). /Bulletin 515/

Bailey P. T. (ed.) (2007): *Pests of field crops and pastures: identification and control.* CSIRO Publishing, Collingwood (Victoria).

Beczner L., Bodor J. & Paizs L.-né (1970): Beczner L., Bodor J. & Paizs L.-né: *Zöldségfélék növényvédelme.* Mezőgazdasági Kiadó, Budapest.

Bedini S., Flamini G., Cosci F., Ascrizzi R., Benelli G. & Conti B. (2016): *Cannabis sativa* and *Humulus lupulus* essential oils as novel control tools against the invasive mosquito *Aedes albopictus* and fresh water snail *Physella acuta*. *Industrial Crops and Products* **85**: 318–323.

Benda T., Csivincsik Á., Nemes Cs., Turbók J., Zsolnai A., Simonyai E., Majoros G. & Nagy G. (2017): Lethal *Angiostrongylus vasorum* infection in a Hungarian dog. *Acta Parasitologica* **62**(1): 221–224.

Benkő-Kiss Á. (2012): The invasive Chinese Pond Mussel (*Sinanodonta woodiana*, Lea, 1834) as a danger for waterside tourism. *Lucrări Științifice Universitatea de Științe Agricole Și Medicină Veterinară a Banatului* Seria I. *Management Agricol* **14**(4): 5–12.

Benkő-Kiss Á., Ferincz Á., Kováts N. & Paulovits G. (2013): Spread and distribution pattern of *Sinanodonta woodiana* in Lake Balaton. *Knowledge and Management of Aquatic Ecosystems* **408**: 9.

Beran L. & Glöer P. (2006): *Gyraulus chinensis* (Dunker, 1848) – a new greenhouse species for the Czeh Republic (Gastropoda: Planorbidae). *Malacologica Bohemoslovaca* **5**: 25–28.

Beran L. & Horsák M. (2002): *Gyraulus parvus* (Mollusca: Gastropoda) in the Czech Republic. *Acta Societatis Zoologicae Bohemicae* **66**(2): 81–84.

Boag D. A. (1986): Dispersal in pond snails: potential role of waterfowl. *Canadian Journal of Zoology* **64**(4): 904–909.

Bobeldyk A. M., Bossenbroek J. M., Evan-White M. A., Lodge D. M. & Lamberti G. A. (2005): Secondary spread of Zebra Mussels (*Dreissena polymorpha*) in lake-stream systems. *Ecoscience* **12**(3): 414–421.

Bódis E. (2015): Betolakodók a Balatonban. Őshonos és inváziós kagylófajok versengése. *Élet és Tudomány* **70**(15): 454–456.

Bódis E., Nosek J., Oertel N., Tóth B. & Fehér Z. (2011): A comparative study of two *Corbicula* morphs (Bivalvia, Corbiculidae) inhabiting River Danube. *International Review of Hydrobiology* **96**(3): 257–273.

Bódis E., Tóth B. & Sousa R. (2014a): Impact of *Dreissena* fouling on the physiological condition of native and invasive bivalves: interspecific and temporal variations. *Biological Invasions* **16**(7): 1373–1386.

Bódis E., Tóth B. & Sousa R. (2014b): Massive mortality of invasive bivalves as a potential resource subsidy for the adjacent terrestrial food web. *Hydrobiologia* **735**(1): 253–262.

Boeters H. D., Glöer P., Georgiev D. & Dedov I. (2015): A new species of *Caspia* Clessin et W. Dybowski, 1887 (Gastropoda: Truncatelloidea: Hydrobiidae) in the Danube of Bulgaria. *Folia Malacologica* **23**(3): 177–186.

Bognár S. & Huzián L. (1974): *Növényvédelmi állattan.* Mezőgazdasági Kiadó, Budapest.

Bonney R., Cooper C. B., Dickinson J., Kelling S., Phillips T., Rosenberg K. V. & Shirk J. (2009): Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience* **59**(11): 977–984.

Boschi C. (2011): *Die Schneckenfauna der Schweiz. Ein umfassendes Bild- und Bestimmungsbuch.* Haupt Verlag, Bern – Stuttgart – Wien.

Botka J. & Varga A. (1984): Az *Arion (Arion) rufus* (Linné, 1758) előfordulása Magyarországon. *Folia Historico-naturalia Musei Matraensis* **9**: 167–168.

Bowler P. A. (1991): The rapid spread of the freshwater hydrobiid snail *Potamopyrgus antipodarum* (Gray) in the Middle Snake River, southern Idaho. *Proceedings of the Desert Fishes Council* **20–21**: 173–182.

Boycott A. E. (1936): The habitats of fresh-water Mollusca in Britain. *Journal of Animal Ecology* **5**(1): 116–186.

Bössneck U. & Feldmann A. (2003): Zur Ausbreitung von Neozoa im Stadtgebiet von Erfurt am Beispiel der Landschnecken *Cernuella neglecta* (Draparnaud, 1805), *Monacha cartusiana* (O. F.

Müller, 1774) und *Krynickillus melanocephalus* Kaleniczenko, 1851 (Mollusca: Gastropoda). *Veröffentlichungen des Naturkundemuseums Erfurt* **22**: 115–125.

Brown D. S. (1980): *Freshwater snails of Africa and their medical importance.* Taylor & Francis Ltd., London.

Bunje P. M. E. (2005): Pan-European phylogeography of the aquatic snail *Theodoxus fluviatilis* (Gastropoda: Neritidae). *Molecular Ecology* **14**(14): 4323–4340.

Burch J. B. (1960): Chromosomes of *Gyraulus circumstratius*, a freshwater snail. *Nature* **186**(4723): 497–498.

Burch J. B. (1989): *North American freshwater snails. Identification keys, generic synonymy, supplemental notes, glossary, references, index.* Malacological Publications, Hamburg (Michigan). /Walkerana 4./

Burch J. Q. (1944): [Checklist of west American mollusks]. Family Corbiculidae. *Minutes of the Conchological Club of Southern California* **36**: 18.

Čejka T. & Čačaný J. (2014): The first record of the Turkish Snail (*Helix lucorum* L., 1758) in the Slovak Republic. *Malacologica Bohemoslovaca* **13**: 124–125

Čejka T. & Horsák M. (2002): First records of *Theodoxus fluviatilis* and *Sphaerium solidum* (Mollusca) from Slovakia. *Biologia (Bratislava)* **57**(5): 561–562.

Čejka T., Beran L., Korábek O., Hlaváč J. Č., Horáčková J., Coufal R., Drvotová M., Maňas M., Horsáková V. & Horsák M. (2020): Malacological news from the Czech and Slovak Republics in 2015–2019. *Malacologica Bohemoslovaca* **19**: 71–106.

Čejka T., Dvořák L. & Horsák M. (2006): Malakologické novinky na Slovensku v poslednom štvrťstoročí. *Malakologický Bulletin* 14 Agust 2006 – http://mal-bull.blogspot.com

Chevallier H. (1972): Arionidae (Mollusca, Pulmonata) des Alpes et du Jura français. *Haliotis* **2**: 7–23.

Cilia D. P., Sciberras A. & Sciberras J. (2013): Two non-indigenous populations of *Melanoides tuberculata* (Müller, 1774) (Gastropoda, Cerithioidea) in Malta. *MalaCo* **9**: 447–450.

Clarke G. M., Gross S., Matthews M., Catling P. C., Baker B., Hewitt C. L., Crowther D. & Saddler S. R. (2000): Environmental pest species in Australia. *In: Australia: state of the environment. Second Technical Paper Series (Biodiversity).* Department of the Environment and Heritage, Canberra.

Clench W. J. (1969): *Melanoides tuberculata* (Muller) in Florida. *Nautilus* **83**(2): 72.

Coelho P. M. Z., & Caldeira R. L. (2016): Critical analysis of molluscicide application in schitosomiasis control programs in Brazil. *Infectious Diseases of Poverty* **5**(1): 57.

Collado G. A. (2014): Out of New Zealand: molecular identification of the highly invasive freshwater mollusk *Potamopyrgus antipodarum* (Gray, 1843) in South America. *Zoological Studies* **53**(1): 70.

Coughlan N. E., Cuthbert R. N., Potts S., Cunningham E. M., Crane K., Caffrey J. M., Lucy F. E., Davis E. & Dick J. T. A. (2019): Beds Are Burning: eradication and control of invasive Asian clam, *Corbicula fluminea*, with rapid open-flame burn treatments. *Management of Biological Invasions* **10**(3): 486–499.

Cowie R. H., Dillon R. T., Robinson D. G. & Smith J. W. (2009): Alien non-marine snails and slugs of priority quarantine importance in the United States: A preliminary risk assessment. *American Malacological Bulletin* **27**(1–2): 113–132.

Csányi B. (1999): Spreading invaders along the Danubian highway: first record of *Corbicula fluminea* (O. F. Müller, 1774) and *C. fluminalis* (O. F. Müller, 1774) in Hungary (Mollusca: Bivalvia). *Folia Historica Naturalis Musei Matraensis* **23**: 343–345.

Csányi B. (ed.) (2002): *Joint Danube Survey: Investigation of the Tisza River and its tributaries. Final report. May 2002.* Institute for Water Pollution Control, Vituki Plc. – Secretariat of the International Commission for the Protection of the Danube River, [Budapest – Wien].

Csányi B. & Varga A. (2017): Behurcolt és invazív puhatestűek. *Magyar Tudomány* **178**(4): 419–425.

Csiki E. (1906): *A magyar birodalom állatvilága. A magyar birodalomból eddig ismert állatok rendszeres lajstroma.* II. *Mollusca.* K. M. Természettudományi Társulat, Budapest.

Dányi L., Balázs G. & Angyal D. (2015): Mint giliszta a vízben – avagy Zicsi András nyomdokán a Baradla Rövid-Alsó-barlangban. *Állattani Közlemények* **100**(1–2): 331–332.

Darrigran G. (2002): Potential impact of filter-feeding invaders on temperate inland freshwater environments. *Biological Invasions* **4**(1–2): 145–156.

Dedov I. K. & Mitev T. (2011): Mollusks fauna (Mollusca: Gastropoda: Bivalvia) of Mountain Osogovo. *Acta Zoologica Bulgarica* **63**(1): 37–46.

Deli T. & Farkas R. (2006): A bánáti csiga (*Drobacia banatica* Rossmäsler, 1838) legújabb hazai lelőhelyei a Szamos mentén. *Natura Bekesienis* **8**: 19–28.

Derraik J. G. B. (2008): The potential significance to human health associated with the establishment of the snail *Melanoides tuberculata* in New Zealand. *The New Zealand Medical Journal* **121**(1280): 25–32.

Doležal J. (2021): Non-native *Helix lucorum* Linnaeus, 1758 (Gastropoda: Eupulmonata: Helicidae) after twelve years in Prague, Czech Republic. *Folia Malacologica* **29**(2): 117–120.

Domokos T. & Majoros G. (2008): A *Lucilla singleyana* (Pilsbry, 1889) (Gastropoda: Helicodiscidae) – „talajlakó laposcsigácska" – előfordulása hazánkban, különös tekintettel a Körös–Maros közére (Magyarország és Románia). *Malakológiai Tájékoztató* **26**: 19–32.

Domokos T. & Pelbárt J. (2011): A magyarországi recens puhatestűek (Mollusca) magyar köznyelvi elnevezései (2011). *Malakológiai Tájékoztató* **29**: 25–39.

Douglas M. R. & Tooker J. F. (2012): Slug (Mollusca: Agriolimacidae, Arionidae) ecology and management in no-till field crops, with an emphasis on the mid-Atlantic region. *Journal of Integrated Pest Management* **3**(1): C1–C9.

Draparnaud J.-P.-R. [1805]: *Histoire naturelle des Mollusques terrestres et fluviatiles de la France.* Plassan – Renaud, Paris – Montpellier.

Dreijers E., Reise H. & Hutchinson J. M. C. (2013): Mating of the slugs *Arion lusitanicus* auct. non Mabille and *A. rufus* (L.): different genitalia and mating behaviours are incomplete barriers to interspecific sperm exchange. *Journal of Molluscan Studies* **79**(1): 51–63.

Dreijers E., Stalažs A., Pilāte D., Jakubāne I. & Jundzis M. (2017): Mīkstgliemežu dzimtas sugu nozīme lauksaimniecībā un pirmās ziņas par *Krynickillus melanocephalus* Kaleniczenko, 1851 (Gastropoda: Agriolimacidae) kaitējumu dārzkopībā Latvijā. *In: Līdzsvarota lauksaimniecība. Zinātniski praktsikās konferences. Raksti.* Latvijas Lauksaimniecības Universitāte, Jelgava: 93–96.

Dudgeon D. & Morton B. (1983): The population dynamics and sexual strategy of *Anodonta woodiana* (Bivalvia: Unionacea) in Plover Cove Reservoir, Hong Kong. *Journal of Zoology* **201**(2): 161–183.

Dudgeon D. & Morton B. (1984): Site selection and attachment duration of *Anodonta woodiana* (Bivalvia: Unionacea) glochidia on fish host. *Journal of Zoology* **204**(3): 355–362.

Dvořák L. & Horsák M. (2003): Současné poznatky o plzáku *Arion lusitanicus* (Mollusca: Pulmonata) v České republice. *Časopis Slezského Musea v Opavě* Série A *Vědy Přírodní* **52**: 67–71.

Egorov R. (2017): *Helix lucorum lucorum* Linnaeus, 1758 (Pulmonata, Helicidae) in the city of Moscow. *Malacologica Bohemoslovaca* **16**: 28–32.

Entz G. (1898): Vándor kagyló. *Természettudományi Közlöny* **30**(350): 518–521.

Entz G. (1934): A Magyar Biológiai Kutatóintézet munkálatairól. *Matematikai és Természettudományi Értesítő* **51**: 582–599.

Erőss Z. (1980): Adatok a Déli-Börzsöny puhatestűfaunájához. *Soosiana* **8**: 49–54.

Faltýnková A. & Haas W. (2006): Larval trematodes in freshwater molluscs from the Elbe to Danube rivers (Southeast Germany): before and today. *Parasitology Research* **99**(5): 572–582.

Fehér Z. & Gubányi A. (2001): *A magyarországi puhatestűek elterjedése. Az MTM Puhatestűgyűjteményének katalógusa.* Magyar Természettudományi Múzeum, Budapest.

Fehér Z., Majoros G. & Varga A. (2006): A scoring method for the assessment of rarity and conservation value of the Hungarian freshwater molluscs. *Heldia* **6**(3–4): 101–114.

Fehér Z., Szabó K., Bozsó M. & Pénzes Zs. (2009): Recent range expansion of *Pomatias rivulare* (Eichwald, 1829) (Mollusca: Pomatiidae) in Central-Eastern Europe. *Acta Zoologica Academiae Scientiarum Hungaricae* **55**(1): 67–75.

Ferreira-Rodríguez N., Sousa R. & Pardo I. (2018): Negative effects of *Corbicula fluminea* over native freshwater mussels. *Hydrobiologia* **810**(1): 85–95.

Fischer W. & Reischütz P. L. (1998): Grundsätzliche Bemerkungen zum Schadschneckenproblem. *Die Bodenkultur* **49**(4): 281–292.

Fischer W., Novak J. & Reinelt K. (2008): Beiträge zur Kenntnis der österreichischen Molluskenfauna XIII. Zum Vorkommen von *Helix lucorum* Linne 1758, *Cernuella neglecta* (Draparnaud 1805) und *Cernuella virgata* (Da Costa 1758) in Wien (Gastropoda: Mollusca). *Nachrichtenblatt der Ersten Vorarlberger Malakologischen Gesellschaft* **15**: 63–64.

Flasarová M. & Flasar I. (1965): Isopoda a Gastropoda skleníkû v severočeském kraji. *Zoologicke Listy* **14**(3): 251–260.

Fofonoff P. W., Ruiz G. M., Steves B. & Carlton J. T. (2003): *Melanoides tuberculata. In: National Exotic Marine and Estuarine Species Information System.* – www.invasions.si.edu/nemesis/

Frandsen F. & Madsen H. (1979): A review of *Helisoma duryi* in biological control. *Acta Tropica* **36**(1): 67–84.

Fried B., Nanni T. J., Reddy A. & Fujino T. (1996): Maintenance of the life cycle of *Echinostoma trivolvis* (Trematoda) in dexamethasone-treated ICR mice and laboratory-raised *Helisoma trivolvis* (Gastropoda). *Parasitology Research* **83**(1): 16–19.

Fűköh L. (1995): Holocene malacostratigraphy in Hungary. *Malakológiai Tájékoztató* Supplementum 1: 113–198.

Georgiev D. (2017): Updated and corrected list of the inland molluscs of Samothraki Island (N Aegean, Greece). *ZooNotes* 2017: 113.

Gerber J. (2014): First American record of the exotic slug *Tandonia kusceri* (Gastropoda: Milacidae). *The Nautilus* **128**(2): 59–63.

Gergs R., Koester M., Grabow K., Schöll F., Thielsch A. & Martens A. (2015): *Theodoxus fluviatilis*' re-establishment in the River Rhine: a native relict or a cryptic invader? *Conservation Genetics* **16**(1): 247–251.

Gillis P. L. & Mackie G. L. (1994): Impact of the Zebra Mussel, *Dreissena polymorpha*, on populations of Unionidae (Bivalvia) in Lake St. Clair. *Canadian Journal of Zoology* **72**(7): 1260–1271.

Gittenberger E. & Janssen A. W. (red.) (1998): *De Nederlandse zoetwatermollusken. Recente en fossiele weekdieren uit zoet en brak water. Nationaal Natuurhistorisch Museum Naturalis – KNNV Uitgeverij – EIS-Nederland, Leiden. / Nederlanse Fauna 2./*

Giusti F., Manganelli G. & Schembri P. J. (1995): *The non-marine molluscs of the Maltese Islands*. Museo Regionale di Scienze Naturali, Torino. / Monografie XV/

Glöer P. (2019): *The freshwater gastropods of the West-Palaearctis. Identification key, anatomy, ecology, distribution.* Volume I. *Neritidae, Hydrocenidae, Ampullariidae, Viviparidae, Thiaridae, Potamididae, Melanopsidae, Bithyniidae, Cochliopidae, Tateidae, Hydrobiidae, Lithoglyphidae, Bythinellidae, Emmericiidae, Truncatellidae, Assiminiidae, Valvatidae, Lymnaeidae, Physidae, Planorbidae, Acroloxidae, Ellobiidae, Otinidae.* Hetlingen.

Glöer P. & Meier-Brook C. (1998): *Süsswassermollusken. Ein Bestimmungsschlüssel für die Bundesrepublik Deutschland.* 12. Auflage. Deutscher Jugendbund für Naturbeobachtung, Hamburg.

Glöer P. & Pešić V. (2015): The morphological plasticity of *Theodoxus fluviatilis* (Linnaeus, 1758) (Mollusca: Gastropoda: Neritidae). *Ecologica Montenegrina* **2**(2): 88–92.

Godan D. (1983): *Pest slugs and snails. Biology and controls.* Springer-Verlag, Berlin – Heidelberg – New York.

Grossinger J. B. (1794): *Universa historia physica regni Hungariae secundum tria regni naturae digesta.* Tomus III. *Regni animalis.* Pars III. *Ichthyologia, sive historia piscium et amphibiorum Hungariae.* Sumptibus & Typis Simonis Petri Weber, Posonii et Comaromii.

Guimarães C. T., de Souza C. P. & de Moura Soares D. (2001): Possible competitive displacement of planorbids by *Melanoides tuberculata* in Minas Gerais, Brazil. *Memórias do Instituto Oswaldo Cruz (Rio de Janeiro)* **96** (Supplement): 173–176.

Gunn A. (1992): The ecology of the introduced slug *Boettgerilla pallens* (Simroth) in North Wales. *Journal of Molluscan Studies* **58**(4): 449–453.

Gural-Sverlova N., Gleba V. & Gural R. (2019): Einschleppung von *Tandonia kusceri* (Pulmonata: Milacidae) nach Transkarpatien und Verbreitung von *Tandonia*-Arten in der Ukraine. *Malacologica Bohemoslovaca* **18**: 19–26.

Gutiérrez Gregoric D. E., Beltramino A. A., Vogler R. E., Cuezzo M. G., Núnez V., Gomes S. R., Virgillito M. & Miquel S. E. (2013): First records of four exotic slugs in Argentina. *American Malacological Bulletin* **31**(2): 245–256.

Hakenkamp C. C. & Palmer M. A. (1999): Introduced bivalves in freshwater ecosystems: the impact of *Corbicula* on organic matter dynamics in a sandy stream. *Oecologia* **119**(3): 445–451.

Harrison A. D. (1966): The effects of Bayluscid on gastropod snails and other aquatic fauna in Rhodesia. *Hydrobiologia* **28**(3–4): 371–384.

den Hartog C., van den Brink F. W. B. & van der Velde G. (1992): Why was the invasion of the River Rhine by *Corophium curvispinum* and *Corbicula* species so successful? *Journal of Natural History* **26**(6): 1121–1129.

Hazay J. (1881): *Die Mollusken-Fauna von Budapest: mit besonderer Rücksichtnahme auf die embryonalen* *und biologischen Verhältnisse ihrer Vorkommnisse.* Verlag von Theodor Fischer, Cassel.

Hebert P. D. N., Muncaster B. W. & Mackie G. L. (1989): Ecological and genetic studies on *Dreissena polymorpha* (Pallas): a new mollusc in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* **46**(9): 1587–1591.

Hirschfelder H.-J., Salewski V., Nerb W. & Korb J. (2011): Schnelle Ausbreitung einer Schwarzmeerform der Gemeinen Kahnschnecke *Theodoxus fluviatilis* (Linnaeus 1758) in der bayerischen Donau. *Mitteilungen der Deutsche Malakozoologische Gesellschaft* **85**: 1–10.

Holomuzki J. R. & Biggs B. J. F. (1999): Distributional responses to flow disturbance by a stream-dwelling snail. *Oikos* **87**(1): 36–47.

Horsák M., Juřičková L. & Picka J. (2013): *Měkkýši České a Slovenské republiky. Molluscs of the Czech and Slovak Republics.* Nakladatelství Kabourek, Zlín.

Horváth A. (1950): A *Physa acuta* Drap. és a *Physa fontinalis* L. *Hidrológiai Közlöny* **30**(11–12): 449–450.

Horváth A. (1955): Beiträge zur Kenntnis der Molluskenfauna der Tisza. *Acta Zoologica (Acta Universitatis Szegediensis, Sectio Scientiarum Naturalium, Pars Zoologica)* **2**(1–4): 21–32.

Horváth Zs. (2010): *Egzotikus akváriumi csigák Magyarországon.* Szakdolgozat. Szent István Egyetem, Állatorvos-tudományi Kar, Parazitológiai és Állattani Tanszék, Budapest.

Hutchinson J. M. C., Reise H. & Robinson D. G. (2014): A biography of an invasive terrestrial slug: the spread, distribution and habitat of *Deroceras invadens*. *NeoBiota* **23**: 17–64.

Hutchinson J. M. C., Reise H. & Schlitt B. (2022): Will the real *Limax nyctelius* please step forward: *Lehmannia*, *Ambigolimax*, or *Malacolimax*? No, *Letourneuxia*! *Archiv für Molluskenkunde* **151**(1): 19–41.

Hutchinson J. M. C., Schlitt B., Kořínková T., Reise H. & Barker G. M. (2020): Genetic evidence illuminates the origin and global spread of the slug *Deroceras invadens*. *Journal of Molluscan Studies* **86**(4): 306–322.

Ituarte C. F. (1994): *Corbicula* and *Neocorbicula* (Bivalvia: Corbiculidae) in the Paraná, Uruguay, and Río de la Plata basins. *The Nautilus* **107**(4): 129–135.

Jarne P., Perdieu M.-A., Pernot A.-F., Delay B. & David P. (2000): The influence of self-fertilization and grouping on fitness attributes in the freshwater snail *Physa acuta*: population and individual inbreeding depression. *Journal of Evolutionary Biology* **13**(4): 645–655.

Jokela J., Lively C. M., Dybdahl M. F. & Fox J. A. (1997): Evidence for a cost of sex in the freshwater snail *Potamopyrgus antipodarum*. *Ecology* **78**(2): 452–460.

Juřičková L. (1995): Škůdce mezi měkkýši – plzák *Arion lusitanicus* v ČR. *Živa* **43**(1): 30.

Kangas P. & Skoog G. (1978): Salinity tolerance of *Theodoxus fluviatilis* (Mollusca, Gastropoda) from freshwater and from different salinity regimes in the Baltic Sea. *Estuarine and Coastal Marine Science* **6**(4): 409–416.

Kantor Y. I., Vinarski M. V., Schileyko A. A. & Sysoev A. V. (2010): *Catalogue of the continental mollusks of Russia and adjacent territories.* Version 2.3.1. – http://konstantinz.byethost32.com/books/kantor_2010.pdf?i=1

Karatayev A. Y., Burlakova L. E., Karatayev V. A. & Padilla D. K. (2009): Introduction, distribution, spread, and impacts of exotic freshwater gastropods in Texas. *Hydrobiologia* **619**(1): 181–194.

Karatayev A. Y., Mastitsky S. E., Burlakova L. E., Karatayev V. A., Hajduk M. M. & Conn D. B. (2012): Exotic molluscs in the Great Lakes host epizootically important trematodes. *Journal of Shellfish Research* **31**(3): 885–894.

Kebapçi U. & Van Damme D. (2012): *Theodoxus fluviatilis* (errata version published in 2017). *In: The IUCN Red List of Threatened Species 2012*: e.T165352A113400624 – www.iucnredlist.org

Keller R. P., Drake J. M., & Lodge D. M. (2007): Fecundity as a basis for risk assessment of nonindigenous freshwater molluscs. *Conservation Biology* **21**(1): 191–200.

Kerney M. P., Cameron R. A. D. & Jungbluth J. H. (1979): *Die Landschnecken Nord- und Mitteleuropas*. Paul Parey, Hamburg.

Kinzelbach R. (1991): Die Körbchenmuscheln *Corbicula fluminalis*, *Corbicula fluminea* und *Corbicula fluviatilis* in Europa (Bivalvia: Corbiculidae). *Mainzer Naturwissenschaftliches Archiv* **29**: 215–228.

Kirkegaard J. (2006): Life history, growth and production of *Theodoxus fluviatilis* in Lake Esrom, Denmark. *Limnologica – Ecology and Management of Inland Waters* **36**(1): 26–41.

Kiss Á. (1990): *Az amuri kagyló (Anodonta woodiana woodiana, Lea 1834) (Mollusca: Unionidae) szaporítása, növekedése és biomasszája.* Kandidátusi disszertáció alapján. Gödöllői Agrártudományi Egyetem, Tópusi és Szubtrópusi Tanszék, Gödöllő.

Kiss Á. & Pekli J. (1988): On the growth rate of *Anodonta woodiana woodiana* (Lea 1834) (Bivalvia: Unionacea). *Bulletin of the University of Agricultural Sciences Gödöllő* 1988 (1): 119–124.

Kiss É. & Pintér L. (1983): Magyarország recens Clausiliidái. *Folia Historico-naturalia Musei Matraensis* **8**: 137–156.

Kiss É. & Pintér L. (1985): A magyarországi recens Clausiliidák revíziója (Gastropoda). *Soosiana* **13**: 93–144.

Korábek O., Čejka T. & Juřičková L. (2016): *Tandonia kusceri* (Pulmonata: Milacidae), a slug new for Slovakia. *Malacologica Bohemoslovaca* **15**: 3–8.

Korábek O., Juřičková L., Balashov I. & Petrusek A. (2018): The contribution of ancient and modern anthropogenic introductions to the colonization of Europe by the land snail *Helix lucorum* Linnaeus, 1758 (Helicidae). *Contributions to Zoology* **87**(2): 61–74.

Korol E. N. & Kornyushin A. V. (2002): Obnaruzheniye introdutsirovannogo vida slizney *Krynickillus melanocephalus* (Mollusca, Gastropoda, Stylommatophora) v Kiyeve i predvaritelnye rezultati yego gelmintologicheskogo issledovaniya. *Vestnik Zoologii* **36**(6): 57–59.

Kosmala M., Wiggins A., Swanson A. & Simmons B. (2016): Assessing data quality in citizen science. *Frontiers in Ecology and the Environment* **14**(10): 551–560.

Kovács Gy. (1976): A *Cepaea nemoralis* (L.) faj uj lelőhelye Magyarországon. *Soosiana* **4**: 62.

Kovács Gy. (1977): A *Cepaea hortensis* (O. F. Müller) faj uj alföldi lelőhelye. *Soosiana* **5**: 62.

Kovács Gy. (1979): Új vízi csigafaj Magyarországon. *Soosiana* **7**: 35–36.

Kozłowski J. (2007): The distribution, biology, population dynamics and harmfulness of *Arion lusitanicus* Mabille, 1868 (Gastropoda: Pulmonata: Arionidae) in Poland. *Journal of Plant Protection Research* **47**(3): 219–230.

Kozłowski J. (2012): The significance of alien and invasive slug species for plant communities in agrocenoses. *Journal of Plant Protection Research* **52**(1): 67–76.

Kozłowski J. & Kozłowski R. J. (2000): Periods of occurence and fecundity of *Arion lusitanicus* (Gastropoda: Stylommatophora) in crop plant habitats in Poland. *Journal of Plant Protection Research* **40**(3–4): 260–266.

Kozłowski J., Jaskulska M. & Kozłowska M. (2014): Evaluation of the effectiveness of iron phosphate and the parasitic nematode *Phasmarhabditis hermaphrodita* in reducing plant damage caused by the slug *Arion vulgaris* Moquin–Tandon, 1885. *Folia Malacologica* **22**(4): 293–300.

Kozłowski J., Kałuski T. & Kozłowski R. J. (2008): Rozmieszczenie i ekspansja populacji ślinika luzytańskiego (*Arion lusitanicus* Mabille) na terenie Polski. *Progress in Plant Protection* **48**(3): 893–897.

Kraszewski A. & Zdanowski B. (2001): The distribution and abundance of the Chinese Mussel *Anodonta woodiana* (Lea, 1834) in the heated Konin Lakes. *Archives of Polish Fisheries* **9**(2): 253–265.

Krolopp E. (1975): *Helicella obvia* (Hartmann 1840) a magyarországi pleisztocénből. *Soosiana* **3**: 7–10.

Krolopp E. (1983): Verzeichnis der pleistozänen Mollusken Ungarns. *Soosiana* **10–11**: 75–78.

Krolopp E. & Varga A. (1991): A *Pomatias elegans* (O. F. Müller, 1774) újra felfedezett hazai lelőhelye (Mollusca: Pomatiasidae). *Folia Historico-naturalis Musei Matraensis* **16**: 95–103.

Krull W. H. (1931): Importance of laboratory-raised snails in helminthology with life history notes on *Gyraulus parvus. Occasional Papers of Museum of Zoology (University of Michigan)* **226**: 1–10.

Ladd H. L. A. & Rogowski D. L. (2012): Egg predation and parasite prevalence in the invasive freshwater snail, *Melanoides tuberculata* (Müller, 1774) in a west Texas spring system. *Aquatic Invasions* **7**(2): 287–290.

Lampert K. (1904): *Az édesvizek élete.* K. M. Természettudományi Társulat, Budapest.

Lányi Gy. (1961): *Élet a víz tükre alatt.* Gondolat, Budapest.

Lányi Gy. & Wiesinger M. (1955): *Akvarisztika.* Művelt Nép Tudományos és Ismeretterjesztő Kiadó, Budapest.

Lawton S. P., Allan F., Hayes P. M. & Smit N. J. (2018): DNA barcoding of the medically important freshwater snail *Physa acuta* reveals multiple invasion events into Africa. *Acta Tropica* **188**: 86–92.

Lea I. (1834): Observations on the Naïades; and descriptions of new species of that and other families. *Transactions of the American Philosophical Society (New Series)* **4**(2): 63–121.

Lennert J. (1997): A Hármas-Körös békésszentandrási duzzasztójának vízi Mollusca faunája, különös tekintettel a *Theodoxus (Th.) fluviatilis* (Linné 1758) új előfordulására. *Malakológiai Tájékoztató* **16**: 75–78.

Leonov S. V. (2007): The first record of the *Tandonia kusceri* (Pulmonata, Milacidae) in Crimea and a few remarks about its natural habitats. *Vestnik Zoologii* **41**(2): 142.

Lévêque C. (1972): Mollusques benthiques du lac Tchad: écologie, étude des peuplements et estmation des biomasses. *Cahiers de l'Office de la Recherche Scientifique et Technique d'Outre-Mer, Série Hydrobiologie* **6**(1): 3–45.

Likharev I. M. & Viktor A. J. (1980): *Fauna SSSR. Mollyuski.* Tom. III. vyp. 5. *Slizni fauny SSSR i sopredelnykh stran.* Izdatelstvo Akademii Nauk SSSR, Moskva – Leningrad. /Opredeliteli no faune SSSR Novaya Seriya 122./

Loo S. E., Keller R. P. & Leung B. (2007): Freshwater invasions: using historical data to analyse spread. *Diversity and Distributions* **13**(1): 23–32.

Lucas A. (1959): Les *Hydrobia* (Bythinellidae) de l'Ouest de la France. *Journal de Conchyliologie* **99**(1): 3–14.

Madsen H. (1983): Distribution of *Helisoma duryi*, an introduced competitor of intermediate hosts of schistosomiasis, in an irrigation scheme in northern Tanzania. *Acta Tropica* **40**(3): 297–306.

Madsen H., Waithaka Thiongo F. & Ouma J. H. (1983): Egg laying and growth in *Helisoma duryi* (Wetherby) (Pulmonata: Planorbidae): Effect of population density and mode of fertilization. *Hydrobiologia* **106**(2): 185–191.

Maeder F. (2008): Sea-silk in Aquincum: first production proof in antiquity. *In:* Alfaro C. & Karali L. (eds.): *La producción de bienes de consumo en la Antigüedad.* Universidad de Valencia, Valencia: 109–118.

Majoros G. (1987): Malakofaunisztikai érdekességek. *Malakológiai Tájékoztató* **7**: 19–22.

Majoros G. (2000): *Mételyek fejlődési alakjainak előfordulása és kártétele tógazdasági, valamint természetesvízi halakban és köztigazda csigákban.* Doktori értekezés. Szent István Egyetem, Állatorvos-tudományi Kar, Budapest.

Majoros G. (2006): Az amuri kagyló [*Anodonta (Sinanodonta) woodiana* (Lea, 1834)] megtelepedése a Balatonban és elszaporodásának várható következményei. *Halászat* **99**(4): 143–150.

Majoros G. (2009): Invazív kagylófajok terjeszkedése a Balatonban: esetismertetés és a probléma felvetése. *Halászatfejlesztés* **32**: 57–64.

Majoros G., Fehér Z., Deli T. & Földvári G. (2008): Establishment of *Biomphalaria tenagophila* snails in Europe. *Emerging Infectious Diseases* **14**(11): 1812–1814.

Malek E. A. (1985): *Snail hosts of schistosomiasis and other snail-transmitted diseases in tropical America: A manual.* Pan American Health Organization, Washington. /Scientific publication 478./

Marescaux J., bij de Vaate A. & Van Doninck K. (2012): First records of *Dreissena rostriformis bugensis* (Andrusov, 1897) in the Meuse River. *BioInvasions Records* **1**(2): 109–114.

Marković V., Tomović J., Ilić M., Kračun-Kolarević M., Novaković B., Paunović M. & Nikolić V. (2014): Distribution of the species of *Theodoxus* Montfort, 1810 (Gastropoda: Neritidae) in Serbia: an overview. *Acta Zoologica Bulgarica* **66**(4): 477–484.

McKinley D. C., Miller-Rushing A. J., Ballard H. L., Bonney R., Brown H., Cook-Patton S. C., Evans D. M., French R. A., Parrish J. K., Phillips T. B., Ryan S. F., Shanley L. A., Shirk J. L., Stepenuck K. F., Weltzin J. F., Wiggins A., Boyle O. D., Briggs R. D., Chapin S. F., Hewitt D. A., Preuss P. W. & Soukup M. A. (2017): Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation* **208**: 15–28.

McMahon R. F. (2002): Evolutionary and physiological adaptations of aquatic invasive animals: *r* selection versus resistance. *Canadian Journal of Fisheries and Aquatic Sciences* **59**(7): 1235–1244.

Meier-Brook C. (1979): The planorbid genus *Gyraulus* in Eurasia. *Malacologia* **18**: 67–72.

Meier-Brook C. (1983): Taxonomic studies on *Gyraulus* (Gastropoda: Planorbidae). *Malacologia* **24**(1–2): 1–113.

Meisenheimer J. (1901): Entwicklungsgeschichte von *Dreissensia polymorpha* Pall. *Zeitschrift für Wissenschaftliche Zoologie* **69**(1): 1–137.

Miranda N. A. F. & Perissinotto R. (2012): Stable isotope evidence for dietary overlap between alien and native gastropods in coastal lakes of northern KwaZulu-Natal, South Africa. *PLoS ONE* **7**(2): e31897.

Mitchell A. J. (2002): A copper sulfate–citric acid pond shoreline treatment to control the Ramshorn Snail *Planorbella trivolvis*. *North American Journal of Aquaculture* **64**(3): 182–187.

Mitchell A. J. & Brandt T. M. (2005): Temperature tolerance of Red-rim Melania *Melanoides tuberculatus*, an exotic aquatic snail established in the United States. *Transactions of the American Fisheries Society* **134**(1): 126–131.

Mitchell A. J., Hobbs M. S & Brandt T. M. (2007): The effect of chemical treatments on Red-rim Melania *Melanoides tuberculata*, an exotic aquatic snail that serves as a vector of trematodes to fish and other species in the USA. *North American Journal of Fisheries Management* **27**(4):1287–1293.

Molloy D. P., Karatayev A. Y., Burlakova L. E., Kurandina D. P. & Laruelle F. (1997): Natural enemies of Zebra Mussels: predators, parasites, and ecological competitors. *Reviews in Fisheries Science* **5**(1): 27–97.

Moquin-Tandon A. (1855): *Histoire naturelle des mollusques terrestres et fluviatiles de France*. Tome second. J.-B. Baillière, Paris.

Morgan E. & Shaw S. (2010): *Angiostrongylus vasorum* infection in dogs: continuing spread and developments in diagnosis and treatment. *Journal of Small Animal Practice* **51**(12): 616–621.

Morton B. S. (1987): Polymorphism in *Corbicula fluminea* (Bivalvia: Corbiculidae) from Hong Kong. *Malacological Review* **20**(1–2): 105–127.

Mouthon J. (1981): Sur la présence en France et au Portugal de *Corbicula* (Bivalvia, Corbiculidae) originaire d'Asie. *Basteria* **45**(4–5): 109–116.

Neubauer T. A., van de Velde S., Yanina T. & Wesselingh F. P. (2018): A late Pleistocene gastropod fauna from the northern Caspian Sea with implications for Pontocaspian gastropod taxonomy. *ZooKeys* **770**: 43–103.

Neubert E. (2014): *Revision of Helix Linnaeus, 1758 in its eastern Mediterranean distribution area, and reassignment of Helix godetiana Kobelt, 1878 to Maltzanella Hesse, 1917 (Gastropoda, Pulmonata, Helicidae).* Naturhistorisches Museum der Burgergemeinde Bern, Bern. / Contributions to Natural History No. **26**/

Norton C. G., Johnson A. F. & Nelson B. M. (2018): The genetic basis of albinism in the hermaphroditic freshwater snail *Planorbella trivolvis*. *American Malacological Bulletin* **36**(1): 153–157.

Olenin S., Orlova M., & Minchin D. (1999): *Dreissena polymorpha* (Pallas, 1771). *In:* Gollasch S., Minchin D., Rosenthal H. & Voigt M. (eds.): *Case histories on introduced species: their general biology, distribution, range expansion and impact.* Logos-Verlag Berlin: 37–42.

Orlova M. I., Therriault T. W., Antonov P. I. & Shcherbina G. Kh. (2005): Invasion ecology of Quagga Musses (*Dreissena rostriformis bugensis*): a review of evolutionary and phylogenetic impacts. *Aquatic Ecology* **39**(4): 401–418.

Orzechowski S. C. M., Frederick P. C., Dorazio R. M. & Hunter M. E. (2019): Environmental DNA sampling reveals high occupancy rates of invasive Burmese Pythons at wading bird breeding aggregations in the central Everglades. *PLoS ONE* **14**(4): e0213943.

Ostrovskiy A. M. (2017): Novye nakhodki sinantropnykh vidov slizney *Limacus flavus* (Linnaeus 1758) i *Krynickillus melanocephalus* Kaleniczenko, 1851 (Mollusca, Gastropoda, Stylommatophora) v Belarusi. Ruthenica **27**(14): 155–158.

Ottó L. (1980): Levél a szerkesztőnek: A Lipót községi termálfürdő puhatestűi. *Soosiana* **8**: 9–10.

Pallas P. S. (1771): *Reise durch verschiedene Provinzen des Russischen Reichs*. Erster Theil. Kayserliche Akademie der Wissenschaften, St. Petersburg.

Páll-Gergely B. & Hanti S. (2019): Kell-e félnünk az achátcsigák (*Achatina* spp) megtelepedésétől? *Növényvédelem* **80**/**55**/(5): 219–220.

Páll-Gergely B. & Szentes E. (2010): A két ajtóscsigafaj (*Pomatias elegans* és *P. rivulare*) pontos előfordulási viszonyai Nagymányok térségében (Kelet-Mecsek) (Gastropoda: Pomatiasidae). *Malakológiai Tájékoztató* **28**: 53–55.

Páll-Gergely B., Bacher N., Voláricsné Kun A. & Turóci Á. (2021): *Cantareus apertus* (Born, 1778) (nyekergő csiga) előkerülése Magyarországról. *Növényvédelem* **82**/**57**/(5): 218–221.

Páll-Gergely B., Fehér Z. & Čejka T. (2020a): New records of the Mediterranean land snail *Massylaea vermiculata* (O. F. Müller, 1774) in Hungary and Slovakia. *Folia Malacologica* **28**(4): 337–341.

Páll-Gergely B., Majoros G., Domokos T., Juhász A., Turóci Á., Badacsonyi L., Fekete J. & Asami T. (2019): Realtime Social Networking Service rapidly reveals distributions of non-indigenous land snails in a European capital. *BioInvasions Records* **8**(4): 782–792.

Páll-Gergely B., Sárvári F., Tőkési N. & Fehér Z. (2020b): *Chilostoma* (*Cingulifera*) *cingulatum* (S. Studer, 1820) (Gastropoda: Pulmonata: Helicidae) new to the fauna of Hungary. *Soosiana* **34**: 12–17.

Papp D. (1908): Vándorkagyló (*Dreissensia polymorpha* Pall.) a Zagyvából. *Állattani Közlemények* **7**(1): 30–32.

Păpureanu A.-M., Reise H. & Varga A. (2014): First records of the invasive slug *Arion lusitanicus* auct. non Mabille (Gastropoda: Pulmonata: Arionidae) in Romania. *Malacologica Bohemoslovaca* **13**: 6–11.

Paull S. H. & Johnson P. T. J. (2011): High temperature enhances host pathology in a snail-trematode system: possible consequences of climate change for the emergence of disease. *Freshwater Biology* **56**(4): 767–778.

Paunović M., Csányi B., Knežević S., Simić V., Nedanić D., Jakovčev-Todorović D., Stojanović B. & Cakić P. (2007): Distribution of Asian clams *Corbicula fluminea* (Müller, 1774) and *C. fluminalis* (Müller, 1774) in Serbia. *Aquatic Invasions* **2**(2): 99–106.

Peltanová A., Petrusek A., Kment P. & Juřičková L. (2012): A fast snail's pace: colonization of Central Europe by Mediterranean gastropods. *Biological Invasions* **14**(4): 759–764.

Perjési Gy. (1985): Néhány adat a *Hygromia cinctella* (Draparnaud) ismeretéhez, magyarországi és európai elterjedéséhez. *Soosiana* **13**: 39–42.

Pernecker B., Czirok A., Mauchart P., Boda P., Móra A. & Csabai Z. (2021): No experimental evidence for vector-free, long-range, upstream dispersal of adult Asian clams [*Corbicula fluminea* (Müller, 1774)]. *Biological Invasions* **23**(5): 1393–1404.

Petró E. (1984): A *Hygromia cinctella* (Draparnaud) újabb magyarországi lelőhelye. *Soosiana* **12**: 19–22.

Petró E. (1985): Az *Anodonta woodiana woodiana* (Lea, 1834) kagyló megjelenése Magyarországon. *Állattani Közlemények* **71**(1–4): 189–191.

Pfenninger M., Reinhardt F. & Streit B. (2002): Evidence for cryptic hybridization between different evolutionary lineages of the invasive clam genus *Corbicula* (Veneroida, Bivalvia). *Journal of Evolutionary Biology* **15**(5): 818–829.

Pfenninger M., Weigand A., Bálint M. & Klussmann-Kolb A. (2014): Misperceived invasion: the Lusitanian Slug (*Arion lusitanicus* auct. non-Mabille or *Arion vulgaris* Moquin-Tandon 1855) is native to Central Europe. *Evolutionary Applications* **7**(6): 702–713.

Pianezzola E., Roth S. & Hatteland B. A. (2013): Predation by carabid beetles on the invasive slug *Arion vulgaris* in an agricultural semi-field experiment. *Bulletin of Entomological Research* **103**(2): 225–232.

Pigneur L.-M., Marescaux J., Roland K., Etoundi E. Descy J.-P. & Van Doninck K. (2011): Phylogeny and androgenesis in the invasive *Corbicula* clams (Bivalvia, Corbiculidae) in Western Europe. *BMC Evolutionary Biology* **11**: 147.

Pintér I. (1975): *Cecilioides petitiana* (Benoit) mint növényi kártevő. *Soosiana* **3**: 11–14.

Pintér K. (1989): *Magyarország halai. Biológiájuk és hasznosításuk.* Akadémiai Kiadó, Budapest.

Pintér L. (1973): Magyarország puhatestüinek kritikai jegyzéke. *Soosiana* **1**: 11–17.

Pintér L. (1974): Katalog der rezenten Mollusken Ungarns. *Folia Historico-naturalia Musei Matraensis* **2**: 123–148.

Pintér L. (1978): *Potamopyrgus jenkinsi* (E. A. Smith 1889) in Ungarn (Gastropoda: Hydrobiidae). *Soosiana* **6**: 73–75.

Pintér L. (1984): Magyarország recens puhatestűinek revideált katalógusa (Mollusca). *Folia Historico-naturalia Musei Matraensis* **9**: 79–90.

Pintér L. & Podani J. (1979): *Oxychilus* (*Ortizius*) *translucidus* (Mortillet 1854) Magyarországon (Gastropoda: Zonitidae). *Soosiana* **7**: 95–96.

Pintér L. & S. Szigethy A. (1979): A magyarországi recens puhatestűek elterjedése: Kiegészítések és helyesbítések. *Soosiana* **7**: 97–108.

Pintér L. & Suara R. (2004): Magyarországi puhatestűek katalógusa hazai malakológusok gyűjtései alapján. Magyar Természettudományi Múzeum, Budapest. /A magyarországi puhatestűek elterjedése II./

Pintér L. & Varga A. (1981): *Bulgarica* (*Bulgarica*) *rugicollis* (Rossmässler 1836) neu für Ungarn. *Soosiana* **9**: 65–66.

Pintér L., Richnovszky A. & S. Szigethy A. (1979): A magyarországi recens puhatestűek elterjedése. *Soosiana* Supplementum 1: I–VI, 1–351.

Pointier J.-P. (2001): Invading freshwater snails and biological control in Martinique Island, French West Indies. *Memórias do Instituto Oswaldo Cruz (Rio de Janeiro)* **96** (Supplement): 67–74.

Pointier J. P., David P. & Jarne P. (2005): Biological invasions: the case of planorbid snails. *Journal of Helminthology* **79**(3): 249–256.

Pointier J. P., Guyard A. & Mosser A. (1989): Biological control of *Biomphalaria glabrata* and *B. straminea* by the competitor snail *Thiara tuberculata* in a transmission site of schistosomiasis in Martinique, French West Indies. *Annals of Tropical Medicine and Parasitology* **83**(3): 263–269.

Ponder W. F. (1988): *Potamopyrgus antipodarum* – a molluscan colonizer of Europe and Australia. *Journal of Molluscan Studies* **54**(3): 271–285.

von Proschwitz T. (1992): Spanska skogssnigeln – *Arion lusitanicus* Mabille – en art i snabb spridning med människan i Sverige. *Göteborgs Naturhistoriska Museum, Årstryck* 1992: 35–42.

von Proschwitz T. (2020): Rapid invasion of the slug *Krynickillus melanocephalus* Kaleniczenko, 1851 in Sweden and some notes on the biology and anthropochorous spread of the species in Europe (Gastropoda: Eupulmonata: Agriolimacidae). *Folia Malacologica* **28**(3): 227–234.

von Proschwitz T. & Winge K. (1994): Iberiaskogsnegl – en art på spredning i Norge. *Fauna* **47**: 195–203.

Quiñonero Salgado S., López Alabau A. & García Meseguer A. J. (2010): Nuevas localidades de *Helix lucorum* (Linnaeus, 1758) para la península Ibérica. *Spira* **3**(3–4): 45–47.

Rabitsch W. (2009): *Arion vulgaris* (Moquin-Tandon, 1855), Spanish Slug (Arionidae, Mollusca). *In:* DAISIE (ed.): *Handbook of alien species in Europe.* Springer, *sine loco*: 328.

Rae R., Verdun C., Grewal P. S., Robertson J. F. & Wilson M. J. (2007): Biological control of terrestrial molluscs using *Phasmarhabditis hermaphrodita* – progress and prospects. *Pest Management Science* **63**(12): 1153–1164.

Rasmussen O. (1975): *Helisoma duryi in biological control of bilharziasis.* Danish Bilharziasis Laboratory.

Reise H., Hutchinson J. M. C., Schunack S. & Schlitt B. (2011): *Deroceras panormitanum* and congeners from Malta and Sicily, with a redescription of the widespread pest slug as *Deroceras invadens* n. sp. *Folia Malacologica* **19**(4): 201–223.

Reise H., Schwarzer A.-K., Hutchinson J. M. C. & Schlitt B. (2020): Genital morphology differentiates three subspecies of the terrestrial slug *Arion ater* (Linnæus, 1758) s. l. and reveals a continuum of intermediates with the invasive *A. vulgaris* Moquin-Tandon, 1855. *Folia Malacologica* **28**(1): 1–34.

Rhousdy M. Z. & el-Emam M. (1981): A natural population of *Helisoma duryi* in the River Nile in Egypt. *Egyptian Journal of Bilharziasis* **8**(1–2): 87–89.

Richards D. C. (2002): The New Zealand Mudsnail invades the Western United States. *Aquatic Nuisance Species Digest* **4**(4): 42–44.

Roe S. L. & MacIsaac H. J. (1997): Deepwater population structure and reproductive state of Quagga Mussels (*Dreissena bugensis*) in Lake Erie. *Canadian Journal of Fisheries and Aquatic Sciences* **54**(10): 2428–2433.

Rotarides M. (1927): Szeged és közvetlen környékének Mollusca-(puhatestü) faunájáról. *Acta Litterarum ac Scientiarum Regiae Universitatis Hungaricae Francisco-Josephinae: Sectio Scientiarum Naturalium* **2**(3): 177–213.

Rotarides M. (1931): Beiträge zur Kenntnis der Anatomie von *Limax flavus* L. Mikroskopisch-anatomische Studie. *Acta Biologica* **1**(3): 239–275.

Rowson B., Turner J., Anderson R. & Symondson B. (2014): *Slugs of Britain and Ireland. Identification, understanding and control.* FSC Publications – National Museum of Wales, Telford.

Ryan P. A. (1982): Energy contents of some New Zealand freshwater animals. *New Zealand Journal of Marine and Freshwater Research* **16**(3–4): 283–287.

Sands A. F., Glöer P., Gürlek M. E., Albrecht C. & Neubauer T. A. (2020): A revision of the extant species of *Theodoxus* (Gastropoda, Neritidae) in Asia, with the description of three new species. *Zoosystematics and Evolution* **96**(1): 25–66.

Sárkány-Kiss E. (1986): *Anodonta woodiana woodiana* (Lea, 1834) a new species in Romania (Bivalvia, Unionacea). *Travaux du Museum National d'Histoire Naturelle „Grigore Antipa"* **28**: 15–17.

Schloesser D. W., Nalepa T. F. & Mackie G. L. (1996): Zebra Mussel infestation of unionid bivalves (Unionidae) in North America. *American Zoologist* **36**(3): 300–310.

Schmid G. (1970): *Arion lusitanicus* in Deutschland. *Archiv für Molluskenkunde* **100**: 95–102.

Schrenck L. v. (1867): *Mollusken des Amur-Landes und des Nordjapanischen Meeres. In:* Schrenck L. v.: *Reisen und Forschungen im Amur-Lande in den Jahren 1854–1856.* Zweiter Band. *Zoologie: Lepidopteren, Coleopteren, Mollusken.* Kaiserliche Akademie der Wissenschaften, St. Petersburg: 259–974.

Sebestyén O. (1934): A vándorkagyló (*Dreissensia polymorpha* Pall.) és a szövőbolharák (*Corophium curvispinum* G. O. Sars forma *devium* Wundsch) megjelenése és rohamos térfoglalása a Balatonban. *Magyar Biologiai Kutatóintézet Munkái* **7**: 190–204.

Sebestyén O. (1935): A *Dreissena polymorpha* elszaporodása a Balatonban. *Állattani Közlemények* **32**(3–4): 123–126.

Sherpa S., Ansart A., Madec L., Martin M.-C., Dréano S. & Guiller A. (2018): Refining the biogeographical scenario of the land snail *Cornu aspersum aspersum*: Natural spatial expansion and human-mediated dispersal in the Mediterranean basin. *Molecular Phylogenetics and Evolution* **120**: 218–232.

SMITH E. A. (1889): Notes on British *Hydrobiæ* with a description of a supposed new species. *Journal of Conchology* **6**(4): 142–146.

SON M. O. (2007): Native range of the Zebra Mussel and Quagga Mussel and new data on their invasions within the Ponto-Caspian Region. *Aquatic Invasions* **2**(3): 174–184.

SOÓS L. (1933): Akvárium-csigáink. *Természet-tudományi Közlöny* **65**(975–976): 115–124.

SOÓS L. (1943): *A Kárpát-medence Mollusca-faunája.* Magyar Tudományos Akadémia, Budapest. / Magyarország természetrajza I. Állattani rész/

SOÓS L. (1955): *Lamellibranchia (Bivalvia) – Kagylók.* Akadémiai Kiadó, Budapest. /Magyarország állatvilága XIX kötet, 1. füzet/

SOUSA R., ANTUNES C. & GUILHERMINO L. (2008): Ecology of the invasive Asian clam *Corbicula fluminea* (Müller; 1774) in aquatic ecosystems: an overview. *Annales de Limnologie – International Journal of Limnology* **44**(2): 85–94.

SOUTH A. (1992): *Terrestrial slugs. Biology, ecology and control.* Chapman & Hall, London.

SPYRA A., CIEPLOK A., STRZELEC M. & BABCZYŃSKA A. (2019): Freshwater alien species *Physella acuta* (Draparnaud, 1805) – A possible model for bioaccumulation of heavy metals. *Ecotoxicology and Environmental Safety* **185**: 109703.

STALAŽS A., DREIJERS E., IVINSKIS P., RIMŠAITĖ J. & DŽIUGELIS M. (2017): Records of *Krynickillus melanocephalus* Kaleniczenko, 1851 (Gastropoda: Agriolimacidae) in Lithuania. *Bulletin of the Lithuanian Entomological Society* **1**(29): 124–128.

STAROBOGATOV YA. I. (red.): (1994): *Dreyssena. Freshwater Zebra Mussel: Dreissena polymorpha (Pall.) (Bivalvia, Dreissenidae): Sistematika, ekologiya, prakticheskoye znacheniye.* Nauka, Moskva.

STEGER J. & BISENBERGER A. (2011): Erstnachweis der Gemeinen Kahnschnecke *Theodoxus fluviatilis* (Linnaeus 1758) (Mollusca: Gastropoda: Neritidae) im oberösterreichischen Donaugebiet. *Beiträge zur Naturkunde Oberösterreichs* **21**: 359–368.

STERBA G. (1979): *Aquarienkunde.* Band I. *Aquarientechnik, Ökologie und Anatomie der Fische. Einzelbeschreibung der Arten.* Urania Verlag, Leipzig – Jena – Berlin.

STRAYER D. L. (1999): Effects of alien species on freshwater mollusks in North America. *Journal of the North American Benthological Society* **18**(1): 74–98.

SVERLOVA N. V. & SON M. O. (2006): Mollyuski-introdutsety i ikh mesto v gorodskikh malakotsenozakh. *In:* CHERNOBAY YU. N. & SVERLOVA N. V. (red.): *Fauna, ekologiya i vnutrividovaya izmenchivost nazemnykh mollyuszkov v urbanizirovannoy srede.* Natsionalnaya akademiya nauk Ukrainy – Gosudarstvenniy prirodovedcheskiy muzey, Lvov: 42–59.

SYMONDSON W. O. C. (1994): The potential of *Abax parallelepipedus* (Col.: Carabidae) for mass breeding as a biological control agent against slugs. *Entomophaga* **39**(3–4): 323–333.

SYSOEV A. & SCHILEYKO A. (2009): *Land snails and slugs of Russia and adjacent countries.* Pensoft Publishers, Sofia. /Pensoft Series Faunistica 87./

SZABÓ I. & SZABÓ M. (1934): Epitheliale Geschwulstbildung bei einem wirbellosen Tier *Limax flavus* L. *Zeitschrift für Krebsforschung* **40**: 540–545.

SZEKERES J., BEERMANN A., NEUBAUER T. A., OČADLIK M., PAUNOVIĆ M., RAKOVIĆ M., CSÁNYI B., VARGA A., WEIGAND A., WILKE T. & FEHÉR Z. (2022): Rapid spread of a new alien and potentially invasive species, *Clathrocaspia knipowitschii* (Makarov, 1938) (Gastropoda: Hydrobiidae), in the River Danube. *Archives of Biological Sciences* **74**(1): 81–89.

SZEKERES J., SZALÓKY Z. & BODOLAI K. (2008): Első adat a *Dreissena bugensis* (Andrusov, 1897) (Bivalvia: Dreissenidae) magyarországi megjelenéséről. *Malakológiai Tájékoztató* **26**: 33–36.

SZEKERES M. (1976): New aspects of an *Alopia*-system (Mollusca: Gastropoda). *Acta Zoologica Academiae Scientiarum Hungaricae* **22**(3–4): 389–396.

TAKÁCS P., ÁCS A., BÁNÓ B., CZEGLÉDI I., CSABA J., ERŐS T., FÉSŰS-MÓRÉ M., PREISZNER B. STASZNY Á., VITÁL Z., WEIPERTH A. & FERINCZ Á. (2019): „Invasion in progress": first occurrence and spread of River Nerite (*Theodoxus fluviatilis* L., 1758) in the largest Central European shallow lake, Lake Balaton, Hungary. *BioInvasions Records* **8**(2): 273–280.

TAYLOR D. W. (2003): Introduction to Physidae (Gastropoda: Hygrophyla); biogeography, classification, morphology. *Revista de Biología Tropical* **51** (Suppl. 1): 1–287.

TELEBAK B., BRAJKOVIĆ M. & ĆURČIĆ S. (2013): Contribution to the knowledge of the slugs (Gastropoda: Stylommatophora: Limacidae and Milacidae) from Montenegro. *Bulletin of the Natural History Museum* **6**: 55–64.

Therriault T. W., Docker M. F., Orlova M. I., Heath D. D. & MacIsaac H. J. (2004): Molecular resolution of the family Dreissenidae (Mollusca: Bivalvia) with emphasis on Ponto-Caspian species, including first report of *Mytilopsis leucophaeata* in the Black Sea basin. *Molecular Phylogenetics and Evolution* **30**(3): 479–489.

Towns D. R. (1981): Life histories of benthic invertebrates in a kauri forest stream in northern New Zealand. *Australian Journal of Marine and Freshwater Research* **32**(2): 191–211.

Turóci Á. & Páll-Gergely B. (2020): Meztelencsigák határozása és kártétele Magyarországon: Mit tudunk és mit nem? *Magyar Növényvédő Mérnöki és Növényorvosi Kamara Lapja*, XV. Növényorvosi Nap: 79–81.

Turóci Á., Fehér Z., Krízsik V. & Páll-Gergely B. (2020a): Two new alien slugs, *Krynickillus melanocephalus* Kaleniczenko, 1851 and *Tandonia kusceri* (H. Wagner, 1931), are already widespread in Hungary. *Acta Zoologica Academiae Scientiarum Hungaricae* **66**(3): 265–282.

Turóci Á., Fehér Z., Varga A., Zsigó Gy. & Páll-Gergely B. (2020b): A spanyol meztelencsiga (*Arion vulgaris* Moquin–Tandon, 1855) gazdasági károkozása és a védekezés lehetőségei. *Növényvédelem* **81**/**56**/(8): 361–369.

Uherkovich Á. (2009): A *Pomatias elegans* (O. F. Müller, 1774) és a *Pomatias rivularis* (Eichwald, 1829) (Gastropoda, Pomatiasidae) együttes előfordulása a Mecsekben. *Malakológiai Tájékoztató* **27**: 47–49.

Urbańska M. & Andrzejewski W. (2019): An invasion in progress – *Sinanodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae) in Poland. *Folia Malacologica* **27**(4): 327–335.

Vajon I. (1959): Adatok az egri szennyvíz-derítőben ősszel található állatok ismeretéhez. *Az Egri Pedagógiai Főiskola Évkönyve* **5**: 489–494.

van Regteren Altena C. O. (1971): Neue Fundorte von *Arion lusitanicus* Mabille. *Archiv für Molluskenkunde* **101**: 183–185.

van Regteren Altena C. O., Aten D. & Schouten A. R. (1955): Notes sur les limaces. 3. Sur la présence en France d'*Arion lusitanicus* Mabille. *Journal de Conchyliologie* **95**(3): 89–99.

Varga A. (1977): A Bükk-hegység Mollusca-faunája. *Folia Historico-naturalia Musei Matraensis* **4**: 37–62.

Varga A. (1980): A *Boettgerilla pallens* Simroth 1912 újabb magyarországi lelőhelye. *Soosiana* **8**: 47–48.

Varga A. (1986): Az *Arion (Arion) lusitanicus* Mabille, 1868 előfordulása Magyarországon (Mollusca). *Folia Historico-naturalia Musei Matraensis* **11**: 110.

Varga A. (1995): A *Helix lucorum* (Linné, 1758) magyarországi betelepítése. *Malakológiai Tájékoztató* **14**: 21–22.

Varga A. (2006): A Velencei-tó Mollusca faunájáról. *Malakológiai Tájékoztató* **24**: 61–74.

Varga A. (2009): Régi anyagok a Mátra Múzeum (Gyöngyös) Mollusca-gyűjteményében. *Folia Historico Naturalia Musei Matraensis* **33**: 25–51.

Varga A. & Csányi B. (1997): Vízicsiga-fajok elterjedésének adatai hazai folyóinkban az elmúlt évtized faunisztikai feltárása alapján. *Folia Historico Naturalia Musei Matraensis* **22**: 285–322.

Varga A., Király G. & Sulyok K. M. (2010): A *Cornu aspersum* (O. F. Müller, 1774) és a *Helix lucorum* Linnaeus, 1758 adventív csigafajok hazai előfordulásának aktualizálása. *Malakológiai Tájékoztató* **28**: 85–90.

Vaz J. F., Teles H. M. S., Correa M. A. & de Silva Leite S. P. (1986): Ocorrência no Brasil de *Thiara (Melanoides) tuberculata* (O. F. Muller, 1774) (Gastropoda, Prosobranchia), primeiro hospedeiro intermediário de *Clonorchis sinensis* (Cobbold, 1875) (Trematoda, Plathyhelmintes). *Revista de Saúde Pública* **20**(4): 318–322.

Verdcourt B. (1974): A new species of *Gulella* Pfeiffer known only from European greenhouses (Mollusca: Streptaxidae). *Archiv für Molluskenkunde* **104**(4–6): 121–122.

Verhaegen G., Neiman M. & Haase M. (2018): Ecomorphology of a generalist freshwater gastropod: complex relations of shell morphology, habitat, and fecundity. *Organisms Diversity & Evolution* **18**(4): 425–441.

Visnya A. & Wagner J. (1938): Újabb malakofaunisztikai adatok Dunántúlról (1936–37). *Vasi Szemle* **5**(5–6): 325–327.

Wada S., Kawakami K. & Chiba S. (2011): Snails can survive passage through a bird's digestive system. *Journal of Biogeography* **39**(1): 69–73.

Wagner J. (1933): Egy új *Helicella*-faj Magyarország faunájában. *Állattani Közlemények* **30**(3–4): 151–159.

Wagner J. (1936): Magyarország, Horvátország és Dalmácia hazátlan csigái. III. rész. *Annales Historico-naturales Musei Nationalis Hungarici* **30** (Pars zoologica): 67–104.

Wagner H. (1938): Neue Schneckenfunde aus dem Transdanubium (1936–1937). *Fragmenta Faunistica Hungarica* **1**(1): 14–16.

Wagner J. (1939): A *Hygromia cinctella* Drap. újabb budapesti előfordulásai. *Állattani Közlemények* **36**(3–4): 174–175.

Wagner H. (1940): Über das Vorkommen von *Hygromia cinctella* Drap. in Budapest. *Archiv für Molluskenkunde* **72**(2–3): 83–84.

Walther F. & Neiber M. T. (2012): Über die Gattung *Alopia* (Gastropoda: Clausiliidae) in Deutschland: eine Klarstellung. *Mitteilungen der Deutschen Malakozoologischen Gesellschaft* **87**: 1–6.

Walton K. (2017): *Hygromia cinctella* (Draparnaud, 1801) (Mollusca: Gastropoda: Hygromiidae): a new adventive land snail for New Zealand. *New Zealand Journal of Zoology* **44**(1): 9–13.

Warwick T. (1952): Strains in the mollusc *Potamopyrgus jenkinsi* (Smith). *Nature* **169**(4300): 551–552.

Watters G. T. (1997): A synthesis and review of the expanding range of the Asian Freshwater Mussel *Anodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae). *The Veliger* **40**(2): 152–156.

Welter-Schultes F. (2012): *European non-marine molluscs, a guide for species identification.* Planet Poster Editions, Göttingen.

Wesselingh F. P., Neubauer T. A., Anistratenko V. V., Vinarski M. V., Yanina T., ter Poorten J. J., Kijashko P., Albrecht C., Anistratenko O. Yu., D'Hont A., Frolov P., Gándara A. M., Gittenberger A., Gogaladze A., Karpinsky M., Lattuada M., Popa L., Sands A. F., van de Velde S., Vandendorpe J. & Wilke T. (2019): Mollusc species from the Pontocaspian region – an expert opinion list. *ZooKeys* **827**: 31–124.

Wiesinger M. (1975): *Akvarisztika.* Gondolat, Budapest.

Wiktor A. (1987): Milacidae (Gastropoda, Pulmonata) – systematic monograph. *Annales Zoologici* **41**(3): 153–319.

Wiktor A. (1996): The slugs of the former Yugoslavia (Gastropoda terrestria nuda – Arionidae, Milacidae, Limacidae, Agriolimacidae). *Annales Zoologici* **46**(1–2): 1–110.

Wiktor A. (2000): Agriolimacidae (Gastropoda: Pulmonata) – a systematic monograph. *Annales Zoologici* **49**(4): 347–590.

Wiktor A. & Szigethy A. S. (1983): The distribution of slugs in Hungary (Gastropoda: Pulmonata). *Soosiana* **10–11**: 87–111.

Wiktor A., De-Niu C. & Ming W. (2000): Stylommatophoran slugs of China (Gastropoda: Pulmonata) – prodromus. *Folia Malacologica* **8**(1): 3–35.

De Winter A. J. (1989): *Arion lusitanicus* Mabille in Nederland (Gastropoda, Pulmonata, Arionidae). *Basteria* **53**(1–3): 49–51.

Winterbourn M. J. (1973): A guide to the freshwater Mollusca of New Zealand. *Tuatara* **20**(3): 141–158.

Work K. & Mills C. (2013): Rapid population growth countered high mortality in a demographic study of the invasive snail, *Melanoides tuberculata* (Müller, 1774), in Florida. *Aquatic Invasions* **8**(4): 417–425.

Yildirim M. Z., Kebapçi Ü. & Gümüş B. A. (2004): Edible snails (terrestrial) of Turkey. *Turkish Journal of Zoology* **28**(4): 329–335.

Yousif F., El-Emam M. & Roushdy M. Z. (1993): *Helisoma duryi*: its present range of distribution and implications with schistosomiasis snails in Egypt. *Journal of the Egyptian Society of Parasitology* **23**(1): 195–211.

Zając K. S., Gaweł M., Filipiak A. & Kramarz P. (2017): *Arion vulgaris* Moquin-Tandon, 1855 – the aetiology of an invasive species. *Folia Malacologica* **25**(2): 81–93.

Zając K. S., Hatteland B. A., Feldmeyer B., Pfenninger M., Filipiak A., Noble L. R. & Lachowska-Cierlik D. (2019): A comprehensive phylogeographic study of *Arion vulgaris* Moquin-Tandon, 1855 (Gastropoda: Pulmonata: Arionidae) in Europe. *Organisms Diversity & Evolution* **20**: 37–50.

Zemanova M. A., Knopf E. & Heckel G. (2016): Phylogeographic past and invasive presence of *Arion* pest slugs in Europe. *Molecular Ecology* **25**(22): 5747–5764.

Zettler M. L., Frankowski J. & Bochert R. & Röhner M. (2004): Morphological and ecological features of *Theodoxus fluviatilis* (Linnaeus, 1758) from Baltic brackish water and German freshwater populations. *Journal of Conchology* **38**(3): 305–316.

Žganec K., Lajtner J., Ćuk R., Crnčan P., Pušić I., Atanacković A., Kralj T., Valić D., Jelić M. & Maguire I. (2020): Alien macroinvertebrates in Croatian freshwaters. *Aquatic Invasions* **15**(4): 593–615.

Zhadin V. I. (1938): *Fauna SSSR. Mollyuski.* T. IV, vyp. 1. *Sem. Unoinidea.* Izdatelstvo Akademii Nauk SSSR, Moskva – Leningrad. / Zoologicheskiy Institut Akademii Nauk SSSR Novaya Seriya 18./

Zhadin V. I. (1952): *Mollyuski presnykh i solonovatykh vod SSSR.* Izdatelstvo Akademii Nauk SSSR, Moskva – Leningrad. /Opredeliteli po faune SSSR 46./

NEMATODES – Nematoda

Braasch H. (2001): *Bursaphelenchus* species in conifers in Europe: distribution and morphological relations. *EPPO Bulletin* **31**(2): 127–142.

Costa R., Ribeiro P., Evaristo I., Ribeiro B., Aguiar A., Carrasquinho I., Santos C. & Vasconcelos M. (2011): Are there any *Pinus pinaster* trees resistant to *Bursaphelenchus xylophilus*? Studies implemented in Portugal to address this question. *BMC Proceedings* **5** (Supplement 7): 119.

Dwinell L. D. (1990): Heat-treating and drying southern pine lumber infested with Pinewood Nematodes. *Forest Products Journal* **40**(11–12): 53–56.

Dwinell L. D. (1997): The Pine Wood Nematode: regulation and mitigation. *Annual Review of Phytopathology* **35**: 153–166.

EPPO & CABI (1996): *Bursaphelenchus xylophilus. In:* EPPO & CABI (prep.): *Quarantine pests for Europe. Data sheets on quarantine pests for the European Union and for the European and Mediterranean Plant Protection Organization.* 2nd edition. CAB International, Wallingford: 443–447.

EPPO Reporting Service (2010a): Isolated finding of *Bursaphelenchus xylophilus* in Spain. *In: EPPO Global Database.* EPPO Reporting Service no. 03 – 2010 Num. article 2010/051. – https://gd.eppo.int/reporting/article-418

EPPO Reporting Service (2010b): Situation of recently introduced pests in Spain. *In: EPPO Global Database.* EPPO Reporting Service no. 03 – 2010 Num. article 2010/058. – https://gd.eppo.int/reporting/article-429

EPPO Reporting Service (2011): Situation of *Bursaphelenchus xylophilus* in Portugal. *In: EPPO Global Database.* EPPO Reporting Service no. 04 – 2011 Num. article 2011/070. – https://gd.eppo.int/reporting/article-186

Evans H., McNamara D. G., Braash H., Chadoeuf J. & Magnusson C. (1996): Pest Risk Analysis (PRA) for the territories of the European Union (as PRA area) on *Bursaphelenchus xylophilus* and its vectors in the genus *Monochamus. EPPO Bulletin* **26**(2): 199–249.

Halik S. & Bergdahl D. R. (1990): Development of *Bursaphelenchus xylophilus* populations in wood chips with different moisture contents. *Journal of Nematology* **22**(1): 113–118.

Ishibashi N. & Kondo E. (1977): Occurrence and survival of the dispersal forms of Pine Wood Nematode, *Bursaphelenchus lignicolus* Mamiya and Kiyohara. *Applied Entomology and Zoology* **12**(4): 293–302.

Malek R. B. & Appleby J. E. (1984): Epidemiology of pine wilt in Illinois. *Plant Disease* **68**(3): 180–186.

Mamiya Y. (1984): The Pine Wood Nematode. *In:* Nickle W. R. (ed.): *Plant and insect nematodes.* Marcel Dekker, New York – Basel: 589–627.

Mamiya Y. & Tamura H. (1977): Transpiration reduction of pine seedlings inoculated with the Pinewood Nematode *Bursaphelenchus lignicolus. Journal of Japanese Forestry Society* **59**(2): 59–63.

Mota M. M., Braasch H., Bravo M. A., Penas A. C., Burgermeister W., Metge K. & Sousa E. (1999): First report of *Bursaphelenchus xylophilus* in Portugal and Europe. *Nematology* **1**(7–8):724–734.

Nakamura-Matori K. (2008): Vector-host tree relationships and the abiotic environment. *In:* Zhao B. G., Futai K., Sutherland J. R. & Takeuchi Y. (eds.): *Pine wilt disease.* Springer, New York: 144–161.

Oku H., Shiraishe T. & Kurozuini S. (1979): Participation of toxin in wilting of Japanese pines caused by a nematode. *Naturwissenschaften* **66**(4): 210.

Roques A. (2009): *Bursaphelenchus xylophilus* (Steiner & Bührer), Pine Wood Nematode (Parasitaphelenchidae, Nematoda). *In:* DAISIE (2009): *Handbook of alien species in Europe.* Springer, *sine loco*: 330.

Rutherford T. A. & Webster J. M. (1987): Distribution of pine wilt disease with respect to temperature in North America, Japan, and Europe. *Canadian Journal of Forest Research* **17**(9): 1050–1059.

Ryss A., Vieira P., Mota M. & Kulinich O. (2005): A synopsis of the genus *Bursaphelenchus* Fuchs, 1937 (Aphelenchida: Parasitaphelenchidae) with keys to species. *Nematology* **7**(3): 393–458.

Shaheen F., Winter R. E. K. & Bolla R. I. (1984): Phytotoxin production in *Bursaphelenchus xylophilus*-infected *Pinus sylvestris. Journal of Nematology* **16**(1): 57–61.

Schröder T., McNamara D. & Gaar V. (2009): Guidance on sampling to detect Pine Wood Nematode *Bursaphelenchus xylophilus* in trees, wood and insects. *EPPO Bulletin* **39**(2): 179–188.

Shin S.-C. (2008): Pine wilt disease in Korea. *In:* Zhao B. G., Futai K., Sutherland J. R. & Takeuchi Y. (eds.): *Pine wilt disease.* Springer, New York: 26–32.

Sousa E., Bravo M. A., Pires J., Naves P., Penas A. C., Bonifácio L. & Mota M. M. (2001): *Bursaphelenchus xylophilus* (Nematoda; Aphelenchoididae) associated with *Monochamus galloprovincialis* (Colepotera; Cerambycidae) in Portugal. *Nematology* **3**(1): 89–91.

Sutherland J. R. (2008) A brief overview of the Pine Wood Nematode and pine wilt disease in Canada and the United States. *In:* Zhao B. G, Futai K, Sutherland J. R & Takeuchi Y. (eds.): *Pine wilt disease.* Springer, New York: 13–25.

Tóth Á. (2011): *Bursaphelenchus xylophilus,* the Pinewood Nematode: its significance and a historical review. *Acta Biologica Szegediensis* **55**(2): 213–217.

Yusheng F., Zhuo K. & Zhao J. (2002): Description of *Bursaphelenchus aberrans* n. sp. (Nematoda: Parasitaphelenchidae) isolated from pine wood in Guangdong Province, China. *Nematology* **4**(7): 791–794.

Wingfield M. J. (1987): A comparison of the mycophagous and the phytophagous phases of the Pine Wood Nematode. *In:* Wingfield M. J. (ed.): *Pathogenicity of the Pine Wood Nematode Symposium Series.* The American Phytopathological Society Press, St. Paul: 81–90.

Zhao B. G., Futai K., Sutherland J. R. & Takeuchi Y. (eds.) (2008): *Pine wilt disease.* Springer, New York.

DECAPODS – Decapoda

Adams S., Schuster G. A. & Taylor C. A. (2010): *Orconectes limosus. In: The IUCN Red List of Threatened Species 2010*: e.T153764A4541724. – www.iucnredlist.org

Andriantsoa R., Tönges S., Panteleit J., Theissinger K., Carneiro V. C., Rasamy J. & Lyko F. (2019): Ecological plasticity and commercial impact of invasive Marbled Crayfish populations in Madagascar. *BMC Ecology* **19**: 8.

Bódis E., Borza P., Potyó I., Puky M., Weiperth A. & Guti G. (2012): Invasive mollusc, crustacean, fish and reptile species along the Hungarian stretch of the River Danube and some connected waters. *Acta Zoologica Academiae Scientiarum Hungaricae* **58** (Supplement 1): 29–45.

Botta-Dukát Z. (szerk.) (2016): *Inváziós fajok terjedési útvonalainak átfogó elemzése és hazai értékelése. Kutatási zárójelentés.* MTA ÖK Ökológiai Botanikai Intézet, Vácrátót.

Chucholl C. (2011a): Disjunct distribution pattern of *Procambarus clarkii* (Crustacea, Decapoda, Astacida, Cambaridae) in an artificial lake system in Southwestern Germany. *Aquatic Invasions* **6**(1): 109–113.

Chucholl C. (2011b): Population ecology of an alien „warm water" crayfish (*Procambarus clarkii*) in a new cold habitat. *Knowledge and Management of Aquatic Ecosystems* **401**: 29.

Chucholl C. & Pfeiffer M. (2010): First evidence for an established Marmorkrebs (Decapoda, Astacida, Cambaridae) population in Southwestern Germany, in syntopic occurrence with *Orconectes limosus* (Rafinesque, 1817). *Aquatic Invasions* **5**(4): 405–412.

Copp G. H., Godard M. J., Vilizzi L., Ellis A. & Riley W. D. (2017): Predation by invasive Signal Crayfish on early life stages of European Barbel may be limited. *Aquatic Conservation (Marine and Freshwater Ecosystems)* **27**(5): 1056–1060.

D'Agaro E., De Luise G. & Lanari D. (1999): The current status of crayfish farming in Italy. *Freshwater Crayfish* **12**: 506–517.

Dorn N. J. & Trexler J. C. (2007): Crayfish assemblage shifts in a large drought-prone wetland: the roles of hydrology and competition. *Freshwater Biology* **52**(12): 2399–2411.

Dorn N. J. & Volin J. C. (2009): Resistance of crayfish (*Procambarus* spp.) populations to wetland drying depends on species and substrate. *Journal of the North American Benthological Society* **28**(4): 766–777.

Faulkes Z. (2015): The global trade in crayfish as pets. *Crustacean Research* **44**: 75–92.

Ferincz Á., Kováts N., Benkő-Kiss Á. & Paulovits G. (2014): New record of the Spiny-cheek Crayfish, *Orconectes limosus* (Rafinesque, 1817) in the catchment of Lake Balaton (Hungary). *BioInvasions Records* **3**(1): 35–38.

Food and Agriculture Organisation of the United Nations (2020): *Fischeries and aquaculture. Global aquaculture production. Ouantity (1950–2020).* – www.fao.org

Frutiger A. & Müller R. (2002): *Der Rote Sumpfkrebs im Schübelweiher (Gemeinde Küsnacht ZH). Auswertung der Massnahmen 1998–2001 und Erkenntnisse.* EAWAG, Dübendorf.

Gál B., Gábris V., Csányi B., Cser B., Danyik T., Farkas A., Farkas J., Gebauer R., Répás E., Szajbert B., Kouba A., Patoka J., Pârvulescu L. & Weiperth A. (2018): A vörös mocsárrák *Procambarus clarkii* (Girard, 1852) jelenlegi elterjedése és hatása a Duna egyes magyarországi befolyóinak halfaunájára. *Pisces Hungarici* **12**: 71–76.

Gherardi F., Aquiloni L., Diéguez-Uribeondo J. & Tricarico E. (2011): Managing invasive crayfish: is there a hope? *Aquatic Sciences* **73**(2): 185–200.

Gross H., Burk C. & Hill A. (2008): Die Flusskrebsfauna in NRW. *Natur in NRW* 2008 (4): 52–56.

Gutekunst J., Andriantsoa R., Falckenhayn C., Hanna K., Stein W., Rasamy J. & Lyko F. (2018): Clonal genome evolution and rapid invasive spread of the Marbled Crayfish. *Nature Ecology & Evolution* **2**(3): 567–573.

Gutekunst J., Maiakovska O., Hanna K., Provataris P., Horn H., Wolf S., Skelton C. E., Dorn N. J. & Lyko F. (2021): Phylogeographic reconstruction of the Marbled Crayfish origin. *Communications Biology* **4**: 1096.

Haubrock P. J., Oficialdegui F. J. & Kouba A. (2021a): Redclaw – an aquaculture jewel or invader? *Worldfishing & Aquaculture* 2021 (April): 26–27.

Haubrock P. J., Oficialdegui F. J., Zeng Y., Patoka J., Yeo D. C. J. & Kouba A. (2021b): The Redclaw Crayfish: A prominent aquaculture species with invasive potential in tropical and subtropical biodiversity hotspots. *Reviews in Aquaculture* **13**(3): 1488–1530.

Hegedűs R. (2007): A hazai folyami rákok elterjedése. *Halászat* **100**(2): 88–97.

Hein C. L., Roth B. M., Ives A. R. & Vander Zanden M. J. (2006): Fish predation and trapping for Rusty Crayfish (*Orconectes rusticus*) control: a whole-lake experiment. *Canadian Journal of Fisheries and Aquatic Sciences* **63**(2): 383–393.

Hendrix A. N., Armstrong D. & Grace C. (1998): *Life history, ecology, and interactions of Everglades crayfishes.* National Park Service, Homestead (Florida).

Herborg L.-M., Rushton S. P., Clare A. S. & Bentley M. G. (2003): Spread of the Chinese Mittern Crab (*Eriocheir sinensis* H. Milne Edwards) in continental Europe: analysis of a histrorical data set. *Hydrobilogia* **503**: 21–28.

Hobbs H. H. (1974a): *A checklist of the North and Middle American crayfishes (Decapoda: Astacidae and Cambaridae).* Smithsonian Institution Press, Washington. /Smithsonian Contributions to Zoology 166./

Hobbs H. H. (1974b): *Synopsis of the families and genera of crayfishes (Crustacea: Decapoda).* Smithsonian Institution Press, Washington. / Smithsonian Contributions to Zoology 164./

Hobbs H. H. (1984): On the distribution of the crayfish genus *Procambarus* (Decapoda: Cambaridae). *Journal of Crustacean Biology* **4**(1):12–24.

Holdich D. M. & Sibley P. J. (2009): ICS and NICS in Britain in the 2000s. *In:* Brickland J., Holdich D. M. & Imhoff E. M. (eds): *Crayfish conservation in the British Isles. Proceedings of a conference held on 25th March.* British Waterways Offices, Leeds: 13–33.

Holdich D. M., Reynolds J. D., Souty-Grosset C. & Sibley P. J. (2009): A review of the ever increasing threat to European crayfish from non-indigenous crayfish species. *Knowledge and Management of Aquatic Ecosystems* **394–395**: 11.

Holdich D. M., Rogers W. D. & Reynolds J. D. (1999): Native and alien crayfish in the British Isles. *In:* Gherardi F. & Holdich D. M. (eds.): *Crayfish in Europe as alien species. How to make the best of a bad situation?* A. A. Balkema, Rotterdam: 221–235.

Huner J. V. (2002): *Procambarus. In:* Holdich D. M. (ed.): *Biology of freshwater crayfish.* Blackwell Scientific Press, Oxford: 541–574.

ISSG (2016): *Global Invasive Species Database (GISD).* Invasive Species Specialist Group of the IUCN Species Survival Commission. – https://www.gbif.org/dataset/b351a324-77c4-41c9-a909-f30f77268bc4

Jabłońska A., Mamos T., Gruszka P., Szlauer-Łukaszewska A. & Grabowski M. (2018): First record and DNA barcodes of the aquarium shrimp, *Neocaridina davidi*, in Central Europe from thermally polluted River Oder canal, Poland. *Knowledge and Management of Aquatic Ecosystems* **419**: 14.

Jezerinac R. F., Stocker G. W. & Tarter D. C. (1995): *The crayfishes (Decapoda: Cambaridae) of West Virginia.* Ohio Biological Survey.

Jin G., Li Z. & Xie P. (2001): The growth pattern of juvenile and precocious Chinese Mitten Crabs, *Eriocheir sinensis* (Decapoda, Grapsidae), stocked in freshwater lakes of China. *Crustaceana* **74**(3): 261–273.

Jones J. P. G., Rasamy J. R., Harvey A., Toon A., Oidtmann B., Randrianarison M. H., Raminosoa N. & Ravoahangimalala O. R. (2009): The perfect invader: a parthenogenic crayfish poses a new threat to Madagascar's freshwater biodiversity. *Biological Invasions* **11**(6): 1475–1482.

Kawai T., Scholtz G., Morioka S., Ramanamandimby F., Lukhaup C. & Hanamura Y. (2009): Parthenogenetic alien crayfish (Decapoda: Cambaridae) spreading in Madagascar. *Journal of Crustacean Biology* **29**(4): 562–567.

Keller N. S., Pfeiffer M., Roessink I., Schulz R. & Schrimpf A. (2014): First evidence of crayfish plague agent in populations of the Marbled Crayfish (*Procambarus fallax* forma *virginalis*). *Knowledge and Management for Aquatic Ecosystems* **414**: 15.

Klotz W., Miesen F. W., Hüllen S. & Herder F. (2013): Two Asian fresh water shrimp species found in a thermally polluted stream system in North Rhine-Westphalia, Germany. *Aquatic Invasions* **8**(3): 333–339.

Kouba A., Petrusek A. & Kozák P. (2014): Continental-wide distribution of crayfish species in Europe: update and maps. *Knowledge and Management of Aquatic Ecosystems* 413: 5.

Kovács K., Nagy P. T. & Mayer R. (2015): Adatok a tízlábú rákok (Decapoda: Astacidae, Cambaridae) északnyugat-magyarországi előfordulásához. Egy *Procambarus* faj első előkerülése természetes élőhelyről Magyarországon. *Acta Biologica Debrecina Supplementum Oecologica Hungarica* **33**: 177–186.

Kovács T., Juhász P. & Ambrus A. (2005): Adatok a Magyarországon élő folyami rákok (Decapoda: Astacidae, Cambaridae) elterjedéséhez. *Folia Historico Naturalia Musei Matraensis* **29**: 85–89.

Kozák P., Ďuriš Z., Petrusek A., Buřič M., Horká I., Koub A., Kozubíková-Balcarová E. & Policar T. (2015): *Crayfish biology and culture.* University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters, Vodňany.

Kozubíková E., Puky M., Kiszely P. & Petrusek A. (2010): Crayfish plague pathogen in invasive North American crayfish species in Hungary. *Journal of Fish Diseases* **33**(11): 925–929.

Lawrence C. & Jones C. (2002): *Cherax*. *In:* Holdich D. M. (ed.): *Biology of freshwater crayfish.* Blackwell Science Ltd., Oxford: 635–669.

Liziczai M., Csányi B., Szekeres J. & Weiperth A. (2020): Jelzőrák (*Pacifastacus leniusculus*, Dana 1852) megjelenése a Mosoni-Duna és a Duna magyarországi főágában. *Halászat* **113**(3): 87.

Loureiro T. G., Anastácio P. M. S. G., Araujo P. B., Souty-Grosset C. & Almerão M. P. (2015): Red Swamp Crayfish: biology, ecology and invasion – an overview. *Nauplius* **23**(1): 1–19.

Lőkkös A., Müller T., Kovács K., Várkonyi L., Specziár A. & Martin P. (2016): The alien, parthenogenetic Marbled Crayfish (Decapoda: Cambaridae) is entering Kis-Balaton (Hungary), one of Europe's most important wetland biotopes. *Knowledge and Management of Aquatic Ecosystems* **417**: 16.

Ludányi M., Peeters E. T. H. M. E., Kiss B. & Roessink I. (2016): Distribution of crayfsh species in Hungarian waters. *Global Ecology and Conservation* **8**: 254–262.

Lukhaup C. (2001): *Procambarus* sp. – Der Marmorkrebs. *Aquaristik Aktuell* **9**(7–8): 48–51.

Maciaszek R., Jabłońska A., Hoitsy M., Prati S. & Świderek W. (2021): First record and DNA barcodes of non-native shrimp, *Caridina babaulti* (Bouvier, 1918) in Europe. *The European Zoological Journal* **88**(1): 816–823.

Maiakovska O., Andriantsoa R., Tönges S., Legrand C., Gutekunst J., Hanna K., Pârvulescu L., Novitsky R., Weiperth A., Sciberras A., Deidun A., Ercoli F., Kouba A. & Lyko F. (2021): Genome analysis of the monoclonal Marbled Crayfish reveals genetic separation over a short evolutionary timescale. *Communications Biology* **4**: 74.

Majoros G. & Puky M. (2012): Egy behurcolt, invazív, parazitozoonosist terjesztő, kínai gyapjasollós rák (*Eriocheir sinensis* Milne Edwards, 1853) negatív eredményű parazitológiai vizsgálata. *Magyar Állatorvosok Lapja* **134**(8): 487–490.

MARTIN P., DORN N. J., KAWAI T., VAN DER HEIDEN C. & SCHOLTZ G. (2010a): The enigmatic Marmorkrebs (Marbled Crayfish) is the parthenogenetic form of *Procambarus fallax* (Hagen, 1870). *Contributions to Zoology* **79**(3): 107–118.

MARTIN P., SHEN H., FÜLLNER G. & SCHOLTZ G. (2010b): The first record of the parthenogenetic Marmorkrebs (Decapoda, Astacida, Cambaridae) in the wild in Saxony (Germany) raises the question of its actual threat to European freshwater ecosystems. *Aquatic Invasions* **5**(4): 397–403.

MOZSÁR A., ÁRVA D., JÓZSA V., GYÖRE K., KAJÁRI B., CZEGLÉDI I., ERŐS T., WEIPERTH A. & SPECZIÁR A. (2021): Only one can remain? Environmental and spatial factors influencing habitat partitioning among invasive and native crayfishes in the Pannonian Ecoregion (Hungary). *Science of the Total Environment* **770**, Paper: 145240.

MRUGAŁA A., BUŘIČ M., PETRUSEK A. & KOUBA A. (2019): May atyid shrimps act as potential vectors of crayfish plague? *NeoBiota* **51**: 65–80.

MRUGAŁA A., KOZUBÍKOVÁ-BALCAROVÁ E., CHUCHOLL C., CABANILLAS RESINO S., VILJAMAA-DIRKS S., VUKIĆ J. & PETRUSEK A. (2015): Trade of ornamental crayfish in Europe as a possible introduction pathway for important crustacean diseases: crayfish plague and white spot syndrome. *Biological Invasions* **17**(5): 1313–1326.

OFICIALDEGUI F. J., HAUBROCK P. J. & KOUBA A. (2021): Are we making the same mistake again? The Redclaw Crayfish, a prominent aquaculture species introduced worldwide. *Aquaculture Magazine* **47**(1): 30–32.

PANNING A. (1939): The Chinese Mitten Crab. *Annual Report of the Board of Regents of the Smithsonian Institution* 1938: 361–375.

PAPAVLASOPOULOU I., PERDIKARIS C., VARDAKAS L. & PASCHOS I. (2014): Enemy at the gates: introduction potential of non-indigenous freshwater crayfish in Greece via the aquarium trade. *Central European Journal of Biology* **9**(1): 11–18.

PATOKA J., BLÁHA M., DEVETTER M., RYLKOVÁ K., ČADKOVÁ Z. & KALOUS L. (2016): Aquarium hitchhikers: attached commensals imported with freshwater shrimps via the pet trade. *Biologocal Invasions* **18**(2): 457–461.

PATOKA J., KALOUS L. & KOPECKÝ O. (2015): Imports of ornamental crayfish: the first decade from the Czech Republic's perspective. *Knowledge and Management of Aquatic Ecosystems* **416**: 4.

PATOKA J., PETRTÝL M. & KALOUS L. (2014): Garden ponds as potential introduction pathway of ornamental crayfish. *Knowledge and Management of Aquatic Ecosystems* **414**: 13.

PAUNOVIC M., CAKIC P., HEGEDIS A., KOLAREVIC J. & LENHARDT M. (2004): A report of *Eriocheir sinensis* (H. Milne Edwards, 1854) [Crustacea: Brachyura: Grapsidae] from the Serbian part of the Danube River. *Hydrobiologia* **529**(1): 275–277.

PEDRAZA-LARA C., DOADRIO I., BREINHOLT J. W. & CRANDALL K. A. (2012): Phylogeny and evolutionary patterns in the dwarf crayfish subfamily (Decapoda: Cambarellinae). *PLoS ONE* **7**(11): e48233.

PUKY M. (2004): Zoological mapping along the Hungarian lower Danube: Importance, aims and necessity discussed with the example of tree unrelated groups, Decapoda, Amphibia and Reptilia. *In:* TEODOROVIĆ I., RADULOVIĆ S. & BLOESCH J. (eds.): *Preoceedings of the 35th IAD Conference, Novi Sad, Serbia and Montenegro, 2004.* Visio Mundi Academic Press – Natinonal Committee of IAD Serbia and Montenegro, Novi Sad: 613–618.

PUKY M. (2012): Do researchers have anything to do with „Danubian killer machines"? *Eriocheir sinensis* in Hungary. *In:* BERCZIK Á., DINKA M. & KISS A. (eds.): *Living Danube. 39th IAD Conference. 21–24 August, 2012, Szentendre, Hungary. Proceedings.* MTA Ökológiai Kutatóközpont DKI, Göd – Vácrátót: 211–215.

PUKY M. (2014): Invasive crayfish on land: *Orconectes limosus* (Rafinesque, 1817) (Decapoda: Cambaridae) crossed a terrestrial barrier to move from a side arm into the Danube River at Szeremle, Hungary. *Acta Zoologica Bulgarica* Supplement 7: 143–146.

PUKY M. & SCHÁD P. (2006): Magyarországi tízlábú rák (Decapoda) fajok elterjedése és természetvédelmi helyzete. *Acta Biologica Debrecina Supplementum Oecologica Hungarica* **14**: 195–204.

PUKY M., REYNOLDS J. D. & SCHÁD P. (2005): Native and alien Decapoda species in Hungary: distribution, status, conservation importance. *Bulletin Français de La Pêche et de La Pisciculture* **376–377**: 553–568.

RABITCH W. & SCHIEMER F. (2003): Chinesische Wollhandkrabbe (*Eriocheir sinensis*) in der österreichischen Donau festgestellt. *Österreichs Fischerei* **56**(2–3): 61–65.

ROBBINS R. S., SAKARI M., BALUCHI S. N. & CLARK P. F. (2006): The occurrence of *Eriocheir sinensis* H. Milne Edwards, 1853 (Crustacea: Brachyura:

Varunidae) from the Caspian Sea region, Iran. *Aquatic Invasions* **1**(1): 32–34.

Savolainen R., Westman K. & Pursiainen M. (1996): Fecundity of Finnish Noble Crayfish, *Astacus astacus* L., and Signal Crayfish, *Pacifastacus leniusculus*, in various natural habitats and in culture. *Freshwater Crayfish* **11**(1): 319–338.

Scholtz G., Braband A., Tolley L., Reimann A., Mittmann B., Lukhaup C., Steuerwald F. & Vogt G. (2003). Parthenogenesis in an outsider crayfish. *Nature* **421**(6925): 806.

Schulz R. & Smietana P. (2001): Occurrence of native and introduced crayfish in northeastern Germany and northwestern Poland. *Bulletin Français de La Pêche et de La Pisciculture* **361**: 629–641.

Seitz R., Vilpoux K., Hopp U., Harzsch S. & Maier G. (2005): Ontogeny of the Marmorkrebs (Marbled Crayfish): a parthenogenetic crayfish with unknown origin and phylogenetic position. *Journal of Experimental Zoology* Part A *Comparative Experimental Biology* **303A**(5): 393–405.

Seprős R., Csányi B., Danyik T., Farkas A., Gábris V., Gál B., Répás E., Szajbert B. & Weiperth A. (2018a): Idegenhonos inváziós tízlábú rákok (Crustacea: Decapoda) aktuális helyzete. *In: Magyarország környezeti állapota 2017.* Herman Ottó Intézet, Budapest: 62–70.

Seprős R., Farkas A., Sebestyén A., Lőkkös A., Kelbert B., Gál B., Puky M. & Weiperth A. (2018b): Current status and distribution of non-native Spiny Cheek Crayfish (*Faxonius limosus* Rafinesque, 1817) in Lake Balaton. *Hungarian Agricultural Research* **27**(3): 20–26.

Sewell J. (2016): Chinese Mitten Crab, *Eriocheir sinensis. In:* GB Non-native Species Secretariat (NNSS): *Non-native species.* – www.nonnativespecies.org

Souty-Grosset C., Holdich D. M., Noël P. Y., Reynolds J. D. & Haffner P. (eds.) (2006): *Atlas of crayfish in Europe.* Muséum National d'Historie Naturelle, Paris. /Patrimoines Naturels 64/

Svoboda J., Mrugała A., Kozubíková-Balcarová E., Kouba A., Diéguez-Uribeondo J. & Petrusek A. (2014): Resistance to the crayfish plague pathogen, *Aphanomyces astaci*, in two freshwater shrimps. *Journal of Invertebrate Pathology* **121**: 97–104.

Svoboda J., Mrugała A., Kozubíková-Balcarová E. & Petrusek A. (2017): Hosts and transmission of the crayfish plague pathogen *Aphanomyces astaci*: a review. *Journal of Fish Diseases* **40**(1): 127–140.

Szajbert B., Bátky G., Sevcsik A., Tóth B. & Weiperth A. (2021): A márványrák (*Procambarus virginalis*) újabb hazai előfordulásai. *Halászat* **114**(3): 99.

Szendőfi B., Bérces S., Csányi B., Gábris V., Gál B., Gönye Zs., Répás E., Seprős R., Tóth B., Kouba A., Patoka J, & Weiperth A. (2018): Egzotikus halfajok és decapodák a Barát- és Dera-patakban, valamint a torkolatuk dunai élőhelyein. *Pisces Hungarici* **12**: 47–52.

Szepesi Zs. & Harka Á. (2011): Adatok a tízlábú rákok (Decapoda) magyarországi előfordulásáról, különös tekintettel a cifrarák (*Orconectes limosus*) terjedésére. *Folia Historico Naturalia Musei Matraensis* **35**: 15–20.

Takács P., Maász G., Vitál Z. & Harka Á. (2015): Akváriumi halak a Hévíz-lefolyó termálvizében. *Pisces Hungarici* **9**: 59–64.

Taylor C. A., Schuster G. A., Cooper J. E., DiStefano R. J., Eversole A. G., Hamr P., Hobbs H. H., Robison H. W., Skelton C. E. & Thoma R. F. (2007): A reassessment of the conservation status of crayfishes of the United States and Canada after 10+ years of increased awareness. *Fisheries* **32**(8): 372–389.

Tropea C., Stumpf L. & López Greco L. S. (2015): Effect of temperature on biochemical composition, growth and reproduction of the ornamental Red Cherry Shrimp *Neocaridina heteropoda heteropoda* (Decapoda, Caridea). *PLoS ONE* **10**(3): e0119468.

Veilleux É. & de Lafontaine Y. (2007): *Biological synopsis of the Chinese Mitten Crab (Eriocheir sinensis).* Environment Canada, Aquatic Ecosystem Protection Research Division, Montreal. /Canadian Manuscript Report of Fisheries and Aquatic Sciences 2812/

Veselý L., Ruokonen T. J., Weiperth A., Kubec J., Szajbert B., Guo W., Ercoli F., Bláha M., Buřič M., Hämäläinen H. & Kouba A. (2021): Trophic niches of three sympatric invasive crayfish of EU concern. *Hydrobiologia* **848**(2): 727–737.

Vogt G. (2010): Suitability of the clonal Marbled Crayfish for biogerontological research: a review and perspective, with remarks on some further crustaceans. *Biogerontology* **11**(6): 643–669.

Vogt G., Huber M., Thiemann M., van den Boogaart G., Schmitz O. J. & Schubart C. D. (2008): Production of different phenotypes from the same genotype in the same environment by developmental variation. *Journal of Experimental Biology* **211**(4): 510–523.

Weber S. & Traunspurger W. (2016): Influence of the ornamental Red Cherry Shrimp *Neocaridina davidi* (Bouvier, 1904) on freshwater meiofaunal assemblages. *Limnologica* **59**: 155–161.

Weiperth A., Bányai Zs., Ferincz Á., Juhász V., Sevcsik A., Staszny Á., Szalóky Z. & Tóth B. (2020a): Az Ipoly magyarországi szakaszán élő tízlábú rákokra és a halakra vonatkozó faunisztikai kutatások áttekintése. *Pisces Hungarici* **14**: 33–44.

Weiperth A., Bláha M., Szajbert B., Seprős R., Bányai Zs., Patoka J. & Kouba A. (2020b): Hungary: a European hotspot of non-native crayfish biodiversity. *Knowledge and Management of Aquatic Ecosystems* **421**: 43.

Weiperth A., Czeglédi I., Dragán P. E., Boross N., Erős T., Ferincz Á., Gál B., Juhász V., Lőkkös A., Lőkkösné Kelbert B., Specziár A., Staszny Á., Szivák I., Takács P., Vitál Z. & Preiszner B. (2020c): Tízlábú rákfajok aktuális elterjedése a Balatonban és vízgyűjtőjén. *Pisces Hungarici* **14**: 145–150.

Weiperth A., Csányi B., Gál B., György Á. I., Szalóky Z., Szekeres J., Tóth B. & Puky M. (2015): Egzotikus rák-, hal- és kétéltűfajok a Budapest környéki víztestekben. *Pisces Hungarici* **9**: 65–70.

Weiperth A., Gábris V., Danyik T., Farkas A., Kuříková P., Kouba A. & Patoka J. (2019a): Occurrence of non-native red cherry shrimp in European temperate waterbodies: a case study from Hungary. *Knowledge and Management for Aquatic Ecosystems* **420**: 9.

Weiperth A., Gál B., Kuříková P., Bláha M., Kouba A. & Patoka J. (2017): *Cambarellus patzcuarensis* in Hungary: The first dwarf crayfish established outside of North America. *Biologia* **72**(12):1529–1532.

Weiperth A., Gál B., Kuříková P., Langorová I., Kouba A. & Patoka J. (2019b): Risk assessment of pet-traded decapod crustaceans in Hungary with evidence of *Cherax quadricarinatus* (von Martens, 1868) in the wild. *North-western Journal of Zoology* **15**(1): 42–47.

Weiperth A., Kouba A., Csányi B., Danyik T., Farkas A., Gál B., Józsa V., Patoka J., Juhász V., Pârvulescu L., Mozsár A., Seprős R., Staszny Á., Szajbert B. & Ferincz Á. (2020d): Az idegenhonos tízlábú rákok (Crustacea: Decapoda) helyzete Magyarországon. *Halászat* **113**(2): 61–69.

Wutz S. & Geist J. (2013): Sex- and size-specific migration patterns and habitat preferences of invasive Signal Crayfish (*Pacifastacus leniusculus* Dana). *Limnologica* **43**(2): 59–66.

Xu L., Wang T., Li F.& Yang F. (2016): Isolation and preliminary characterization of a new pathogenic iridovirus from Redclaw Crayfish *Cherax quadricarinatus*. *Diseases of Aquatic Organisms* **120**(1): 17–26.

PERACARIDES – Pericarida

Arbačiauskas K., Rakauskas V. & Virbickas T. (2010): Initial and long-term consequences of attempts to improve fish-food resources in Lithuanian waters by introducing alien peracaridan species: a retrospective overview. *Journal of Applied Ichthyoligy* **26** (Suppl. 2): 28–37.

Arbačiauskas K., Višinskienė G., Smilgevičienė S. & Rakauskas V. (2011): Non-indigenous macroinvertebrate species in Lithuanian fresh waters, Part 1: Distributions, dispersal and future. *Knowledge and Management of Aquatic Ecosystems* **402**: 12.

Audzijonyte A., Baltrūnaitė L., Väinölä R. & Arbačiauskas K. (2015): Migration and isolation during the turbulent Ponto-Caspian Pleistocene create high diversity in the crustacean *Paramysis lacustris*. *Molecular Ecology* **24**(17): 4537–4555.

Audzijonyte A., Baltrūnaitė L., Väinölä R. & Arbačiauskas K. (2017): Human-mediated lineage admixture in an expanding Ponto-Caspian crustacean species *Paramysis lacustris* created a novel genetic stock that now occupies European waters. *Biological Invasions* **19**(8): 2443–2457.

Audzijonyte A., Wittmann K. J. & Väinölä R. (2008): Tracing recent invasions of the Ponto-Caspian mysid shrimp *Hemimysis anomala* across Europe and to North America with mitochondrial DNA. *Diversity and Distributions* **14**(2): 179–186.

Audzijonyte A., Wittmann K. J., Ovcarenko I. & Väinölä R. (2009): Invasion phylogeography of the Ponto-Caspian crustacean *Limnomysis benedeni* dispersing across Europe. *Diversity and Distributions* **15**(2): 346–355.

Bacela-Spychalska K. & Van der Velde G. (2013): There is more than one 'killer shrimp': trophic positions and predatory abilities of invasive amphipods of Ponto-Caspian origin. *Freshwater Biology* **58**(4): 730–741.

Bacela-Spychalska K., Grabowski M., Rewicz T., Konopacka A. & Wattier R. (2013): The 'killer shrimp' *Dikerogammarus villosus* (Crustacea, Amphipoda) invading Alpine lakes: overland transport by recreational boats and scuba-diving gear as potential entry vectors? *Aquatic Conservation (Marine and Freshwater Ecosystems)* **23**(4): 606–618.

Bernerth H. & Dorow S. (2010): *Chelicorophium sowinskyi* (Crustacea, Amphipoda) ist aus der Donau in den Main vorgedrungen – Anmerkungen zur Verbreitung und Morphologie der Art. *Lauterbornia* **70**: 53–71.

Bernerth H. & Stein S. (2003): *Crangonyx pseudogracilis* und *Corophium robustum* (Amphipoda), zwei neue Einwanderer im hessischen Main sowie Erstnachweis für Deutschland von *C. robustum*. *Lauterbornia* **48**: 57–60.

Bij de Vaate A., Jazdzewski K., Ketelaars H. A. M., Gollasch S. & Van der Velde G. (2002): Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. *Canadian Journal of Fisheries and Aquatic Sciences* **59**(7): 1159–1174.

Błońska D., Grabowska J., Kobak J., Jermacz Ł. & Bącela-Spychalska K. (2015): Feeding preferences of an invasive Ponto-Caspian goby for native and non-native gammarid prey. *Freshwater Biology* **60**(10): 2187–2195.

Boonstra H., Wiggers R. & Swarte M. (2016): First record of the Ponto-Caspian amphipod *Obesogammarus obesus* (Sars, 1894) (Amphipoda: Pontogammaridae) from the Netherlands. *BioInvasions Records* **5**(3): 155–158.

Borza P. (2009): First record of the Ponto-Caspian amphipod *Echinogammarus trichiatus* (Martynov, 1932) (=*Chaetogammarus trichiatus*) (Crustacea: Amphipoda) for the Middle-Danube (Slovakia and Hungary). *Aquatic Invasions* **4**(4): 693–696.

Borza P. (2011): Revision of invasion history, distributional patterns, and new records of Corophiidae (Crustacea: Amphipoda) in Hungary. *Acta Zoologica Academiae Scientiarum Hungaricae* **57**(1): 75–84.

Borza P. (2014): Life history of invasive Ponto-Caspian mysids (Crustacea: Mysida): A comparative study. *Limnologica* **44**: 9–17.

Borza P. & Boda P. (2013): Range expansion of Ponto-Caspian mysids (Mysida, Mysidae) in the River Tisza: first record of *Paramysis lacustris* (Czerniavsky, 1882) for Hungary. *Crustaceana* **86**(11): 1316–1327.

Borza P., Czirok A., Deák C., Ficsór M., Horvai V., Horváth Z., Juhász P., Kovács K., Szabó T. & Vad Cs. F. (2011): Invasive mysids (Crustacea: Malacostraca: Mysida) in Hungary: distributions and dispersal mechanisms. *North-Western Journal of Zoology* **7**(2): 222–228.

Borza P., Csányi B., Đanić V., Kenderov L., Kladarić L., Lešťáková M., Muc T., Němejcová D., Očadlík M., Paunović M., Rotar B., Szekeres J., Veseli M. & Zorić K. (2021): Peracarid crustaceans in the River Danube and its tributaries: results of the 4th Joint Danube Survey. *BioInvasions Records* **10**(3): 623–628.

Borza P., Csányi B., Huber T., Leitner P., Paunović M., Remund N., Szekeres J. & Graf W. (2015): Longitudinal distributional patterns of Peracarida (Crustacea, Malacostraca) in the River Danube. *Fundamental and Applied Limnology* **187**(2): 113–126.

Borza P., Huber T., Leitner P., Remund N. & Graf W. (2017): Current velocity shapes co-existence patterns among invasive *Dikerogammarus* species. *Freshwater Biology* **62**(2): 317–328.

Borza P., Huber T., Leitner P., Remund N. & Graf W. (2018a): How to coexist with the 'killer shrimp' *Dikerogammarus villosus*? Lessons from other invasive Ponto-Caspian peracarids. *Aquatic Conservation (Marine and Freshwater Ecosystems)* **28**(6): 1441–1450.

Borza P., Huber T., Leitner P., Remund N. & Graf W. (2018b): Niche differentiation among invasive Ponto-Caspian *Chelicorophium* species (Crustacea, Amphipoda, Corophiidae) by food particle size. *Aquatic Ecology* **52**(2–3): 179–190.

Borza P., Kovács K., György A., Török J. K. & Egri Á. (2019): The Ponto-Caspian mysid *Paramysis lacustris* (Czerniavsky, 1882) has colonized the Middle Danube. *Knowledge & Management of Aquatic Ecosystems* **420**: 1.

Bovy H. C., Barrios-O'Neill D., Emmerson M. C., Aldridge D. C. & Dick J. T. A. (2014): Predicting the predatory impacts of the "demon shrimp" *Dikerogammarus haemobaphes*, on native and previously introduced species. *Biological Invasions* **17**(2): 597–607.

Brown M. E., Buffington K. L., Cleckner L. B. & Razavi N. R. (2022): Elevated methylmercury concentration and trophic position of the non-native bloody red shrimp (*Hemimysis anomala*) increase biomagnification risk in nearshore food webs. *Journal of Great Lakes Research* **48**(1): 252–259.

Cooper J. E., Wallquist E., Holeck K. T., Hoffman C. E., Mills E. L. & Mayer C. M. (2012): Density and distribution of amphipods in Oneida Lake, New York, after the introduction of the exotic amphipod *Echinogammarus ischnus*. *Northeastern Naturalist* **19**(2): 249–266.

Coughlan N. E., O'Hara S., Crane K., Dick J. T. A., MacIsaac H. J. & Cuthbert R. N. (2020): Touch too much: aquatic disinfectant and steam exposure treatments can inhibit further spread of invasive bloody-red mysid shrimp *Hemimysis anomala*. *Wetlands Ecology and Management* **28**: 397–402.

Crawford G. I. (1935): *Corophium curvispinum*, G. O. Sars, var. *devium*, Wundsch, in England. *Nature* **136**(3443): 685–686.

Cristescu M. E. A., Witt J. D. S., Grigorovich I. A., Hebert P. D. N. & MacIsaac H. J. (2004): Dispersal of the Ponto-Caspian amphipod *Echinogammarus ischnus*: invasion waves from the Pleistocene to the present. *Heredity* **92**(3): 197–203.

Csabai Z., Borza P., Rewicz T., Pernecker B., Berta B. J. & Móra A. (2020): Mass appearance of the Ponto-Caspian invader *Pontogammarus robustoides* in the River Tisza catchment: bypass in the southern invasion corridor? *Knowledge and Management of Aquatic Ecosystems* **421**: 9.

De Gelder S., van der Velde G., Platvoet D., Leung N., Dorenbosch M., Hendriks H. W. M. & Leuven R. (2016): Competition for shelter sites: Testing a possible mechanism for gammarid species displacements. *Basic and Applied Ecology* **17**(5): 455–462.

Dick J. T., Platvoet D. & Kelly D. W. (2002): Predatory impact of the freshwater invader *Dikerogammarus villosus* (Crustacea: Amphipoda). *Canadian Journal of Fisheries and Aquatic Sciences* **59**(6): 1078–1084.

Dudich E. (1927): Új rákfajok Magyarország faunájában. *Archivum Balatonicum* **1**: 343–387.

Dudich E. (1930): A *Jaera Nordmanni* Rathke, egy új víziászka a magyar faunában. *Állattani Közlemények* **27**(1–2): 120.

Evans T. M., Naddafi R., Weidel B. C., Lantry B. F., Walsh M. G., Boscarino B. T., Johannsson O. E. & Rudstam L. G. (2018): Stomach contents and stable isotopes analysis indicate *Hemimysis anomala* in Lake Ontario are broadly omnivorous. *Journal of Great Lakes Research* **44**(3): 467–475.

Fink P. & Harrod C. (2013): Carbon and nitrogen stable isotopes reveal the use of pelagic resources by the invasive Ponto-Caspian mysid *Limnomysis benedeni*. *Isotopes in Environmental and Health Studies* **49**(3): 312–317.

Fink P., Kottsieper A., Heynen M. & Borcherding J. (2012): Selective zooplanktivory of an invasive Ponto-Caspian mysid and possible consequences for the zooplankton community structure of invaded habitats. *Aquatic Sciences* **74**(1): 191–202.

Gallardo B. & Aldridge D. C. (2013): Priority setting for invasive species management: risk assessment of Ponto-Caspian invasive species into Great Britain. *Ecological Applications* **23**(2): 352–364.

Gergs R., Hanselmann A. J., Eisele I. & Rothhaupt K.-O. (2008): Autecology of *Limnomysis benedeni* Czerniavsky, 1882 (Crustacea: Mysida) in Lake Constance, Southwestern Germany. *Limnologica* **38**(2): 139–146.

Grabowski M., Jażdżewski K. & Konopacka A. (2007): Alien Crustacea in polish waters – Amphipoda. *Aquatic Invasions* **2**(1): 25–38.

Gumuliauskaitė S. & Arbačiauskas K. (2008): The impact of the invasive Ponto-Caspian amphipod *Pontogammarus robustoides* on littoral communities in Lithuanian lakes. *In:* Nõges T., Eckmann R., Kangur K., Nõges P., Reinart A., Roll G., Simola H. & Viljanen M. (eds.): *European large lakes. Ecosystem changes and their ecological and socioeconomic impacts.* Springer, Dordrecht: 127–134.

Hanselmann A. J. (2010): *Katamysis warpachowskyi* Sars, 1877 (Crustacea, Mysida) invaded Lake Constance. *Aquatic Invasions* **5** (Supplement 1): S31–S34.

Hanselmann A. J., Hodapp B. & Rothhaupt K.-O. (2013): Nutritional ecology of the invasive freshwater mysid *Limnomysis benedeni*: field data and laboratory experiments on food choice and juvenile growth. *Hydrobiologia* **705**(1): 75–86.

Holdich D., Gallagher S., Rippon L., Harding P. & Stubbington R. (2006): The invasive Ponto-Caspian mysid, *Hemimysis anomala*, reaches the UK. *Aquatic Invasions* **1**(1): 4–6.

Iacarella J. C., Dick J. T. A. & Ricciardi A. (2015): A spatio-temporal contrast of the predatory impact of an invasive freshwater crustacean. *Diversity and Distributions* **21**(7): 803–812.

Jażdżewska A. M., Rewicz T., Mamos T., Wattier R., Bącela-Spychalska K. & Grabowski M. (2020): Cryptic diversity and mtDNA phylogeography of the invasive demon shrimp, *Dikerogammarus haemobaphes* (Eichwald, 1841), in Europe. *NeoBiota* **57**: 53–86.

Jermacz Ł., Dzierżyńska A., Kakareko T., Poznańska M. & Kobak J. (2015): The art of choice: predation risk changes interspecific competition between freshwater amphipods. *Behavioral Ecology* **26**(2): 656–664.

Juhász P., Kovács K., Szabó T., Csipkés R., Kiss B. & Müller Z. (2006): Faunistical results of the Malacostraca investigations carried out in the frames of the ecological survey of the surface waters of Hungary (ECOSURV) in 2005. *Folia Historico Naturalia Musei Matraensis* **30**: 319–323.

Kesselyák A. (1938): Die Arten der Gattung *Jaera* Leach (Isopoda, Asellota). *Zoologischer Jahrbücher (Abteilung für Systematik, Ökologie und Geographie der Tiere)* **71**: 219–252.

Ketelaars H. A. M., Lambregts-van de Clundert F. E., Carpentier C. J., Wagenvoort A. J. & Hoogenboezem W. (1999): Ecological effects of the mass occurrence of the Ponto–Caspian invader, *Hemimysis anomala* G. O. Sars, 1907 (Crustacea: Mysidacea), in a freshwater storage reservoir in the Netherlands, with notes on its autecology and new records. *Hydrobiologia* **394**: 233–248.

Kley A. & Maier G. (2006): Reproductive characteristics of invasive gammarids in the Rhine-Main-Danube catchment, South Germany. *Limnologica* **36**(2): 79–90.

Kobak J., Kakareko T., Poznańska M. & Żbikowski J. (2009): Preferences of the Ponto-Caspian amphipod *Dikerogammarus haemobaphes* for living Zebra Mussels. *Journal of Zoology* **279**(3): 229–235.

Kobak J., Rachalewski M. & Bącela-Spychalska K. (2016): Conquerors or exiles? Impact of interference competition among invasive Ponto-Caspian gammarideans on their dispersal rates. *Biological Invasions* **18**(7): 1953–1965.

Labat F., Piscart C. & Fontan B. (2011): First records, pathways and distributions of four new Ponto-Caspian amphipods in France. *Limnologica* **41**(4): 290–295.

Lantry B. F., Gumtow C. F., Walsh M. G., Weidel B. C., Boscarino B. T. & Rudstam L. G. (2012): Seasonal consumption of *Hemimysis anomala* by fish in Southeastern Lake Ontario, 2009–2010. *Journal of Great Lakes Research* **38** (Supplement 2): 73–78.

Lesutienė J., Gorokhova E., Gasiūnaitė Z. R. & Razinkovas A. (2007): Isotopic evidence for zooplankton as an important food source for the mysid *Paramysis lacustris* in the Curonian Lagoon, the South-Eastern Baltic Sea. *Estuarine, Coastal and Shelf Science* **73**(1–2): 73–80.

Lesutienė J., Gorokhova E., Gasiūnaitė Z. R. & Razinkovas A. (2008): Role of mysid seasonal migrations in the organic matter transfer in the Curonian Lagoon, south-eastern Baltic Sea. *Estuarine, Coastal and Shelf Science* **80**(2): 225–234.

Lipinskaya T., Radulovici A. & Makaranka A. (2018): First DNA barcoding based record of *Echinogammarus trichiatus* (Martynov, 1932) (Crustacea, Gammaridae) in Belarus. *BioInvasions Records* **7**(1): 55–60.

Moedt S. & van Haaren T. (2018): *Pontogammarus robustoides* (Sars, 1894), a new non-indigenous amphipod in the Netherlands (Crustacea: Amphipoda). *Lauterbornia* **85**: 123–126.

Muskó I. B. & Leitold H. (2003): Hínárosban élő felsőrendű (Malacostraca) rákok minőségi és mennyiségi viszonyai a Balaton különböző medencéiben. *In:* Bíró P. (szerk.): *XLIV. Hidrobiológus napok. „Ritkán vizsgált és különleges vizek". Tihany, 2002. október 2–4.* Magyar Hidrológiai Társaság – Magyar Tudományos Akadémia Balatoni Limnológiai Kutatóintézete – Magyar Tudományos Akadémia Veszprémi Területi Bizottsága, Budapest – Tihany – Veszprém: 14–16.

Muskó I. B., Balogh Cs., Tóth Á. P., Varga É. & Lakatos Gy. (2007): Differential response of invasive malacostracan species to lake level fluctuations. *Hydrobiologia* **590**(1): 65–74.

Müller J. C., Schramm S. & Seitz A. (2002): Genetic and morphological differentiation of *Dikerogammarus* invaders and their invasion history in Central Europe. *Freshwater Biology* **47**(11): 2039–2048.

Nehring S. (2006): The Ponto-Caspian amphipod *Obesogammarus obesus* (Sars, 1894) arrived the Rhine River via the Main-Danube Canal. *Aquatic Invasions* **1**(3): 148–153.

Nesemann H., Pöckl M. & Wittmann K. J. (1995): Distribution of epigean Malacostraca in the middle and upper Danube (Hungary, Austria, Germany). *Miscellanea Zoologica Hungarica* **10**: 49–68.

Platvoet D., Van der Velde G., Dick J. T. A. & Li S. (2009): Flexible omnivory in *Dikerogammarus villosus* (Sowinsky, 1894) (Amphipoda) – Amphipod Pilot Species Project (AMPIS) Report 5. *Crustaceana* **82**(6): 703–720.

Ponyi E. (1956): Ökologische, ernährungsbiologische und systematische Untersuchungen an verschiedenen *Gammarus*-Arten. *Archiv für Hydrobiologie* **52**(3): 367–387.

Ponyi J. & P. Zánkai N. (1996): Két izeltlábú állatfaj felbukkanása a Balatonban. *Állattani Közlemények* **81**: 199–201.

Pothoven S. A., Grigorovich I. A., Fahnenstiel G. L. & Balcer M. D. (2007): Introduction of the Ponto-Caspian bloody-red mysid *Hemimysis anomala* into the Lake Michigan basin. *Journal of Great Lakes Research* **33**(1): 285–292.

Pöckl M. (2009): Success of the invasive Ponto-Caspian amphipod *Dikerogammarus villosus* by life history traits and reproductive capacity. *Biological Invasions* **11**(9): 2021–2041.

Rachalewski M., Konopacka A., Grabowski M. & Bącela-Spychalska K. (2013): *Echinogammarus trichiatus* (Martynov, 1932) — a new Ponto-Caspian amphipod invader in Poland with remarks on other alien amphipods from the Oder River. *Crustaceana* **86**(10): 1224–1233.

Rakauskas V. (2019): The impact of introduced Ponto-Caspian mysids (*Paramysis lacustris*) on the trophic position of Perch (*Perca fluviatilis*) in European mesotrophic lakes. *Knowledge and Management of Aquatic Ecosystems* **420**: 38.

Rewicz T., Grabowski M., MacNeil C. & Bącela-Spychalska K. (2014): The profile of a 'perfect' invader – the case of killer shrimp, *Dikerogammarus villosus*. *Aquatic Invasions* **9**(3): 267–288.

Rewicz T., Wattier R., Grabowski M., Rigaud T. & Bącela-Spychalska K. (2015): Out of the Black Sea: phylogeography of the invasive killer shrimp *Dikerogammarus villosus* across Europe. *PLoS ONE* **10**(2): e0118121.

Ricciardi A., Avlijas S. & Marty J. (2012): Forecasting the ecological impacts of the *Hemimysis anomala* invasion in North America: Lessons from other freshwater mysid introductions. *Journal of Great Lakes Research* **38** (Supplement 2): 7–13.

Rothhaupt K.-O., Hanselmann A. J. & Yohannes E. (2014): Niche differentiation between sympatric alien aquatic crustaceans: An isotopic evidence. *Basic and Applied Ecology* **15**(5): 453–463.

Semenchenko V. & Vezhnovetz V. (2008): Two new invasive Ponto-Caspian amphipods reached the Pripyat River, Belarus. *Aquatic Invasions* **3**(4): 445–447.

Specziár A. (2010): A Balaton halfaunája: a halállomány összetétele, az egyes halfajok életkörülményei és a halállomány korszerű hasznosításának feltételrendszere. *Acta Biologica Debrecina Supplementum Oecologica Hungarica* **23**: 7–185.

Tittizer T., Schöll F., Banning M., Haybach A. & Schleuter M. (2000): Aquatische Neozoen im Makrozoobenthos der Binnenwasserstraßen Deutschlands. *Lauterbornia* **39**: 1–72.

Unger E. (1918): A *Corophium devium* előfordulása a Dunában. *Állattani Közlemények* **17**(3–4): 148–149.

Van den Brink F. W. B., van der Velde G. & bij de Vaate A. (1993): Ecological aspects, explosive range extension and impact of a mass invader, *Corophium curvispinum* Sars, 1895 (Crustacea: Amphipoda), in the Lower Rhine (The Netherlands). *Oecologia* **93**(2): 224–232.

Van Riel M. C., Van der Velde G., Rajagopal S., Marguillier S., Dehairs F. & Bij de Vaate A. (2006): Trophic relationships in the Rhine food web during invasion and after establishment of the Ponto-Caspian invader *Dikerogammarus villosus*. *Hydrobiologia* **565**(1): 39–58.

Witt J. D. S., Hebert P. D. N. & Morton W. B. (1997): *Echinogammarus ischnus*: another crustacean invader in the Laurentian Great Lakes basin. *Canadian Journal of Fisheries and Aquatic Sciences* **54**(2): 264–268.

Wittmann K. J. (2002): Weiteres Vordringen pontokaspischer Mysidacea (Crustacea) in die mittlere und obere Donau: Erstnachweise von *Katamysis warpachowskyi* für Ungarn, die Slowakei und Österreich mit Notizen zur Biologie und zum ökologischen Gefährdungspotential. *Lauterbornia* **44**: 49–63.

Wittmann K. J. (2008): Weitere Ausbreitung der pontokaspischen Schwebgarnele (Crustacea: Mysida: Mysidae) *Katamysis warpachowskyi* in der oberen Donau: Erstnachweis für Deutschland. *Lauterbornia* **63**: 83–86.

Woynárovich E. (1954): Vorkommen der *Limnomysis benedeni* Czern. im ungarischen Donauabschnitt. *Acta Zoologica Academiae Scientiarum Hungaricae* **1**(1–2): 177–185.

Zettler M. L. (2015): Kurze Notiz über die Ankunft von *Echinogammarus trichiatus* im Ostseegebiet und den Erstnachweis von *Paramysis lacustris* in Deutschland. *Lauterbornia* **79**: 151–156.

HEMIPTERANS – Hemiptera

Adu-Mensah K. & Kumar R. (1977): Ecology of *Oxycarenus* species (Heteroptera: Lygaeidae) in southern Ghana. *Biological Journal of the Linnean Society* **9**(4): 349–377.

Ahn S. J., Son D., Choo H. Y. & Park C. G. (2013): The first record of *Leptoglossus occidentalis* (Hemiptera: Coreidae) in Korea, a potential pest of pinaceous tree species. *Journal of Asia-Pacific Entomology* **16**(3): 281–284.

Altenkirch W. (1986): *Die Veränderung natürlicher Waldgesellschaften Norddeutschlands und ihre Folgen für den Ökosystem- und Artenschutz aus zoologischer Sicht.* Arb. Gem. Forstenrichtung. Arb. Kreis Zustandserfassung und Planung, Jahrestagung, Luxemburg 21–23 May, 1986.

Alvarado M., Durán J. M., Serrano A., De la Rosa A. & Ortiz E. (1998): Contribución al conocimiento de las chinches (Heteroptera) fitófagas del algodón en Andalucía Occidental. *Boletín de Sanidad Vegetal, Plagas* **24**(4): 817–828.

Amyot C.-J.-B. & Serville A. (1843): *Histoire naturelle des insectes. Hémiptères.* Librairie Encyclopédique de Roret, Paris.

Anonym (1995): Phyto Régions. Provence-Alpes-Côte d'Azur. Une mineuse et *Metcalfa*. *Phytoma (La Défense des Végétaux)* **475**: 3.

Arslangündoğdu Z., Hizal E. & Acer S. (2018): First record of *Oxycarenus lavaterae* (Fabricius, 1787) (Heteroptera, Lygaeidae) in Turkey. *Applied Ecology and Environmental Research* **16**(2): 1305–1311.

Arzone A., Vidano C. & Alma A. (1987): Auchenorrhyncha introducted into Europe from the Nearctic region: taxonomic and phytopathological problems. *In:* Wilson M. R. & Nault L. R. (eds.): *Proceedings of 2nd International Workshop on Leafhoppers and Planthoppers of Economic Importance. Brigham Young University, Provo, Utah, USA, 28th July – 1st August 1986.* CAB International Institute of Entomolgy, London: 3–17.

Aukema B. (1989): Annotated checklist of Hemiptera-Heteroptera of The Netherlands. *Tijdschrift voor Entomologie* **132**(1): 1–104.

Aukema B. (2016): Nieuwe en interessante Nederlandse wantsen VI (Hemiptera: Heteroptera). *Nederlandse Faunistische Mededelingen* **46**: 57–85.

Bălăcenoiu F., Neţoiu C., Tomescu R., Simon D. C., Buzatu A., Toma D. & Petriţan I. C. (2021): Chemical control of *Corythucha arcuata* (Say, 1832), an invasive alien species, in oak forests. *Forests* **12**(6): 770.

Barber N. A. (2010): Light environment and leaf characteristics affect distribution of *Corythucha arcuata* (Hemiptera: Tingidae). *Environmental Entomology* **39**(2): 492–497.

Barta M. (2009): New facts about distribution and host spectrum of the invasive Nearctic conifer pest, *Leptoglossus occidentalis* (Heteroptera: Coreidae) in south-western Slovakia. *Forestry Journal* **55**(2): 139–143.

Barta M. (2010): Preliminary evaluation of insect-pathogenic Hypocreales against *Leptoglossus occidentalis* (Heteroptera: Coreidae) in laboratory conditions. *Folia Oecologica* **37**(2): 137–143.

Barta M. (2016): Biology and temperature requirements of the invasive seed bug *Leptoglossus occidentalis* (Heteroptera: Coreidae) in Europe. *Journal of Pest Science* **89**(1): 31–44.

Bates S. L. (2005): Damage to common plumbing materials caused by overwintering *Leptoglossus occidentalis* (Hemiptera: Coreidae). *The Canadian Entomologist* **137**(4): 492–496.

Bates S. L. & Borden J. H. (2004): Parasitoids of *Leptoglossus occidentalis* Heidemann (Heteroptera: Coreidae) in British Columbia. *Journal of the Entomological Society of British Columbia* **101**: 143–144.

Ben Jamâa M. L., Mejri M., Naves P. & Sousa E. (2013): Detection of *Leptoglossus occidentalis* Heidemann, 1910 (Heteroptera: Coreidae) in Tunisia. *African Entomology* **21**(1): 165–167.

Bernardinelli I. (2006): Potential host plants of *Corythucha arcuata* (Het., Tingidae) in Europe: a laboratory study. *Journal of Applied Entomology* **130**(9–10): 480–484.

Bernardinelli I. & Zandigiacomo P. (2001): Prima segnalazione di *Corythucha arcuata* (Say) (Heteroptera, Tingidae) in Europa. *Informatore Fitopatologico* **50**(12): 47–49.

Bianchi Z. & Stehlík J. L. (1999): *Oxycarenus lavaterae* (Fabricius, 1787) in Slovakia (Heteroptera: Lygaeidae). *Acta Musei Moraviae, Scientiae Biologicae* **84**: 203–204.

Billen W. (2004): Kurzbericht über das Auftreten einer neuen Wanze in Deutschland. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* **56**(12): 309–310.

Blatt S. E. (1994): An unusually large aggregation of the Western Conifer Seed Bug, *Leptoglossus occidentalis* (Hemiptera: Coreidae), in a man-made structure. *Journal of the Entomological Society of British Columbia* **91**: 71–72.

Blatt S. E. & Borden J. H. (1996): Evidence for a male-produced aggregation pheromone in the Western Conifer Seed Bug, *Leptoglossus occidentalis* Heidemann (Hemiptera: Coreidae). *Canadian Entomologist* **128**(4): 777–778.

Bolívar I. & Chicote C. (1879): Enumeracion de los Hemípteros observados en España y Portugal. *Anales de la Sociedad Española de Historia Natural* **8**: 147–186.

Bosco L., Moraglio S. T. & Tavella L. (2018): *Halyomorpha halys*, a serious threat for hazelnut in newly invaded areas. *Journal of Pest Science* **91**(2): 661–670.

Bozsik G., Kerezsi V. & Kontschán J. (2021): Attraction of adults of *Halyomorpha halys* (Stål, 1855) and *Nezara viridula* (Linnaeus, 1758) (Hemiptera: Pentatomidae) by artificially heated shelters. *Acta Zoologica Bulgarica* **73**(3): 451–455.

Burlini M. (1949): Infestazione di *Oxycarenus lavatarae* F. su *Tilia americana* L. (Rhynchota Lygaeidae). *Bollettino della Società Entomologica Italiana* **79**: 15–16.

Callot H. & Brua C. (2013): *Halyomorpha halys* (Stål, 1855), la Punaise diabolique, nouvelle espèce pour la faune de France (Heteroptera Pentatomidae). *L'Entomologiste* **69**(2): 69–71.

Camponogara P., Festi M. & Battisti A. (2003): La cimice dei semi americana: unospite indesiderato delle conifere. *Vita in Campagna* 2003: 7–8.

Candian V., Pansa M. G., Briano R., Peano C., Tedeschi R. & Tavella L. (2018): Exclusion nets: a promising tool to prevent *Halyomorpha halys* from damaging nectarines and apples in NW Italy. *Bulletin of Insectology* **71**(1): 21–30.

Çerçi B. & Koçak Ö. (2016): Contribution to the knowledge of Heteroptera (Hemiptera) fauna of Turkey. *Journal of Insect Biodiversity* **4**(15): 1–18.

Cesari M., Maistrello L., Piemontese L., Bonini R., Dioli P., Lee W., Park C.-G., Partsinevelos G. K., Rebecchi L. & & Guidetti R. (2018): Genetic diversity of the Brown Marmorated Stink Bug *Halyomorpha halys* in the invaded territories of Europe and its patterns of diffusion in Italy. *Biological Invasions* **20**(4): 1073–1092.

Chérot F. (1998): Au sujet de *Deraeocoris (s. str.) flavilinea* (Costa, 1862) et de *Deraeocoris (s. str.) ruber* (Linné, 1758) (Insecta, Heteroptera: Miridae). *Lambillionea* **98**(4): 523–529.

Chireceanu C., Teodoru A. & Chiriloaie A. (2017): New records of Oak Lace Bug *Corythucha arcuata* (Say, 1832) (Hemiptera: Tingidae) in Southern Romania. *Acta Zoologica Bulgarica* Supplementum 9: 297–299.

Ciampolini M. & Trematerra P. (1987): Rilievi biologici su *Oxycarenus lavaterae* (F.) (Rhyncota, Heteroptera, Lygaeidae). *Bolletino di Zoologia Agraria e di Bachicoltura* **19**: 187–197.

Ciampolini M., Grossi A. & Zottarelli G. (1987): Danni alla soia per attacchi di *Metcalfa pruinosa*. *Informatore Agrario* **43**(15): 101–103.

Čokl A., McBrien H. L. & Millar J. G. (2001): Comparison of substrate-borne vibrational signals of two stink bug species, *Acrosternum hilare* and *Nezara viridula* (Heteroptera: Pentatomidae). *Annals of the Entomological Society of America* **94**(3): 471–479.

Colombi L. & Brunetti R. (2002): *Rapporto del Servizio Fitosanitario del cantone Ticino 2002.* Servizio Fitosanitario, Bellinzona.

Connelly A. E. & Schowalter T. D. (1991): Seed losses to feeding by *Leptoglossus occidentalis* (Heteroptera: Coreidae) during two periods of second-year cone development in Western White Pine. *Journal of Economic Entomology* **84**(1): 215–217.

Costa A. (1862): *Additamenta ad Centurias Cimicum Regni Neapolitani.* Napoli.

Cunev J. & Kment P. (2017): First record of the plant bug *Deraeocoris flavilinea* (Hemiptera: Heteroptera: Miridae) in Slovakia. *Klapalekiana* **53**: 1–5.

Cuní y Martorell M. (1881): Datos para una flora de los insectos de Cataluña. *Anales de la Sociedad Española de Historia Natural* **10**: 433–461.

Csepelényi M., Hirka A., Mikó Á., Szalai Á. & Csóka Gy. (2017a): A tölgy-csipkéspoloska (*Corythucha arcuata*) 2016/2017-es áttelelése Délkelet-Magyarországon. *Növényvédelem* **78**(7): 285–288.

Csepelényi M., Hirka A., Szénási Á., Mikó Á., Szőcs L. & Csóka Gy. (2017b): Az inváziós tölgy csipkéspoloska [*Corythucha arcuata* (Say, 1832)] gyors terjeszkedése és tömeges fellépése Magyarországon. *Erdészettudományi Közlemények* **7**(2): 127–134.

Csóka Gy. (2017): Egy sikeres, de kevéssé kívánt hódító – az amerikai lepkekabóca. *Méhészújság* 2017 (augusztus): 8–9.

Csóka Gy. & Ambrus A. (2016): Erdei fa- és cserjefajok szerepe a herbivor rovarok fajgazdagságának fenntartásában. *In:* Korda M. (szerk.): *Az erdőgazdálkodás hatása az erdők biológiai sokféleségére.* Tanulmánygyűjtemény. Duna–Ipoly Nemzeti Park Igazgatóság, Budapest: 155–192.

Csóka Gy., Hirka A. & Somlyai M. (2013): A tölgy csipkéspoloska (*Corythuca arcuata* Say, 1832 – Hemiptera, Tingidae) első észlelése Magyarországon. *Növényvédelem* **49**(7): 293–296.

Csóka Gy., Hirka A. & Szőcs L. (2012): Rovarglobalizáció a magyar erdőkben. *Erdészettudományi Közlemények* **2**(1): 187–198.

Csóka Gy., Hirka A., Mutun S., Glavendekić M., Mikó Á., Szőcs L., Paulin M., Eötvös Cs. B., Gáspár Cs., Csepelényi M., Szénási Á., Franjević M., Gninenko Y., Dautbašić M., Muzejinović O., Zúbrik M., Netoiu C., Buzatu A., Bălăcenoiu F., Jurc M., Jurc D., Bernardinelli I., Streito J.-C., Avtzis D. & Hrašovec B. (2020): Spread and potential host range of the invasive Oak Lace Bug [*Corythucha arcuata* (Say, 1832) – Heteroptera: Tingidae] in Eurasia. *Agricultural and Forest Entomology* **22**(1): 61–74.

D'Urso V. (1995): *Homoptera Auchenorrhyncha.* Calderini, Bologna. /Checklist delle specie della fauna italiana 41./

Damos P., Soulopoulou P. & Thomidis T. (2019): Establishment and current status of *Halyomorpha halys* damaging peaches and olives in the prefecture of Imathia in Northern Greece. *In:* Branco M., Franco J. C., Gross J. & Ioriatti C. (eds.): *Working Groups „Pheromones and Other Semiochemicals in Integrated Production" & „Integrated Protection of Fruit Crops". Proceedings of the meeting at/à Lisbon (Portugal), 20–25 January 2019: „Merging pheromones and other semiochemicals with integrated fruit production: current approaches and applications from research to field implementation in a changing environment"*: 111–113.

Dautbašić M., Zahirović K., Mujezinović O. & Margaletić J. (2018): Prvi nalaz hrastove mrežaste stjenice (*Corythucha arcuata*) u Bosni i Hercegovini. *Šumarski List* **142**(3–4): 179–181.

De Bergevin E. (1932): Note à propos de cas d'hybridation constatés entre *Oxycarenus lavaterae* F. et *Oxycarenus hyalinipennis* Costa (Hémiptères Ligæidae) et description d'une nouvelle espèce d'*Oxycarenus* provenant du Sud-tunisien. *Bulletin de la Société d'Histoire Naturelle de l'Afrique du Nord* **23**: 253–256.

Denosmaison J.-C. (2001): Hétéroptères nouveaux pour la région parisienne. *L'Entomologiste* **57**(2): 84.

Derjanschi V. & Mocreac S. N. (2018): Tigrul stejarului *Corythucha arcuata* (Say, 1832) (Heteroptera, Tingidae) – specie nouă invazivă în fauna Republicii Moldova. *Buletin Ştiinţific. Revistă de Etnografie, Ştiinţele Naturii şi Muzeologie (Serie Nouă)* **28/41**/: 30–35.

Dethier M. (1989): Les Pentatomoidea de la collection Kappeller. *Archives des Sciences* **42**(3): 553–568.

DeWitt N. B. & Godfrey G. L. (1972): *The literature of arthropods associated with soybeans. II. A bibliography of the Southern Green Stink Bug Nezara viridula (Linnaeus) (Hemiptera: Pentatomidae).* State of Illinois, Department of Registration and Education, Natural History Survey Division, Urbana. /Biological Notes 78./

Dioli P. (1993): Eterotteri insubrici ed eterotteri xerotermici nei territori perilacustri della Lombardia e del Ticino (Hemiptera, Heteroptera). *Memorie Società Ticinese Scienze Naturali* **4**: 81–86.

Dobreva M., Simov N., Georgiev G., Mirchev P. & Georgieva M. (2013): First record of *Corythucha arcuata* (Say) (Heteroptera: Tingidae) on Balkan Peninsula. *Acta Zoologica Bulgarica* **65**(3): 409–412

Don I., Don C. D., Sasu L. R., Vidrean D. & Brad M. L. (2016): Insect pests on the trees and shrubs from the Macea Botanical Garden. *Studia Universitatis „Vasile Goldiş"* **11**(2): 23–28.

Drekić M., Poljaković-Pajnik L., Milović M., Kovačević B., Pilipović A. & Pap P. (2021): Efficacy of some insecticides for control of Oak Lace Bug (*Corythucha arcuata* Say). *Topola/Poplar* **208**: 21–26.

Drosopoulos S. (1980): Hemipterological studies in Greece. Part II. Homoptera – Auchernorrhyncha, a catalogue of the reported species. *Biologia Gallo-Hellenica* **9**(1): 187–194.

Dutto M. & Bertero M. (2013): Dermatosis caused by *Corythuca ciliata* (Say, 1932) (Heteroptera, Tingidae). Diagnostic and clinical aspects of an unrecognized pseudoparasitosis. *Journal of Preventive Medicine and Hygiene* **54**(1): 57–59.

EPPO Global Database (2022): *Metcalfa pruinosa.* – https://gd.eppo.int

Esquivel J. F., Musolin D. L., Jones W. A., Rabitsch W., Greene J. K., Toews M. D., Schwertner C. F., Grazia J. & McPherson R. M. (2018): *Nezara viridula* (L.). *In:* McPherson J. E. (ed.): *Invasive stink bugs and related species (Pentatomoidea): biology, higher systematics, semiochemistry, and management.* CRC Press, Boca Raton: 351–423.

Fabricius I. C. (1775): *Systema entomologiae, sistens insectorum classes, ordines, genera, species, adjectis synonymis, locis, descriptionibus, observationibus.* Officina Libraria Kortius, Flensburg – Lipsia.

Fabricius I. C. (1787): *Mantissa insectorum sistens species nuper detectas adiectis synonymis, observationibus, descriptionibus, emendationibus.* Tom. II. Christ. Gottl. Proft, Hafnia.

Fabricius J. C. (1798): *Supplementum entomologiae systematicae.* Proft et Storch, Hafnia.

Faúndez E. I., Rocca J. R. & Villablanca J. (2017): Detection of the invasive Western Conifer Seed Bug *Leptoglossus occidentalis* Heidemann, 1910 (Heteroptera: Coreidae: Coreinae) in Chile. *Arquivos Entomolóxicos* **17**: 317–320.

Fent M. & Kment P. (2011): First record of the invasive Western Conifer Seed Bug *Leptoglossus occidentalis* (Heteroptera: Coreidae) in Turkey. *North-Western Journal of Zoology* **7**(1): 72–80.

Ferrari A., Schwertner C. F. & Grazia J. (2010): Review, cladistic analysis and biogeography of *Nezara* Amyot & Serville (Hemiptera: Pentatomidae). *Zootaxa* **2424**(1): 1–41.

Fieber F. X. (1852): Rhynchotographien. *Abhandlungen der Königlichen Böhmischen Gesellschaft der Wissenschaften (Fünfter Folge)* **7**: 427–488.

Forster B., Giacalone I., Moretti M., Dioli P. & Wermelinger B. (2005): Die amerikanische Eichennetzwanze *Corythucha arcuata* (Say) (Heteroptera, Tingidae) hat die Südschweiz erreicht. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* **78**(3–4): 317–323.

Frey-Gessner E. (1863): Zusammenstellung der durch Herrn Meyer-Dürr im Frühling im Tessin und Anfang Sommer 1863 im Ober-Engadin beobachteten und gesammelten Hemiptern und Orthoptern. *Mittheilungen der Schweizerischen Entomologischen Gesellschaft* **1**(5): 150–154.

Gall W. K. (1992): Further eastern range extension and host records for *Leptoglossus occidentalis* (Heteroptera: Coreidae): well-documented dispersal of a household nuisance. *The Great Lakes Entomologist* **25**(3): 159–171.

Gapon D. A. (2012): First records of the Western Conifer Seed Bug *Leptoglossus occidentalis* Heid. (Heteroptera, Coreidae) from Russia and Ukraine, regularities in its distribution and possibilities of its range expansion in the Palaearctic Region. *Entomological Review* **93**(2): 174–181.

Gariepy T. D., Bruin A., Haye T., Milonas P. & Vétek G. (2015): Occurrence and genetic diversity of new populations of *Halyomorpha halys* in Europe. *Journal of Pest Science* **88**(3): 451–460.

Gariepy T. D., Haye T., Fraser H. & Zhang J. (2014): Occurrence, genetic diversity, and potential pathways of entry of *Halyomorpha halys* in newly invaded areas of Canada and Switzerland. *Journal of Pest Science* **87**(1): 17–28.

Gariepy T. D., Musolin D. L., Konjević A., Karpun N. N., Zakharchenko V. Y., Zhuravleva E. N., Tavella L., Bruin A. & Haye T. (2021): Diversity and distribution of cytochrome oxidase I (COI) haplotypes of the Brown Marmorated Stink Bug, *Halyomorpha halys* Stål (Hemiptera, Pentatomidae), along the eastern front of its invasive range in Eurasia. *NeoBiota* **68**: 53–77.

Gessé F. (2011): Heterópteros terrestres (Hemiptera: Heteroptera) de Castelldefels (Barcelona, Cataluña, noreste de la Península Ibérica). *Heteropterus Revista de Entomología* **11**(2): 245–256.

Gil F. & Grosso-Silva J. M. (2021): *Corythucha arcuata* (Say, 1832) (Hemiptera: Tingidae), new species for the Iberian Peninsula. *Arquivos Entomolóxicos* **24**: 307–308.

Gillerfors G. & Coulianos C.-C. (2005): Fynd av för Sverige nya och sällsynta skinnbaggar (Hemiptera Heteroptera). *Entomologisk Tidskrift* **126**(4): 215–223.

Girolami V. & Camporese P. (1994): Prima moltiplicazione in Europa di *Neodryinus typhlocybae* (Ashmead) (Hymenoptera: Dryinidae) su *Metcalfa pruinosa* (Say) (Homoptera: Flatidae). *In: Atti XVII Congresso Nazionale Italiano di Entomologia. Udine, 13–18 giugno 1994.* Arti Grafiche Friulane, Udine: 655–658.

Girolami V. & Mazzon L. (1999): Controllo di *Metcalfa pruinosa* ad opera di *Neodryinus typhlocybae. L'Informatore Agrario* **55**(19): 87–91.

Girolami V., Conte L., Camporese, P., Benuzzi M., Rota Martir G. & Dradi D. (1996): Possibilità di controllo biologico della *Metcalfa pruinosa. L'Informatore Agrario* **52**(25): 61–65.

Gjonov I. & Shishiniova M. (2014): Alien Auchenorryncha (Insecta, Hemiptera: Fulgoromorpha and Cicadomorpha) to Bulgaria. *Bulgarian Journal of Agricultural Science* **20** (Supplement 1): 151–156.

Glavendekić M. & Vuković Bojanović V. (2017): Prvi nalaz hrastove mrežaste stenice *Corythucha arcuata* (Say.) (Hemiptera: Tingidae) u Bosni i Hercegovini i novi nalazi u Srbiji. *In:* Glavendekić M. (ured.): *XI Simpozijum entomologa Srbije 2017 sa međunarodnim učešćem. Zbornik rezimea. Nastavna baza „Goč", 17–21. septembar 2017.* Entomološko Društvo Srbije, Beograd: 70–71.

Gninenko Yu., Kostyukov V. V. & Kosheleva O. V. (2011): Novye invazivnye nasekomye v lesakh i ozelenitelnykh posadkakh Krasnodarskogo kraya. *Zashchita i Karantin Rasteniy* **4**: 49–50.

Gogala A. (2003): Listonožka (*Leptoglossus occidentalis*) že v Sloveniji (Heteroptera: Coreidae). *Acta Entomologica Slovenica* **11**(2): 189–190.

Gogala A. (2006): Heteroptera of Slovenia, III: Miridae. *Annales, Anali za Istrske in Mediteranske Študije, Series Historia Naturalis* **16**(1): 77–112.

Gotlin Čuljak T., Ostojić I., Skelin I., Grubišić D. & Jelovčan S. (2007): *Metcalfa pruinosa* (Say, 1830) (Homoptera: Flatidae) potencijalno opasan štetnik u novim područjima. *Entomologia Croatica* **11**(1–2): 75–81.

Goula M., Espinosa M., Eritja R. & Aranda C. (1999): *Oxycarenus lavaterae* (Fabricius, 1787) en Cornellà de Llobregat (Barcelona, España) (Heteroptera, Lygaeidae). *Bulletin de la Société Entomologique de France* **104**(1): 39–43.

Göllner-Scheiding U. (1991): Neufunde von Heteropteren für den östlichen Teil Deutschlands (Insecta, Heteroptera: Miridae et Microphysidae). *Faunistische Abhandlungen des Staatlichen Museum für Tierkunde Dresden* **18**: 91–92.

Grozea I., Gogan A., Virteiu A. M., Grozea A., Stef R., Molnar L., Carabet A. & Dinnesen S. (2011): *Metcalfa pruinosa* Say (Insecta: Homoptera: Flatidae): A new pest in Romania. *African Journal of Agricultural Research* **6**(27): 5870–5877.

Grozea I., Ştef R., Virteiu A. M., Cărăbeţ A. & Molnar L. (2012): Southern Green Stink Bugs (*Nezara viridula* L.) a new pest of tomato crops in western Romania. *Research Journal of Agricultural Science* **44**(2): 24–27.

Günthart H. (1980): Neuer Fundort und neuer Name für die altbekannte Büffelzikade *„Ceresa bubalus"* (Hom. Auch. Membracidae). *Mitteilungen der Entomologischen Gesellschaft Basel (N. F.)* **30**(3): 105–109.

Hahn C. W. (1835): *Die wanzenartigen Insekten. Getreu nach der Natur abgebildet und beschrieben*. Dritter Band. C. H. Zeh'schen Buchhandlung, Nürnberg.

Hamilton G. C., Ahn J. J., Bu W., Leskey T. C., Nielsen A. L., Park Y.-L., Rabitsch W. & Hoelmer K. A. (2018): *Halyomorpha halys* (Stål). *In:* McPherson J. E. (ed.): *Invasive stink bugs and related species (Pentatomoidea): biology, higher systematics, semiochemistry, and management.* CRC Press, Boca Raton: 243–292.

Hancock T. J., Lee D.-H., Bergh J. C., Morrison W. R. & Leskey T. C. (2019): Presence of the invasive Brown Marmorated Stink Bug *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) on home exteriors during the autumn dispersal period: Results generated by citizen scientists. *Agricultural and Forest Entomology* **21**(1): 99–108.

Hanselmann D. (2017): Aliens and citizens in Germany: *Halyomorpha halys* (Stål, 1855) and *Nezara viridula* (Linnaeus, 1758) new to Rhineland-Palatinate, *Oxycarenus lavaterae* (Fabricius, 1787) new to Saxony, *Arocatus longiceps* Stål, 1872 new to Hesse. *Mainzer Naturwissenschaftliches Archiv* **53**: 159–177.

Harmat B., Kondorosy E. & Rédei D. (2006): A nyugati levéllábú poloska (*Leptoglossus occidentalis* Heidemann) első magyarországi megjelenése (Heteroptera: Coreidae). *Növényvédelem* **42**(9): 491–494.

Hebda G. & Olbrycht T. (2016): *Oxycarenus lavaterae* (Fabricius, 1787) (Hemiptera: Heteroptera: Oxycarenidae) – gatunek nowy dla fauny Polski. *Wiadomości Entomologiczne* **35**(3): 133–136.

Hedlin A. F., Yates H. O., Tovar D. C., Ebel B. H., Koerber T. W. & Merkel E. P. (1981): *Cone and seed insects of North American conifers*. 2nd print. Canadian Forestry Service, Pacific Forestry Centre – United States Forest Service – Secretaría de Agricultura y Recursos Hidráulicos, Victoria – México.

Hemala V. & Kment P. (2017): First record of *Halyomorpha halys* and mass occurrence of *Nezara viridula* in Slovakia. *Plant Protection Science* **53**(4): 247–253.

Hirka A. (1991): Bükk, luc és kocsánytalan tölgy éves kerületnövekedési menetének vizsgálata. *Erdészeti Kutatások* **82–83**(2): 15–23.

Hoffrichter O. & Tröger E. J. (1973): *Ceresa bubalus* F (Homoptera: Membracidae) – Beginn der Einwanderung in Deutschland. *Mitteilungen des Badischen Landesvereins für Naturkunde und Naturschutz (N. F.)* **11**(1): 33–43.

Holzinger W. E., Kammerlander I. & Nickel H. (2003): *The Auchenorrhyncha of Central Europe.* Volume 1. Fulgoromorpha, Cicadomorpha excl. Cicadellidae. Koninklijke Brill NV, Leiden – Boston.

Hornok S. & Kontschán J. (2017): The Western Conifer Seed Bug (Hemiptera: Coreidae) has the potential to bite humans. *Journal of Medical Entomology* **54**(4): 1073–1075.

Horváth G. (1912): Az amerikai bivalykabócza Magyarországon. *Rovartani Lapok* **19**(10–12): 145–147.

Hrašovec B., Posarić D., Lukić I. & Pernek M. (2013): Prvi nalaz hrastove mrežaste stjenice (*Corythucha arcuata*) u Hrvatskoj. *Šumarski List* **137**(9–10): 499–503.

İpekdal K., Oğuzoğlu Ş., Oskay F., Aksu Y., Lehtijärvi H. T. D., Lehtijärvi A. T., Can T., Aday Kaya A. G., Özçankaya M. & Avci M. (2019): *Çam kozalak emici böceği Leptoglossus occidentalis Heidemann (1910) (Hemiptera: Coreidae): Türkiye ve Dünyadaki Son Durum.* Orman Genel Müdürlüğü Matbaası, Ankara.

Ishikawa T. & Kikuhara Y. (2009): *Leptoglossus occidentalis* Heidemann (Hemiptera: Coreidae), a presumable recent invader to Japan. *Japanese Journal of Entomology (New Series)* **12**(3): 115–116.

Izri A., Andriantsoanirina V., Chosidow O. & Durand R. (2015): Dermatosis caused by blood-sucking *Corythucha ciliata*. *JAMA Dermatology* **151**(8): 909–910.

Janský V., Krištín A. & Okáli I. (1988): Der gegenwärtige Stand der Verbreitung und neue Erkenntnisse über die Bionomie der Art *Stictocephala bisonia* (Homoptera, Membracidae) in der Slowakei. *Biológia (Bratislava)* **43**(6): 527–533.

Járó Z. & Tátraaljai E.-né (1985): A fák éves növekedése. *Erdészeti Kutatások* **76–77**: 221–234.

Jerinić-Prodanović D. & Protić L. (2011): New data on true bug predators (Heteroptera: Miridae) of jumping plant-lice (Sternorrhyncha: Psylloidea) in Serbia. *Acta Entomologica Serbica* **16**(1–2): 143–146.

Jermini M., Bonavia M., Brunetti R., Mauri G. & Cavalli V. (1995): *Metcalfa pruinosa* Say, *Hyphantria cunea* (Drury) et *Dichelomyia oenophila* Haimah., trois curiosités entomologiques ou trois nouveaux problèmes phytosanitaires pour le Tessin et la Suisse? *Revue Suisse de Viticulture Arboriculture Horticulture* **27**(1): 57–63.

Jones W. A. & Sullivan M. J. (1983): *Seasonal abundance and relative importance of stink bugs insoybean.* South CarolinaAgricultural Experiment Station – Clemson University, Clemson. /S. C. Agricultural Experiment Station Technical Bulletin 1087./

Jurc M. & Jurc D. (2017): The first record and the beginning the spread of Oak Lace Bug, *Corythucha arcuata* (Say, 1832) (Heteroptera: Tingidae), in Slovenia. *Šumarski List* **141**(9–10): 485–488.

Kalushkov P. (2000): Observations on the biology of *Oxycarenus lavaterae* (Fabricius) (Heteroptera: Lygaeidae), a new Mediterranean species in the Bulgarian fauna. *Acta Zoologica Bulgarica* **52**(1): 13–15.

Kalushkov P. & Nedvěd O. (2010): Suitability of food plants for *Oxycarenus lavaterae* (Heteroptera: Lygaeidae), a Mediterranean bug invasive in Central and South-East Europe. *Comptes Rendus de l'Académie Bulgare des Sciences* **63**(2): 271–276.

Kalushkov P., Simov N. & Tzankova R. (2007): Laboratory and field investigation on the biology of *Oxycarenus lavaterae* (Fabricius) (Heteroptera: Lygaeidae) in Bulgaria. *Acta Zoologica Bulgarica* **59**(2): 217–219.

Kavar T., Pavlovčič P., Sušnik S., Meglič V. & Virant-Doberlet M. (2006): Genetic differentiation of geographically separated populations of the Southern Green Stink Bug *Nezara viridula* (Hemiptera: Pentatomidae). *Bulletin of Entomological Research* **96**(2): 117–128.

Kawada H. & Kitamura C. (1983): The reproductive behavior of the Brown Marmorated Stink Bug, *Halyomorpha mista* Uhler (Heteroptera: Pentatomidae). I. Observation of mating behavior and copulation. *Applied Entomology and Zoology* **18**(2): 234–242.

Kennedy C. E. J. & Southwood T. R. E. (1984): The number of species of insects associated with British trees: a re-analysis. *Journal of Animal Ecology* **53**(2): 455–478.

Keszthelyi S. & Vanyúr Gy. (2012): Az amerikai lepkakabóca (*Metcalfa pruinosa* Say, 1830) kártétele kukoricában. *Növényvédelem* **48**(9): 429–431.

Kirichenko A. N. (1951): *Nastoyashchiye poluzhestkokrylye Jevropeyskoy chasti SSSR (Hemiptera). Opredelitel i bibliografiya.* Izdatelstvo Akagemii Nauk SSSR, Moskva – Leningrad / Opredeliteli po faune SSSR 42./

Kiss B., Karap A., Kis A. & Szita É. (2013): Az amerikai lepkekabóca (*Metcalfa pruinosa*) és a tujakabóca (*Liguropia juniperi*) előfordulása hazai autópálya pihenőhelyeken. *Növényvédelem* **49**(12): 571–575.

Kiyak S. (2020): The first record of *Deraeocoris flavilinea* (A. Costa, 1862) (Hemiptera: Heteroptera: Miridae) as an Invasive Alien Species (IAS) in the Anatolian Peninsula (Turkey). *Journal of the Heteroptera of the Turkey* **2**(2): 69–74.

Kment P. (2009): *Oxycarenus lavaterae*, an expansive species new to Romania (Hemiptera: Heteroptera: Oxycarenidae). *Acta Musei Moraviae, Scientiae Biologicae* **94**: 23–25.

Kment P., Bryja J., Hradil K. & Jindra Z. (2005): New and interesting records of true bugs (Heteroptera) from the Czech Republic and Slovakia III. *Klapalekiana* **41**(3–4): 157–213.

Kment P., Vahala O. & Hradil K. (2006): First record of *Oxycarenus lavaterae* (Heteroptera: Oxycarenidae) from the Czech Republic, with review of its distribution and biology. *Klapalekiana* **42**(1–3): 97–127.

Knight K. M. M. & Gurr G. M. (2007): Review of *Nezara viridula* (L.) management strategies and potential for IPM in field crops with emphasis on Australia. *Crop Protection* **26**(1): 1–10.

Kóbor P. (2017): Magyarország invazív címerespoloskái (Heteroptera: Pentatomidae). *Növényvédelem* **78**(11): 491–496.

Kóbor P., Kondorosy E. & Markó V. (2022): *Almaültetvények poloskanépessége – előzetes eredmények.* II. Debreceni Alkalmazott Rovartani Konferencia, 2022. április 7., Debrecen.

Koerber T. W. (1963): *Leptoglossus occidentalis* (Hemiptera, Coreidae), a newly discovered pest of coniferous seed. *Annals of the Entomological Society of America* **56**(1): 229–234.

Kondorosy E. (1995): Az *Oxycarenus lavaterae* bodobácsfaj (Heteroptera: Lygaeidae) hazai megjelenése. *Folia Entomologica Hungarica* **56**: 237–238.

Kondorosy E., Markó V. & Cross J. V. (2010): Heteropteran fauna of apple orchards in South-East England. *Acta Phytopathologica et Entomologica Hungarica* **45**(1): 173–193.

Kontkanen P. (1956): Kokousselostuksia 29. XI. 1956. *Suomen Hyönteistieteellinen Aikakauskirja* **22**(4): 185–188.

Kovač M., Gorczak M., Wrzosek M., Tkaczuk C. & Pernek M. (2020): Identification of entomopathogenic fungi as naturally occurring enemies of the invasive Oak Lace Bug, *Corythucha arcuata* (Say) (Hemiptera: Tingidae). *Insects* **11**(10): 679.

Kovač M., Linde A., Lacković N., Bollmann F. & Pernek M. (2021): Natural infestation of entomopathogenic fungus *Beauveria pseudobassiana* on overwintering *Corythucha arcuata* (Say) (Hemiptera: Tingidae) and its efficacy under laboratory conditions. *Forest Ecology and Management* **491**: 119193.

Krištín A., Jansky V. & Okáli I. (1987): Is *Stictocepbata bisonia* (Membracidae) an invasion species? *In:* Vidano C. & Arzone A. (eds.): *Proceedings of the 6th Auchenorryncha Meeting, 7–11 Sept. 1987, Turin, Italy.* Consiglio Nazionale Delle Ricerche, Torino: 417–424.

Lallemand V. (1920): Un Membracide (Hem.) nouveau pour la faune française. *Bulletin de la Société Entomologique de France* **25**(3): 53.

Lauterer P. (1995): Ostnohřbetka *Stictocephala bisonia* nový škůdce na Moravě. *Rostlinolékař* **6**(1): 17.

Lee H.-S. & Wilson S. W. (2010): First report of the Nearctic flatid planthopper *Metcalfa pruinosa* (Say) in the Republic of Korea (Hemiptera: Fulgoroidea). *Entomological News* **121**(5): 506–513.

Lesieur V., Lombaert E., Guillemaud T., Courtial B., Strong W., Roques A. & Auger-Rozenberg M.-A. (2018): The rapid spread of *Leptoglossus occidentalis* in Europe: a bridgehead invasion. *Journal of Pest Science* **92**(2): 189–200.

Leskey T. C. & Nielsen A. L. (2018): Impact of the invasive Brown Marmorated Stink Bug in North America and Europe: history, biology, ecology, and management. *Annual Review of Entomology* **63**: 599–618.

Lindberg H. (1932): Inventa entomologica itineris Hispanici et Maroccani, quod a. 1926 fecerunt Harald et Hakan Lindberg. XIII. Hemiptera Heteroptera (excl. Capsidae et Hydrobiotica). *Commentationes Biologicae (Societas Scientiarum Fennica)* **3**(19): 1–53.

Lindberg H. (1953): Hemiptera Insularum Canariensium (Systematik, Ökologie und Verbreitung der Kanarischen Heteropteren und Cicadinen). *Commentationes Biologicae (Societas Scientiarum Fennica)* **14**(1): 1–304.

Linnæus C. (1758): *Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis.* Tomus I. Editio decima, reformata. Laurentius Salvius, Holmia.

Lis J. A., Lis B. & Gubernator J. (2008): Will the invasive Western Conifer Seed Bug *Leptoglossus occidentalis* Heidemann (Hemiptera: Heteroptera: Coreidae) seize all of Europe? *Zootaxa* **1740**: 66–68.

Macavei L. I., Bâețan R., Oltean I., Florian T., Varga M., Costi E. & Maistrello L. (2015): First detection of *Halyomorpha halys* Stål, a new invasive species with a high potential of damage on agricultural crops in Romania. *Lucrări Științifice (Seria Agronomi)* **58**(1): 105–108.

Maistrello L., Dioli P., Vaccari G., Nannini R., Bortolotti P., Caruso S., Costi E., Montermini A., Casoli L. & Bariselli M. (2014): Primi rinvenimenti in Italia della cimice esotica *Halyomorpha halys*, una nuova minaccia per la frutticoltura. *ATTI Giornate Fitopatologiche* **1**: 283–288.

Malipatil M. B. (1979): The biology of some Lygaeidae (Hemiptera: Heteroptera) of south-east Queensland. *Australian Journal of Zoology* **27**(2): 231–249.

Malumphy C. (2014): Second interception of *Halyomorpha halys* (Stål)) (Hemiptera: Pentatomidae) in Britain. *Het News (3rd series)* **21**: 4–5.

Malumphy C. & Reid S. (2007): Non-native Heteroptera associated with imported plant material in England during 2006 & 2007. *Het News (2nd Series)* **10**: 2–4.

Marshall S. A. (1991): A new Ontario record of a seed eating bug (Hemiptera: Coreidae) and other examples of the role of regional insect collections in tracking changes to Ontario's fauna. *Proceedings of the Entomological Society of Ontario* **122**: 109–111.

Mas H., Naya M., Pérez-Laorga E., Aguado A., Marco M., Aragoneses J. & Rodrigo E. (2013): Estudio del ciclo biológico de *Leptoglossus occidentalis* Heidemann, 1910 (Hemiptera, Coreidae) en la Comunitat Valenciana. *In: 6º Congreso Forestal Español. Montes: Servicios desarrollo rural, 10–14 junio 2013, Vitoria-Gasteiz.* Sociedad Española de Ciencias Forestales, Vitoria-Gasteiz: 1–13.

Matošević D. & Pernek M. (2011): Strane i invazivne vrste fitofagnih kukaca u šumama hrvatske i procjena njihove štetnosti. *Šumarksi List* **135**(13): 264–271.

McPherson J. E., Packauskas R. J., Taylor S. J. & O'Brien M. F. (1990): Eastern range extension of *Leptoglossus occidentalis* with a key to *Leptoglossus* species of America north of Mexico (Heteroptera: Coreidae). *The Great Lake Entomologist* **23**(2): 99–104.

Mertelík J. & Liška J. (2020): Faunistic records from the Czech Republic – 495. Hemiptera: Heteroptera: Tingidae. *Klapalekiana* **56**(1–2): 295–296.

Mihajlović Lj. (2007): *Metcalfa pruinosa* (Say) (Homoptera: Auchenorrhyncha) nova štetna vrsta za entomofaunu Srbije. *Glasnik Šumarskog Fakulteta, Beograd* **95**: 127–134.

Miller D. J. P. (2001): *Deraeocoris flavilinea* (A. Costa) (Hemiptera: Miridae), new to Britain. *British Journal of Entomology and Natural History* **14**(3): 133–136.

Milonas P. G. & Partsinevelos G. K. (2014): First report of Brown Marmorated Stink Bug *Halyomorpha halys* Stål (Hemiptera: Pentatomidae) in Greece. *EPPO Bulletin* **44**(2): 183–186.

Mitchell R. J., Bellamy P. E., Ellis C. J., Hewison R. L., Hodgetts N. G., Iason G. R., Littlewood N. A., Newey S., Stockan J. A. & Taylor A. F. S. (2019): Collapsing foundations: The ecology of the British oak, implications of its decline and mitigation options. *Biological Conservation* **233**: 316–327.

Mitchell W. C. & Mau R. F. L. (1971): Response of the female Southern Green Stink Bug and its parasite, *Trichopoda pennipes*, to male stink bug pheromones. *Journal of Economic Entomology* **64**(4): 856–859.

Mjøs A. T., Nielsen T. R. & Ødegaard F. (2010): The Western Conifer Seed Bug (*Leptoglossus occidentalis* Heidemann, 1910) (Hemiptera, Coreidae) found in SW Norway. *Norwegian Journal of Entomology* **57**(1): 20–22.

Morrison W. R., Blaauw B. R., Short B. D., Nielsen A. L., Bergh J. C., Krawczyk G., Park Y-L., Butler B., Khirmian A. & Leskey T. C. (2019): Successful management of *Halyomorpha halys* (Hemiptera: Pentatomidae) in commercial apple orchards with an attract-and-kill strategy. *Pest Management Science* **75**(1): 104–114.

Musolin D. L. & Numata H. (2003): Timing of diapause induction and its life-history consequences in *Nezara viridula*: is it costly to expand the distribution range? *Ecological Entomology* **28**(6): 694–703.

Musolin D. L., Fujisaki K. & Numata H. (2007): Photoperiodic control of diapause termination, colour change and postdiapause reproduction in the Southern Green Stink Bug, *Nezara viridula*. *Physiological Entomology* **32**(1): 64–72.

Mutun S. (2003): First report of the Oak Lace Bug, *Corythucha arcuata* (Say, 1832) (Heteroptera:

Tingidae) from Bolu, Turkey. *Israel Journal of Zoology* **49**(4): 323–324.

Mutun S., Ceyhan Z. & Sözen C. (2009): Invasion by the Oak Lace Bug, *Corythucha arcuata* (Say) (Heteroptera: Tingidae), in Turkey. *Turkish Journal of Zoology* **33**(3): 263–268.

Nagy A., Szanyi K., Szalárdi T. & Szanyi Sz. (2021): First record, new cultivated host and host plant preference of the invasive Oak Lace Bug (*Corythucha arcuata* Say, 1832) (Heteroptera: Tingidae) in Transcarpathia (West Ukraine). *Silva Balcanica* **22**(3): 41–48.

Nast J. (1987): The Auchenorrhyncha (Homoptera) of Europe. *Annales Zoologici* **40**(15): 535–661.

Nedvěd O., Chehlarov E. & Kalushkov P. (2014): Life history of the invasive bug *Oxycarenus lavaterae* (Heteroptera: Oxycarenidae) in Bulgaria. *Acta Zoologica Bulgarica* **66**(2): 203–208.

Neimorovets V. V., Shchurov V. I., Bondarenko A. S., Skvortsov M. M. & Konstantinov F. V. (2017): First documented outbreak and new data on the distribution of *Corythucha arcuata* (Say, 1832) (Hemiptera: Tingidae) in Russia. *Acta Zologica Bulgarica* Supplementum 9: 139–142.

Neimorovets V. V., Shchurov V. I. & Zamotajlov A. S. (2020): Report on findings of *Oxycarenus lavaterae* (Fabricius, 1787) (Heteroptera, Lygaeidae) in Russia. *Entomological Review* **100**(4): 521–528.

Nemer N. (2015): *Report on insect pests associated with conelet losses and their management in Pinus pinea forests in Lebanon*. FAO, *sine loco.*

Nemer N., El Khoury Y., Noujeim E., Zgheib Y., Tarasco E. & van der Heyden T. (2019): First records of the invasive species *Leptoglossus occidentalis* Heidemann (Hemiptera: Coreidae) on different coniferous species including the cedars of Lebanon. *Revista Chilena de Entomología* **45**(4). 507–513.

Nickel H. (2016): Die nearktische Bläulingszikade *Metcalfa pruinosa* (Say, 1830) nun auch in Deutschland und der Nordschweiz. *Entomo Helvetica* **9**: 129–136.

Nielsen A. L., Hamilton G. C. & Matadha D. (2008): Developmental rate estimation and life table analysis for *Halyomorpha halys* (Hemiptera: Pentatomidae). *Environmental Entomology* **37**(2): 348–355.

Nikolić N., Pilipović A., Drekić M., Kojić D., Poljaković-Pajnik L., Orlović S. & Arsenov D. (2019): Physiological responses of Pedunculate Oak (*Quercus robur* L.) to *Corythucha arcuata* (Say, 1832) attack. *Archives of Biological Sciences* **71**(1): 167–176.

Oğuzoğlu Ş. & Avci M. (2020): Türkiye'de *Leptoglossus occidentalis* Heidemann, 1910 (Hemiptera: Coreidae) üzerine biyolojik gözlemler, parazitoitleri ve yayılışına katkılar. *Ormancılık Araştırma Dergisi* **7**(1): 9–21.

Okali I. (1974): *Stictocephala bubalus* (Fabricius, 1794) (Homoptera, Membracidae) – eine neue Art für die Fauna der Tschechoslowakei. *Acta Rerum Naturalium Musei Nationalis Slovacae* **20**: 257–258.

Pansa M. G., Asteggiano L., Costamagna C., Vittone G. & Tavella L. (2013): Primo ritrovamento di *Halyomorpha halys* nei pescheti piemontesi. *Informatore Agrario* **69**(37): 60–61.

Pap P., Drekić M., Poljaković-Pajnik L., Marković M. & Vasić V. (2015): Monitoring zdravstvenog stanja šuma na teritoriji Vojvodine u 2015. godini. *Topola* **195–196**: 117–133.

Paulin M., Hirka A., Csepelényi M., Fürjes-Mikó Á., Tenorio-Baigorria I., Eötvös Cs., Gáspár Cs. & Csóka Gy. (2021): Overwintering mortality of the Oak Lace Bug (*Corythucha arcuata*) in Hungary – a field survey. *Central European Forestry Journal* **67**(2): 108–112.

Paulin M., Hirka A., Eötvös Cs. B., Gáspár Cs., Fürjes-Mikó Á. & Csóka Gy. (2020a): Known and predicted impacts of the invasive Oak Lace Bug (*Corythucha arcuata*) in European oak ecosystems – a review. *Folia Oecologica* **47**(2): 131–139.

Paulin M., Hirka A., Mikó Á., Tenorio-Baigorria I., Eötvös Cs., Gáspár Cs. & Csóka Gy. (2019): Tölgycsipkéspoloska – helyzetjelentés 2019 őszén. *In:* Csiha I. & Csiha S. (szerk.): *Alföldi Erdők Egyesület Kutatói Nap. Tudományos eredmények a gyakorlatban. Lakitelek 2019.* Alföldi Erdőkért Egyesület, Kecskemét: 110–119.

Paulin M., Hirka A., Mikó Á., Tenorio-Baigorria I., Eötvös Cs., Gáspár Cs. & Csóka Gy. (2020b): A tölgy-csipkéspoloska Magyarországon – helyzetkép 2019 őszén. *Növényvédelem* **81**(6): 245–250.

Pénzes B. (2004): Újabb kártevő kabóca Magyarországon. *Kertészet és Szőlészet* **53**(35): 16–17.

Pénzes B. & Hári K. (2016): Az amerikai lepkekabóca (*Metcalfa pruinosa* Say). *Agrofórum* **27**(3): 56–60.

Péricart J. (1965): Contribution a la faunistique de la Corse: Hétéroptères Miridae et Anthocoridae (Hem.). *Bulletin Mensuel de la Societe Linnéenne de Lyon* **34**(9): 377–384.

Péricart J. (1998): *Hémiptères Lygaeidae euro-méditerranéens.* Volume 2. *Systématique: seconde partie. Oxycareninae, Bledionotinae, Rhyparochrominae (1).* Fédération Française des Sociétés de Sciences Naturelles, Paris. /*Faune de France et régiones limitrophes* 84 B/

Péricart J. (2001): Family Lygaeidae Schilling, 1829 – Seed-bugs. *In:* Aukema B. & Rieger C. (eds.): *Catalogue of the Heteroptera of the Palaearctic Region.* Volume 4. *Pentatomomorpha I.* The Netherlands Entomological Society, Amsterdam: 35–220.

Peverieri G. S., Talamas E., Bon M. C., Marianelli L., Bernardinelli I., Malossini G., Benvenuto L., Roversi P. F. & Hoelmer K. (2018): Two Asian egg parasitoids of *Halyomorpha halys* (Stål) (Hemiptera, Pentatomidae) emerge in northern italy: *Trissolcus mitsukurii* (Ashmead) and *Trissolcus japonicus* (Ashmead) (Hymenoptera, Scelionidae). *Journal of Hymenoptera Research* **67**: 37–53.

Poljaković-Pajnik L., Drekić M., Pilipović A., Nikolić N., Pap P., Vasić V. & Marković M. (2015): Pojava velikih šteta od *Corythucha arcuata* (Say) (Heteroptera: Tingidae) u šumama hrasta u Vojvodini. *In: XIII Savetovanje o Zaštiti Bilja. Zbornik rezimea radova. 23–26. novembar 2015. godine, Zlatibor.* Društvo za Zaštitu Bilja Srbije, Beograd: 63.

Ponce-Herrero L., Farinha A. O., Fernández V. P., Pajares Alonso J. A. & Alves Santos F. M. (2022): Native egg parasitoids on *Leptoglossus occidentalis* Heidemann (Hemiptera: Coreidae) in Spain: Potential biological control agents? *Journal of Applied Entomology* **146**(5): 525–538.

Protić Lj. & Stojanović A. (2001): *Oxycarenus lavaterae* (Fabricius, 1787) (Heteroptera: Lygaeidae) još jedna nova u entomofauni Srbije. *Zaštita Prirode* **52**(2): 61–63.

Putchkov P. V. (2013): Invasive true bugs (Heteroptera) established in Europe. *Ukrainskiy Entomologichniy Zhurnal* 2013 (2): 11–28.

Puttler B., Bailey W. C. & Triapitsyn S. V. (2014): Notes on distribution, host associations, and bionomics of *Erythmelus klopomor* Triapitsyn (Hymenoptera, Mymaridae), an egg parasitoid of lace bugs in Missouri, USA, with particular reference to its primary host *Corythucha arcuata* (Say) (Hemiptera, Tingidae). *Journal of Entomological and Acarological Research* **46**(1): 30–34.

Rabitsch W. (2002): *Deraeocoris flavilinea* (A. Costa, 1862) erstmals in Österreich festgestellt (Heteroptera: Miridae). *Beiträge zur Entomofaunistik* **3**: 181–183.

Rabitsch W. (2008): Alien true bugs of Europe (Insecta: Hemiptera: Heteroptera). *Zootaxa* **1827**(1): 1–44.

Rabitsch W. & Adlbauer K. (2001): Erstnachweis und bekannte Verbreitung von *Oxycarenus lavaterae* (Fabricius, 1787) in Österreich (Heteroptera: Lygaeidae). *Beiträge zur Entomofaunistik* **2**: 49–54.

Rabitsch W. & Friebe G. J. (2015): From the west and from the east? First records of *Halyomorpha halys* (Stål, 1855) (Hemiptera: Heteroptera: Pentatomidae) in Vorarlberg and Vienna (Austria). *Beiträge zur Entomofaunistik* **16**: 126–129.

Rédei D. & Torma A. (2003): Occurrence of the Southern Green Stink Bug, *Nezara viridula* (Heteroptera: Pentatomidae) in Hungary. *Acta Phytopathologica et Entomologica Hungarica* **38**(3): 365–367.

Rédei D. & Vétek G. (2005): Tömegesen károsít a vándorpoloska Budapesten. *Kertészet és Szőlészet* **54**(43): 10.

Reichensperger A. (1922): Rheinlands Hemiptera heteroptera. I. *Verhandlungen des Naturhistorischen Vereins der Preußischen Rheinlande und Westfalens* **77**: 35–77.

Ribes J., Piñol J., Espadaler X. & Cañellas N. (2004a): Heterópteros de un cultivo ecológico de cítricos de Tarragona (Cataluña, NE España) (Hemiptera: Heteroptera). *Orsis* **19**: 21–35.

Ribes J., Serra A. & Goula M. (2004b): *Catàleg dels heteròpters de Catalunya (Insecta, Hemiptera, Heteroptera).* Institució Catalana d'Història Natural, Secció de Ciències Biològiques de l'Institut d'Estudis Catalans, Barcelona.

Rice R. E., Uyemoto J. K., Ogawa J. M. & Pemberton W. M. (1985): New findings on pistachio problems. *California Agriculture* **39**(1): 15–18.

Ridge-O'Connor G. E. (2001): Distribution of the Western Conifer Seed Bug, *Leptoglossus occidentalis* Heidemann (Heteroptera: Coreidae) in Connecticut and parasitism by a tachinid fly, *Trichopoda pennipes* (F.) (Diptera: Tachinidae). *Proceedings of the Entomological Society of Washington* **103**(2): 364–366.

Rot M., Devetak M., Carlevaris B., Žežlina J. & Žežlina I. (2018): First record of Brown Marmorated Stink Bug (*Halyomorpha halys* (Stål, 1855)) (Hemiptera: Pentatomidae) in Slovenia. *Acta Entomologica Slovenica* **26**(1): 5–12.

Roversi P. F., Sabbatini Peverieri G., Maltese M., Furlan P., Strong W. B. & Caleca V. (2014): Pre-release risk assessment of the egg-parasitoid

Gryon pennsylvanicum for classical biological control of *Leptoglossus occidentalis*. *Journal of Applied Entomology* **138**(1–2): 27–35.

Sabbatini Peverieri G., Furlan P., Simoni S., Strong W. B. & Roversi P. F. (2012): Laboratory evaluation of *Gryon pennsylvanicum* (Ashmead) (Hymenoptera, Platygastridae) as a biological control agent of *Leptoglossus occidentalis* Heidemann (Heteroptera, Coreidae). *Biological Control* **61**(1): 104–111.

Salisbury A., Barclay M. V. L., Reid S. & Halstead A. (2009): The current status of the Southern Green Shield Bug, *Nezara viridula* (Hemiptera: Pentatomidae), an introduced pest species recently established in south-east England. *British Journal of Entomology and Natural History* **22**(3): 189–194.

Sallmannshofer M., Ette S., Hinterstoisser W., Cech T. L. & Hoch G. (2019): Erstnachweis der Eichennetzwanze, *Corythucha arcuata*, in Österreich. *Forstschutz Aktuell* **66**: 1–6.

Samin N. & Linnavuori R. E. (2011): A contribution to the Tingidae (Heteroptera) from north and northwestern Iran. *Entomofauna* **32**(25): 373–380.

Samy O. (1969): A revision of the African species of *Oxycarenus* (Hemiptera: Lygaeidae). *Transactions of the Royal Entomological Society of London* **121**(4): 79–165.

Šapina I. & Jelaska L. Š. (2018): First report of invasive Brown Marmorated Stink Bug *Halyomorpha halys* (Stål, 1855) in Croatia. *EPPO Bulletin* **48**(1): 138–143.

Saunders G. S. (1906): *Oxycarenus lavateræ*, F., an Hemipteron infesting lime trees on Lago Maggiore. The *Entomologist's Monthly Magazine* **42**(9): 215.

Savvidis G., Zartaloudis Z. & Vafeas G. (2009): Massive fish losses in Rainbow Trout cultures of Louros River (N.W. Greece) after strong summer rainfall. Implication of the Sycamore Lace Bug *Corythucha ciliata* (Hemiptera: Tingidae). *Bulletin of the European Association of Fish Pathologists* **29**(2): 66–72.

Schaffner J. C. (1967): The occurrence of *Theognis occidentalis* in the midwestern United States (Heteroptera: Coreidae). *Journal of the Kansas Entomological Society* **40**(2): 141–142.

Schedl W. (1991): Invasion der Amerikanischen Büffelzikade (*Stictocephala bisonia* Kopp und Yonke, 1977) nach Österreich (Homoptera, Auchenorrhyncha, Membracidae). *Anzeiger für Schädlingskunde, Pflanzenschutz, Umweltschutz* **64**(1): 9–13.

Schmitz G. (1986): Captures „insolites" d'hétéroptères. *Bulletin and Annales de la Société Royale Belge d'Entomologie* **122**(1–3): 33–38.

Schouteden H. (1912): Les Hémiptères parasites des Cotonniers en Afrique. *Revue Zoologique Africaine* **1**(3): 297–321.

Šeat J. (2015): *Halyomorpha halys* (Stål, 1855) (Heteroptera: Pentatomidae) a new invasive species in Serbia. *Acta Entomologica Serbica* **20**: 167–171.

Seljak G. (2002): Non-European Auchenorrhyncha (Hemiptera) and their geographical distribution in Slovenia. *Acta Entomologica Slovenica* **10**(1): 97-102.

Seward E. A., Votýpka J., Kment P., Lukeš J. & Kelly S. (2017): Description of *Phytomonas oxycareni* n. sp. from the salivary glands of *Oxycarenus lavaterae*. *Protist* **168**: 71–79.

Simov N., Langourov M., Grozeva S. & Gradinarov D. (2012): New and interesting records of alien and native true bugs (Hemiptera: Heteroptera) from Bulgaria. *Acta Zoologica Bulgarica* **64**(3): 241–252.

Sotirovski K., Srebrova K. & Nacheski S. (2019): First records of the Oak Lace Bug *Corythucha arcuata* (Say, 1832) (Hemiptera: Tingidae) in North Macedonia. *Acta Entomologica Slovenica* **27**(2): 91–98.

Souliotis C., Papanikolaou N. E., Papachristos D. & Fatouros N. (2008): Host plants of the planthopper *Metcalfa pruinosa* (Say) (Hemiptera: Flatidae) and observations on its phenology in Greece. *Hellenic Plant Protection Journal* **1**: 39–41.

Sönmez E., Demirbağ Z. & Demir İ. (2016): Pathogenicity of selected entomopathogenic fungal isolates against the Oak Lace Bug, *Corythucha arcuata* Say. (Hemiptera: Tingidae), under controlled conditions. *Turkish Journal of Agriculture and Forestry* **40**: 715–722.

Stål C. (1872): *Enumeratio Hemipterorum. Bidrag till en förteckning öfver alla hittills kända Hemiptera, jemte systematiska meddelanden.* 2. P. A. Norstedt & Söner, Stockholm. /Kongliga Svenska Vetenskaps-Akademiens Handlingar Bandet 10. No 4./

Streito J.-C., Balmès V., Aversenq P., Weill P., Chapin E., Clément M. & Piednoir F. (2018): *Corythucha arcuata* (Say, 1832) et *Stephanitis lauri* Rietschel, 2014, deux espèces invasives nouvelles pour la faune de France (Hemiptera, Tingidae). *L'Entomologiste* **74**: 133–136.

Świerczewski D. & Stroiński A. (2011): The first record of the Nearctic treehopper *Stictocephala bisonia* in Poland (Hemiptera: Cicadomorpha: Membracidae) with some comments on this potential pest. *Polish Journal of Entomology* **80**(1): 13–22.

Szöllősi-Tóth P., Korányi D. & Vétek G. (2017): First record of *Neodryinus typhlocybae* in Hungary (Hymenoptera: Dryinidae). *Folia Entomologica Hungarica* **78**: 97–100.

Szőnyi L. (1962): Adatok néhány fafaj vastagsági növekedéséhez. *Az Erdő* **97**(7): 289–300.

Tamanini L. (1981): *Gli eterotteri della Basilicata e della Calabria (Italia meridionale) (Hemiptera, Heteroptera).* Museo Civico di Storia Naturale, Verona. /Memorie del Museo Civico di Storia Naturale di Verona Ser. 2. A 3./

Taszakowski A., Walczak M., Morawski M. & Baran B. (2015): Piewiki (Hemiptera: Fulgoromorpha et Cicadomorpha) Beskidu Wschodniego. *Acta Entomologica Silesiana* **23**: 83–96.

Tescari G. (2001): *Leptoglossus occidentalis*, coreide neartico rinvenuto in Italia – (Heteroptera, Coreidae). *Lavori – Società Veneziana di Scienze Naturali* **26**: 3–5.

Tescari G. (2004): First record of *Leptoglossus occidentalis* (Heteroptera: Coreidae) in Croatia. *Entomologia Croatica* **8**(1–2): 73–75.

Tuba K., Horváth B. & Lakatos F. (2012): *Inváziós rovarok fás növényeken.* Nyugat-magyarországi Egyetem Kiadó, Sopron.

Uvarov B. P. (1939): An American Membracid in Jugoslavia (Hemiptera). *Proceedings of the Royal Entomological Society of London. Series A. General Entomology* **14**(2–3): 48.

Uyemoto J. K., Ogawa J. M., Rice R. E., Teranishi H. R., Bostock R. M. & Pemberton W. M. (1986): Role of several true bugs (Hemiptera) on incidence and seasonal development of pistachio fruit epicarp lesion disorder. *Journal of Economic Entomology* **79**(2): 395–399.

van der Heyden T. (2019a): First record of *Leptoglossus occidentalis* Heidemann (Heteroptera: Coreidae: Coreinae: Anisoscelini) in Costa Rica. *Revista Chilena de Entomología* **45**(1): 51–53.

van der Heyden T. (2019b): *Leptoglossus occidentalis* Heidemann (Heteroptera: Coreidae: Coreinae: Anisoscelini) in Israel. *Revista Chilena de Entomología* **45**(3): 435–437.

van der Heyden T. & Faúndez E. I. (2020): First records of *Leptoglossus occidentalis* Heidemann, 1910 (Hemiptera: Heteroptera:Coreidae) in Brazil and South Africa. *Boletín del Museo Nacional de Historia Natural del Paraguay* **24**(1): 28–30.

Van Lenteren J. C., Babendreier D., Bigler F., Burgio G., Hokkanen H. M. T., Kuske S., Loomans A. J. M., Menzler-Hokkanen I., van Rijn P. C. J., Thomas M. B., Tommasini M. G. & Zheng Q.-Q. (2003): Environmental risk assessment of exotic natural enemies used in inundative biological control. *BioControl* **48**(1): 3–38.

Varga Á., Korányi D., Haltrich A. & Markó V. (2014): First record of *Deraeocoris flavilinea* in Hungary (Heteroptera, Miridae: Deraeocorinae). *Folia Entomologica Hungarica* **75**: 9–13.

Vásárhelyi T. (1983): *Poloskák III. – Heteroptera III.* Akadémiai Kiadó, Budapest. /Magyarország állatvilága – Fauna Hungariae XVII. kötet 3. füzet/

Velimirović V., Durović Z. & Raičević M. (1992): Bug *Oxycarenus lavaterae* Fabricius (Lygaeidae, Heteroptera) new pest on lindens on southern part of Montenegro. *Zaštita Bilja* **43**(1): 69–72.

Vétek G. (2020): A lepkekabóca-ollósdarázs magyarországi térhódítása. *Mezőhír* **24**(6): 52–55.

Vétek G. & Korányi D. (2017): Severe damage to vegetables by the invasive Brown Marmorated Stink Bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), in Hungary. *Periodicum Biologorum* **119**(2): 131–135.

Vétek G. & Rédei D. (2014): First record of the Southern Green Stink Bug, *Nezara viridula*, from Slovakia (Hemiptera: Heteroptera: Pentatomidae). *Klapalekiana* **50**: 241–245.

Vétek G., Károlyi B., Mészáros Á., Horváth D. & Korányi D. (2018): The invasive Brown Marmorated Stink Bug (*Halyomorpha halys*) is now widespread in Hungary. *Entomologia Generalis* **38**(1): 3–14.

Vétek G., Korányi D., Mezőfi L., Bodor J., Pénzes B. & Olmi M. (2019): *Neodryinus typhlocybae*, a biological control agent of *Metcalfa pruinosa*, spreading in Hungary and reaching Slovakia. *Bulletin of Insectology* **72**(1): 1–11.

Vétek G., Papp V., Haltrich A. & Rédei D. (2014): First record of the Brown Marmorated Stink Bug, *Halyomorpha halys* (Hemiptera: Heteroptera: Pentatomidae), in Hungary, with description of the genitalia of both sexes. *Zootaxa* **3780**(1): 194–200.

Viggiani G. (1971): Osservazioni biologiche sul miride predatore *Deraeocoris ruber* (L.) (Rhynchota, Heteroptera). *Bollettino del Laboratorio di Entomologia Agraria „Filippo Silvestri”* **29**: 270–286.

Wachmann E., Melber A. & Deckert J. (2004): *Wanzen.* Band 2. *Cimicomorpha. Teil 2. Microphysidae (Flechtenwanzen), Miridae (Weichwanzen).* Goecke & Evers, Keltern. /Die Tierwelt Deutschlands 75./

Wagner E. (1971): Die Miridae Hahn, 1831, des Mittelmeerraumes und der Makaronesischen Inseln (Hemiptera, Heteroptera). Teil. 1. *Entomologische Abhandlungen* **37** (Suppl.): i–iii, 1–484.

Walczak M., Brożek J., Junkiert Ł., Kalandyk-Kołodziejczyk M., Musik K., Kaszyca N., Łazuka A. & Gierlasiński G. (2018): *Stictocephala bisonia* Kopp et Yonke, 1977 (Hemiptera: Cicadomorpha, Membracidae) in Poland. *Annals of the Upper Silesian Museum in Bytom, Entomology* **27**(online 010): 1–13.

Wang H.-J. & Liu G.-Q. (2005): Hemiptera: Scutelleridae, Tessaratomidae, Dinindoridae and Pentatomidae. *In:* Tang K.-K. (ed.): *Insect fauna of middle-west Quinling Range and south mountains of Gansu Province.* China Science and Technology Press, Beijing: 279–292.

Wermelinger B., Wyniger D. & Forster B. (2005): Massenauftreten und erster Nachweis von *Oxycarenus lavaterae* (F.) (Heteroptera, Lygaeidae) auf der Schweizer Alpennordseite. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* **78**(3–4): 311–316.

Wermelinger B., Wyniger D. & Forster B. (2008): First records of an invasive bug in Europe: *Halyomorpha halys* Stål (Heteroptera: Pentatomidae), a new pest on woody ornamentals and fruit trees? *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* **81**(1–2): 1–8.

Werner D. J. (2005): *Nezara viridula* (Linnaeus, 1758) in Köln und in Deutschland (Heteroptera, Pentatomidae). *Heteropteron* **21**: 29–31.

Yothers M. A. (1934): *Biology and control of tree hoppers injurious to fruit trees in the Pacific Northwest.* United States Department of Agriculture, Washington. /Technical Bulletin 40./

Yukawa J., Kiritani K., Gyoutoku N., Uechi N., Yamaguchi D. & Kamitani S. (2007): Distribution range shift of two allied species, *Nezara viridula* and *N. antennata* (Hemiptera: Pentatomidae), in Japan, possibly due to global warming. *Applied Entomology and Zoology* **42**(2): 205–215.

Zangheri S. & Donadini P. (1980): Comparsa nel Veneto di un Omottero neartico: *Metcalfa pruinosa* Say (Homoptera, Flatidae). *Redia* **63**: 301–305.

Zhu G.-P., Rédei D., Kment P. & Bu W.-J. (2014): Effect of geographic background and equilibrium state on niche model transferability: predicting areas of invasion of *Leptoglossus occidentalis. Biological Invasions* **16**(5): 1069–1081.

Zhu W. B. (2010): Exotic coreid bugs introduced into China. *In: Proceedings of the 4th meeting of the International Heteropterist's Society. Nankai University, Tianjin, China, July 12–17, 2010.* Nankai University, Tianjin: 71.

Zúbrik M., Gubka A., Rell S., Kunca A., Vakula J., Galko J., Nikolov C. & Leontovyč R. (2019): First record of *Corythucha arcuata* in Slovakia – Short Communication. *Plant Protection Science* **55**(2): 129–133.

BEETLES – Coleoptera

Agricultural Research Service (1982): *Controlling the Japanese Beetle.* Slightly revised. United States Department of Agriculture, *sine loco.* /Home and Garden Bulletin 159/

Alonso-Zarazaga M. A., Barrios H., Borovec R., Bouchard P., Caldara R., Colonnelli E., Gültekin L., Hlaváč P., Korotyaev B., Lyal C. H. C., Machado A., Meregalli M., Pierotti H., Ren L., Sánchez-Ruiz M., Sforzi A., Silfverberg H., Skuhrovec J., Trýzna M., Velázquez de Castro A. J. & Yunakov N. N. (2017): *Cooperative catalogue of Palaearctic Coleoptera Curculionoidea.* Sociedad Entomológica Aragonesa S.E.A., Zaragoza. /Monografías electrónicas SEA 8./

Balachowsky A. (1949): *Faune de France.* 50. *Coléoptères Scolytides.* Librairie de la Faculte des Sciences, Paris.

Baranchikov Y., Mozolevskaya E., Yurchenko G. & Kenis M. (2008): Occurrence of the Emerald Ash Borer, *Agrilus planipennis* in

Russia and its potential impact on European forestry. *EPPO Bulletin* **38**(2): 233–238.

Baranchikov Yu. N., Seraya L. G. & Grinash M. N. (2014): Vse vidy yevropeyskih yaseney neustoychivy k uzkoteloy zlatke *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) – dalnevostochnomu invayderu. *Sibirskiy Lesnoy Zhurnal* 2014 (6): 80–85.

Batra L. R. (1967): Ambrosia fungi: A taxonomic revision, and nutritional studies of some species. *Mycologia* **59**(6): 976–1017.

Beaver R. A. & Liu L. Y. (2010): An annotated synopsis of Taiwanese bark and ambrosia beetles, with new synonymy, new combinations and new records (Coleoptera: Curculionidae: Scolytinae). *Zootaxa* **2602**: 1–47.

Björklund N. & Boberg J. (2017): *Rapid pest risk analysis Xylosandrus germanus.* Swedish University of Agricultural Sciences, Unit for Risk Assessment of Plant Pests, Uppsala.

Borchert D. M., Magarey R. D. & Fowler G. A. (2003): *Pest assessment: Japanese Beetle, Popillia japonica Newman, (Coleoptera: Scarabaeidae).* USDA – APHIS – PPQ – CPHST – PERAL / NCSU.

Bordon J. H., Handley J. R., McLean J. A., Silverstein R. M., Chong L., Slessor K. N., Johnston B. D. & Schuler H. R. (1980): Enantiomer-based specificity in pheromone communication by two sympatric *Gnathotrichus* species (Coleoptera: Scolytidae). *Journal of Chemical Ecology* **6**(2): 445–456.

Bouget C. & Noblecourt T. (2005): Short-term development of Ambrosia and Bark Beetle assemblages following a windstorm in French broadleaved temperate forests. *Journal of Applied Entomology* **129**(6): 300–310.

Brown P. M. J., Adriaens T., Bathon H., Cuppen J., Goldarazena A., Hägg T., Kenis M., Klausnitzer B. E. M., Kovář I., Loomans A. J. M., Majerus M. E. N., Nedved O., Pedersen J., Rabitsch W., Roy H. E., Ternois V., Zakharov I. A. & Roy D. B. (2008): *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. *BioControl* **53**(1): 5–21.

Brown P. M. J., Thomas C. E., Lombaert E., Jeffries D. L., Estoup A. & Handley L.-J. L. (2011): The global spread of *Harmonia axyridis* (Coleoptera: Coccinellidae): distribution, dispersal and routes of invasion. *BioControl* **56**(4): 623–641.

Buchanan W. D. (1940): Ambrosia Beetle, *Xylosandrus germanus*, transmits Dutch elm disease under controlled conditions. *Journal of Economic Entomology* **33**(5): 819–820.

Bussler H., Bouget C., Brustel H., Brändle M., Riedinger V., Brandl R. & Müller J. (2011): Abundance and pest classification of scolytid species (Coleoptera: Curculionidae, Scolytinae) follow different patterns. *Forest Ecology and Management* **262**(9): 1887–1894.

Byrne K. J., Swigar A. A., Silverstein R. M., Borden J. H. & Stokkink E. (1974): Sulcatol: population aggregation pheromone in the scolytid beetle, *Gnathotrichus sulcatus*. *Journal of Insect Physiology* **20**(10): 1895–1900.

Campbell J. M., Sarazin M. J. & Lyons B. (1989): *Canadian beetles (Coleoptera) injurious to crops, ornamentals, stored products, and buildings.* Research Branch, Agricultural Canada, Ottawa.

Ciampitti M., Bertoglio M., Cavagna B., Suss L. & Bianchi A. (2016): Prime esperienze di difesa contro *Popillia japonica*. *L'Informatore Agrario* 2016 (47): 58–60.

Cocquempot C. & Lindelöw Å. (2010): Longhorn beetles (Coleoptera, Cerambycidae). Chapter 8.1. *In:* Roques A., Kenis M., Lees D., Lopez-Vaamonde C., Rabitsch W., Rasplus J.-Y. & Roy D. B. (eds.): *Alien terrestrial arthropods of Europe.* Pensoft, Sofia – Moscow: 193–218.

Csóka Gy. & Ambrus A. (2016): Erdei fa- és cserjefajok szerepe a herbivor rovarok fajgazdagságának fenntartásában. *In:* Korda M. (szerk.): *Az erdőgazdálkodás hatása az erdők biológiai sokféleségére. Tanulmánygyűjtemény.* Duna–Ipoly Nemzeti Park Igazgatóság, Budapest: 155–192.

Csóka Gy. & Hirka A. (2016): Az ázsiai lombfacincér (*Anoplophora glabripennis*). *Agrofórum* **27**(7): 45–49.

Csóka Gy. & Kovács T. (1999): *Xilofág rovarok.* Erdészeti Tudományos Intézet – Agroinform Kiadó, Budapest.

Csóka Gy., Hirka A., Koltay A. & Kolozs L. (2013): *Erdőkárok. Képes útmutató.* NÉBIH Erdészeti Igazgatósága – Erdészeti Tudományos Intézet, Budapest.

Dancsházy Zs. (2019): A kőrisrontó karcsúdíszbogár (*Agrilus planipennis*) terjedésének nemzetközi tapasztalatai, lehetőségek az európai kőrisek hosszú távú védelmére. *Növényvédelem* **80**(4): 145–156.

Dickerson E. L. & Weiss H. B. (1918): *Popilia japonica* Newm., a recently introduced Japanese pest. *The Canadian Entomologist* **50**(7): 217–221.

Donovan G. H., Butry D. T., Michael Y. L., Prestemon J. P., Liebhold A. M., Gatziolis D. & Mao M. Y. (2013): The relationship between trees and human health. Evidence from the spread of the Emerald Ash Borer. *American Journal of Preventive Medicine* **44**(2): 139–145.

Drogvalenko A. N., Orlova-Bienkowskaja M. J. & Bieńkowski A. O. (2019): Record of the Emerald Ash Borer (*Agrilus planipennis*) in Ukraine is confirmed. *Insects* **10**(10): 338.

EPPO (2006): *Popillia japonica*. *EPPO Bulletin* 50(1): 88–98.

EPPO (2022): *Popillia japonica*. EPPO datasheets on pests recommended for regulation. – https://gd.eppo.int

EPPO Reporting Service (2014): First report of *Popillia japonica* in Italy. *In: EPPO Global Database.* EPPO Reporting Service No. 10. – 2014. Num. article 2014/179. – https://gd.eppo.int/reporting/article-3272

EPPO Reporting Service (2017): First report of *Popillia japonica* in Switzerland. *In: EPPO Global Database.* EPPO Reporting Service No. 09. – 2017. Num. article 2017/160. – https://gd.eppo.int/reporting/article-6128

Faccoli M. & Favaro R. (2016): Host preference and host colonisation of the Asian Long-horned Beetle, *Anoplophora glabripennis* (Coleoptera Cerambycidae), in Southern Europe. *Bulletin of Entomological Research* **106**(3): 359–367.

Faccoli M. & Gatto P. (2016): Analysis of costs and benefits of Asian Longhorn Beetle eradication in Italy. *Forestry* **89**(3): 301–309.

Favaro M., Battisti A. & Faccoli M. (2013): Dating *Anoplophora glabripennis* introduction in North-East Italy by growth-ring analysis. *Journal of Entomological and Acarological Research* **4** (Supplement 1): 34–35.

Fiala T., Holuša J., Procházka J., Čížek L., Dzurenko M., Foit J., Galko J., Kašák J., Kulfan J., Lakatos F., Nakládal O., Schlaghamerský J., Svatoš M., Trombik J., Zábranský P., Zach P. & Kula E. (2020): *Xylosandrus germanus* in Central Europe: Spread into and within the Czech Republic. *Journal of Applied Entomology* **144**(6): 423–433.

Fleming W. E. (1972): *Biology of the Japanese Beetle.* Agricultural Research Service, United States Department of Agriculture, Washington. / Technical Bulletin No. 1449/

Flø D., Krokene P. & Økland B. (2015): Invasion potential of *Agrilus planipennis* and other *Agrilus* beetles in Europe: import pathways of deciduous wood chips and MaxEnt analyses of potential distribution areas. *EPPO Bulletin* **45**(2): 259–268.

Galko J., Dzurenko M., Ranger C. M., Kulfan J., Kula E., Nikolov C., Zúbrik M. & Zach P. (2019): Distribution, habitat preference, and management of the invasive Ambrosia Beetle *Xylosandrus germanus* (Coleoptera: Curculionidae, Scolytinae) in European forests with an emphasis on the West Carpathians. *In:* Avtzis D. N. & Wegensteiner R. (eds.): *Forest insects and pathogens in a changing environment: ecology, monitoring & genetics (IUFRO Joint Meeting of WP7.03.05 & 7.03.10).* MDPI, Basel: 32–49.

Gaskó B. (1998): Cincérek a Maros-parton. A Maros ártérről előkerült Kárpát-medencére nézve új cincér (Coleoptera Cerambycidae) fajok. *In:* Halmágyi P. (szerk.): *Tanulmányok. Tóth Ferenc köszöntése.* Csongrád Megyei Múzeumok Igazgatósága, Szeged – Makó: 165–182.

Graf E. & Manser P. (2000): Beitrag zum eingeschleppten Schwarzen Nutzholzborkenkäfer *Xylosandrus germanus.* Biologie und Schadenpotential an im Wald gelagertem Rundholz im Vergleich zu *Xyloterus lineatus* und *Hylecoetus dermestoides. Schweizerische Zeitschrift für Forstwesen* **151**(8): 271–281.

Groschke F. (1952): Der „schwarze Nutzholzborkenkäfer“, *Xylosandrus germanus* Blandf., ein neuer Schädling in Deutschland. *Zeitschrift für Angewandte Entomologie* **34**(2): 297–302.

Haack R. A., Law K. R., Mastro V. C. (1997): New York's battle with the Asian Long-horned Beetle. *Journal of Forestry* **95**(12): 11–15.

Hamilton R. M. (2003): *Remote sensing and GIS studies on the spatial distribution and management of Japanese Beetle adults and grubs.* PhD Dissertation. Purdue University, West Lafayette (Indiana).

Hegyessy G. & Kutasi Cs. (2010): *Trichoferus* species new to Hungary (Coleoptera: Cerambycidae). *Folia Entomologica Hungarica* **71**: 35–41.

Helbig C. & Müller M. (2018): Asian Longhorned Beetle (*Anoplophora glabripennis*) from a forest health point of view. *Mitteilungen der Deutschen Gesellschaft für Allgemeine und Angewandte Entomologie* **21**: 329–330.

Held B. W., Simeto S., Rajtar N. N., Cotton A. J., Showalter D. N., Bushley K. E. & Blanchette R. A. (2021): Fungi associated with galleries of the Emerald Ash Borer. *Fungal Biology* **125**(7): 551–559:

Herms D. A. & McCullough D. G. (2014): Emerald Ash Borer invasion of North America: History, biology, ecology, impacts, and management. *Annual Review of Entomology* **59**(1): 13–30.

Holzschuh C. (1993): Erster Nachweis des Schwarzen Nutzholzborkenkäfers (*Xylosandrus germanus*) in Österreich. *Forstschutz Aktuell* 1993 (12–13): 10.

Horion A. (1974): *Faunistik der Mitteleuropäischen Käfer.* Band XII. *Cerambycidae – Bockkäfer.* Überlingen am Bodensee.

Hoyer-Tomiczek U. & Hoch G. (2020): Progress in the use of detection dogs for Emerald Ash Borer monitoring. *Forestry* **93**(2): 326–330.

Hoyer-Tomiczek U., Sauseng G. & Hoch G. (2016): Scent detection dogs for the Asian Longhorn Beetle, *Anoplophora glabripennis*. *EPPO Bulletin* **46**(1): 148–155.

Imrei Z., Lohonyai Zs., Csóka Gy., Muskovits J., Szanyi Sz., Vétek G., Fail J., Tóth M. & Domingue M. J. (2020): Improving trapping methods for buprestid beetles to enhance monitoring of native and invasive species. *Forestry* **93**(2): 254–264.

Imrei Z., Matula E., Lohonyai Zs., Csóka Gy., Muskovits J., Szanyi Sz., Vétek G., Bozsik G., Fail J., Vuts J., Domingue M. J. & Tóth M. (2021): Csapdázási módszerfejlesztés honos és inváziós díszbogárfajok rajzáskövetésére. *Növényvédelem* **82**(3): 113–132.

Ito M. & Kajimura H. (2017): Landscape-scale genetic differentiation of a mycangial fungus associated with the Ambrosia Beetle, *Xylosandrus germanus* (Blandford) (Curculionidae: Scolytinae) in Japan. *Ecology and Evolution* 7(22): 9203–9221.

Kamp H. J. (1968): Der „Schwarze Nutzholzborkenkäfer" *Xylosandrus germanus* Blandf., ein Neuling der heimischen Insektenfauna. *Entomologische Blätter* **64**: 31–39.

Kaszab Z. (1971): *Cincérek – Cerambycidae.* Akadémiai Kiadó, Budapest. /Magyarország állatvilága – Fauna Hungariae IX. kötet 5. füzet/

Kenis M., Roy H. E., Zindel R. & Majerus M. E. N. (2008): Current and potential management strategies against *Harmonia axyridis*. *BioControl* **53**(1): 235–252.

Keszthelyi S. (2021): Red-Headed Ash Borer *Neoclytus acuminatus acuminatus* (Fabricius) (Coleoptera: Cerambycidae): the global distribution, current spreading and the seasonal activity depending on its different habitats. *Journal of Plant Diseases and Protection* **128**(5): 1187–1199.

Kirkendall L. R. & Faccoli M. (2010): Bark beetles and pinhole borers (Curculionidae, Scolytinae, Platypodinae) alien to Europe. *ZooKeys* **56**: 227–251.

Klausnitzer B. (1978): *Ordnung Coleoptera (Larven).* Akademie-Verlag – W. Junk, Berlin – The Hague. /Bestimmungsbücher zur Boden-Fauna Europas 10./

Kovacs K. F., Mercader R. J., Haight R. G., Siegert N. W., McCullough D. G. & Liebhold A. M. (2011): The influence of satellite populations of Emerald Ash Borer on projected economic costs in U.S. communities, 2010–2020. *Journal of Environment Management* **92**(9): 2170–2181.

Kovács T. (2010): A *Chlorophorus annularis* (Fabricius, 1787) Magyarországon (Coleoptera: Cerambycidae). *Folia Historico Naturalia Musei Matraensis* **34**: 131–132.

Kovács T. & Gebei L. (2021): Ritka és természetvédelmi szempontból jelentős bogarak (Coleoptera) a Hortobágyi Nemzeti Park Igazgatóság működési területéről. *Folia Historico-naturalia Musei Matraensis* **44**: 103–135.

Kovács T. & Hegyessy G. (1992): Új és ritka fajok Magyarország cincérfaunájában (Coleoptera, Cerambycidae). *Folia Historico-naturalia Musei Matraensis* **17**: 181–188.

Lakatos F. (2019): Honos, behurcolt és várható, a fatestben fejlődő szúfajok Magyarországon. *Növényvédelem* **80**(12): 523–535.

Lakatos F. & Kajimura H. (2007): Occurence of the introduced *Xylosandrus germanus* (Blandford, 1894) in Hungary – a genetic evidence (Coleoptera: Scolytidae). *Folia Entomologica Hungarica* **68**: 97–104.

Lindell C. A., McCullough D. G., Cappaert D., Apostolou N. M. & Roth M. B. (2008): Factors influencing woodpecker predation on Emerald Ash Borer. *American Midland Naturalist* **159**(2): 434–444.

Lingafelter S. W. & Hoebke E. R. (2002): *Revision of the Genus Anoplophora (Coleoptera: Cerambycidae).* The Entomological Society of Washington, Washington.

Maksymov J. K. (1987): Erstmaliger Massenbefall des schwarzen Nutzholzborkenkäfers, *Xylosandrus germanus* Blandf., in der Schweiz. *Schweizerische Zeitschrift für Forstwesen* **138**(3), 215–227.

Marianelli L., Paoli F., Sabbatini Peverieri G., Benvenuti C., Barzanti G. P., Bosio G., Venanzio D. Giacometto E. & Roversi P. F. (2018): Long-lasting insecticide-treated nets: a new integrated pest management approach for *Popillia japonica* (Coleoptera: Scarabaeidae).

Integrated Environmental Assessment and Management **15**(2): 259–265.

Markó V. (2016): A harlekinkatica (*Harmonia axyridis*). *Agrofórum* **27**(10): 56–61.

Markó V. & Pozsgai G. (2009): A harlekinkatica (*Harmonia axyridis* Pallas, 1773) (Coleoptera, Coccinellidae) elterjedése Magyarországon és megjelenése Romániában és Ukrajnában. *Növényvédelem* **45**(9): 481–492.

Martins A. & Simões N. (1985): Population dynamics of the Japanese Beetle (Coleoptera: Scarabaeideae) in Terceira Island – Azores. *Arquipélago* **6**: 57–62.

Martins A. & Simões N. (1988): Suppression of the Japanese Beetle in the Azores: an ecological approach. *Ecological Bulletins* **39**: 99–100.

Mazur A., Witkowski R., Góral J. & Rogowski G. (2018): Occurrence of *Gnathotrichus materiarius* (Fitch, 1858) (Coleoptera, Curculionidae, Scolytinae) in south-western Poland. *Folia Forestalia Polonica, Series A – Forestry* **60**(3): 154–160.

Mazza G., Paoli F., Strangi A., Torrini G., Marianelli L., Sabbatini Peverieri G., Binazzi F., Bosio G., Sacchi S., Benvenuti C., Venanzio D., Giacometto E., Roversi P. F. & Poinar G. O. (2017): *Hexamermis popilliae* n. sp. (Nematoda: Mermithidae) parasitizing the Japanese Beetle *Popillia japonica* Newman (Coleoptera: Scarabaeidae) in Italy. *Systematic Parasitology* **94**(8): 915–926.

Merkl O. (2008): A harlekinkatica (*Harmonia axyridis* Pallas) Magyarországon (Coleoptera: Coccinellidae). *Növényvédelem* **44**(5): 239–242.

Merkl O. & Vig K. (2009): *Bogarak a pannon régióban*. Vas Megyei Múzeumok Igazgatósága – B. K. L. Kiadó – Magyar Természettudományi Múzeum, Szombathely.

Metcalf R. L. & Metcalf R. A. (1993): *Destructive and useful insects. Their habits and control.* 5th edition, McGraw-Hill, New York.

Mezőfi L. & Korányi D. (2017): A harlekinkatica (*Harmonia axyridis* Pallas 1773) színváltozatai Magyarországon és polimorfizmusának ökológiai vonatkozásai. *Növényvédelem* **78**(5): 193–205.

Orlova-Bienkowskaja M. J. (2015): Cascading ecological effects caused by the establishment of the Emerald Ash Borer *Agrilus planipennis* (Coleoptera: Buprestidae) in European Russia. *European Journal of Entomology* **112**(4): 778–789.

Orlova-Bienkowskaja M. J., Drogvalenko A. N., Zabaluev I. A., Sazhnev A. S., Peregudova E. Y., Mazurov S. G., Komarov E. V., Struchaev V. V., Martynov V. V., Nikulina T. V. & Bieńkowski A. O. (2020): Current range of *Agrilus planipennis* Fairmaire, an alien pest of ash trees, in European Russia and Ukraine. *Annals of Forest Science* **77**(2): 29.

Paoli F., Marianelli L., Binazzi F., Mazza G., Benvenuti C., Sabbatini Peverieri G., Bosio G., Venanzio D., Giacometto E., Klein M. & Roversi P. F. (2017): Effectiveness of different doses of *Heterorhabditis bacteriophora* against *Popillia japonica* 3rd instars: laboratory evaluation and field application. *Redia* **100**: 135–138.

Pavesi M. (2014): *Popillia japonica* specie aliena invasiva segnalata in Lombardia. *L'Informatore Agrario* 2014 (32): 53–55.

Petty B. M., Johnson D. T. & Steinkraus D. C. (2015): Changes in abundance of larvae and adults of *Popillia japonica* (Coleoptera: Scarabaeidae: Rutelinae) and other white grub species in Northwest Arkansas their relation to regional temperatures. *Florida Entomologist* **98**(3): 1006–1008.

Pfeffer A. (1995): *Zentral- und westpaläarktische Borken- und Kernkäfer (Coleoptera: Scolytidae, Platypididae).* Pro Entomologia – Naturhistorisches Museum, Basel.

Ploetz R. C., Hulcr J., Wingfield M. J. & de Beer Z. W. (2013): Destructive tree diseases associated with ambrosia and bark beetles: Black Swan events in tree pathology? *Plant Disease* **95**(7): 856–872.

Postner M. (1974): Scolytidae (Ipidae), Borkenkäfer. *In:* Schwenke W. (Hrsg.): *Die Forstschädlinge Europas. Ein Handbuch in fünf Bänden.* 2. Band. *Käfer.* Verlag Paul Parey, Hamburg – Berlin: 334–482.

Potter D. A. & Held D. W. (2002): Biology and management of the Japanese Beetle. *Annual Review of Entomology* **47**: 175–205.

Rabaglia R. J., Dole S. A. & Cognato A. I. (2006): Review of American Xyleborina (Coleoptera: Curculionidae: Scolytinae) occurring north of Mexico, with an illustrated key. *Annals of the Entomological Society of America* **99**(6): 1034–1056.

Reding M. E., Ranger C. M., Sampson B. J., Werle C. T., Oliver J. B. & Schultz P. B. (2015): Movement of *Xylosandrus germanus* (Coleoptera: Curculionidae) in ornamental nurseries and surrounding habitats. *Journal of Economic Entomology* **108**(4): 1947–1953.

Sauvard D., Branco M., Lakatos F., Faccoli M. & Kirkendall L. R. (2010): Weevils and bark beetles (Coleoptera, Curculionoidea). *In:* Roques A., Kenis M., Lees D., Lopez-Vaamonde C., Rabitsch W., Rasplus J.-Y. &

Roy D. B. (eds.): *Alien terrestrial arthropods of Europe*. Pensoft Publishers, Sofia – Moscow: 219–266.

Sim R. J. (1934): *Characters useful in distinguishing larvae of Popillia japonica and other introduced Scarabaeidae from native species.* United States Department of Agriculture, Washington. / Circular No. 334/

Simões N. & Martins A. (1985): Life cycle of *Popillia japonica* Newman (Coleoptera: Scarabaeidae) in Terceira Island – Azores. *Arquipélago* **6**: 173–179.

Simões N., Laumond C. & Bonifassi E. (1993): Effectiveness of *Steinernema* spp. and *Heterorhabditis bacteriophora* against *Popillia japonica* in the Azores. *Journal of Nematology* **25**(3): 480–485.

Straw N. A., Fielding N. J., Tilbury C., Williams D. T. & Cull T. (2016): History and development of an isolated outbreak of Asian Longhorn Beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in southern England. *Agricultural and Forest Entomology* **18**(3): 280–293.

Switzer P. V. & Cumming R. M. (2014): Effectiveness of hand removal for small-scale management of Japanese Beetles (Coleoptera Scarabaeidae). *Journal of Economic Entomology* **107**(1): 293–298.

Szeőke K. & Hegyi T. (2002): A szőlő új kártevője az amerikai darázscincér (*Neoclytus acuminatus* Olivier). *Növényvédelem* **38**(5): 268–269.

Tomiczek C. (2001): First occurrence of the "Asian Longhorned Beetle" in Europe. – http//:fbva.forvie.ac.at/400/1517.html

Traser Gy. (1996): Egy ritka cincér faj előfordulása a Duna-ártéren. *Erdészeti Lapok* **131**(11): 344.

Tuba K., Balogh K., Vörös-Torma Sz., Jakab J. & Kelemen G. (2021): Magas kőrisesek (*Fraxinus excelsior* L.) újabb erdővédelmi problémái. *Növényvédelem* **82**(12): 511–520.

Tuba K., Horváth B. & Lakatos F. (2012): *Inváziós rovarok fás növényeken.* Nyugat-magyarországi Egyetem Kiadó, Sopron.

Tuncer C., Kushiyev R., Erper I., Ozdemir I. O. & Saruhan I. (2019): Efficacy of native isolates of *Metarhizium anisopliae* and *Beauveria bassiana* against the invasive ambrosia beetle, *Xylosandrus germanus* Blandford (Coleoptera: Curculionidae: Scolytinae). *Egyptian Journal of Biological Pest Control* **29**(1): 28.

USDA APHIS PPQ (2020): *Initial county EAB detections in North America – August 3, 2020.* Cooperative Emerald Ash Borer Project, United States Department of Agriculture. –www.emeraldashborer.info

Vail K. M., Hale F., Williams H. E. & Mannion C. (1999): *The Japanese Beetle and its control.* Agricultural Extension Service, The University of Tennessee. /PB 946/

Vieira V. (2008): The Japanese Beetle *Popillia japonica* Newman, 1938 (Coleoptera: Scarabaeidae) in the Azores islands. *Boletín Sociedad Entomológica Aragonesa* **43**: 450–451.

Vittum P. (1986): Biology of the Japanese Beetle (Coleoptera: Scarabaeidae) in eastern Massachusetts. *Journal of Economic Entomology* **79**(2): 387–391.

Volkovitsh M. G., Orlova-Bienkowskaja M. J., Kovalev A. V. & Bieńkowski A. O. (2020): An illustrated guide to distinguish Emerald Ash Borer (*Agrilus planipennis*) from its congeners in Europe. *Forestry* **93**(2): 316–325.

Wang X.-Y., Yang Z.-Q., Gould J. R., Zhang Y.-N., Liu G.-J. & Liu E.-S. (2010): The biology and ecology of the Emerald Ash Borer, *Agrilus planipennis*, in China. *Journal of Insect Science* **10**: 128.

Weber B. C. & McPherson J. E. (1983): World list of host plants of *Xylosandrus germanus* (Blandford) (Coleoptera: Scolytidae). *The Coleopterists Bulletin* **37**(2): 114–134.

Weber B. C. & McPherson J. E. (1985): Relation between attack by *Xylosandrus germanus* (Coleoptera: Scolytidae) and disease symptoms in black walnut. *The Canadian Entomologist* **117**(10): 1275–1277.

Wichmann H. E. (1955): Zur derzeitigen Verbreitung des Japanischen Nutzholzborkenkäfers *Xylosandrus germanus* Blandf. im Bundesgebiete. *Zeitschrift für Angewandte Entomologie* **37**(2): 250–258.

Wichmann H. E. (1957): Einschleppungsgeschichte und Verbreitung des *Xylosandrus germanus* Blandf. in Westdeutschland (nebst einem Anhang: *Xyleborus adumbratus* Blandf.). *Zeitschrift für Angewandte Entomologie* **40**(1): 82–99.

Witkowski R., Góral J., Nowik K., Rogowski K. S. & Mazur A. (2016): *Gnathotrichus materiarius* (Fitch, 1858) (Coleoptera: Curculionidae, Scolytinae) – new species of beetle in the Polish fauna. *Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria* **15**(1): 43–47.

Wood S. L. & Bright D. E. (1992): *A catalog of Scolytidae and Platypodidae (Coleoptera).* Part 2. *Taxonomic index*. Brigham Young University, Provo.

Wright R. J., Villani M. G. & Agudelo-Silva F. (1988): Steinernematid and heterorhabditid nematodes for control of larval European Chafers and Japanese Beetles (Coleoptera: Scarabaeidae) in potted yew. *Journal of Economic Entomology* **81**(1): 152–157.

Yang Z.-Q., Strazanac J. S., Marsh P. M., van Achterberg C. & Choi W.-Y. (2005): First recorded parasitoid from China of *Agrilus planipennis*: a new species of *Spathius* (Hymenoptera: Braconidae: Doryctinae). *Annals of the Entomological Society of America* **98**(5): 636–642.

HYMENOPTERANS – Hymenoptera

Antropov A. V., Astafurova Yu. V., Belokobylskij S. A., Byvaltsev A. M., Danilov Yu. N., Dubovikoff D. A., Fadeev K. I., Fateryga A. V., Kurzenko N. V., Lelej A. S., Levchenko T. V., Loktionov V. M., Mokrousov M. V., Nemkov P. G., Proshchalykin M. Yu., Rosa P., Sidorov D. A., Sundukov Yu. N., Yusupov Z. M. & Zaytseva L. A. (2017): Annotated catalogue of the Hymenoptera of Russia. Volume I. Symphyta and Apocrita: Aculeata. *Proceedings of the Zoological Institute of the Russian Academy of Sciences* Supplement 6: 5–475.

Blank S. M., Hara H., Mikulás J., Csóka Gy., Ciornei C., Constantineanu R., Constantineanu I., Roller L., Altenhofer E., Huflejt T. & Vétek G. (2010): *Aproceros leucopoda* (Hymenoptera: Argidae): An East Asian pest of elms (*Ulmus* spp.) invading Europe. *European Journal of Entomology* **107**(3): 357–367.

Blank S. M., Köhler T., Pfannenstill T., Neuenfeldt N., Zimmer B., Jansen E., Taeger A. & Liston A. D. (2014): Zig-zagging across Central Europe: recent range extension, dispersal speed and larval hosts of *Aproceros leucopoda* (Hymenoptera, Argidae) in Germany. *Journal of Hymenoptera Research* **41**: 57–74.

Blummer A. G. (2015): Zig-zag Elm Saw Fly *Aproceros leucopoda* Takeuchi, 1939 (Hymenoptera: Argidae) – economically significant pest of elm from East Asia, expanding invasive area in the European part of Russia. *Plant Health Research and Practice* **14**(4): 17–19.

Boevé J.-L. (2013): First record in Belgium of the invasive sawfly *Aproceros leucopoda* (Hymenoptera: Argidae) and some related ecological data. *Bulletin de la Société Royale Belge d'Entomologie* **149**: 217–221.

Cremer S., Ugelvig L. V., Drijfhout F. P., Schlick-Steiner B. C., Steiner F. M., Steiner F. M., Seifert B., Hughes D. P., Schulz A., Petersen K. S., Konrad H., Stauffer C., Kiran K., Espadaler X., d'Ettorre P., Aktaç N., Eilenberg J., Jones G. R., Nash D. R., Pedersen J. S. & Boomsma J. J. (2008): The evolution of invasiveness in garden ants. *PLoS ONE* **3**(12): e3838.

Csathó A. I., Gallé L., Lőrinczi G., Tartally A., Báthori F., Kovács É., Maák I., Markó B., Módra G., Nagy Cs., Somogyi A. Á. & Csősz S. (2021): A hazánkban előforduló és az ismertebb külföldi hangyafajok magyar nevei. *Állattani Közlemények*. **106**(1–2): 47–102.

Csóka Gy. & Ambrus A. (2016): Erdei fa- és cserjefajok szerepe a herbivor rovarok fajgazdagságának fenntartásában. *In:* Korda M. (szerk.): *Az erdőgazdálkodás hatása az erdők biológiai sokféleségére. Tanulmánygyűjtemény.* Duna–Ipoly Nemzeti Park Igazgatóság, Budapest: 155–192.

Csóka Gy., Hirka A., Koltay A. & Kolozs L. (2013): *Erdőkárok. Képes útmutató.* NÉBIH Erdészeti Igazgatósága – Erdészeti Tudományos Intézet, Budapest.

Dautbašić M., Mujezinović O., Zahirović K. & Margaletić J. (2018): Prvi nalaz brijestove ose listarice (*Aproceros leucopoda*) u Bosni i Hercegovini. *Šumarski List* **142**(5–6): 283–285.

Doychev D. (2015): First record of the invasive Elm Sawfly *Aproceros leucopoda* Takeuchi (Hymenoptera: Argidae) in Bulgaria. *Silva Balcanica* **16**(1): 108–112.

Espadaler X. & Bernal V. (2020): *Lasius neglectus* a polygynous, sometimes invasive, ant. – lasius.creaf.cat

Espadaler X. & Rey S. (2001): Biological constraints and colony founding in the polygynous invasive ant *Lasius neglectus* (Hymenoptera, Formicidae). *Insectes Sociaux* **48**(2): 159–164.

Espadaler X., Rey S. & Bernal V. (2004): Queen number in a supercolony of the Invasive Garden Ant, *Lasius neglectus*. *Insectes Sociaux* **51**(3): 232–238.

Espadaler X., Tartally A., Schultz R., Seifert B. & Nagy Cs. (2007): Regional trends and preliminary results on the local expansion rate in the Invasive Garden Ant, *Lasius neglectus* (Hymenoptera, Formicidae). *Insectes Sociaux* **54**(3): 293–301.

Forest Research (2018): Elm Zigzag Sawfly (*Aproceros leucopoda*) – https://www.forestresearch.gov.uk/tools-and-resources/pest-and-disease-resources/elm-zigzag-sawfly/

Fragnière Y., Song Y.-G., Fazan L., Manchester S. R., Garfi G. & Kozlowski G. (2021): Biogeographic overview of Ulmaceae: diversity, distribution, ecological preferences, and conservation status. *Plants* **10**(6): 1111.

Glavendekić M., Petrović J. & Petaković M. (2011): Strana invazivna vrsta *Aproceros leucopoda* Takeuchi (Hymenoptera: Argidae) – štetočina brestova u Srbiji. Šumarstvo **65**(1–2): 47–56.

Hölling D. (2018): *Aproceros leucopoda* Takeuchi, 1939 – Erstbeobachtung der Zickzack-Ulmenblattwespe in der Schweiz (Hymenoptera: Argidae). *Entomo Helvetica* **11**: 149–152.

Kraus M., Liston A. D. & Taeger A. (2011): Die invasive Zick-Zack-Ulmenblattwespe *Aproceros leucopoda* Takeuchi, 1939 (Hymenoptera: Argidae) in Deutschland. *DGaaE Nachrichten* **25**(3): 117–119.

Lengesova N. A. & Mishchenko A. V. (2013): Biologiya, ekologiya i molekulyarno-geneticheskoye issledovaniye ilmovogo pililshchika Aproceros leucopoda (Takeuchi, 1939) (Hymenoptera: Argidae) – reditelya vyaza v Srednem Povolzhe. *Kavkazskiy Entomologicheskiy Byulleten* **9**(1): 163–167.

Lovas M. (2012): *Egy Európa faunájára új szilkártevő, a kanyargós szillevéldarázs (Aproceros leucopoda) hazai elterjedésének, biológiájának és jelentőségének vizsgálata.* Diplomadolgozat. Budapest: Corvinus Egyetem, Kertészettudományi Kar, Rovartani Tanszék, Budapest.

Martel V., Morin O., Monckton S. K., Eiseman C. S., Béliveau C., Cusson M. & Blank S. M. (2022): Elm Zigzag Sawfly, *Aproceros leucopoda* (Hymenoptera: Argidae), recorded for the first time in North America through community science. *The Canadian Entomologist* **154**(1): e1.

Matošević D. (2012): Prvi nalaz brijestove ose listarice (*Aproceros leucopoda*), nove invazivne vrste u Hrvatskoj. *Šumarski List* **136**(1–2): 57–61.

Nagy Cs., Tartally A., Vilisics F., Merkl O., Szita É., Szél Gy., Podlussány A., Rédei D., Csősz S., Pozsgai G., Orosz A., Szövényi G. & Markó V. (2009): Effects of the Invasive Garden Ant, *Lasius neglectus* van Loon, Boomsma et Andrásfalvy, 1990 (Hymenoptera: Formicidae), on arthropod assemblages: pattern analyses in the type supercolony. *Myrmecological News* **12**: 171–181.

Papp V. (2018): *Az invazív kanyargós szillevéldarázs (Aproceros leucopoda Takeuchi, 1939) életmódja.* Doktori értekezés. Szent István Egyetem, Kertészettudományi Kar, Kertészettudományi Doktori Iskola, Budapest.

Papp V., Ladányi M. & Vétek G. (2018): Temperature-dependent development of *Aproceros leucopoda* (Hymenoptera: Argidae), an invasive pest of elms in Europe. *Journal of Applied Entomology* **142**(6): 589–597.

Roques A., Auger-Rozenberg M.-A., Blackburn T. M., Garnas J., Pyšek P., Rabitsch W., Richardson D. M., Wingfield M. J., Liebhold A. M. & Duncan R. P. (2016): Temporal and interspecific variation in rates of spread for insect species invading Europe during the last 200 years. *Biological Invasions* **18**(4): 907– 920.

Schultz R. & Seifert B. (2005): *Lasius neglectus* (Hymenoptera: Formicidae) – a widely distributed tramp species in Central Asia. *Myrmecologische Nachrichten* **7**: 47–50.

Seifert B. (2000): Rapid range expansion in *Lasius neglectus* (Hymenoptera, Formicidae) – an Asian invader swamps Europe. *Mitteilungen aus dem Museum für Naturkunde in Berlin. Deutsche Entomologische Zeitschrift* **47**(2): 173–179.

Stukalyuk S. V., Radchenko A. G., Ahkmedov A. & Reshetov A. A. (2020): Uzbekistan – the alleged native range of the invasive ant *Lasius neglectus* (Hymenoptera, Formicidae): geographical, ecological and biological evidences. *Zoodiversity* **54**(2): 111–122.

Takeuchi K. (1939): A systematic study on the suborder Symphyta (Hymenoptera) of the Japanese Empire (II). *Tenthredo* **2**(4): 393–439.

Tartally A. (2000): Notes on the coexistence of the supercolonial *Lasius neglectus* van Loon, Boomsma et Andrásfalvy 1990 (Hymenoptera:

Formicidae) with other ant species. *Tiscia* **32**: 43–46.

Tartally A. (2006): Long term expansion of a supercolony of the Invasive Garden Ant *Lasius neglectus* (Hymenoptera: Formicidae). *Myrmecologische Nachrichten* **9**: 21–25.

Tartally A. & Báthori F. (2015): Does *Laboulbenia formicarum* (Ascomycota: Laboulbeniales) fungus infect the Invasive Garden Ant, *Lasius neglectus* (Hymenoptera: Formicidae), in Hungary? *e-Acta Naturalia Pannonica* **8**: 117–123.

Tartally A., Antonova V., Espadaler X., Csősz S., Czechowski W. (2016): Collapse of the Invasive Garden Ant, *Lasius neglectus*, populations in four European countries. *Biological Invasions.* **18**(11): 3127–3131.

Tartally A., Hornung E. & Espadaler X. (2004): The joint introduction of *Platyarthrus schoblii* (Isopoda: Oniscidea) and *Lasius neglectus* (Hymenoptera: Formicidae) into Hungary. *Myrmecologische Nachrichten* **6**: 61–66.

Tuba K., Horváth B. & Lakatos F. (2012): *Inváziós rovarok fás növényeken.* Nyugat-magyarországi Egyetem Kiadó, Sopron.

Ugelvig L. V., Drijfhout F. P., Kronauer D. J. C., Boomsma J. J., Pedersen J. S. & Cremer S. (2008): The introduction history of Invasive Garden Ants in Europe: Integrating genetic, chemical and behavioural approaches. *BMC Biology* **6**: 11.

Van Loon A. J., Boomsma J. J. & Andrasfalvy A. (1990): A new polygynous *Lasius* species (Hymenoptera; Formicidae) from Central Europe. I. Description and general biology. *Insectes Sociaux* **37**(4): 348–362.

Vétek G., Bartha D. & Oláh R. (2017): Occurrence of the alien Zigzag Elm Sawfly, *Aproceros leucopoda* (Hymenoptera: Argidae), in arboretums and botanical gardens of Hungary. *Periodicum Biologorum* **119**(2): 101–106.

Vétek G., Csávás K. Fail J. & Ladányi M. (2022): Host plant range of *Aproceros leucopoda* is limited within Ulmaceae. *Agricultural and Forest Entomology* **24**(1): 1–7.

Vétek G., Fekete V., Ladányi M., Cargnus E., Zandigiacomo P., Oláh R., Schebeck M. & Schopf A. (2020): Cold tolerance strategy and cold hardiness of the invasive Zigzag Elm Sawfly *Aproceros leucopoda* (Hymenoptera: Argidae). *Agricultural and Forest Entomology* **22**(3): 231–237.

Vétek G., Mikulás J., Csóka Gy. & Blank S. M. (2010): A kanyargós szilleveldarázs (*Aproceros leucopoda* Takeuchi, 1939) Magyarországon. *Növényvédelem* **46**(11): 519–521.

Vétek G., Papp V., Fail J., Ladányi M. & Blank S. M. (2016): Applicability of coloured traps for the monitoring of the invasive Zigzag Elm Sawfly, *Aproceros leucopoda* (Hymenoptera: Argidae). *Acta Zoologica Academiae Scientiarum Hungaricae* **62**(2): 165–173.

Wu X.-Y. (2006): Studies on the biology and control of *Aproceros leucopoda. Plant Protection* **32**: 98–100.

Wu X.-Y. & Xin H. (2006): A new record species of the Genus *Aproceros* Malaise (Hymenoptera: Argidae) from China. *Entomotaxonomia* **28**(4): 279–280.

Zandigiacomo P., Cargnus E. & Villani A. (2011): First record of the invasive sawfly *Aproceros leucopoda* infesting elms in Italy. *Bulletin of Insectology* **64**(1): 145–149.

LEPIDOPTERANS – Lepidoptera

Bálint Zs. & Katona G. (2018): *A tölgypávaszem: a háziasított lepke.* – https://mttmuzeum.blog.hu/2018/09/11/a_tolgypavaszem_a_haziasitott_lepke

Buszko J., Šefrová H. & Laštůvka Z. (2000): Invasive species of Lithocolletinae in Europe and their spreading (Gracillariidae). *In: XII European Congress of Lepidopterology SEL. Programme and Abstracts. Białowieża, Poland, 29 May – 2 June 2000.* Białowieża: 22–23.

CABI (2022): *Phyllonorycter issikii* (Lime Leafminer). – https://www.cabi.org/isc/datasheet/40593

Csóka Gy. & Traser G. (1995): Hasznos károsítók. *Erdészeti Lapok* **130**(3): 80–81.

EPPO Global Database (2022): *Hyphantria cunea.* – https://gd.eppo.int/taxon/HYPHCU

EPPO Reporting Service (2003a): Occurrence of *Phyllonorycter issikii* in Estonia. *In: EPPO Global Database.* EPPO Reporting Service No. 09. – 2003. Num. article 2003/136. – https://gd.eppo.int/reporting/article-2122

EPPO Reporting Service (2003b): Occurrence of *Phyllonorycter issikii* in trees of Tilia cordata in Germany. *In: EPPO Global Database.* EPPO Reporting Service No. 09. – 2003. Num. article 2003/135. – https://gd.eppo.int/reporting/article-2121

Ermolaev I. V. & Zorin D. A. (2011): Ecological consequences of invasion of *Phyllonorycter issikii* (Lepidoptera, Gracillariidae) in lime forests in Udmurtia. *Entomological Review* **91**(5): 592–598.

Ermolaev I. V., Yefremova Z. A. & Domrachev T. B. (2018): The influence of parasitoids (Hymenoptera, Eulophidae) on survival of the Lime Leafminer *Phyllonorycter issikii* (Lepidoptera, Gracillariidae) in Udmurtia. *Entomological Review* **98**(4): 407–413.

Ermolaev I. V., Yefremova Z. A. & Izhboldina N. V. (2011): Parasitoids as a mortality factor for the Lime Leafminer (*Phyllonorycter issikii*, Lepidoptera, Gracillariidae). *Entomological Review* **91**(3): 326–334.

Guérin-Méneville M. (1861): Société impériale et centrale d'agriculture de France. *Revue et Magasin de Zoologie Pure et Appliquée* 2e série **13**(4): 187–192.

Győrfi J. (1954): *Hyphantria cunea* Drury. *Erdészeti Tudományos Intézet Évkönyve* **2**: 183–198.

Haltrich A. & Bodor J. (2017): Amerikai fehér medvelepke (*Hyphantria cunea* Drury, 1773). *Agrofórum* **28**(7): 40–45.

Herman L. H. (2001): Catalog of the Staphylinidae (Insecta: Coleoptera). 1758 to the end of the second millennium. I. Introduction, history, biographical sketches, and Omaliine group *Bulletin of the American Museum of Natural History* 2001 (265): 1–659.

Issekutz L. (1946): Uj lepkefaj a magyar faunában. A fehér medveszövőlepke *Hyphantria extor* Harr. *Rovartani Közlemények* **1**(3–4): 86–87.

Jermy T. (1957): Adatok a *Hyphantria cunea* Drury hernyóiban élősködő fürkészlegyek (Tachinidae) ismeretéhez. *Növényvédelmi Kutató Intézet Évkönyve* **7**: 253–262.

Kean J. M. & Kumarasinghe L. B. (2007): Predicting the seasonal phenology of Fall Webworm (*Hyphantria cunea*) in New Zealand. *New Zealand Plant Protection* **60**: 279–285.

Keve A. & Reichart G. (1960): Die Rolle der Vögel bei der Abwehr des amerikanischer Bärenspinners. *Der Falke* **7**(1): 20–26.

Kirichenko N. I., Zakharov E. V. & Lopez-Vaamonde C. (2022): Tracing the invasion of a leaf-mining moth in the Palearctic through DNA barcoding of historical herbaria. *Scientific Reports* **12**: 5065.

Klepikov M. A. (2005): Obzor fauny krivousykh krokhotok-moley i moley-pestryanok (Lepidoptera: Bucculatricidae, Gracillariidae) roslavskoy oblasti. *Eversmanniya* 2005 (3–4): 56–62.

Kovács L. (1957): A magyar nagylepkefauna gyarapodása 1956-ban. *Rovartani Közlemények* **10**(4): 125–132.

Kozlov M. V. (1991): Miniruyushchaya mol-pestryanka – vreditel lipy. *Zashchita Rasteniy* 1991 (4): 46.

Kumata T. (1963): Taxonomic studies on the Lithocolletinae of Japan (Lepidoptera: Gracillariidae). Part I. *Insecta Matsumurana* **25**(2): 53–90.

Kumata T., Kuroko H. & Park K.-T. (1983): Some Korean species of the subfamily Lithocolletinae (Gracillariidae, Lepidoptera). *Korean Journal of Plant Protection* **22**(3): 213–227.

Kuznetsov V. I. (1981): 24. Sem. Gracillariidae (Lithocolletidae) – moli-pestryanki In: Medvedeva G. S. (red.): *Opredelitel naszekomykh yevropeyszkoy chasti SSSR.* Tom. IV. *Cheshuyekrylye. Vtoraya chast.* Nauka, Leningrad: 149–311.

Macek J., Dvořák J., Traxler L. & Červenka V. (2007): *Motýli a housenky střední Evropy. Noční motýli I.* Academia, Praha.

Machay L. (1954): Az amerikai fehér szövőlepke elleni védekezés *Nosema bombycis* útján. *Rovartani Közlemények* **7**(12): 155–162.

Machay M. L. & Lovas B. (1955): Der Erreger der Viruskrankheit von *Hyphantria cunea* Drury. *Acta Microbiologica Academiae Scientiarum Hungaricae* **3**(1–2): 117–124.

Matošević D. (2007): *Lisni mineri drvenastog bilja u Hrvatskoj i njihovi parazitoidi.* Disertacija. Sveučilište u Zagrebu, Šumarsky Facultet, Zagreb.

Medzini M. (1971): *French policy in Japan during the closing years of the Tokugawa regime.* Harvard University Asia Center, Cambridge. /Harvard East Asian Monographs 41./

Mészáros Z. (2005): *A magyarországi molylepkék gyakorlati albuma.*:Agroinform Kiadó, Budapest. /*Növényvédelem* Különszám/

Mey W. (1991): Über die Bedeutung autochthoner Parasitoidenkomplexe bei der rezenten Arealexpansion von vier *Phyllonorycter*-Arten in Europa (Insecta, Lepidoptera, Hymenoptera). *Mitteilungen aus dem Zoologischen Museum in Berlin* **67**(1): 177–194.

Nagy B. (1953): A *Hyphantria* (szövőlepke) parazitamentés elvi és gyakorlati alapjai. *A Növényvédelem Időszerű Kérdései* 1953 (4): 24–28.

Nagy B., Reichart G. & Ubrizsy G. (1953): *Amerikai fehér szövőlepke (Hyphantria cunea Drury) Magyarországon.* Mezőgazdasági Kiadó, Budapest. /Növényvédelmi Kutató Intézet kiadványai 1./

Nahirnić A. & Beshkov S. (2015): The first report of Japanese Oak Silkmoth *Antheraea yamamai* (Guérin-Méneville, 1861) (Lepidoptera: Saturniidae) in Montenegro. *ZooNotes* **82**: 449–457.

Noreika R. (1998): *Phyllonorycter issikii* (Kumata) (Lepidoptera, Gracillariidae) in Lithuania. *Acta Zoologica Lituanica. Entomologia* **8**(3): 34–37.

Orlinskiy A. D., Sakhramanov I. K. & Mukhanov S. Yu. & Maslyakov V. Yu. (1991): Potentsialnye karantinnye vrediteli lesa v SSSR. Zashchita Rasteniy 1991 (11): 37–42.

Perny B. (2007): Lindenminiermotte *Phyllonorycter issikii*: Vorkommen in Österreich nach mehreren Verdachtsfällen nun bestätigt. *Forstschutz Aktuell* **38**: 9–11.

Pittaway A. R. (2022): *Saturniidae of the Western Palaearctic (including Europe, North Africa, the Middle East, western Siberia and western Central Asia).* – https://tpittaway.tripod.com/silk/satlist.htm.

Reichart G. (1993): Amerikai fehér medvelepke (*Hyphantria cunea* Drury). *In:* Jermy T. & Balázs K. (szerk.): *A növényvédelmi állattan kézikönyve.* 4/b kötet. Akadémiai Kiadó, Budapest: 695–705.

Rougeot P.-C. & Viette P. (1978): *Guide des papillons nocturnes d'Europe et d'Afrique du Nord. Hétérocères (partim).* Delachaux – Niestlé, Neuchâtel – Paris.

Sáfián Sz. & Szegedi B. (2008): A behurcolt tölgy-selyemlepke (*Antheraea yamamai* Guérin-Méneville, 1861) (Saturniidae: Lepidoptera) megjelenése a Soproni-hegyvidéken. *Szélkiáltó* **13**: 29.

Šefrová H. (2002): *Phyllonorycter issikii* (Kumata, 1963) – bionomics, ecological impact and spread in Europe (Lepidoptera, Gracillariidae). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* **50**(3): 99–104.

Šefrová H. (2003): Invasions of Lithocolletinae species in Europe – causes, kinds, limits and ecological impact (Lepidoptera, Gracillariidae). *Ekológia* **22**(2):132–142.

Surányi P. (1946): A fehér medveszövőlepke és életmódja. *Rovartani Közlemények* **1**(3–4): 87–90.

Szabóky Cs. & Csóka Gy. (2003): A hárslevél sátorosmoly (*Phyllonorycter issikii* Kumata, 1963 Lep. Gracillariidae) előfordulása Magyarországon. *Növényvédelem* **39**(1): 23–24.

Szelényi G. (1957): Újabb adatok az amerikai fehér szövőlepke élősködőinek ismeretéhez. *Növényvédelmi Kutató Intézet Évkönyve* **7**: 295–312.

Szeőke K. & Csóka Gy. (2012): Jövevény kártevő ízeltlábúak áttekintése Magyarországon. Lepkék (Lepidoptera). *Növényvédelem* **48**(3): 105–115.

Szőcs L., Hirka A. & Csóka Gy. (2016): A japán tölgy-selyemlepke (*Antheraea yamamai* Guérin-Méneville, 1861) Magyarországon. *In:* Kovács E., Kúti Zs. & Puskás J. (szerk.): *Fénycsapdán innen és túl... Tiszteletkötet Mészáros Zoltán és Nowinszky László professzor urak 80. születésnapjára.* Savaria University Press, Szombathely: 74–82.

Szőcs L., Melika G., Thuróczy Cs. & Csóka Gy. (2014): Adatok az invázív hárslevél sátorosmoly (*Phyllonorycter issikii* Kumata, 1963) magyarországi parazitoid együtteseinek ismeretéhez. *Növényvédelem* **50**(10): 445–451.

Szőcs L., Melika G., Thuróczy Cs. & Csóka Gy. (2015): Parasitoids of the Lime Leaf Miner *Phyllonorycter issikii* (Lepidoptera: Gracillariide) recorded throughout the area it recently colonized. *European Journal of Entomology* **112**(4): 591–598.

Tuba K., Horváth B. & Lakatos F. (2012): *Inváziós rovarok fás növényeken.* Nyugat-magyarországi Egyetem Kiadó, Sopron.

Uherkovich Á. (1984): Jelenkori terjedési jelenségek dél-dunántúli nagylepkéknél (Lepidoptera). *Állattani Közlemények* **71**(1–4): 165–176.

Wallace A. (1867): On the Oak feeding Silkworm from Japan, *Bombyx Yamamai* (Guérin-Méneville). *Transactions of the Royal Entomological Society of London* Third series **5**(5): 355–428.

Yefremova Z. A. & Mishchenko A. V. (2008): The parasitoids complex (Hymenoptera, Eulophidae) of the *Phyllonorycter issikii* (Kumata) (Lepidoptera, Gracillariidae) in the Middle Volga Basin. *Entomological Review* **88**(2): 178–185.

Yefremova Z. A. & Mishchenko A. V. (2010): The dynamics of the populations of dominant parasitoids (Hymenoptera, Eulophidae) of moth *Phyllonorycter issikii* (Kumata) (Lepidoptera, Gracillariidae) in the Middle Volga Basin. *Proceeding of the Russian Entomological Society* **80**(2): 64–75

Yermolayev V. P. (1977): Ekologo-faunisticheskiy obzor miniruyushchikh moley-pestryanok (Lepidoptera, Gracillariidae) Yuzhnovo Primorya. *Trudy Zoologicheskogo Instituta Akademii Nauk SSSR* **70**(6): 98–116.

DIPTERANS – Diptera

Adhami J. & Reiter P. (1998): Introduction and establishment of *Aedes (Stegomyia) albopictus* Skuse (Diptera: Culicidae) in Albania. *Journal of the American Mosquito Control Association* **14**(3): 340–343.

Andreadis T. G. & Wolfe R. J. (2010): Evidence for reduction of native mosquitoes with increased expansion of invasive *Ochlerotatus japonicus japonicus* (Diptera: Culicidae) in the northeastern United States. *Journal of Medical Entomology* **47**(1): 43–52.

Andreadis T. G., Anderson J. F., Munstermann L. E., Wolfe R. J. & Florin D. A. (2001): Discovery, distribution, and abundance of the newly introduced mosquito *Ochlerotatus japonicus* (Diptera: Culicidae) in Connecticut, USA. *Journal of Medical Entomology* **38**(6): 774–779.

Andreeva Y. V., Khrabrova N. V., Alekseeva S. S., Abylkassymova G. M., Simakova A. V. & Sibataev A. K. (2021): First record of the invasive mosquito species *Aedes koreicus* (Diptera, Culicidae) in the Republic of Kazakhstan. *Parasites* **28**: 52.

Apperson C. S., Hassan H. K., Harrison B. A., Savage H. M., Aspen S. E., Farajollahi A., Crans W., Daniels T. J., Falco R. C., Benedict M., Anderson M., McMillen L. & Unnasch T. R. (2004): Host feeding patterns of established and potential mosquito vectors of West Nile virus in the eastern United States. *Vector-borne and Zoonotic Diseases* **4**(1): 71–82.

Armistead J. S., Arias J. R., Nishimura N. & Lounibos L. P. (2008): Interspecific larval competition between *Aedes albopictus* and *Aedes japonicus* (Diptera: Culicidae) in northern Virginia. *Journal of Medical Entomology* **45**(4): 629–637.

Armistead J. S., Nishimura N., Arias J. R. & Lounibos L. P. (2012): Community ecology of container mosquitoes (Diptera: Culicidae) in Virginia following invasion by *Aedes japonicus*. *Journal of Medical Entomology* **49**(6): 1318–1327.

Asplen M. K., Anfora G., Biondi A., Choi D.-S., Chu D., Daane K. M., Gilbert P., Gutierrez A. P., Hoelmer K. A., Hutchison W. D., Isaacs R., Jiang Z.-L., Kárpáti Zs., Kimura M. T., Pascual M., Philips C. R., Plantamp C., Ponti L., Vétek G., Vogt H., Walton V. M.., Yu Y., Zappalà L. & Desneux N. (2015): Invasion biology of Spotted Wing Drosophila (*Drosophila suzukii*): a global perspective and future priorities. *Journal of Pest Science* **88**(3): 469–494.

Bakonyi T., Ferenczi E., Erdélyi K., Kutasi O., Csörgő T., Seidel B., Weissenböck H., Brugger K., Bán E. & Nowotny N. (2013): Explosive spread of a neuroinvasive lineage 2 West Nile virus in Central Europe, 2008/2009. *Veterinary Microbiology* **165**(1–2): 61–70.

Bakonyi T., Ivanics É., Erdélyi K., Ursu K., Ferenczi E., Weissenböck H. & Nowotny N. (2006): Lineage 1 and 2 strains of encephalitic West Nile virus, central Europe. *Emerging Infectious Diseases* **12**(4): 618–623.

Baldacchino F., Caputo B., Chandre F., Drago A., della Torre A., Montarsi F. & Rizzoli A. (2015): Control methods against invasive *Aedes* mosquitoes in Europe: a review. *Pest Management Science* **71**(11): 1471–1485.

Barna M. (2010): *Vadmadarak nyugat-nílusi vírus fertőzöttségének vizsgálata.* Szent István Egyetem, Állatorvos-tudományi Kar, Járványtani és Mikrobiológiai Tanszék, Budapest.

Bezzhonova O. V., Patraman I. V., Ganuskina L. A., Vysemirskiy O. I. & Sergiyev V. P. (2014): Pervaya nahodka invazivnogo vida

Aedes (Finlaya) koreicus (Edwards, 1917) v yevropeyskoy chasti Rossii. *Medicinskaya Parazitologiya i Parazitarnye Bolezni* **1**(1): 16–19.

Bonilauri P., Bellini R., Calzolari M., Angelini R., Venturi L., Fallacara F., Cordioli P., Angelini P., Venturelli C., Merialdi G. & Dottori M. (2008). Chikungunya virus in *Aedes albopictus*, Italy. *Emerging Infectious Diseases* **14**(5): 852–854.

Calba C., Guerbois-Galla M., Franke F., Jeannin C., Auzet-Caillaud M., Grard G., Pigaglio L., Decoppet A., Weicherding J., Savaill M.-C., Munoz-Riviero M., Chaud P., Cadiou B., Ramalli L., Fournier P., Noël H., De Lamballerie X., Paty M.-C. & Leparc-Goffart I. (2017): Preliminary report of an autochthonous chikungunya outbreak in France, July to September 2017. *Euro Surveillance* **22**(39): 17-00647.

Cancrini G., Frangipane di Regalbono A., Ricci I., Tessarin C., Gabrielli S. & Pietrobelli M. (2003a): *Aedes albopictus* is a natural vector of *Dirofilaria immitis* in Italy. *Veterinary Parasitology* **118**(3–4): 195–202.

Cancrini G., Romi R., Gabrielli S., Toma L., Di Paolo M. & Scaramozzino P. (2003b): First finding of *Dirofilaria repens* in a natural population of *Aedes albopictus*. *Medical and Veterinary Entomology* **17**(4): 448–51.

Capelli G., Drago A., Martini S., Montarsi F., Soppelsa M., Delai N., Ravagnan S., Mazzon L., Schaffner F., Mathis A., Di Luca M., Romi R. & Russo F. (2011): First report in Italy of the exotic mosquito species *Aedes (Finlaya) koreicus*, a potential vector of arboviruses and filariae. *Parasites & Vectors* **4**(1): 188.

Cini A., Anfora G., Escudero-Colomar L. A., Grassi A., Santosuosso U., Seljak G. & Papini A. (2014): Tracking the invasion of the alien fruit pest *Drosophila suzukii* in Europe. *Journal of Pest Science* **87**(4): 559–566.

Ciocchetta S., Prow N. A., Darbro J. M., Frentiu F. D., Savino S., Montarsi F., Capelli G., Aaskov J. G. & Devine G. J. (2018): The new European invader *Aedes (Finlaya) koreicus*: a potential vector of chikungunya virus. *Pathogens and Global Health* **112**(3): 107–114.

Enriquez T. & Colinet H. (2017): Basal tolerance to heat and cold exposure of the Spotted Wing Drosophila, *Drosophila suzukii*. *PeerJ* **5**: e3112.

Farkas R., Mag V., Gyurkovszky M., Takács N., Vörös K. & Solymosi N. (2020): The current situation of canine dirofilariosis in Hungary. *Parasitology Research* **119**(1): 129–135.

Forattini O. P. (1986): *Aedes (Stegomyia) albopictus* (Skuse) identification in Brazil. *Revista de Saúde Pública* **20**(3): 244–245.

Fraimout A., Debat V., Fellous S., Hufbauer R. A., Foucaud J., Pudlo P., Marin J.-M., Price D. K., Cattel J., Chen X., Deprá M., Duyck P. F., Guedot C., Kenis M., Kimura M. T., Loeb G., Loiseau A., Martinez-Sañudo I., Pascual M., Polihronakis Richmond M., Shearer P., Singh N., Tamura K., Xuéreb A., Zhang J. & Estoup A. (2017): Deciphering the routes of invasion of *Drosophila suzukii* by means of ABC random forest. *Molecular Biology and Evolution* **34**(4): 980–996.

Fuehrer H.-P., Schoener E., Weiler S., Barogh B. S., Zittra C. & Walder G. (2020): Monitoring of alien mosquitoes in Western Austria (Tyrol, Austria, 2018). *PLoS Neglected Tropical Diseases* **14**(6): e0008433.

Ganushkina L. A., Patraman I. V., Rezza G., Migliorini L., Litvinov S. K. & Sergiev V. P. (2016): Detection of *Aedes aegypti*, *Aedes albopictus*, and *Aedes koreicus* in the area of Sochi, Russia. *Vector-borne and Zoonotic Diseases* **16**(1): 58–60.

Gaspar J. P., McKay T. & Huss M. J. (2012): First report of *Aedes japonicus* in natural and artificial habitats in northeastern Arkansas. *Journal of the American Mosquito Control Association* **28**(1): 38–42.

Glávits R., Ferenczi E., Ivanics É., Bakonyi T., Mató T., Zarka P. & Palya V. (2005): Co-occurrence of West Nile Fever and circovirus infection in a goose flock in Hungary. *Avian Pathology* **34**(5): 408–414.

Global Invasive Species Database (2022): Species profile: *Aedes albopictus*. – http://www.iucngisd.org/gisd/species.php?sc=109

Hardstone M. C & Andreadis T. G. (2012): Weak larval competition between the invasive mosquito *Aedes japonicus japonicus* (Diptera: Culicidae) and three resident container-inhabiting mosquitoes in the laboratory. *Journal of Medical Entomology* **49**(2): 277–285.

Japoshvili G., Dzneladze N., Kirkitadze G., Kiss B. & Kaydan M. B. (2018): A new and dangerous pest for the Caucasus – *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae). *Annals of Agrarian Science* **16**(4): 464–465.

Kalan K., Šušnjar J., Ivović V. & Buzan E. (2017): First record of *Aedes koreicus* (Diptera, Culicidae) in Slovenia. *Parasitology Research* **116**(8): 2355–2358.

Kampen H., Zielke D. & Werner D. (2012): A new focus of *Aedes japonicus japonicus* (Theobald, 1901) (Diptera, Culicidae) distribution in Western Germany: rapid spread or a further introduction event? *Parasites & Vectors* **5**(1): 284.

Kecskeméti S., Bajmócy E., Bacsadi Á., Kiss I. & Bakonyi T. (2007): Encephalitis due to West Nile virus in a sheep. *The Veterinary Record* **161**(16): 568–569.

Kiss B., Kis A. & Kákai Á. (2016): The rapid invasion of Spotted Wing Drosophila, *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae), in Hungary. *Phytoparasitica* **44**(3): 429–433.

Knudsen A. B. (1995): Global distribution and continuing spread of *Aedes albopictus*. *Parasitologia* **37**(2–3): 91–97.

Kurucz K., Kepner A., Krtinic B., Hederics D., Földes F., Zana B., Jakab F. & Kemenesi G. (2018): Blood-meal analysis and avian malaria screening of mosquitoes collected from human-inhabited areas in Hungary and Serbia. *Journal of the European Mosquito Control Association* **36**: 3–13.

Kurucz K., Kiss V., Zana B., Schmieder V., Kepner A., Jakab F. & Kemenesi G. (2016): Emergence of *Aedes koreicus* (Diptera: Culicidae) in an urban area, Hungary, 2016. *Parasitology Research* **115**(12): 4687–4689.

Kurucz K., Manica M., Delucchi L., Kemenesi G. & Marini G. (2020): Dynamics and distribution of the invasive mosquito *Aedes koreicus* in a temperate European city. *International Journal of Environmental Research and Public Health* **17**(8): 2728.

Laird M., Calder L., Thornton R. C., Syme R., Holder P. W. & Mogi M. (1994): Japanese *Aedes albopictus* among four mosquito species reaching New Zealand in used tires. *Journal of the American Mosquito Control Association* **10**(1): 14–23.

Lorenz A. R., Walker E. D. & Kaufman M. G. (2013): Does autocthonous primary production influence oviposition by *Aedes japonicus japonicus* (Diptera: Culicidae) in container habitats? *Journal of Medical Entomology* **50**(1): 69–78.

Marini G., Arnoldi D., Baldacchino F., Capelli G., Guzzetta G., Merler S., Montarsi F., Rizzoli A. & Rosà R. (2019): First report of the influence of temperature on the bionomics and population dynamics of *Aedes koreicus*, a new invasive alien species in Europe. *Parasites & Vectors* **12**(1): 524.

Marini G., Guzzetta G., Baldacchino F. Arnoldi D., Montarsi F., Capelli G., Rizzoli A., Merler S. & Rosà R. (2017): The effect of interspecific competition on the temporal dynamics of *Aedes albopictus* and *Culex pipiens*. *Parasites & Vectors* **10**(1): 102.

Medlock J. M., Avenell D., Barrass I. & Leach S. (2006): Analysis of the potential for survival and seasonal activity of *Aedes albopictus* (Diptera: Culicidae) in the United Kingdom. *Journal of Vector Ecology* **31**(2): 292–304.

Medlock J. M., Hansford K. M., Schaffner F., Versteirt V., Hendrickx G., Zeller H. & Van Bortel W. (2012): A review of the invasive mosquitoes in Europe: ecology, public health risks, and control options. *Vector-borne and Zoonotic Diseases* **12**(6): 435–447.

Medlock J. M., Snow K. R. & Leach S. (2005): Potential transmission of West Nile virus in the British Isles: an ecological review of candidate mosquito bridge vectors. *Medical and Veterinary Entomology* **19**(1): 2–21.

Montarsi F., Ciocchetta S., Devine G., Ravagnan S., Mutinelli F., Frangipane di Regalbono A., Otranto D. & Capelli G. (2015): Development of *Dirofilaria immitis* within the mosquito *Aedes (Finlaya) koreicus*, a new invasive species for Europe. *Parasites & Vectors* **8**(1): 177.

Montarsi F., Martini S., Dal Pont M., Delai N., Ferro Milone N., Mazzucato M., Soppelsa F., Cazzola L., Cazzin S., Ravagnan S., Ciocchetta S., Russo F. & Capelli G. (2013): Distribution and habitat characterization of the recently introduced invasive mosquito *Aedes koreicus* [*Hulecoeteomyia koreica*], a new potential vector and pest in north-eastern Italy. *Parasites & Vectors* **6**(1): 292.

Orosz S., Kiss B., Szántóné Veszelka M., Pestiné Jánoska Zs., Torzsa S., Krocskó G. & Kákai Á. (2018): A pettyesszárnyú muslica térhódítása hazánkban. *Növényvédelem* **79**(6): 237–245.

Paupy C., Delatte H., Bagny L., Corbel V. & Fontenille D. (2009): *Aedes albopictus*, an arbovirus vector: From the darkness to the light. *Microbes and Infection* **11**(14–15): 1177–1185.

Poyet M., Le Roux V., Gibert P., Meirland A., Prévost G., Eslin P. & Chabrerie O. (2015). The wide potential trophic niche of the Asiatic Fruit Fly *Drosophila suzukii*: The key of its invasion success in temperate Europe? *PLoS ONE* **10**(11): e0142785.

Riccardo F., Venturi G., Di Luca M., Del Manso M., Severini F., Andrianou X., Fortuna

C., Remoli M. E., Benedetti E., Caporali M. G., Fratto F., Mignuoli A. D., Rizzo L., De Vito G., De Giorgio V., Surace L., Vairo F., Angelini P., Re M. C., Amendola A., Fiorentini C., Marsili G., Toma L., Boccolini D., Romi R., Pezzotti P., Rezza G. & Rizzo C. (2019): Secondary autochthonous outbreak of chikungunya, Southern Italy, 2017. *Emerging Infectious Diseases* **25**(11): 2093–2095.

Romi R., Severini F. & Toma L. (2006): Cold acclimation and overwintering of female *Aedes albopictus* in Roma. *Journal of the American Mosquito Control Association* **22**(1): 149–151.

Ryan G. D., Emiljanowicz L., Wilkinson F., Kornya M. & Newman J. A. (2016): Thermal tolerances of the Spotted-Wing Drosophila *Drosophila suzukii* (Diptera: Drosophilidae). *Journal of Economic Entomology* **109**(2): 746–752.

Sardelis M. R., Turell M. J. & Andre R. G. (2003): Experimental transmission of St. Louis encephalitis virus by *Ochlerotatus j. japonicus*. *Journal of the American Mosquito Control Association* **19**(2): 159–162.

Sárdi S., Szentpáli-Gavallér K., Bakonyi T., Szenci O. & Kutasi O. (2012): Lovak nyugat-nílusi vírus okozta agy- és gerincvelő gyulladása. Irodalmi áttekintés. *Magyar Állatorvosok Lapja* **134**(12): 707–717.

Schaffner F., Chouin S. & Guilloteau J. (2003): First record of *Ochlerotatus (Finlaya) japonicus japonicus* (Theobald, 1901) in metropolitan France. *Journal of the American Mosquito Control Association* **19**(1): 1–5.

Schaffner F., Kaufmann C., Hegglin D. & Mathis A. (2009): The invasive mosquito *Aedes japonicus* in Central Europe. *Medical and Veterinary Entomology* **23**(4): 448–451.

Schaffner F., Vazeille M., Kaufmann C., Failloux A.-B. & Mathis A. (2011): Vector competence of *Aedes japonicus* for chikungunya and dengue viruses. *European Mosquito Bulletin* **29**: 141–142.

Scholte E.-J. & Schaffner F. (2007): Waiting for the tiger: establishment and spread of the *Aedes albopictus* mosquito in Europe. *In:* Takken W & Knols B. G. J. (eds.): *Emerging pests and vector-borne diseases in Europe.* Volume 1. Wageningen Academic Publishers, Wageningen: 241–300.

Seidel B., Montarsi F., Huemer H. P., Indra A. Capelli G. Allerberger F. & Nowotny N. (2016): First record of the Asian Bush Mosquito, *Aedes japonicus japonicus*, in Italy: invasion from an established Austrian population. *Parasites & Vectors* **9**(1): 284.

Soltész Z. & Zöldi V. (2017): Behurcolt és invazív csípőszúnyogok Magyarországon. *Magyar Tudomány* **178**(4): 410–412.

Sprenger D. & Wuithiranyagool T. (1986): The discovery and distribution of *Aedes albopictus* in Harris County, Texas. *Journal of the American Mosquito Control Association* **2**(2): 217–219.

Stockton D. G., Wallingford A. K. & Loeb G. M. (2018): Phenotypic plasticity promotes overwintering survival in a globally invasive crop pest, *Drosophila suzukii*. *Insects* **9**(3): 105.

Suter T., Flacio E., Fariña B. F., Engeler L., Tonolla M. & Müller P. (2015): First report of the invasive mosquito species *Aedes koreicus* in the Swiss-Italian border region. *Parasites & Vectors* **8**(1): 402

Tait G., Grassi A., Pfab F., Crava C. M., Dalton D. T., Magarey R., Ometto L., Vezzulli S., Rossi-Stacconi M. V., Gottardello A., Pugliese A., Firrao G., Walton V. M. & Anfora G. (2018): Large-scale spatial dynamics of *Drosophila suzukii* in Trentino, Italy. *Journal of Pest Science* **91**(4): 1213–1224.

Tait G., Mermer S., Stockton D., Lee J., Avosani S., Abrieux A., Anfora G., Beers E., Biondi A., Burrack H., Cha D., Chiu J. C., Choi M.-Y., Cloonan K., Crava C. M., Daane K. M., Dalton D. T., Diepenbrock L., Fanning P., Ganjisaffar F., Gómez M. I., Gut L., Grassi A., Hamby K., Hoelmer K. A., Ioriatti C., Isaacs R., Klick J., Kraft L., Loeb G., Rossi-Stacconi M. V., Nieri R., Pfab F., Puppato S., Rendon D., Renkema J., Rodriguez-Saona C., Rogers M., Sassù F., Schöneberg T., Scott M. J., Seagraves M., Sial A., Van Timmeren S., Wallingford A., Wang X., Yeh D. A., Zalom F. G. & Walton V. M. (2021): *Drosophila suzukii* (Diptera: Drosophilidae): A decade of research towards a sustainable integrated pest management program. *Journal of Economic Entomology* **114**(5): 1950–1974.

Takashima I. & Rosen L. (1989): Horizontal and vertical transmission of Japanese encephalitis virus by *Aedes japonicus* (Diptera: Culicidae). *Journal of Medical Entomology* **26**(5): 454–458.

Tanaka K., Mizusawa K. & Saugstad E. S. (1979): A revision of the adult and larval mosquitoes of Japan (including the Ryukyu Archipelago and the Ogasawara islands) and Korea (Diptera: Culicidae). *Contributions of the American Entomological Institute* **16**: 1–987.

Thomas S. M., Obermayr U., Fischer D., Kreyling J. & Beierkuhnlein C. (2012): Low-temperature threshold for egg survival of a post-diapause and non-diapause European aedine strain, *Aedes albopictus* (Diptera: Culicidae). *Parasites & Vectors* **5**(1): 100.

Tochen S., Dalton D. T., Wiman N., Hamm C., Shearer P. W. & Walton W. M. (2014): Temperature-related development and population parameters for *Drosophila suzukii* (Diptera: Drosophilidae) on cherry and blueberry. *Environmental Entomology* **43**(2): 501–510.

Tóth S. (2004): *Magyarország csípőszúnyog-faunája (Diptera: Culicidae).* Somogy Megyei Múzeumok Igazgatósága, Kaposvár. /Natura Somogyiensis 6./

Turell M. J., Byrd B. D. & Harrison B. A. (2013): Potential for populations of *Aedes j. japonicus* to transmit Rift Valley fever virus in the USA. *Journal of the American Mosquito Control Association* **29**(2): 133–137.

Versteirt V., De Clercq E. M., Fonseca D. M., Pecor J., Schaffner F., Coosemans M. & Van Bortel W. (2012): Bionomics of the established exotic mosquito species *Aedes koreicus* in Belgium, Europe. *Journal of Medical Entomology* **49**(6): 1226–1232.

Versteirt V., Schaffner F., Garros C., Dekoninck W., Coosemans M. & Van Bortel W. (2009): Introduction and establishment of the exotic mosquito species *Aedes japonicus japonicus* (Diptera: Culicidae) in Belgium. *Journal of Medical Entomology* **46**(6): 1464–1467.

Werner D., Zielke D. E. & Kampen H. (2016): First record of *Aedes koreicus* (Diptera: Culicidae) in Germany. *Parasitology Research* **115**(3): 1331–1334.

Wong P.-S. J., Li M. I., Chong C.-S., Ng L.-C. & Tan C.-H. (2013): *Aedes (Stegomyia) albopictus* (Skuse): a potential vector of Zika virus in Singapore. *PLoS Neglected Tropical Diseases* **7**(8): e2348.

FISHES – Pisces

Adámek Z., Andreji J. & Gallardo J. M. (2007): Food habits of four bottom-dwelling gobiid species at the confluence of the Danube and Hron rivers (South Slovakia). *International Review of Hydrobiology* **92**(4–5): 554–563.

Ahnelt H., Bănărescu P., Spolwind R., Harka Á. & Waidbacher H. (1998): Occurrence and distribution of three gobiid species (Pisces, Gobiidae) in the middle and upper Danube region – examples of different dispersal patterns? *Biologia (Bratislava)* **53**(5): 665–678.

Ahnelt H., Bianco P. G. & Schwammer H. (1995): Systematics and zoogeography of *Knipowitschia caucasica* (Teleostei: Gobiidae) based on new records from the Aegean Anatolian area. *Ichthyological Exploration of Freshwaters* **6**(1): 49–60.

Allen Y., Kirby S., Copp G. H. & Brazier M. (2006): Toxicity of rotenone to Topmouth Gudgeon *Pseudorasbora parva* for eradication of this non-native species from a tarn in Cumbria, England. *Fisheries Management and Ecology* **13**(5): 337–340.

Allendorf F. W. & Utter F. M. (1979): Population genetics. *In:* Hoar W. S., Randall D. J. & Brett J. R. (eds.): *Fish physiology.* Volume 8. *Bioenergetics and growth.* Academic Press, New York: 407–454.

Almeida D., Merino-Aguirre R., Vilizzi L. & Copp G. H. (2014): Interspecific aggressive behaviour of invasive Pumpkinseed *Lepomis gibbosus* in Iberian fresh waters. *PLoS ONE* **9**(2): e88038.

Balogh R. E., Borzák R., Doszpoly A., Mári Á. & Weiperth A. (2021): A feketeszájú géb (*Neogobius melanostomus*) első bányatavi észlelése Magyarországon. *Halászat* **114**(3): 98.

Bănărescu P. (1992): *Zoogeography of fresh waters.* Volume 2. *Distribution and dispersal of freshwater animals in North America and Eurasia.* AULA-Verlag, Weisbaden.

Barros L. C., Santos U., Zanuncio J. C. & Dergam J. A. (2012): *Plagioscion squamosissimus* (Sciaenidae) and *Parachromis managuensis* (Cichlidae): a threat to native fishes of the Doce River in Minas Gerais, Brazil. *PLoS ONE* **7**(6): e39138.

Báskay I., Pénzes B. & Repkényi Z. (1998): Adatok a szúnyogirtó fogasponty (*Gambusia affinis holbrooki* Girard, 1859) táplálkozásához és szaporodásához hazai körülmények között. *Állattani Közlemények* **83**: 67–82.

Behnke R. (1992): *Native trout of Western North America.* American Fisheries Society, Bethesda. /American Fisheries Society Monograph 6./

Berg L. S. (1949): *Ryby presnykh vod SSSR i sopredelnykh stran.* Ch. 3. 4-ye izd. Izd-vo Akademii nauk SSSR, Moskva – Leningrad.

Berinkey L. (1960): The Sticleback (*Gasterosteus aculeatus* L.), a new fish species from Hungary. *Vertebrata Hungarica* **2**(1): 1–10.

Berinkey L. (1966): *Pisces – Halak.* Akadémiai Kiadó, Budapest.

Beukeboom L. W. & Vrijenhoek R. C. (1998): Evolutionary genetics and ecology of sperm-dependent parthenogenesis. *Journal of Evolutionary Biology* **11**(6): 755–782.

Billard R. (1997): *Les poissons d'eau douce des rivières de France. Identification, inventaire et répartition des 83 espèces.* Delachaux & Niestlé, Lausanne. /Les encyclopédies du naturaliste/

Bíró P. (1971): Egy új gébféle (*Neogobius fluviatilis* Pallas) a Balatonból. *Halászat* **18/64**/(1): 22–23.

Biró P. (1972): *Neogobius fluviatilis* in Lake Balaton – a Ponto-Caspian goby new to the fauna of central Europe. *Journal of Fish Biology* **4**(2): 249–255.

Blanchet S., Loot G., Grenouillet G. & Brosse S. (2007): Competitive interactions between native and exotic salmonids: a combined field and laboratory demonstration. *Ecology of Freshwater Fish* **16**(2): 133–143.

Bódis E., Borza P., Potyó I., Puky M., Weiperth A. & Guti G. (2012): Invasive mollusc, crustacean, fish and reptile species along the Hungarian stretch of the River Danube and some connected waters. *Acta Zoologica Academiae Scientiarum Hungaricae* **58** (Supplement 1): 29–45.

Bonar S. A., Bolding B. & Divens M. (2002): Effects of triploid Grass Carp on aquatic plants, water quality, and public satisfaction in Washington State. *North American Journal of Fisheries Management* **22**(1): 96–105.

Borcherding J., Hertel A. & Breiden S. (2013): Activity and competitive behaviour of invasive *Neogobius melanostomus* and *Ponticola kessleri* (Gobiidae) from the River Rhine, Germany. *Ethology Ecology & Evolution* **25**(4): 351–365.

Borza P., Erős T. & Oertel N. (2009): Food resource partitioning between two invasive gobiid species (Pisces, Gobiidae) in the littoral zone of the River Danube, Hungary. *International Review of Hydrobiology* **94**(5): 609–621.

Botta I., Keresztessy K. & Neményi I. (1984): Halfaunisztikai és ökológiai tapasztalatok természetes vizeinkben. *Állattani Közlemények* **71**(1–4): 39–50.

Brandner J., Auerswald K., Cerwenka A. F., Schliewen U. K. & Geist J. (2013): Comparative feeding ecology of invasive Ponto-Caspian gobies. *Hydrobiologia* **703**(1): 113–131.

Brett B. L. H. & Turner B. L. (1983): Genetic divergence in the *Poecilia sphenops* complex in Middle America. *Biochemical Systematics and Ecology* **11**(2): 127–137.

Brown T. G., Runciman B., Pollard S. & Grant A. D. A. (2009): *Biological synopsis of Largemouth Bass (Micropterus salmoides).* Fisheries and Oceans Canada, Science Branch, Pacific Region, Pacific Biological Station, Nanaimo (British Columbia). /Canadian Manuscript Report of Fisheries and Aquatic Sciences 2884./

CABI (2021): *Gambusia affinis* (Western Mosquitofish). *In: Invasive Species Compendium.* CAB International, Wallingford. – www.cabi.org

Caiola N. & de Sostoa A. (2002): First record of the Asiatic cyprinid *Pseudorasbora parva* in the Iberian Peninsula. *Journal of Fish Biology* **61**(4): 1058–1060.

Charlebois P. M., Corkum L. D., Jude D. J. & Knight C. (2001): The Round Goby (*Neogobius melanostomus*) invasion: current research and future needs. *Journal of Great Lakes Research* **27**(3): 263–266.

Copp G. H. & Fox M. G. (2007): Growth and life history traits of introduced Pumpkinseed (*Lepomis gibbosus*) in Europe, and the relevance to its potential invasiveness. *In:* Gherardi F. (ed.): *Biological invaders in inland waters: Profiles, distribution, and threats.* Springer, Dordrecht: 289–306.

Copp G. H., Britton J. R., Guo Z., Edmonds-Brown V. R., Pegg J., Vilizzi L. & Davidson P. I. (2017): Trophic consequences of non-native Pumpkinseed *Lepomis gibbosus* for native pond fishes. *Biological Invasions* **19**(1): 25–41.

Copp G. H., Garthwaite R. & Gozlan R. E. (2005): Risk identification and assessment of non-native freshwater fishes: a summary of concepts and perspectives on protocols for the UK. *Journal of Applied Ichthyology* **21**(4): 371–373.

Copp G. H., Tarkan A. S., Masson G., Godard M. J., Koščo J., Kováč V., Novomeská A., Miransa R., Cucherousset J., Pedicillo G. & Blackwell B. G. (2016): A review of growth and life-history traits of native and non-native European populations of Black Bullhead *Ameiurus melas*. *Reviews in Fish Biology and Fisheries* **26**(3): 441–469.

Courtenay W. R. (2006): *U. S. Fish and Wildlife Service Lacey Act Evaluation Criteria. Rotan, Perccottus glenii (Pisces, Odontobutidae).* Technical Assistance Document to the United States Fish and Wildlife Service.

Courtenay W. R. & Meffe G. K. (1989): Small fishes in strange places: a review of introduced poeciliids. *In:* Meffe G. K. & Snelson F. F. (eds.): *Ecology and evolution of livebearing fishes (Poeciliidae).* Prentice Hall, Englewood Cliffs (New Jersey): 319–331.

Cowen R. K., Chiarella L. A., Gomez C. J. & Bell M. A. (1991): Offshore distribution, size, age, and lateral plate variation of late larval/early juvenile Sticklebacks (*Gasterosteus*) off the Atlantic coast of New Jersey and New York. *Canadian Journal of Fisheries and Aquatic Sciences* **48**(9): 1679–1684.

Crawford S. S. & Muir A. M. (2008): Global introductions of salmon and trout in the genus *Oncorhynchus*: 1870–2007. *Reviews in Fish Biology and Fisheries* **18**(3): 313–344.

Czeglédi I., Preiszner B., Vitál Z., Kern B., Boross N., Specziár A., Takács P. & Erős T. (2019): Habitat use of invasive Monkey Goby (*Neogobius fluviatilis*) and Pumpkinseed (*Lepomis gibbosus*) in Lake Balaton (Hungary): a comparison of electrofishing and fyke netting. *Hydrobiologia* **846**(1): 147–158.

Csipkés R., Szatmári L. & Soós N. (2012): Nyugati pikó (*Gasterosteus gymnurus*) a Drávában. *Halászat* **105**(1): 17–18.

Dillon A. K. & Stepien C. A. (2001): Genetic and biogeographic relationships of the invasive Round (*Neogobius melanostomus*) and Tubenose (*Proterorhinus marmoratus*) Gobies in the Great Lakes versus Eurasian populations. *Journal of Great Lakes Research* **27**(3): 267–280.

Erős T. (2007): Partitioning the diversity of riverine fish: the roles of habitat types and non-native species. *Freshwater Biology* **52**(7): 1400–1415.

Erős T. & Guti G. (1997): Kessler-géb (*Neogobius kessleri* Günther, 1861) a Duna magyarországi szakaszán – új halfaj előfordulásának igazolása. *Halászat* **90**(2): 83–84.

Erős T., Bammer V., György Á. I., Pehlivanov L., Schabuss M., Zornig H., Weiperth A. & Szalóky Z. (2017): Typology of a great river using fish assemblages: implications to the bioassessment of the Danube River. *River Research and Applications* **33**(1): 37–49.

Erős T., Sevcsik A. & Tóth B. (2005): Abundance and night-time habitat use patterns of Ponto-Caspian gobiid species (Pisces, Gobiidae) in the littoral zone of the River Danube, Hungary. *Journal of Applied Ichthyology* **21**(4): 350–357.

Erős T., Takács P., Sály P., Specziár A., György Á. I. & Bíró P. (2008a): Az amurgéb, a *Perccottus glenii* Dybowski, 1877 megjelenése a Balaton vízgyűjtőjén. *Halászat* **101**(2): 75–77.

Erős T., Tóth B., Sevcsik A. & Schmera D. (2008b): Comparison of fish assemblage diversity in natural and artificial rip-rap habitats in the littoral zone of a large river (River Danube, Hungary). *International Review of Hydrobiology* **93**(1): 88–105.

Etnier D. A. & Starnes W. C. (1993): *The fishes of Tennessee*. The University of Tennessee Press, Knoxville.

FAO (2021): *Hypophthalmichthys nobilis* (Richardson, 1845) [Cyprinidae]. *In: Cultured aquatic species fact sheets.* – www.fao.org/fishery/

Farský M., Hajdú J., Pekárik L. & Kautman J. (2013): On the occurence of the Siberian Sturgeon (*Acipenser baerii* Brandt, 1869) in Slovak–Hungarian section of the Danube. *Pisces Hungarici* **7**: 139–140.

Ferincz Á., Horváth Zs., Staszny Á., Ács A, Kováts N., Vad Cs. F., Csaba J., Sütő Sz. & Paulovits G. (2016a): Desiccation frequency drives local invasions of non-native Gibel Carp (*Carassius gibelio*) in the catchment of a large, shallow lake (Lake Balaton, Hungary). *Fisheries Research* **173**(1): 37–44.

Ferincz Á., Staszny Á., Weiperth A., Takács P., Urbányi B., Vilizzi L., Paulovits G. & Copp G. H. (2016b): Risk assessment of non-native fishes in the catchment of the largest Central-European shallow lake (Lake Balaton, Hungary). *Hydrobiologia* **780**(1): 85–97.

Ferincz Á., Juhász V., Staszny Á., Urbányi B. & Takács P. (2019): Idegenhonos halak Magyarországon. A betelepítések okai, trendjei és forrásai. *Magyar Horgász* **73**(3): 24–25.

Fobert E., Fox M. G., Ridgway M. & Copp G. H. (2011): Heated competition: how climate change will affect non-native Pumpkinseed *Lepomis gibbosus* and native Perch *Perca fluviatilis* interactions in the U. K. *Journal of Fish Biology* **79**(6): 1592–1607.

Freedman J. A., Butler S. E. & Wahl D. H. (2012): *Impacts of invasive Asian carps on native food webs. Final project report.* Kaskaskia Biological Station, Illinois Natural History Survey, University of Illinois at Urbana-Champaign, Champaign (Illinois).

Freyhof J. & Kottelat M. (2008): *Babka gymnotrachelus. In: The IUCN Red List of Threatened Species 2008*: e.T188118A8643960. – www.iucnredlist.org

Friedrich T., Gessner J., Reinartz R. & Striebel-Greiter B. (eds.) (2018): *Pan-European Action Plan for Sturgeons. Multi Species Action Plan for the: Russian Sturgeon complex (Acipenser gueldenstaedtii, A. persicus-colchicus), Adriatic Sturgeon (Acipenser naccarii), Ship Sturgeon (Acipenser nudiventris), Atlantic/Baltic Sturgeon, (Acipenser oxyrinchus), Sterlet (Acipenser ruthenus), Stellate Sturgeon (Acipenser stellatus), European/Common Sturgeon (Acipenser sturio), and Beluga (Huso huso).* Convention on the Conservation of European Wildlife and Natural Habitats, Strassbourg.

Friedrich T., Reinartz R. & Gessner J. (2019): Sturgeon re-introduction in the Upper and Middle Danube River Basin. *Journal of Applied Ichthyology* **35**(5): 1059–1068.

Frimodt C. (1995): *Illustrated multilingual guide to the world's commercial warmwater fish.* John Wiley and Sons Ltd., Oxford.

Froese R. & Pauly D. (eds.) (2021a): *Ctenopharyngodon idella* (Valenciennes, 1844). Grass Carp. *In: FishBase.* – www.fishbase.org

Froese R. & Pauly D. (eds.) (2021b): *Gambusia affinis* (Baird & Girard, 1853). Mosquitofish. *In: FishBase.* – www.fishbase.org

Froese R. & Pauly D. (eds.) (2021c): *Hypophthalmichthys molitrix* (Valenciennes, 1844). *In: FishBase.* – www.fishbase.org

Frommen J. G., Herder F., Engqvist L., Mehlis M., Bakker T. C. M., Schwarzer J. & Thünken T. (2011): Costly plastic morphological responses to predator specific odour cues in Three-spined Sticklebacks (*Gasterosteus aculeatus*). *Evolutionary Ecology* **25**(3): 641–656.

Fuller P. & Cannster M. (2022): *Lepomis gibbosus* (Linnaeus, 1758). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida) – https://nas.er.usgs.gov

Gante H. F. & Santos C. D. (2002): First records of the North American Catfish *Ameiurus melas* in Portugal. *Journal of Fish Biology* **61**(6): 1643–1646.

García-Berthou E. (2002): Ontogenetic diet shifts and interrupted piscivory in introduced Largemouth Bass (*Micropterus salmoides*). *International Review of Hydrobiology* **87**(4): 353–363.

Gestring K. & Shafland P. (1997): Selected life history attributes of the exotic Jaguar Guapote (*Cichlasoma managuense*) in Florida. *Florida Scientist* **60**(3): 137–142.

Gheorghiev J. M. (1964): Some new and little known bullheads (Gobiidae, Pisces) to Bulgarian ichthyofauna. *Izvestija na Instituta po Ribovdstvo i Ribolov (Varna)* **4**: 189–206.

Gherardi F., Gollasch S., Minchin D., Olenin S. & Panov V. E. (2009): Alien invertebrates and fish in European inland waters. *In:* DAISIE (ed.): *Handbook of alien species in Europe.* Springer, *sine loco:* 81–92.

Gozlan R. E., Pinder A. C. & Shelley J. (2002): Occurrence of the Asiatic cyprinid *Pseudorasbora parva* in England. *Journal of Fish Biology* **61**(1): 298–300.

Gozlan R. E., St-Hilaire S., Feist S. W., Martin P. & Kent M. L. (2005): Disease threat to European fish. *Nature* **435**(7045): 1046.

Grabowska J., Tarkan A. S., Błońska D., Karakuş N. T., Janic B. & Przybylski M. (2021): Prolific pioneers and reserved settlers. Changes in the life-history of the Western Tubenose Goby (*Proterorhinus semilunaris*) at different invasion stages. *Science of the Total Environment* **750**: 142316.

Guti G. (2005): A csupasztorkú géb, *Neogobius gymnotrachelus* (Kessler, 1857) megjelenése a Duna magyarországi szakaszán. *Halászat* **98**(4): 161–162.

Guti G., Erős T., Szalóky Z. & Tóth B. (2003): A kerekfejű géb, a *Neogobius melanostomus* (Pallas, 1811) megjelenése a Duna magyarországi szakaszán. *Halászat* **96**(3): 116–119

Györe K. (1995): *Magyarország természetesvízi halai (Szervezettan, élettan, ökológia, rendszertan).* Környezetgazdálkodási Intézet, [Budapest]. / Vízi természet- és környezetvédelem 1./

Halasi-Kovács B. & Antal L. (2011): Új ponto-kaszpikus gébfaj, kaukázusi törpegéb (*Knipowitschia caucasica* Berg, 1916) a Kárpát-medencében – a terjeszkedés ökológiai kérdései. *Halászat* **104**(3–4): 120–128.

Halasi-Kovács B., Antal L. & Nagy S. A. (2011): First record of a Ponto-Caspian *Knipowitschia* species (Gobiidae) in the Carpathian basin, Hungary. *Cybium* **35**(3): 257–258.

Halasi-Kovács B., Szepesi Zs. & Harka Á. (2015): Kaukázusi törpegéb (*Knipowitschia caucasica*) a Körös vízrendszerében. *Halászat* **108**(3): 13–14.

Halverson M. A. (2008): Stocking trends: A quantitative review of governmental fish stocking in the United States, 1931 to 2004. *Fisheries* **33**(2): 69–75.

Hanel L., Plesník J., Andreska J., Lusk S., Novák J. & Plíštil J. (2011): Alien fishes in European waters. *Bulletin Lampetra* **7**: 148–185.

Hänfling B., Bolton P., Harley M. & Carvalho G. R. (2005): A molecular approach to detect hybridisation between Crucian Carp (*Carassius carassius*) and non-indigenous carp species (*Carassius* spp. and *Cyprinus carpio*). *Freshwater Biology* **50**(3): 403–417.

Hansson L.-A., Johansson L. & Persson L. (1987): Effects of fish grazing on nutrient release and succession of primary producers. *Limnology and Oceanography* **32**(2): 723–729.

Harka Á. (1998): Magyarország faunájának új halfaja: az amurgéb (*Perccottus glehni* Dybowsky, 1877). *Halászat* **91**(1): 32–33.

Harka Á. & Sallai Z. (2004): *Magyarország halfaunája. Képes határozó és elterjedési tájékoztató.* Nimfea Természetvédelmi Egyesület, Szarvas.

Harka Á. & Szepesi Zs. (2010): Hány pikófaj (*Gasterosteus* sp.) él Magyarországon? *Pisces Hungarici* **4**: 101–103.

Harka Á. & Szepesi Zs. (2016): The successful establishment of Eastern Mosquitofish (*Gambusia holbrooki* Girard, 1859) in the River Zagyva. *Pisces Hungarici* **10**: 85–87.

Harka Á., Nyeste K., Nagy L. & Erős T. (2014): Bíborsügérek (*Hemichromis guttatus* Günther, 1862) a Hévízi-tó termálvizében. *Pisces Hungarici* **8**: 29–34.

Harka Á., Šanda R. & Halasi-Kovács B. (2012): Egy új invazív gébfaj, a kaukázusi törpegéb – *Knipowitschia caucasica* (Berg, 1916) – megjelenése a Tiszában, valamint a populáció morfológiai és genetikai vizsgálatának első eredményei. *Pisces Hungarici* **7**: 5–11.

Heckel J. J. (1863): Magyarország édesvizi halainak rendszeres átnézete, jegyzetekkel s az új fajok rövid leirásával. Fordította és a tudomány újabbkori haladásával bővítette Chyzer Kornél. *In:* Halász G. (szerk.): *A Magyar Orvosok és Természetvizsgálók 1847. augustus 11–17. Sopronban tartott VIII. nagygyülésének történeti vázlata és munkálatai.* Emich Gusztáv, Pest: 193–216.

Hensel K. (1971): Some notes on the systematic status of *Carassius auratus gibelio* (Bloch, 1782) with further record of this fish from the Danube river in Czechoslovakia. *Věstník Československé Společnosti Zoologické* **35**(3): 186–198.

Herman O. (1887): *A magyar halászat könyve.* K. M. Természettudományi Társulat, Budapest.

Holmes B. J., Williams S. M. & Power T. N. (2020): Evidence of naturalisation of the invasive Jaguar Cichlid *Parachromis managuensis* (Günther, 1867), in Queensland, Australia. *BioInvasions Records* **9**(1): 146–157.

Horn P. & Zsilinszky S. (2005): *Akvarisztika.* 15., bővített kiadás. Mezőgazda Kiadó, Budapest. / Állatbarátok könyvtára/

Howell D. H., Woodford D. J., Weyl O. L. F. & Froneman W. (2013): Population dynamics of the invasive fish, *Gambusia affinis*, in irrigation impoundments in the Sundays River Valley, Eastern Cape, South Africa. *Water SA* **39**(4): 485–490.

Huckstorf V. (2012): *Hypophthalmichthys nobilis. In: The IUCN Red List of Threatened Species 2012*: e.T166172A1116524. – www.iucnredlist.org

Jackson P. F. R. (1976): Threats to Lake Atitlán, Guatemala. *Environmental Conservation* **3**(3): 199.

Jaroszewska M., Dabrowski K., Wilczyńska B. & Kakareko T. (2008): Structure of the gut of the Racer Goby *Neogobius gymnotrachelus* (Kessler, 1857). *Journal of Fish Biology* **72**(7): 1773–1786.

Jennings D. P. (1988): *Bighead Carp (Hypophthalmichthys nobilis): biological synopsis.* U.S. Department of the Interior, Fish and Wildlife Service, Washington. /Biological Report 88(29)/

Jude D. J., Reider R. H. & Smith G. R. (1992): Establishment of Gobiidae in the Great Lakes basin. *Canadian Journal of Fisherises and Aquatic Sciences* **49**(2): 416–42.

Jurajda P., Černý J., Polačik M., Valová Z., Janáč M., Blažek R. & Ondračková M. (2005): The recent distribution and abundance of non-native *Neogobius* fishes in the Slovak section of the River Danube. *Journal of Applied Ichthyology* **21**(4): 319–323.

Keszte Sz., Ferincz Á., Tóth-Ihász K., Balogh R. E., Staszny Á., Hegyi Á., Takács P., Urbnyi B. & Kovács B. (2021): Mitochondrial sequence diversity reveals the hybrid origin of invasive Gibel Carp (*Carassius gibelio*) populations in Hungary. *PeerJ* **9**: e12441.

Kevrekidis T., Kokkinakis A. K. & Koukouras A. (1990): Some aspects of the biology and ecology of *Knipowitschia caucasica* (Teleostei: Gobiidae) in the Evros Delta (North Aegean Sea). *Helgoländer Meeresuntersuchungen* **44**(2): 173–187.

Kline J. L., Loftus W. F., Kotun K., Trexler J. C., Rehage J. S., Lorenz J. J. & Robinson M. (2013):

Recent fish introductions into Everglades National Park: an unforeseen consequence of water-management? *Wetlands* **34** (Supplement 1): 175–187.

Koščo J., Lusk S., Halačka K. & Lusková V. (2003): The expansion and occurrence of the Amur Sleeper (*Perccottus glenii*) in eastern Slovakia. *Folia Zoologica* **52**(3): 329–336.

Kottelat M. & Freyhof J. (2007): *Handbook of European freshwater fishes.* Publications Kottelat and Freyhof, Cornol – Berlin.

Kottelat M. & Whitten T. (1996): *Freshwater biodiversity in Asia. With special reference to fish.* The World Bank, Washington. /World Bank Technical Paper 343./

Kováč V., Copp G. H. & Sousa R. P. (2009): Life-history traits of invasive Bighead Goby *Neogobius kessleri* (Günther, 1861) from the middle Danube River, with a reflection on which goby species may win the competition. *Journal of Applied Ichthyology* **25**(1): 33–37.

Kovács B. & Urbányi B. (szerk.) (2019): *A kínai növényevő pontyfélék biológiája és tenyésztése.* Vármédia-Print Kft., Gödöllő.

Kriesch J. (1873): Ein neuer *Gobius. Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien* **23**: 369–376.

Leinonen T., Herczeg G., Cano J. M. & Merilä J. (2011): Predation-imposed selection on Threespine Stickleback (*Gasterosteus aculeatus*) morphology: a test of the refuge use hypothesis. *Evolution* **65**(10): 2916–2926.

Leunda P. M., Oscoz J., Elvira B., Agorreta A., Perea S. & Miranda R. (2008): Feeding habits of the exotic Black Bullhead *Ameiurus melas* (Rafinesque) in the Iberian Peninsula: first evidence of direct predation on native fish species. *Journal of Fish Biology* **73**(1): 96–114.

Lever C. (1996): *Naturalized fishes of the world.* Academic Press, San Diego.

Litvinov A. G. & O'Gorman R. (1996): Biology of Amur Sleeper (*Perccottus glehni*) in the Delta of the Selenga River, Buryatia, Russia. *Journal of Great Lakes Research* **22**(2): 370–378.

Loftus W. F., Trexler J. C., Dunker K., Liston S. & Rehage J. S. (2006): *Introduced fishes in short-hydroperiod wetlands: evaluation of sampling, status, and potential effects.* Final report from USGS to Everglades National Park for Agreement # CESI IA F5284-04-0039. U.S. Geological Survey, Homestead (Florida).

Loiselle P. V. (1979): A revision of the genus *Hemichromis* Peters 1858 (Teleostei: Cichlidae). *Annales du Musée Royal de l'Afrique Centrale* Série in-8. *Sciences Zoologiques* **228**: 1–124.

Loiselle P. V. (1992): An annotated key to the genus *Hemichromis* Peters 1958. *Buntbarsche Bulletin* **148**: 2–19.

Lowe S., Browne M., Boudjelas S. & De Poorter M. (2000): *100 of the world's worst invasive alien species. A selection from the global invasive species database.* The IUCN Invasive Species Specalist Group, Auckland.

Ludwig A., Lippold S., Debus L. & Reinartz R. (2009): First evidence of hybridization between endangered Sterlets (*Acipenser ruthenus*) and exotic Siberian Sturgeons (*Acipenser baerii*) in the Danube River. *Biological Invasions* **11**(3): 753–760.

Lutz P. L. & Nilsson G. E. (1994): *The brain without oxygen.* Springer Verlag, Berlin – Heidelberg. / Neuroscience Intelligence Unit/

Makhlin M. D. (1990): *Amurskiy akvarium.* Khabarovskoye Knizhnoye Izdatelstvo, Khabarovsk.

Masár J., Turanský R., Krupka I. & Kautman J. (2006): The first record of the Siberian Sturgeon (*Acipenser baerii*) in Slovak-Hungarian stretch of the Danube river. *Zborník Slovenského Národného Múzea. Prírodné vedy* **52**: 50–55.

Meyer M. K. (2015): *Lebendgebärende Zierfische.* Band 1. *Poecilidae.* Chimaira, Frankfurt.

Miller R. R. (1983): Checklist and key to the mollies of Mexico (Pisces: Poeciliidae: *Poecilia*, subgenus *Mollienesia*). *Copeia* 1983 (3): 817–822.

Molnár K., Nyeste K. & Székely Cs. (2018): Parasitology is a tool for identifying the original biotope of the Gibel Carp (*Carassius auratus gibelio* Berg, 1932). *Pisces Hungarici* **12**: 87–94.

Molnár T., Lehoczky I., Edviné Meleg E., Boros G., Specziár A., Mozsár A., Vitál Z., Józsa V., Allele W., Urbányi B., Al Fatle F. A. & Kovács B. (2021): Comparison of the genetic structure of invasive Bigheaded Carp (*Hypophthalmichthys* spp.) populations in Central-European lacustrine and riverine habitats. *Animals* **11**(7): 2018.

Mungi N. A., Coops N. C., Ramesh K. & Rawat G. S. (2018): How global climate change and regional disturbance can expand the invasion risk? Case study of *Lantana camara* invasion in the Himalaya. *Biological Invasions* **20**(7): 1849–1863.

Müller T., Csorbai B. & Urbányi B. (2007): A széles kárász – *Carassius carassius* (L.) – szaporítása és nevelése a természetesvízi állományok fenntartása és megerősítése érdekében. *Pisces Hungarici* **2**: 73–81.

Nico L. G., Fuller P. & Li J. (2022a): *Hypophthalmichthys molitrix* (Valenciennes in Cuvier and Valenciennes, 1844). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida) – https://nas.er.usgs.gov

Nico L., Fuller P. & Li J. (2022b): *Hypophthalmichthys nobilis* (Richardson, 1845). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida) – https://nas.er.usgs.gov

Nico L., Fuller P. & Neilson M. (2022c): *Parachromis managuensis* (Günther, 1867). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida) – https://nas.er.usgs.gov

Nico L. G., Fuller P. L., Schofield P. J., Neilson M. E., Benson A. J. & Li J. (2022c): *Ctenopharyngodon idella* (Valenciennes in Cuvier and Valenciennes, 1844). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida) – https://nas.er.usgs.gov

Novák J., Kalous L. & Patoka J. (2020): Modern ornamental aquaculture in Europe: early history of freshwater fish imports. *Review in Aquaculture* **12**(4): 2042–2060.

Nyeste K., Gyöngy M. & Antal L. (2018): A feketeszájú géb [*Neogobius melanostomus* (Pallas, 1814)] terjedése a Tisza vízgyűjtőjén. *Pisces Hungarici* **12**: 53–56.

Nyeste K., Nyíri K. & Molnár J. (2017): A feketeszájú géb [*Neogobius melanostomus* (Pallas, 1814)] első észlelése a Tisza vízrendszerében. *Pisces Hungarici* **11**: 89–90.

Ortega-Salas A. A. & Reyes-Bustamante H. (2006): Initial sexual maturity and fecundity of the Goldfish *Carassius auratus* (Perciformes: Cyprynidae) under semi-controlled conditions. *Revista de Biología Tropical* **54**(4): 1113–1116.

Oțel V. (2019): Is *Carassius gibelio* (Pisces, Cyprinidae) a native or non-native species in Romania? *Scientific Annals of the Danube Delta Institute* **24**: 77–83.

Page L. M. & Burr B. M. (1991): *A field guide to freshwater fishes of North America north of Mexico.* Houghton Mifflin Co., Boston. /The Peterson Field Guide Series 42./

Page L. M. & Burr B. M. (2011): *Field guide to freshwater fishes of North America north of Mexico.* 2nd edition. Houghton Mifflin Harcourt, Boston. /Peterson Field Guides Series/

Patoka J., Magalhães A. L. B., Kouba A., Faulkes Z., Jerikho R. & Vitule J. R. S. (2018): Invasive aquatic pets: failed policies increase risks of harmful invasions. *Biodiversity and Conservation* **27**(11): 3037–3046.

Pénzes B. & Tölg I. (1993): Az aranyhal. *Halászat* **86**(3): 125–130.

Perea J. P. (2002): Asian carp invasion: fish farm escapees threaten native river fish communities and boaters as well. *Outdoor Illinois* **10**(5): 8.

Pereira F. W. & Vitule J. R. S. (2019): The Largemouth Bass *Micropterus salmoides* (Lacepède, 1802): impacts of a powerful freshwater fish predator outside of its native range. *Reviews in Fish Biology and Fisheries* **29**(3): 639–652.

Petr T. (2002): Cold water fish and fisheries in countries of the high mountain arc of Asia (Hindu Kush-Pamir-Karakoram-Himalayas). A review. *In:* Petr T. & Swar D. B. (eds.): *Cold water fisheries in the trans-Himalayan countries.* Food and Agriculture Organization of the United Nations, Rome: 1–38.

Pinchuk V. I., Vasil'eva E. D., Vasil'ev V. P. & Miller P. (2003a): *Neogobius fluviatilis* (Kessler, 1857). *In:* Miller P. (ed.): *The freshwater fishes of Europe.* Volume 8/1. *Mugilidae, Atherinidae, Atherionopsidae, Blennidae, Odontobutidae, Gobiidae 1.* AULA-Verlag, Wiesbaden: 223–264.

Pinchuk V. I., Vasil'eva E. D., Vasil'ev V. P. & Miller P. (2003b): *Neogobius gymnotrachelus* (Kessler, 1857). *In:* Miller P. J. (ed.): *The freshwater fishes of Europe.* Volume 8/1. *Mugilidae, Atherinidae, Atherionopsidae, Blennidae, Odontobutidae, Gobiidae 1.* AULA-Verlag, Wiesbaden: 265–279.

Pinchuk V. I., Vasil'eva E. D., Vasil'ev V. P. & Miller P. (2003c): *Neogobius melanostomus* (Pallas, 1811). *In:* Miller P. J. (ed.): *The freshwater fishes of Europe.* Volume 8/1. *Mugilidae, Atherinidae, Atherionopsidae, Blennidae, Odontobutidae, Gobiidae 1.* AULA-Verlag, Wiesbaden: 293–345.

Pinter K. (1980): Exotic fishes in Hungarian waters: their importance in fishery utilization of natural water bodies and fish farming. *Fisheries Management* **11**(4): 163–167.

Pintér K. (1989): *Magyarország halai. Biológiájuk és hasznosításuk.* Akadémiai Kiadó, Budapest.

Pintér K. (2015): *Magyarország halai. Biológiájuk és hasznosításuk.* 4., átdolgozott és bővített kiadás. Mezőgazda Kiadó, Budapest.

Preiszner B., Czeglédi I., Boros G., Liker A., Kern B. & Erős T. (2020): Scavenging behaviour and size-dependent carcass consumption of the Black Bullhead (*Ameiurus melas*). *Journal of Fish Biology* **97**(4): 1113–1119.

Reshetnikov A. N. (2010): The current range of Amur Sleeper *Perccottus glenii* Dybowski, 1877 (Odontobutidae, Pisces) in Eurasia. *Russian Journal of Biological Invasions* **1**(2): 119–126.

Reuter F. (1911–1915): *Die fremdländischen Zierfische in Wort und Bild. Ein Atlas sämtlicher bisher bei uns eingeführten exotischen Zierfische.* Fritz Lehmanns Verlag – Julius E. G. Wegener, Stuttgart.

Ribeiro F., Elvira B., Collares-Pereira M. J. & Moyle P. B. (2008): Life-history traits of non-native fishes in Iberian watersheds across several invasion stages: a first approach. *Biological Invasions* **10**(1): 89–102.

Richardson M. J., Whoriskey F. G. & Roy L. H. (1995): Turbidity generation and biological impacts of an exotic fish *Carassius auratus*, introduced into shallow seasonally anoxic ponds. *Journal of Fish Biology* **47**(4): 576–585.

Roche K, Janáč M., Šlapanský L., Mikl L., Kopeček L. & Jurajda P. (2015): A newly established Round Goby (*Neogobius melanostomus*) population in the upper stretch of the river Elbe. *Knowledge and Management of Aquatic Ecosystem* **416**: 33.

Roche K. F., Janač M. & Jurajda P. (2013): A review of Gobiid expansion along the Danube-Rhine corridor – geopolitical change as a driver for invasion. *Knowledge and Management of Aquatic Ecosystems* **411**: 1.

Ruban G. & Mugue N. (2022): *Acipenser baerii. In: The IUCN Red List of Threatened Species 2022*: e.T244A156718817. – www.iucnredlist.org

Rylková K., Kalous L., Bohlen J., Lamatsch D. K. & Petrtýl M. (2013): Phylogeny and biogeographic history of the cyprinid fish genus *Carassius* (Teleostei: Cyprinidae) with focus on natural and anthropogenic arrivals in Europe. *Aquaculture* **380–383**: 13–20.

Sallai Z. & Sallai M. (2020): Változások a halközösség összetételében a Körös békésszentandrási duzzasztó alatti szakaszán (2009, 2019). *Pisces Hungarici* **14**: 15–32.

Sallai Z., Juhász P. & Vajda Z. (2019): Csupasztorkú géb (*Babka gymnotrachelus*) megjelenése a Tiszában. *Halászat* **112**(1): 13

Sammons S. M. & Maceina M. J. (2005): Activity patterns of Largemouth Bass in a subtropical US reservoir. *Fisheries Management and Ecology* **12**(5): 331–339.

Sass G. G., Hinz C., Erickson A. C., McClelland N. N., McClelland M. A. & Epifanio J. M. (2014): Invasive Bighead and Silver Carp effects on zooplankton communities in the Illinois River, Illinois, USA. *Journal of Great Lakes Research* **40**(4): 911–921.

Schofield P. J., Loftus W. F., Kobza R. M., Cook M. I. & Slone D. H. (2010): Tolerance of nonindigenous cichlid fishes (*Cichlasoma urophthalmus, Hemichromis letourneuxi*) to low temperature: laboratory and field experiments in south Florida. *Biological Invasions* **12**(8): 2441–2457.

Scott D. & Irvine J. R. (2000): Competitive exclusion of Brown Trout *Salmo trutta* L., by Rainbow Trout *Oncorhynchus mykiss* Walbaum, in lake tributaries, New Zealand. *Fisheries Management and Ecology* **7**(3): 225–237.

Scott D. M., Wilson R. W. & Brown J. A. (2007): Can Sunbleak *Leucaspius delineatus* or Topmouth Gudgeon *Pseudorasbora parva* disperse through saline waters? *Journal of Fish Biology* **71** (Supplement D): 70–86.

Shafland P. L. (1996): Exotic fishes of Florida – 1994. *Reviews in Fisheries Science* **4**(2): 101–122.

Shireman J. V. & Smith C. R. (1983): *Synopsis of biological data on the Grass Carp Ctenopharyngodon idella (Cuvier and Valenciennes, 1884).* Food and Agriculture Organization of the United Nations, Rome. / FAO Fisheries Synopsis 135./

Smith D. W. (1989): The feeding selectivity of Silver Carp, *Hypophthalmichthys molitrix* Val. *Journal of Fish Biology* **34**(6): 819–828.

Specziár A. (1999): Öt pontyféle tápláléka és táplálkozási stratégiája a Balaton főbb élőhelyein. *Halászat* **92**(3): 124–132.

Specziár A. (2004): Life history pattern and feeding ecology of the introduced Eastern Mosquitofish, *Gambusia holbrooki*, in a thermal spa under temperate climate, of Lake Hévíz, Hungary. *Hydrobiologia* **522**(1–3): 249–260.

Specziár A. & Rezsu T. E. (2009): Feeding guilds and food resource partitioning in a lake fish assemblage: an ontogenetic approach. *Journal of Fish Biology* **75**(1): 247–267.

Stanković D., Crivelli A. J. & Snoj A. (2015): Rainbow Trout in Europe: introduction, naturalization, and impacts. *Reviews in Fisheries Science & Aquaculture* **23**(1): 39–71.

Stepien C. A. & Tumeo M. A. (2006): Invasion genetics of Ponto-Caspian gobies in the Great Lakes: a 'cryptic' species, absence of founder effects, and comparative risk analysis. *Biological Invasions* **8**(1): 61–78.

Sterbetz I. (1957): Tüskés Pikó – a Dunában. *Halászat* **4**(4): 75.

Szalay M. (1954): Új halfaj Magyarországon – ezüstkárász. *Halászat* **1**(3): 16.

Szalóky Z., Bammer V., György Á. I., Pehlivanov L., Schabuss M., Zornig H., Weiperth A. & Erős T. (2015): Offshore distribution of invasive gobies (Pisces: Gobiidae) along the longitudinal profile of the Danube River. *Fundamental and Applied Limnology / Archiv für Hydrobiologie* **187**(2): 127–133.

Szalóky Z., György Á. I., Weiperth A. & Erős T. (2014): Bentikus élőhelyek halbiológiai vizsgálatai a 3. Nemzetközi Duna-expedicióban. *Pisces Hungarici* **8**: 9–18.

Takács P. & Vitál Z. (2012): Amurgéb (*Perccottus glenii* Dybowski, 1877) a Duna mentén. *Halászat* **105**(4): 16.

Takács P., Czeglédi I. & Ferincz Á. (2015a): Amurgéb (*Perccottus glenii*) a Dráva vízgyűjtőjéről. *Halászat* **108**(1): 15.

Takács P., Czeglédi I., Ferincz Á., Sály P., Specziár A., Vitál Z., Weiperth A. & Erős T. (2017a): Idegenhonos halfajok Magyarországon és a Balaton vízgyűjtőjén; történeti áttekintés és recens elterjedési mintázatok. *A Balaton Ökológiája* **4**: 1–23.

Takács P., Czeglédi I., Ferincz Á., Sály P., Specziár A., Vitál Z., Weiperth A. & Erős T. (2017b): Non-native fish species in Hungarian waters: historical overview, potential sources and recent trends in their distribution. *Hydrobiologia* **795**(1): 1–22.

Takács P., Maász G., Vitál Z. & Harka Á. (2015b): Akváriumi halak a Hévíz-lefolyó termálvizében. *Pisces Hungarici* **9**: 59–64.

Takada M., Tachihara K., Kon T., Yamamoto G., Iguchi K., Miya M. & Nishida M. (2010): Biogeography and evolution of the *Carassius auratus*-complex in East Asia. *BMC Evolutionary Biology* **10**(1): 7.

Tóth B. & Váradi L. (2000): Vizeink ezüstkárász-állományáról. *Halászat* **93**(2): 63–65.

Tóth J. (1977): A brief account on the presence of the Silver Crucian Carp (*Carassius auratus gibelio* Bloch 1783) in the Hungarian section of the Danube. *Annales Universitatis Scientiarum Budapestinensis de Rolando Eötvös nominatae. Section Biologica* **18–19**: 219–220.

Tsoumani M., Liasko R., Moutsaki P., Kagalou I. & Leonardos I. (2006): Length–weight relationships of an invasive cyprinid fish (*Carassius gibelio*) from 12 Greek lakes in relation to their trophic states. *Journal of Applied Ichthyology* **22**(4): 281–284.

Urbányi B. & Horváth Á. (szerk.) (2019): *A tokalakúak biológiája és tenyésztése.* Vármédia Print Kft., Gödöllő.

van Kleef H., van der Velde G., Leuven R. S. E. W. & Esselink H. (2008): Pumpkinseed Sunfish (*Lepomis gibbosus*) invasions facilitated by introductions and nature management strongly reduce macroinvertebrate abundance in isolated water bodies. *Biological Invasions* **10**(8): 1481–1490.

Van Zwol J. A, Neff B. D. & Wilson C. C. (2012): The effect of nonnative salmonids on social dominance and growth of juvenile Atlantic Salmon. *Transactions of the American Fisheries Society* **141**(4): 907–918.

Váradi L. & Tóth B. (1998): Az ezüstkárász (*Carassius auratus gibelio*) szaporodása, mint új evolúciós stratégia. *Halászatfejlesztés* **21**: 102–107.

Varju-Katona M., Doszpoly A., Bógó B., Horváth J., Tóth A., Urbányi B. & Müller T. (2021): Intenzív rendszerben nevelt fekete törpeharcsa (*Ameiurus melas*) indukált szaporítása (Előzetes megfigyelések). *Halászatfejlesztés* **38**: 97–99.

Vassilev M., Apostolou A., Velkov B., Dobrev D. & Zarev V. (2012): *Atlas of the gobies (Gobiidae) in Bulgaria.* Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia.

Veselý L., Ruokonen T. J., Weiperth A., Kubec J., Szajbert B., Guo W., Ercoli F., Bláha M., Buřič M., Hämäläinen H. & Kouba A. (2021): Trophic niches of three sympatric invasive crayfish of EU concern. *Hydrobiologia* **848**(3): 727–737.

Vitál Z., Józsa V., Specziár A., Mozsár A., Lehoczky I., Kovács B., Hliwa P. & Boros G. (2017): Source of Bigheaded Carp (*Hypophthalmichthys* spp.) in Lake Balaton, Hungary: natural recruitment or continuous escapement from aquaculture? *Inland Waters* **7**(2): 218–226.

Weiperth A. (2018): A feketeszájú géb (*Neogobius melanostomus*) első észlelése a Balatonban. *Halászat* **111**(3): 89.

Weiperth A., Bányai Zs., Ferincz Á., Juhász V., Sevcsik A., Staszny Á., Szalóky Z. & Tóth B. (2020): Az Ipoly magyarországi szakaszán élő tízlábú rákokra és a halakra vonatkozó faunisztikai kutatások áttekintése. *Pisces Hungarici* **14**: 33–44.

Weiperth A., Csányi B., György Á. I., Szekeres J., Friedrich T. & Szalóky Z. (2014a): Observation of the sturgeon hybrid (*Acipenser naccarii* × *Acipense baerii*) in the Hungarian section of River Danube. *Pisces Hungarici* **8**: 111–112.

Weiperth A., Gaebele T. & Potyó I. (2010): Csupasztorkú géb (*Neogobius gymnotrachelus*) az Ipolyban. *Halászat* **103**(4): 127.

Weiperth A., Gaebele T., Potyó I. & Puky M. (2014b): A global overview on the diet of the Dice Snake (*Natrix tessellata*) from a geographical perspective: foraging in atypical habitats and feeding spectrum widening helps colonisation and survival under suboptimal conditions for a piscivorous snake. *Zoological Studies* **53**: 42.

Weiperth A., Staszny Á. & Ferincz Á. (2013): Idegenhonos halfajok megjelenése és terjedése a Duna magyarországi szakaszán – Töréneti áttekintés. *Pisces Hungarici* **7**: 103–112.

Welcomme R. L. (1988): *International introductions of inland aquatic species.* Food and Agriculture Organization of the United Nations, Rome. / FAO Fisheries Technical Paper 294./

Weyl O. L. F. & Hecht T. (1999): A successful population of Largemouth Bass, *Micropterus salmoides*, in a subtropical lake in Mozambique. *Environmental Biology of Fishes* **54**(1): 53–66.

Wheeler A. (1978): *Ictalurus melas* (Rafinesque, 1820) and *I. nebulosus* (Lesueur, 1819): the North American catfishes in Europe. *Journal of Fish Biology* **12**(5): 435–439.

Wiesinger M. (1975): *Akvarisztika.* Gondolat, Budapest.

Williot P., Brun R., Rouault T. & Rooryck O. (1991): Management of female spawners of the Siberian Sturgeon, *Acipenser baerii* Brandt: first results. *In:* Willio P. (ed.) *Acipenser.* Cemagref Publ., Bordeaux: 365–379.

Willis K. & Ling N. (2000): Sensitivities of Mosquitofish and Black Mudfish to a piscicide: could rotenone be used to control Mosquitofish in New Zealand wetlands? *New Zealand Journal of Zoology* **27**(2): 85–91.

Winandy L., Darnet E. & Denoël M. (2015): Amphibians forgo aquatic life in response to alien fish introduction. *Animal Behaviour* **109**: 209–216.

Wittenberg R. & Cock M. J. W. (eds.) (2001): *Invasive alien species: a toolkit of best prevention and management practices.* CAB International, Wallingford.

Woynarovich A., Hoitsy Gy. & Moth-Poulsen T. (2011): *Small-scale Rainbow Trout farming.* Food and Agriculture Organization of the United Nations, Rome. /FAO Fisheries and Aquaculture Technical Paper 561./

Xie P. & Liu J. (2001): Practical success of biomanipulation using filter-feeding fish to control cyanobacteria blooms. A synthesis of decades of research and application in a subtropical hypereutrophic lake. *The Scientific World Journal* **1**: 337–356.

Zeiber R. A., Sutton T. M. & Fisher B. E. (2008): Western Mosquitofish predation on native amphibian eggs and larvae. *Journal of Freshwater Ecology* **23**(4): 663–671.

Zupančič P. (2008): *Rare and endangered freshwater fishes of Croatia, Slovenia and Bosnia and Herzegovina – Adriatic basin.* AZV, Dolsko

AMPHIBIANS – Amphibia

Araújo M. B., Alagador D., Cabeza M., Nogués-Bravo D. & Thuiller W. (2011): Climate change threatens European conservation areas. *Ecology Letters* **14**(5): 484–492.

Baláž V., Solský M., González D. L., Havlíková B., Zamorano J. G., Sevilleja C. G., Torrent L. & Vojar J. (2018): First survey of the pathogenic fungus *Batrachochytrium salamandrivorans* in wild and captive amphibians in the Czech Republic. *Salamandra* **54**(1): 87–91.

Brodie E. D., Hensel J. L. & Johnson J. A. (1974): Toxicity of the urodele amphibians *Taricha*, *Notophthalmus*, *Cynops* and *Paramesotriton* (Salamandridae). *Copeia* 1974 (2): 506–511.

Crayon J. J. (2005): *Xenopus laevis* (Daudin, 1802) African Clawed Frog. *In:* Lannoo M. (ed.): *Amphibian declines: The conservation status of United States species.* University of California Press, Berkeley – Los Angeles: 522–526.

Fuller P. (2022): *Cynops orientalis* (David, 1873). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida) – https://nas.er.usgs.gov

Griffiths R. A. (1996): *Newts and salamanders of Europe.* T & AD Poyser, London.

Grigoryan E. N., Mitashov V. I. & Anton H. J. (2002): Urodelean amphibians in studies on microgravity: effects upon organ and tissue regeneration. *Advances in Space Research* **30**(4): 757–764.

Guo K., Yuan S., Whang H., Zhong J., Wu J., Chen W., Hu C. & Chang Q. (2021): Species distribution models for predicting the habitat suitability of Chinese Fire-bellied Newt *Cynops orientalis* under climate change. *Ecology and Evolution* **11**(15): 10147–10154.

Kilpatrick A. M., Briggs C. J. & Daszak P. (2010): The ecology and impact of chytridiomycosis: an emerging disease of amphibians. *Trends in Ecology & Evolution* **25**(2): 109–118.

Kolby J. E., Smith K. M., Berger L., Karesh W. B., Preston A., Pessier A. P. & Skerratt L. F. (2014): First evidence of Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*) and Ranavirus in Hong Kong amphibian trade. *PLoS ONE* **9**(3): e90750.

Kraus F. (2009): Global trends in alien reptiles and amphibians. *Aliens: The Invasive Species Bulletin* **28**: 13–18.

Li S. C., Liu X. L. & Hao X. (2005): Morphologic observation and anatomical study on *Cynops orientalis*. *Chinese Journal of Veterinary Science and Technology* **35**(1): 60–63.

Measey G. J., Rödder D., Green S. L., Kobayashi R., Lillo F., Lobos G., Rebelo R. & Thirion J.-M. (2012): Ongoing invasions of the African Clawed Frog, *Xenopus laevis*: a global review. *Biological Invasions* **14**(11): 2255–2270.

Murphy B. G., Hillman C. & Groff J. M. (2015): Chytridiomycosis in Dwarf African Frogs *Hymenochirus curtipes*. *Diseases of Aquatic Organisms* **114**(1): 69–75.

Schleich H. H., Kästle W. & Kabisch K. (1996): *Amphibians and reptiles of North Africa. Biology, systematics, field guide.* Koeltz Scientific Publishers, Koenigstein. /Koeltz Scientific Books/

Trueb L. (2003): Clawed frogs and Surinam toads (Pipidae). *In:* Hutchins M., Duellman W. E. & Schlager N. (eds.): *Grzimek's animal life encyclopedia.* Volume 6. *Amphibians.* 2nd edition. Gale Group, Farmington Hills (Michigan): 99–107

Weiperth A., Csányi B., Gál B., György Á. I., Szalóky Z., Szekeres J., Tóth B. & Puky M. (2015): Egzotikus rák-, hal- és kétéltűfajok a Budapest környéki víztestekben. *Pisces Hungarici* **9**: 65–70.

Weldon C., du Preez L. H., Hyatt A. D., Muller R. & Speare R. (2004): Origin of the Amphibian Chytrid Fungus. *Emerging Infectious Diseases* **10**(12): 2100–2105.

REPTILES – Reptilia

Alcayde V. S., Andueza I. L., Gimeno J. V. B. & Carrasco A. P. (2015): *Manual para el control y erradicación de Galápagos invasores.* Conselleria d'Agricultura – MediAmbient – Canvi Climàtic i Desenvolupament Rural – Generalitat Valenciana, Valencia. /Colección Manuales Técnicos de Biodiversidad 6./

Asian Turtle Trade Working Group (2016): *Pelodiscus sinensis*. Errata version. *In: The IUCN Red List of Threatened Species 2000*: e.T39620A97401140. – www.iucnredlist.org

Avry C. & Servan J. (1998): Imminent competition between *Trachemys scripta* and *Emys orbicularis* in France. *Mertensiella* **10**: 33–40.

Babocsay G. (2021): Adatok az idegenhonos Kotschy-gekkó, *Mediodactylus kotschyi* (Steindachner, 1870) magyarországi előfordulásáról. *Folia Historico-naturalia Musei Matraensis* **45**: 139–143.

Bódis E., Borza P., Potyó I., Puky M., Weiperth A. & Guti G. (2012): Invasive mollusc, crustacean, fish and reptile species along the Hungarian stretch of the River Danube and some connected waters. *Acta Zoologica Academiae Scientiarum Hungaricae* **58** (Supplement 1): 29–45.

Bonin F., Devaux B. & Dupré A. (2006): *Turtles of the World.* The Johns Hopkins University Press, Baltimore.

Botta-Dukát Z. (szerk.) (2016): *Inváziós fajok terjedési útvonalainak átfogó elemzése és hazai értékelése.* Kutatási zárójelentés. MTA ÖK Ökológiai Botanikai Intézet, Vácrátót.

Brejcha J., Cizelj I., Marić D., Šmíd J., Vamberger M. & Šanda R. (2014): First records of the

Soft-shelled Turtle, *Pelodiscus sinensis* (Wiegmann, 1834), in the Balkans. *Herpetozoa* **26**(3–4): 189–192.

Bringsøe H. (2006): NOBANIS – Invasive Alien Species Fact Sheet – *Trachemys scripta*. *In: Online Database of the North European and Baltic Network on Invasive Alien Species – NOBANIS.* – www.nobanis.org

Cadi A. & Joly P. (2003): Competition for basking places between the endangered European Pond Turtle (*Emys orbicularis galloitalica*) and the introduced Red-eared Slider (*Trachemys scripta elegans*). *Canadian Journal of Zoology* **81**(8): 1392–1398.

Cadi A., Delmas V., Prévot-Julliard A.-C., Joly P., Pieau C. & Girondot M. (2004): Successful reproduction of the introduced slider turtle (*Trachemys scripta elegans*) in the south of France. *Aquatic Conservation. Marine and Freshwater Ecosystems* **14**(3): 237–246.

Carranza S. & Arnold E. N. (2006): Systematics, biogeography, and evolution of *Hemidactylus* geckos (Reptilia: Gekkonidae) elucidated using mitochondrial DNA sequences. *Molecular Phylogenetics and Evolution* **38**(2): 531–545.

Christensen-Dalsgaard J., Brandt C., Willis K. L., Christensen C. B., Ketten D., Edds-Walton P., Fay R. R., Madsen P. T. & Carr C. E. (2012): Specialization for underwater hearing by the tympanic middle ear of the turtle, *Trachemys scripta elegans*. *Proceedings of the Royal Society* **279**(1739): 2816–2824.

COSEWIC (2008): *COSEWIC assessment and status report on the Snapping Turtle Chelydra serpentina in Canada.* Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Ernst C. H. & Barbour R. W. (1989): *Turtles of the World.* Smithsonian Institution Press, Washington – London.

Ernst C. H. & Lovich J. E. (2009): *Turtles of the United States and Canada.* Second edition. The Johns Hopkins University Press, Baltimore.

Farkas B. & Sasvári L. (1999): *Teknősök. Szárazföldi, félvízi és vízi teknősök elterjedéséről, életmódjáról, tartásáról.* 2., javított, bővített kiadás. Kitaibel Kiadó, Budapest.

Farkas B., Újvári B. & Kőszegi G. (1999): *Cyrtopodion kotschyi* (Kotschy's Gecko). *Herpetological Review* **30**(3): 173–174.

Fritz U., Gong S., Auer M., Kuchling G, Schneeweiss N. & Hundsdörfer A. K. (2010): The world's economically most important chelonians represent a diverse species complex (Testudines: Trionychidae: *Pelodiscus*). *Organisms Diversity & Evolution* **10**(3): 227–242.

Fuller P., Foster A. & Somma L. A. (2022): *Chelydra serpentina* (Linnaeus, 1758). *In: U.S. Geological Survey, Nonindigenous Aquatic Species Database.* Gainesville (Florida). – nas.er.usgs.gov

Galbraith D. A., Chandler M. W. &. Brooks R. J. (1987): The fine structure of home ranges of male *Chelydra serpentina*: are Snapping Turtles territorial? *Canadian Journal of Zoology* **65**(11): 2623–2629.

García-Berthou E., Boix D. & Clavero M. (2007): Non-indigenous animal species naturalized in Iberian inland waters. *In:* Gherardi F. (ed.): *Biological invaders in inland waters: Profiles, distribution, and threats.* Springer, Dordrecht: 123–140.

Gibbons J. W. (ed.) (1990): *Life history and ecology of the Slider Turtle.* Smithsonian Institution Press, Washington – London.

Gibbons J. W. & Semlitsch R. D. (1991): *Guide to the reptiles and amphibians of the Savannah River Site.* The University of Georgia Press, Athens – London.

Global Invasive Species Database (2022): Species profile: *Trachemys scripta elegans*. – www.iucngisd.org

Gong S., Vamberger M., Auer M., Praschag P. & Fritz U. (2018): Millennium-old farm breeding of Chinese softshell turtles (*Pelodiscus* spp.) results in massive erosion of biodiversity. *The Science of Nature* **105**(5–6): 34.

Harrower C. A., Scalera R., Pagad S., Schönrogge K. & Roy H. E. (2020): *Guidance for interpretation of the CBD categories of pathways for the introduction.* Publications Office of the European Union, Luxembourg.

Kakuda A., Doi H., Souma R., Nagano M., Minamoto T. & Katano I. (2019): Environmental DNA detection and quantification of invasive Red-eared Sliders, *Trachemy scripta elegans*, in ponds and the influence of water quality. *PeerJ* **7**: e8155.

Keevil M. G., Hewitt B. S., Brooks R. J. & Litzgus J. D. (2017): Patterns of intraspecific aggression inferred from injuries in an aquatic turtle with male-biased size dimorphism. *Canadian Journal of Zoology* **95**(6): 393–403.

King F. W. (2000): Florida Museum of Natural History's checklist of Florida amphibians and reptiles. *In: Florida Museum.* Florida Museum of Natural History – University of Florida, Gainesville. – www.floridamuseum.ufl.edu

Kobayashi R., Hasegawa M. & Miyashita T. (2006): Home range and habitat use of the exotic turtle *Chelydra serpentina* in the Inbanuma Basin, Chiba Prefecture, central Japan. *Current Herpetology* **25**(2): 47–55.

Kong F., Zhu Q., Xiao F., Hong Z., Zhang H. & Shi H. (2021): Home ranges and movement patterns of the Chinese Softshell Turtle (*Pelodiscus sinensis*) in the Yellow River, Northwestern China. *Chelonian Conservation and Biology* **20**(1): 2–9.

Kotsakiozi P., Jablonski D., Ilgaz Ç., Kumlutaş Y., Avci A., Meiri S., Itescu Y., Kukushkin O., Gvoždík V., Scillitani G., Roussos S. A., Jandzik D., Kasapidis P., Lymberakis P. & Poulakakis N. (2018): Multilocus phylogeny and coalescent species delimitation in Kotschy's Gecko, *Mediodactylus kotschyi*: Hidden diversity and cryptic species. *Molecular Phylogenetics and Evolution* **125**: 177–187.

Koynova T., Tzankov N., Popgeorgiev G., Naumov B. & Natchev N. (2017): A new distribution record of the Kotschy's Gecko (*Mediodactylus kotschyi*) from inland north-eastern Bulgaria. *Herpetology Notes* **10**: 1–2.

Köhler G. (2003): *Reptiles of Central America.* Herpeton, Offenbach.

Kraus F. (2015): Impacts from invasive reptiles and amphibians. *Annual Review of Ecology, Evolution, and Systematics* **46**: 75–97.

Krauss U. (2012): 161 invasive alien species present in Saint Lucia and their current status. *In: Caribbean Alien Invasive Species Network (CIASNET).* – www.ciasnet.org

Krysko K. L., Sheehy C. M. & Hooper A. N. (2003): Interspecific communal oviposition and reproduction of four species of lizards (Sauria: Gekkonidae) in the lower Florida Keys. *Amphibia-Reptilia* **24**(3): 390–396.

Kuzmin S. L. (2002): *The turtles of Russia and other ex-soviet republics.* Edition Chimaira, Frankfurt.

Lagler K. F. (1943): Methods of collecting freshwater turtles. *Copeia* 1943 (1): 21–25.

Lei J. & Booth D. T. (2014): Temperature, field activity and post-feeding metabolic response in the Asian House Gecko, *Hemidactylus frenatus*. *Journal of Thermal Biology* **45**: 175–180.

Liu P. C., Lin C. C., Lin S. L., Chen M. H., Lee L. H., Chen Y. K., Chang C. H., Tung K. C., Chen Y. P., Tu C. Y., Hung S. W. & Wang W. S. (2011): Vesicular diseases associated with poxvirus-like infection in cultured Soft Shell Turtles (*Pelodiscus sinensis*) in Taiwan. *Bulletin of the European Association of Fish Pathologists* **31**(2): 73–80.

McKeown S. & Webb R. G. (1982): Softshell turtles in Hawaii. *Journal of Herpetology* **16**(2): 107–111.

Meshaka W. E., Butterfield B. P. & Hauge J. B. (2004): The exotic amphibians and reptiles of Florida. Krieger Publishing Company, Malabar (USA).

Meyer L., Du Preez L., Bonneau E., Héritier L., Quintana M. F., Valdeón A., Sadaoui A., Kechemir-Issad N., Palacios C. & Verneau O. (2015): Parasite host-switching from the invasive American Red-eared Slider, *Trachemys scripta elegans*, to the native Mediterranean Pond Turtle, *Mauremys leprosa*, in natural environments. *Aquatic Invasions* **10**(1): 79–91.

Mohan-Gibbons H. & Norton T. (2010): Turtles, tortoises, and terrapins. *In:* Tynes V. V. (ed.): *Behaviour of exotic pets.* Blackwell Publishing, Chichester: 33–43.

Obbard M. E. & Brooks R. J. (1979): Factors affecting basking in a northern population of the Common Snapping Turtle, *Chelydra serpentina*. *Canadian Journal of Zoology* **57**(2): 435–440

Obbard M. E. & Brooks R. J. (1981): A radio-telemetry and mark-recapture study of activity in the Common Snapping Turtle, *Chelydra serpentina*. *Copeia* 1981 (3): 630–637.

Paterson J. E., Steinberg B. D. & Litzgus J. D. (2012): Generally specialized or especially general? Habitat selection by Snapping Turtles (*Chelydra serpentina*) in central Ontario. *Canadian Journal of Zoology* **90**(2): 139–149.

Perez-Santigosa N., Díaz-Paniagua C. & Hidalgo-Vila J. (2008): The reproductive ecology of exotic *Trachemys scripta elegans* in an invaded area of southern Europe. *Aquatic Conservation. Marine and Freshwater Ecosystems* **18**(7): 1302–1310.

Powell R., Conant R. & Collins J. T. (2016): *Field guide to reptiles and amphibians of eastern and central North America.* Houghton Mifflin Company, New York. /Peterson Field Guides/

Pritchard P. C. H. (1979): *Encyclopedia of turtles.* T. F. H. Publications, Neptune (New Jersey).

Puky M., Schád P. & Szövényi G. (2005): *Magyarország herpetológiai atlasza.* Varangy Akciócsoport Egyesület, Budapest.

Punzo F. (1975): Studies on the feeding behavior, diet, nesting habits and temperature relationships of *Chelydra serpentina osceola* (Chelonia: Chelydridae). *Journal of Herpetology* **9**(2): 207–210.

Punzo F. (2005): The introduction of Hemidactyline geckos in Florida: colonization and impact on native fauna. *In:* Meshaka W. E. & Babbitt K. J. (eds.): *Amphibians and reptiles. Status and conservation in Florida.* Krieger Publishing Company, Malabar (USA): 231–237.

Raney E. C. &. Josephson R. A. (1954): Record of combat in the Snapping Turtle, *Chelydra serpentina*. *Copeia* 1954 (3): 228.

Rhodin A. G. J., Iverson J. B., Bour R., Fritz U., Georges A., Shaffer H. B. & van Dijk P. P. (2017): *Turtles of the World. Annotated checklist and atlas of taxonomy, synonymy, distribution, and conservation status.* 8th ed. Chelonian Research Foundation – Turtle Conservancy, Lunenburg – New York. /Chelonian Research Monographs 7./

Roszkopf S. (2008): Breeding the Common Snapping Turtle *Chelydra s. serpentina* in an outdoor enclosure in Hungary. *Emys* **15**(2): 23–24.

Sancho V. & Lacomba I. (2013): Expansion of *Trachemys scripta* in the Valencian Community (Eastern Spain). *In: International Symposium on Freshwater Turtles Conservation 22–24 May 2013, Vila Nova de Gaia. Portugal.* Águas e Parque Biologico de Gaia, Avintes: 41–49.

Schuett G. W. & Gatten R. E. (1980): Thermal preference in Snapping Turtles (*Chelydra serpentina*). *Copeia* 1980 (1): 149–152.

Schwarz R., Gavriilidi I.-A., Itescu Y., Jamison S., Sagonas K., Meiri S. & Pafilis P. (2016): *Mediodactylus kotschyi* in the Peloponnese peninsula, Greece: distribution and habitat. *Acta Herpetologica* **11**(2): 179–187.

Secretariat of the Convention on Biological Diversity (2010): *Pets, aquarium, and terrarium species: Best practices for addressing risks to biodiversity.* Secretariat of the Convention on Biological Diversity, Montreal. /CBD Technical Series 48./

Seidel M. E. (2002): Taxonomic observations on extant species and subspecies of slider turtles, genus *Trachemys*. *Journal of Herpetology* **36**(2): 285–292.

Sinmuk S., Suda H. & Hatai K. (1996): *Aphanomyces* infection in juvenile Soft-shelled Turtle, *Pelodiscus sinensis*, imported from Singapore. *Mycoscience* **37**(3): 249–254.

Smith M. A. (1931): *The fauna of British India, including Ceylon and Burma. Reptilia and Amphibia.* Vol. I. *Loricata, Testudines.* Taylor & Francis Ltd., London.

Somma L. A., Foster A. & Fuller P. (2022a): *Trachemys scripta elegans* (Wied-Neuwied, 1838). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida). – nas.er.usgs.gov

Somma L. A., Foster A. & Fuller P. (2022b): *Trachemys scripta scripta* (Thunberg in Schoepff, 1792). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida). – nas.er.usgs.gov

Somma L. A., Foster A. & Fuller P. (2022c): *Trachemys scripta troostii* (Holbrook, 1836). *In:* U.S. Geological Survey: *Nonindigenous Aquatic Species Database.* Gainesville (Florida). – nas.er.usgs.gov

Sóvágó A. (2019): *A vörös- és a sárgafülű ékszerteknőssel kapcsolatos társadalmi konfliktusok elemzése.* BSc szakdolgozat. Szent István Egyetem, Mezőgazdaság- és Környezettudományi Kar, Gödöllő.

Speybroeck J., Beukema W., Bok B. & Van Der Voort J. (2016): *Field guide to the amphibians and reptiles of Britain and Europe.* Bloomsbury, London. /Bloomsbury Wildlife Guides/

Standfuss B., Lipovšek G., Fritz U. & Vamberger M. (2016): Threat or fiction: is the Pond Slider (*Trachemys scripta*) really invasive in Central Europe? A case study from Slovenia. *Conservation Genetics* **17**(3): 557–563.

Szajbert B. (2019): *Globális folyamatok hatásainak vizsgálata a főváros és Pest megye számos élőhelyének herpetofaunáján.* MSc szakdolgozat. Eötvös Loránd Tudományegyetem, Természettudományi Kar, Környezettudományi Centrum, Budapest.

Thanh L. T. B., Anh N. T. N. & Ky T. M. (2010): *Trionyx sinensis* Wiegmann 1834. *In: Cultured Aquatic Species Information Programme.* Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Division, Rome. – www.fao.org

Valakos E. D., Pafilis P., Lymberakis P., Maragou P., Sotiropoulos K. & Foufopoulos J. (2008): *Amphibians and reptiles of Greece.* Edition Chimaira, Frankfurt am Main.

Valdeón A., Crespo-Diaz A., Egaña-Callejo A. & Gosá A. (2010): Update of the Pond Slider *Trachemys scripta* (Schoepff, 1792) records in Navarre (Northern Spain), and presentation of the Aranzadi Turtle Trap for its population control. *Aquatic Invasions* **5**(3): 297–302.

Vamberger M., Ihlow F., Asztalos M., Dawson J. E., Jasinski S. E., Praschag P. & Frirt U. (2020): So different, yet so alike: North American Slider Turtles (*Trachemys scripta*). *Vertebrate Zoology* **70**(1): 87–96.

Vamberger M., Lipovšek G. & Gregorič M. (2012): First reproduction record of *Trachemys scripta* (Schoepff, 1792), in Slovenia. *Herpetozoa* **25**(1–2): 76–79.

Van Dijk P. P. (2016): *Chelydra serpentina*. Errata version. *In: The IUCN Red List of Threatened Species 2012*: e.T163424A97408395. – www.iucnredlist.org

Vilizzi L., Copp G. H., Hill J. E., Adamovich B., Aislabie L., Akin D., Al-Faisal A. J., Almeida D., Azmai M. N. A., Bakiu R., Bellati A., Bernier R., Bies J. M., Bilge G., Branco P., Bui T. D., Canning-Clode J., Ramos H. A. C. R., Castellanos-Galindo G. A., Castro N., Chaichana R., Chainho P., Chan J., Cunico A. M., Curd A., Dangchana P., Dashinov D., Davison P. I., de Camargo M. P., Dodd J. A., Donahou A. L. D., Edsman L., Ekmekçi F. G., Elphinstone-Davis J., Erős T., Evangelista C., Fenwick G., Ferincz Á., Ferreira T., Feunteun E., Filiz H., Forneck S. C., Gajduchenko H. S. Monteiro J. G., Gestoso I., Giannetto D., Gilles A. S., Gizzi F., Glamuzina B., Glamuzina L., Goldsmit J., Gollasch S., Goulletquer P., Grabowska J., Harmer R., .Haubrock P. J., He D., Hean J. W., Herczeg G., Howland K. L., İlhan A., Interesova E., Jakubčinová K., Jelmert A., Johnsen S. I., Kakareko T., Kanongdate K., Killi N., Kim J.-E., Kirankaya Ş. G., Kňazovická D., Kopecký O., Kostov V., Koutsikos N., Kozic S., Kuljanishvili T., Kumar B., Kumar L., Kurita Y., Kurtul I., Lazzaro L., Lee L., Lehtiniemi M., Leonardi G., Leuven R. S. E. W., Li S., Lipinskaya T., Liu F., Lloyd L., Lorenzoni M., Luna S. A., Lyons T. J., Magellan K., Malmstrøm M., Marchini A., Marr S. M., Masson J., Masson L., McKenzie C. H., Memedemin D., Mendoza R., Minchin D., Miossec L., Moghaddas S. D., Moshobane M. C., Mumladze L., Naddafi R., Najafi-Majd E., Năstase A., Năvodaru I., Neal J. W., Nienhuis S., Nimtim M., Nolan E. T., Occhipinti-Ambrogi A., Ojaveer H., Olenin S., Olsson K., Onikura N., O'Shaughnessy K., Paganelli D., Parretti P., Patoka J., Pavia R. T. B., Pellitteri-Rosa D., Pelletier-Rousseau M., Peralta E. M., Perdikaris C., Pietraszewski D., Piria M., Pitois S., Pompei L., Poulet N., Preda C., Puntila-Dodd R., Qashqaei A. T., Radočaj T., Rahmani H., Raj S., Reeves D., Ristovska M., Rizevsky V., Robertson D. R., Robertson P., Ruykys L., Saba A. O., Santos J. M., Sari H. M., Segurado P., Semenchenko V., Senanan W., Simard N., Simonović P., Skóra M. E., Slovák Švolíková K., Smeti E., Šmídová T., Špelić I., Srėbalienė G., Stasolla G., Stebbing P., Števove B., Suresh V. R., Szajbert B., Ta K. A. T., Tarkan A. S., Tempesti J., Therriault T. W., Tidbury H. J., Top-Karakuş N., Tricarico E., Troca D. F. A., Tsiamis K., Tuckett Q. M., Tutman P., Uyan U., Uzunova E., Vardakas L., Velle G. Verreycken H., Vintsek L., Wei H., Weiperth A., Weyl O. L. F., Winter E. R., Włodarczyk R., Wood L. E., Yang R., Yapici S., Yeo S. S. B., Yoğurtçuoğlu B., Yunnie A. L. E., Zhu Y., Zięba G., Žitňanová K. & Clarke S. (2021): A global-scale screening of non-native aquatic organisms to identify potentially invasive species under current and future climate conditions. *Science of the Total Environment* **788**: 147868.

Vilizzi L., Piria M., Pietraszewski D., Kopecký O., Špelić I., Radočaj T., Šprem N., Ta K. A. T., Tarkan A. S., Weiperth A., Yoğurtçuoğlu B., Candan O., Herczeg G., Killi N., Lemić D., Szajbert B., Almeida D., Al-Wazzan Z., Atique U., Bakiu R., Chaichana R., Dashinov D., Ferincz Á., Flieller G., Gilles A. S., Goulletquer P., Interesova E., Iqbal S., Koyama A., Kristan P., Li S., Lukas J., Moghaddas S. D., Monteiro J. G., Mumladze L., Olsson K. H., Paganelli D., Perdikaris C., Pickholtz R., Preda C., Ristovska M., Slovák Švolíková K., Števove B., Uzunova E., Vardakas L., Verreycken H., Wei H., Zięba G. (2022): Development and application of a multilingual electronic decision-support tool for risk screening non-native terrestrial animals under current and future climate conditions. *NeoBiota: in press.*

Warwick C. (1991): Conservation of Red-eared Terrapins *Trachemys scripta elegans*: threats from international pet and culinary markets. *Testudo* **3**: 34–44.

Weiperth A., Csányi B., Gál B., György Á. I., Szalóky Z., Szekeres J., Tóth B. & Puky M. (2015): Egzotikus rák-, hal- és kétéltűfajok a Budapest környéki víztestekben. *Pisces Hungarici* **9**: 65–70.

Werner Y. L. (1993): The paradoxical tree gecko of Israel. *Dactylus* **2**: 29–42.

Weterings R & Vetter C. K. (2018): Invasive house geckos (*Hemidactylus* spp.): their current, potential and future distribution. *Current Zoology* **64**(5): 559–567.

Williams T. (1999): The terrible turtle trade. *Audubon* **101**(2): 44–51.

Wogan G., Sumontha M., Phimmachak S., Lwin K., Neang T., Stuart B. L., Thaksintham W., Caicedo J. R., Rivas G., Tjaturadi B. & Iskandar D. (2021): *Hemidactylus frenatus. In: The IUCN Red List of Threatened Species 2021*: e.T99156022A1434103

BIRDS – Aves

Allan J. R., Kirby J. S. & Feare C. J. (1995): The biology of Canada Geese *Branta canadensis* in relation to the management of feral populations. *Wildlife Biology* **1**(3): 129–143.

Batty C. & Lowe T. (2001): Vagrant Canada Geese in Britain and Ireland. *Birding World* **14**(2): 57–61.

Bauer H.-G. (2020a): *Acridotheres tristis* Common Myna. *In:* Keller V., Herrando S., Voříšek P., Franch M., Kipson M., Milanesi P., Martí D., Anton M., Klvaňová A., Kalyakin M. V., Bauer H.-G. & Foppen R. P. B. (eds.): *European breeding bird atlas 2. Distribution, abudance and change.* European Bird Census Council – Lynx Edicions, Barcelona: 708.

Bauer H.-G. (2020b): *Anser indicus* Bar-headed Goose. *In:* Keller V., Herrando S., Voříšek P., Franch M., Kipson M., Milanesi P., Martí D., Anton M., Klvaňová A., Kalyakin M. V., Bauer H.-G. & Foppen R. P. B. (eds.): *European breeding bird atlas 2. Distribution, abudance and change.* European Bird Census Council – Lynx Edicions, Barcelona: 119.

Bauer H.-G., Geiter O., Homma S. & Woog F. (2016): Vogelneozoen in Deutschland – Revision der nationalen Statuseinstufungen. *Vogelwarte* **54**(3): 165–179.

BirdLife International (2015): *Oxyura leucocephala. In: The IUCN Red List of Threatened Species 2015*: e.T22679814A59946951. – www.iucnredlist.org

BirdLife International (2021): *Bubulcus ibis. In: The IUCN Red List of threatened species 2021*: e.T22697109A166319497. – www.iucnredlist.org

BirdLife International (2022): Species factsheet: *Anser indicus.* – www.datazone.birdlife.org

Blake E. R. (1939): African Cattle Heron taken in British Guiana. *The Auk* **56**(4): 470–471.

Blaker D. (1971): Range expansion of the Cattle Egret. *Ostrich* **42** (Suppl. 1): 27–30.

Boross P. (1943): Adatok Sárszentágota vizimadáréletéhez. *Aquila* **50**: 344–351.

Brauneis W. (2013): Weiteren Horstplatzkokurrenz für den Wanderfalken (*Falco peregrinus*). *Acta Ornithoecologica* **7**(3): 158–162.

Brua R. B. (2020): Ruddy Duck (*Oxyura jamaicensis*). Version 1.0. *In:* Rodewald P. G. (ed.): *Birds of the World.* Cornell Lab of Ornithology, Ithaca. – www.birdsoftheworld.org

Burgio K. R., van Rees C. B., Block K. E., Pyle P., Patten M. A., Spreyer M. F. & Bucher E. H. (2020): Monk Parakeet (*Myiopsitta monachus*). Version 1.0. *In:* Rodewald P. G. (ed.): *Birds of the World.* Cornell Lab of Ornithology, Ithaca. – www.birdsoftheworld.org

Callaghan C. T., Brooks D. M. & Pyle P. (2020): Egyptian Goose (*Alopochen aegyptiaca*). Version 1.0. *In:* Billerman S. M. (ed.): *Birds of the World.* Cornell Lab of Ornithology, Ithaca. – www.birdsoftheworld.org

Carboneras C. & Kirwan G. M. (2020): Bar-headed Goose (*Anser indicus*). Version 1.0. *In:* del Hoyo J., Elliott A., Sargatal J., Christie D. A. & de Juana E. (eds.): *Birds of the World.* Cornell Lab of Ornithology, Ithaca. – www.birdsoftheworld.org

Clement P. & Gantlett S. (1993): The origin of species. *Birding World* **6**(5): 206–213.

Cramp S. & Simmons K. E. L. (eds.) (1977): *The birds of the Western Palearctic. Handbook of the birds of Europe, the Middle East and North Africa.* Volume I. *Ostrich to ducks.* Oxford University Press, Oxford.

Crosby G. T. (1972): Spread of the Cattle Egret in the Western Hemisphere. *Bird-Banding* **43**(3): 205–212.

Czajka C., Braun M. P. & Wink M. (2011): Resource use by non-native Ring-necked Parakeets (*Psittacula krameri*) and native Starlings (*Sturnus vulgaris*) in Central Europe. *The Open Ornithology Journal* **4:** 17–22.

Czirák Z. (2021): Parlagi galamb. *In:* Szép T., Csörgő T., Halmos G., Lovászi P., Nagy K. & Schmidt A. (szerk.): *Magyarország madáratlasza.* Agrárminisztérium – Magyar Madártani és Természetvédelmi Egyesület, Budapest: 156–158.

Csernavölgyi L. (1976): Galambok a városban. Mi legyen a sorsuk? *Élet és Tudomány* **31**(47): 2242–2246.

Dami L., Bennetts R. E. & Hafner H. (2006): Do Cattle Egrets exclude Little Egrets from settling at higher quality sites within mixed-species colonies? *Waterbirds* **29**(2): 154–162.

Delany S. (1993a): Introduced and escaped geese. *Birding World* **6**(1): 39–40.

Delany S. (1993b): Introduced and escaped geese in Britain in summer 1991. *British Birds* **86**(12): 591–599.

Eaton M. A. (2020): *Oxyura jamaicensis* Ruddy Duck. *In:* Keller V., Herrando S., Voříšek P., Franch M., Kipson M., Milanesi P., Martí D., Anton M., Klvaňová A., Kalyakin M. V., Bauer H.-G. & Foppen R. P. B. (eds.): *European breeding bird atlas 2. Distribution, abudance and change.* European Bird Census Council – Lynx Edicions, Barcelona: 98.

Ecsedi Z. & Szondi L. (1990): Északkelet-Hortobágy madárvendégei 1990. *Madártani Tájékoztató* 1990 (július–december): 40–44.

Ecsedi Z. & Szondi L. (1993): Az Északkelet-Hortobágy ritka madárvendégei 1985–91 között. *Aquila* **100**: 266–267, 290–291.

Éles B., Horváth M. & Lóránt M. (2006): Barátpapagáj. Kertjeink új barátja, avagy egy újabb nemkívánatos betolakodó a magyar faunában? *Madártávlat* **13**(5): 21–22.

Faragó I. Cs. & Lelkes A. (1999): Kanadai lúd (*Branta canadensis*) megfigyelése a Kis-Balatonon. *Túzok* **4**(4): 118–120.

Feare C. & Craig A. (1998): *Starlings and mynas.* Christopher Helm, London.

Gál Sz. (2017): Adatok a Kis-Balaton fészkelő vízimadár-állományairól és szaporulatairól 2017-ben. *Aquila* **124**: 35–49.

Gál Sz. (2021a): Halcsontfarkú réce. *In:* Szép T., Csörgő T., Halmos G., Lovászi P., Nagy K. & Schmidt A. (szerk.): *Magyarország madáratlasza.* Agrárminisztérium – Magyar Madártani és Természetvédelmi Egyesület, Budapest: 129–130.

Gál Sz. (2021b): Indiai lúd. *In:* Szép T., Csörgő T., Halmos G., Lovászi P., Nagy K. & Schmidt A. (szerk.): *Magyarország madáratlasza.* Agrárminisztérium – Magyar Madártani és Természetvédelmi Egyesület, Budapest: 78.

Gál Sz. (2021c): Kanadai lúd. *In:* Szép T., Csörgő T., Halmos G., Lovászi P., Nagy K. & Schmidt A. (szerk.): *Magyarország madáratlasza.* Agrárminisztérium – Magyar Madártani és Természetvédelmi Egyesület, Budapest: 76.

Gantlett S. (1993): The status and separation of White-headed Duck and Ruddy Duck. *Birding World* **6**(7): 273–281.

Gyimesi A. & Lensik R. (2012): Egyptian Goose: an introduced species spreading in and from The Netherlands, *Wildfowls* **62**: 128–145.

Gyurácz J. & Kóta A. (2020): *Vas megye madarainak névjegyzéke.* Magyar Nyugat Könyvkiadó, Szombathely.

Hadarics T. & Neuwirth N. (1998): Kanadai lúd (*Branta canadensis*) első megfigyelése a Fertő mellett. *Túzok* **3**(2): 57–60.

Hadarics T. (1999): Pásztorgém (*Bubulcus ibis*) előfordulása a Fertő mellett. *Túzok* **4**(1–2): 11–14.

Hadarics T. (2006): Új fajok a Fertő madárfaunájában 1996 és 2003 között. *Szélkiáltó* **12**: 23–27.

Haraszthy L. (2019): Pásztorgém *Bubulcus ibis* (Linnaeus, 1758). *In:* Haraszthy L.: *Magyarország fészkelő madarainak költésbiológiája.* 1. kötet *Fácánféléktől a sólyomfélékig (Non-Passeriformes).* Pro Vértes Nonprofit Zrt., Csákvár: 364–367.

Heggberget T. M. (1991): Establishment of breeding populations and population development in the Canada Goose *Branta canadensis* in Norway. *Ardea* **79**(2): 365–370.

Henderson I. (2010): The eradication of Ruddy Ducks in the United Kingdom. *Aliens: The Invasive Species Bulletin* **29**: 17–24.

Holling M. & Rare Breeding Birds Panel (2017): Non-native breeding birds in the UK 2012–14. *British Birds* **110**(2): 92–108.

Hughes B. (1997): *Oxyura jamaicensis* Ruddy Duck. *In:* Hagemeijer W. J. M. & Blair M. J. (eds.): *The EBCC atlas of European breeding birds. Their distribution and abundance.* T & A D Poyser, London: 128.

Hughes B. (2000): White-headed Duck and Ruddy Duck: an update. *Birding World* **13**(4): 164–165.

Kalotás Zs. (2020): A nílusi lúd költési próbálkozása Szakály község (Tolna megye) határában. *Madártávlat* **27**(2): 24–25.

Kannan R. & James D. A. (2020): Common Myna (*Acridotheres tristis*). Version 1.0. *In:* Billerman S. M. (ed.): *Birds of the World.* Cornell Lab of Ornithology, Ithaca, – www.birdsoftheworld.org

Kárpáti L. (1983): A Fertő táj madárvilágának ökológiai vizsgálata. *Erdészeti és Faipari Tudományos Közlemények* 1982 (1): 111–203.

Kirby J. & Sjöberg K. (1997): *Branta canadensis* Canada Goose. *In:* Hagemeijer W. J. M. & Blair M. J. (eds.): *The EBCC atlas of European breeding birds. Their distribution and abundance.* T & A D Poyser, London: 75.

Kiss B. J. & Szabó L. (2000): First breeding record of certain bird species in Romania, data about the nesting of rare species. *Studii si Cercetări, Biologie (Universitatea Bacău)* **5**: 119–125.

Kovács G., Magyar G. & Kovács G. (1998): Pásztorgém (*Bubulcus ibis*) újabb előfordulása a Hortobágyon. *Aquila* **103–104**: 115, 135.

Lever C. (2005): *Naturalized birds of the world.* T & A D Poyser, London.

Lombardini K., Bennetts R. E. & Tourenq C. (2001): Foraging success and foraging habitat use by Cattle Egrets and Little Egrets in the Camargue, France. *The Condor* **103**(1): 38–44.

Lowe S., Browne M., Boudjelas S. & De Poorter M. (2004): *100 of the world's worst invasive alien species. A selection from the Global Invasive Species Database.* Updated and reprinted version. The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), Auckland.

Maddock M. & Geering D. (1994): Range expansion and migration of the Cattle Egret. *Ostrich* **65**(2): 191–203.

Madge S. & Burn H. (1988): *Wildfowl. An identification guide to the ducks, geese and swans of the world.* Christopher Helm, London.

Magyar G., Hadarics T., Waliczky Z., Schmidt A., Nagy T. & Bankovics A. (1998): *Magyarország madarainak névjegyzéke. Nomenclator avium Hungariae.* KTM Természetvédelmi Hivatal Madártani Intézete – Magyar Madártani és Természetvédelmi Egyesület – Winter Fair, Budapest – Szeged.

Malin J. R. (1968). How did the Cattle Egret get to America? *Bokmakierie* **20**: 79–80.

Matheu E., del Hoyo J., Christie D. A., Kirwan G. M. & Garcia E. F. J. (2020): African Sacred Ibis (*Threskiornis aethiopicus*). Version 1.0. *In:* del Hoyo J., Elliott A., Sargatal J., Christie D. A. & de Juana E. (eds.): *Birds of the World.* Cornell Lab of Ornithology, Ithaca. – www.birdsoftheworld.org

MME Nomenclator Bizottság (2008): *Magyarország madarainak névjegyzéke. Nomenclator avium Hungariae.* Magyar Madártani és Természetvédelmi Egyesület, Budapest.

MME Nomenclator Bizottság (2016): Az MME Nomenclator Bizottság 2013. évi jelentése a Magyarországon ritka madárfajok előfordulásáról. *Aquila* **122–123**: 163–172.

MME Nomenclator Bizottság (2019): Az MME Nomenclator Bizottság 2016. évi jelentése a Magyarországon ritka madárfajok előfordulásáról. *Aquila* **126**: 121–138.

Molina B., Postigo L. J., Muñoz A. R. & Del Moral J. C. (eds.) (2016): *La cotorra argentina en España. Población reproductora en 2015 y método de censo.* SEO/Birdlife, Madrid.

Mowbray T. B., Ely C. R., Sedinger J. S. & Trost R. E. (2020a): Cackling Goose (*Branta hutchinsii*). Version 1.0. *In:* Rodewald P. G. & Keeney B. K. (eds.): *Birds of the World.* Cornell Lab of Ornithology, Ithaca. – www.birdsoftheworld.org

Mowbray T. B., Ely C. R., Sedinger J. S. & Trost R. E. (2020b): Canada Goose (*Branta canadensis*). Version 1.0. *In:* Rodewald P. G. (ed.): *Birds of the World.* Cornell Lab of Ornithology, Ithaca. – www.birdsoftheworld.org

Musgrove A., Aebischer N., Eaton M., Hearn R., Newson S., Noble D., Parsons M., Risely K. & Stroud D. (2013): Population estimates of birds in Great Britain and the United Kingdom. *British Birds* **106**(2): 64–100.

Nagy L. (1935): Adalékok ritkább madaraink ujabb előfordulásához. *Aquila* **38–41**: 364–365, 427–428.

Niehaus G. (2001): Erste erfolgreiche Brut der Schwarzkopf-Ruderente *Oxyura jamaicensis* in Deutschland. *Limicola* **15**(5): 259–261.

Noble D. G. (2020a): *Branta candensis* Canada Goose. *In:* Keller V., Herrando S., Voříšek P., Franch M., Kipson M., Milanesi P., Martí D., Anton M., Klvaňová A., Kalyakin M. V., Bauer H.-G. & Foppen R. P. B. (eds.): *European breeding bird atlas 2. Distribution, abudance and change.* European Bird Census Council – Lynx Edicions, Barcelona: 108–109.

Noble D. G. (2020b): *Psitacula krameri* Rose-ringed parakeet. *In:* Keller V., Herrando S., Voříšek P., Franch M., Kipson M., Milanesi P., Martí D., Anton M., Klvaňová A., Kalyakin M. V., Bauer H.-G. & Foppen R. P. B. (eds.): *European* *breeding bird atlas 2. Distribution, abudance and change.* European Bird Census Council – Lynx Edicions, Barcelona: 530–531.

Oates J. (1999): Canada Goose forms in Aberdeenshire. *Birding World* **12**(3): 124.

Ogilvie M. A. (1977): The numbers of Canada Geese in Britain, 1976. *Wildfowl* **28**: 27–34.

Ondra P. & Klejdus J. (2013): The first confirmed breeding of the Egyptian Goose (*Alopochen aegyptiaca*) in South Moravia. *Crex* **32**: 17–22.

Pârâu L. G., Strubbe D., Mori E., Menchetti M., Ancillotto L., van Kleunen A., White R. L., Luna Á., Hernández-Brito D., Le Louarn M., Clergeau P., Albayrak T., Franz D., Braun M. P., Schroeder J. & Wink M. (2016): Rose-ringed Parakeet *Psittacula krameri* populations and numbers in Europe: a complete overview. *The Open Ornithology Journal* **9**: 1–13.

Pigniczki Cs. (1999): A pásztorgém (*Bubulcus ibis*) első megfigyelése a Péteri-tavon. *Túzok* **4**(1–2): 22.

Porgányi L. (1935): Pásztorgémek előfordulása Mohács vidékén. *Aquila* **38–41**: 365, 428.

Postigo J.-L., Strubbe D., Mori E., Ancillotto L., Carneiro I., Latsoudis P., Menchetti M., Pârâu L. G., Parrott D., Reino L., Weiserbs A. & Senar J. C. (2019): Mediterranean versus Atlantic Monk Parakeets *Myiopsitta monachus*: towards differentiated management at the European scale. *Pest Management Science* **75**(4): 915–922.

Randler C. (2006): Hybrid wildfowl in Central-Europe – an overview. *Waterbirds* **31**(1): 143–146.

Retief E. F., Smit-Robinson H. A. & de Swardt D. H. (2015): Egyptian Geese nesting in Secretarybird nests. *Ornithological Observations* **6**: 215–216.

Robertson P. A., Adriaens T., Caisergues A., Cranswick P. A., Devos K., Gutiérrez-Espósito C., Henderson I., Hughes B., Mill A. C. & Smith G. C. (2015): Towards the European eradication of the North American Ruddy Duck. *Biological Invasions* **17**(1): 9–12.

Rutschke E. (1987): *Die Wildgänse Europas. Biologie, Ökologie und Verhalten.* VEB Deutscher Landwirtschaftsverlag, Berlin.

Sattler T. (2020): *Columba livia* Rock Dove, Feral Pigeon. *In:* Keller V., Herrando S., Voříšek P., Franch M., Kipson M., Milanesi P., Martí D., Anton M., Klvaňová A., Kalyakin M. V., Bauer H.-G. & Foppen R. P. B. (eds.): *European breeding bird atlas 2. Distribution, abudance and change.* European Bird Census Council – Lynx Edicions, Barcelona: 180–181.

Schmidt E. & Sterbetz I. (1962): Pásztorgém a Sasérben. *Aquila* **67–68**: 204, 243–244.

Schmidt E. (1978): Külföldi gyűrűs madarak kézre kerülései – XXVII. gyűrűzési jelentés. *Aquila* **84**: 91–100.

Senar J. C., Carrillo-Ortiz J. G., Ortega-Segalerva A., Dawson Pell F. S. E., Pascual J., Arroyo L., Mazzoni D., Montalvo T. & Hatchwell B. J. (2019): The reproductive capacity of Monk Parakeets *Myiopsitta monachus* is higher in their invasive range. *Bird Study* **66**(1): 136–140.

Si Bachir A., Ferrah F., Barbraud C., Céréghino R. & Santoul F. (2011): The recent expansion of an avian invasive species (the Cattle Egret *Ardea ibis*) in Algeria. *Journal of Arid Environment* **75**(11): 1232–1236.

Sterbetz I. (1964): A pásztorgém rendszeres megjelenése a Saséri rezervátumban. *Aquila* **69–70**: 246–247.

Sterbetz I. (1974): A hódmezővásárhelyi Tisza-ártér természetvédelmi területeinek madárvilága. *Aquila* **78–79**: 45–80.

Sutherland W. J. & Allport G. (1991): The distribution and ecology of naturalized Egyptian Geese *Alopochen aegyptiacus* in Britain. *Bird Study* **38**(2): 128–134.

Szép T., Nagy K., Nagy Zs. & Halmos G. (2012): Population trends of common breeding and wintering birds in Hungary, decline of long-distance migrant and farmland birds during 1999–2012. *Ornis Hungarica* **20**(2): 13–63.

Tóth L. (2016): Nílusi lúd (*Alopochen aegyptiaca*) költése a Zsennyei-horgásztavon. *Cinege* **21**: 42–43.

Urdiales C. & Pereira P. (1993): *Identification key of O. jamaicensis, O. leucocephala and their hybrids.* Ministerio de Agricultura Pesca y Alimentacion, Instituto Nacional para la Conservation de la Naturaleza, Madrid.

Vaslin M. (2005): Prédation de l'Ibis sacré *Threskiornis aethiopicus* sur des colonies de sternes et de guifettes *Ornithos* **12**(2): 106–109.

Vasvári M. (1942): Ornithofaunisztikai adatok Magyarországból. *Aquila* **46–49**: 314–323.

Venema P. (1997): *Alopochen aegyptiacus* Egyptian Goose. *In:* Hagemeijer W. J. M. & Blair M. J. (eds.): *The EBCC atlas of European breeding birds. Their distribution and abundance.* T & A D Poyser, London: 79.

Williams A. J.. & Ward V. L. (2006): Sacred Ibis and Gray Heron predation of Cape Cormorant eggs and chicks; and a review of ciconiiform birds as seabird predators. *Waterbirds* **29**(3): 321–327.

Yésou P. & Clergeau P. (2005): Sacred Ibis: a new invasive species in Europe. *Birding World* **18**(12): 517–526.

Yésou P., Clergeau P., Bastian S., Reeber S. & Maillard J.-F. (2017): The Sacred Ibis in Europe: ecology and managment. *British Birds* **110**(4): 197–212.

Zalai T. & Oláh J. (2017): Új és ritka madárfajok, új fészkelők a Hortobágy faunájában 2004 és 2016 között. *Virgo* **1**: 203–218.

Zörényi M. (1993): Nílusi lúd (*Alopochen aegyptiacus*) első megfigyelése Magyarországon. *Aquila* **100**: 267–268, 292.

MAMMALS – Mammalia

Aiyadurai A. & Jhala Y. V. (2006): Foraging and habitat use by Golden Jackals (*Canis aureus*) in the Bhal region, Gujarat, India. *Journal of the Bombay Natural History Society* **103**(1): 5–12.

Aliev F. F. (1968): Kavkazskiy shakal (*Canis aureus moreoticus* Geoffroy, 1835). *Izvestiya na Zoologicheskiya Institut s Muzey* **26**: 75–82.

Anghi Cs. (1990): *Macskák, cicák.* 3., átdolgozott kiadás. Mezőgazdasági Kiadó, Budapest. /Állatbarát/

Antli I. (2001): *A dámszarvas.* Nimród Vadászújság, *sine loco.* /Nimród Vadászakadémia 10./

Arnold J., Humer A., Heltai M., Murariu D., Spassov N. & Hackländer K. (2011): Current status and distribution of Golden Jackals *Canis aureus* in Europe. *Mammal Review* **42**(1): 1–11.

Ayral F., Kodjo A., Guédon G., Boué F. & Richomme C. (2020): Muskrats are greater carriers of pathogenic *Leptospira* than Coypus in ecosystems with temperate climates. *PLoS ONE* **15**(2): e0228577.

Balog T., Nagy G., Halász T., Csányi E., Zomborszky Z., & Csivincsik Á. (2021): The occurrence of *Echinococcus* spp. in Golden Jackal (*Canis aureus*) in southwestern Hungary: Should we need to rethink its expansion? *Parasitology International* **80**: 102214.

Bartoszewicz M., Okarma H., Zalewski A. & Szczęsna J. (2008): Ecology of the Raccoon (*Procyon lotor*) from western Poland. *Annales Zoologici Fennici* **45**(4): 291–298.

Basu N., Scheuhammer A. M., Bursian S. J., Elliott J., Rouvinen-Watt K. & Chan H. M. (2007): Mink as a sentinel species in environmental health. *Environmental Research* **103**(1): 130–144.

Benko Š., Chudý A. & Ridzoň J. (2016): Prvý priamo zaznamenaný prípad predácie kolónií vodného vtáctva norkom americkým (*Neovision vison*) na Slovensku. *Tichodroma* **28**: 82–85.

Bergman J. (2005): The history of the Dodo bird and the cause of its extinction. *Perspectives on Science and Christian Faith* **57**(3): 221–229.

Bergstrom D. M., Lucieer A., Kiefer K., Wasley J., Belbin L., Pedersen T. K. & Chown S. L. (2009): Management implications of the Macquarie Island trophic cascade revisited: a reply to Dowding *et al.* (2009). *Journal of Applied Ecology* **46**(5): 1133–1136.

Bertolino S., Angelici C., Monaco E., Monaco A. & Capizzi D. (2011): Interactions between Coypu (*Myocastor coypus*) and bird nests in three mediterranean wetlands of central Italy. *Hystrix* **22**(2): 333–339.

Bertolino S., Guichón M. L. & Carter J. (2012): *Myocastor coypus* Molina (Coypu). *In:* Francis R. A. (ed.): *A handbook of global freshwater invasive species.* Earthscan, London – New York: 357–368.

Beschta R. L. & Ripple W. J. (2009): Large predators and trophic cascades in terrestrial ecosystems of the western United States. *Biological Conservation* **142**(11): 2401–2414.

Bihari Z. (2003): A pézsmapocok (*Ondatra zibethicus* (Linnaeus, 1766)) mint inváziv emlősfaj természetvédelmi szempontú értékelése. *In:* Sallai Z. (szerk.): *Hazai invázív gerincesek (halak és emlősök) elleni természetvédelmi stratégiát megalapozó tanulmány.* Hortobágyi Nemzeti Park Igazgatóság, Debrecen: 64–71.

Bihari Z. (2007a): Házi egér *Mus musculus* Linnaeus, 1758. *In:* Bihari Z., Csorba G. & Heltai M. (szerk.): *Magyarország emlőseinek atlasza.* Kossuth Kiadó, Budapest: 193–194.

Bihari Z. (2007b): Pézsmapocok *Ondatra zibethicus* (Linnaeus, 1766). *In:* Bihari Z., Csorba G. & Heltai M. (szerk.): *Magyarország emlőseinek atlasza.* Kossuth Kiadó, Budapest: 174–175.

Biró Zs., Lanszki J., Szemethy L., Heltai M. & Randi E. (2005): Feeding habits of feral Domestic Cats (*Felis catus*), Wild Cats (*Felis silvestris*) and their hybrids: trophic niche overlap among cat groups in Hungary. *Journal of Zoology* **266**(2): 187–196.

Biró Zs., Szemethy L. & Heltai M. (2004): Home range sizes of Wildcats (*Felis silvestris*) and feral Domestic Cats (*Felis silvestris f. catus*) in a hilly region of Hungary. *Mammalian Biology* **69**(5): 302–310.

Blancher P. (2013): Estimated number of birds killed by House Cats (*Felis catus*) in Canada. *Avian Conservation and Ecology* **8**(2): 3.

Bodnár Zs. (2019): A világ egyetlen patkánymentes nagyvárosából patkányparadicsommá válhat Budapest. *In: Quibit.* – www.qubit.hu

Boggess E. K. (1994): *Raccoons.* Cooperative Extension Division, Institute of Agriculture and Natural Resources, University of Nebraska – United States Depoartment of Agriculture, Animal and Plant Health Inspection Service, Animal Damage Control – Great Plains Agricultural Council, Wildlife Committee, Lincoln (Nebraska). / Prevention and control of wildlife damage./

Bonesi L. & Palazon S. (2007): The American Mink in Europe: Status, impacts, and control. *Biological Conservation* **134**(4): 470–483.

Bonesi L., Chanin P. & Macdonald D. W. (2004): Competition between Eurasian Otter *Lutra lutra* and American Mink *Mustela vison* probed by niche shift. *Oikos* **106**(1): 19–26.

Bonnaud E., Medina F. M., Vidal E., Nogales M., Tershy B., Zavaleta E., Donlan C. J., Keitt B., Le Corre M. & Horwath S. V. (2011): The diet of Feral Cats on islands: a review and a call for more studies. *Biological Invasions* **13**(3): 581–603.

Bos D., Kentie R., La Haye M. & Ydenberg R. C. (2019): Evidence for the effectiveness of controlling Muskrat (*Ondatra zibethicus* L.) populations by trapping. *European Journal of Wildlife Research* **65**(3): 45.

Burgin C. J., Wilson D. E., Mittermeier R. A., Rylands A. B., Lacher T. E. & Sechrest W. (2020): *Illustrated checklist of the mammals of the world.* Volume 2. *Eulipotyphla to Carnivora.* Lynx Edicions, Barcelona.

Capel-Edwards M. (1967): Foot-and-mouth disease in *Myocastor coypus*. *Journal of Comparative Pathology* **77**(2): 217–221.

Carter J. & Leonard B. P. (2002): A review of the literature on the worldwide distribution, spread of, and efforts to eradicate the Coypu (*Myocastor coypus*). *Wildlife Society Bulletin* **30**(1): 162–175.

Castello J. R. (2016): *Bovids of the world. Antelopes, gazelles, cattle, goats, sheep and relatives.* Princeton University Press, Princeton – Oxford.

Chapuis J. L., Boussès P. & Barnaud G. (1994): Alien mammals, impact and management in the French subantarctic islands. *Biological Conservation* **67**(2): 97–104.

Christiansen J. L. & Gallaway B. J. (1984): Raccoon removal, nesting success, and hatchling emergence in Iowa turtles with special reference to *Kinosternon flavescens* (Kinosternidae). *The Southwestern Naturalist* **29**(3): 343–348.

Ćirović D., Penezić A. & Krofel M. (2016): Jackals as cleaners: Ecosystem services provided by a mesocarnivore in human-dominated landscapes. *Biological Conservation* **199**: 51–55.

Corbet G. & Ovenden D. (1982): *Pareys Buch der Säugetiere. Alle wildlebenden Säugetiere Europas.* Verlag Paul Parey, Hamburg – Berlin.

Corbett L. K. (1979): *Feeding ecology and social organization of Wildcats (Felis silvestris) and Domestic Cats (Felis catus) in Scotland.* Dissertation, University of Aberdeen, Aberdeen.

Courchamp F., Langlais M. & Sugihara G. (1999): Cats protecting birds: modelling the mesopredator release effect. *Journal of Animal Ecology* **68**(2): 282–292.

Crooks K. R. & Soulé M. E. (1999): Mesopredator release and avifaunal extinctions in a fragmented system. *Nature* **400**(6744): 563–566.

Csanády A., Kisková J., Galušková S., Duranková S., Pristaš P. & Sedláková-Kaduková J. (2021): The House Mouse (*Mus musculus*) in small farmstead buildings in Slovakia. *Biologia* **76**(4): 1205–1213.

Csányi S., Köller J. & Zoltán A. (2010): *Európa vadvilág öröksége. Európai nagyvadfajok világrekord trófeái. A 2008–2009. évi vadászidény legjobb magyar vadásztrófeái.* Nimród Vadászújság, Budapest.

Csányi S., Márton M., Major F. Cs. & Schally G. (2021): *Vadgazdálkodási Adattár. 2020/2021. vadászati év.* Országos Vadgazdálkodási Adattár, Gödöllő.

Davis G. E. & Whiting M. C. (1977): Loggerhead Sea Turtle nesting in Everglades National Park, Florida, USA. *Herpetologica* **33**(1): 18–28.

Demeter A. & Spassov N. (1993): *Canis aureus* Linnaeus, 1758 – Schakal, Goldschakal. *In:* Niethammer J. & Krapp F. (Hrsg.): *Handbuch der Säugetiere Europas.* Band 5/I. *Raubsäuger – Carnivora (Fissipedia). Teil I. Canidae, Ursidae, Procyonidae, Mustelidae 1.* AULA-Verlag, Wiesbaden: 107–138.

Dickman C. R. (1996a): Impact of exotic generalist predators on the native fauna of Australia. *Wildlife Biology* **2**(3): 185–195.

Dickman C. R. (1996b): *Overview of the impact of Feral Cats on Australian native fauna.* Australian Nature Conservation Agency, Canberra.

Doherty T. S., Bengsen A. J. & Davis R. A. (2014): A critical review of habitat use by Feral Cats and key directions for future research and management. *Wildlife Research* **41**(5): 435–446.

Doherty T. S., Davis R. A., van Etten E. J. B., Algar D., Collier N., Dickman C. R., Edwards G., Masters P., Palmer R. & Robinson S. (2015): A continental-scale analysis of Feral Cat diet in Australia. *Journal of Biogeography* **42**(5): 964–975.

Doherty T. S., Dickman C. R., Johnson C. N., Legge S. M., Ritchie E. G. & Woinarski J. C. Z. (2016a): Impacts and management of Feral Cats *Felis catus* in Australia. *Mammal Review* **47**(2): 83–97.

Doherty T. S., Glen A. S., Nimmo D. G., Ritchie E. G. & Dickman C. R. (2016b): Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences* **113**(40): 11261–11265.

Driscoll C. A., Macdonald D. W. & O'Brien S. J. (2009): From wild animals to domestic pets, an evolutionary view of domestication. *Proceedings of the National Academy of Sciences* **106** (Supplement 1): 9971–9978.

Driscoll C. A., Menotti-Raymond M., Roca A. L., Hupe K., Johnson W. E., Geffen E., Harley E. H., Delibes M., Pontier D., Kitchener A. C., Yamaguchi N., O'Brien S. J. & Macdonald D. W. (2007): The Near Eastern origin of cat domestication. *Science* **317**(5837): 519–523.

Drygala F., Zoller H., Stier N. & Roth M. (2010): Dispersal of the Raccoon Dog *Nyctereutes procyonoides* into a newly invaded area in Central Europe. *Wildlife Biology* **16**(2): 150–161.

Duarte A., Fernandes M., Santos N. & Tavares L. (2012): Virological survey in free-ranging Wildcats (*Felis silvestris*) and feral Domestic Cats in Portugal. *Veterinary Microbiology* **158**(3–4): 400–404.

Faragó S. (1994): Vadászati állattan. *In:* Kőhalmy T. (szerk.): *Vadászati enciklopédia.* Mezőgazda Kiadó, Budapest: 81–210.

Faragó S. (2002): *Vadászati állattan.* Mezőgazda Kiadó, Budapest.

Feldhamer G. A., Thompson B. C. & Chapman J. A. (eds.) (2003): *Wild mammals of North America. Biology, management, and conservation.* 2nd edition. The John Hopkins University Press, Baltimore.

Fenton S., Moorcroft P. R., Ćirović D., Lanszki J., Heltai M., Cagnacci F., Breck S., Bogdanović N., Pantelić I., Ács K. & Ranc N. (2021): Movement, space-use and resource preferences of European Golden Jackals in human-dominated landscapes: insights from a telemetry study. *Mammalian Biology* **101**(5): 619–630.

Fitzgerald B. M. (1988): Diet of Domestic Cats and their impact on prey populations. *In:* Turner D. C. & Bateson P. (eds.): *The Domestic Cat. The biology of its behaviour.* Cambridge University Press, Cambridge: 123–144.

French D. D., Corbett L. K. & Easterbee N. (1988): Morphological discriminants of Scottish Wildcats (*Felis silvestris*), Domestic Cats (*F. catus*) and their hybrids. *Journal of Zoology* **214**(2): 235–259.

Fritzell E. K., Hubert G. F., Meyen B. E. & Sanderson G. C. (1985): Age-specific reproduction in Illinois and Missouri Raccoons. *The Journal of Wildlife Management* **49**(4): 901–905.

Galbreath R. & Brown D. (2004): The tale of the lighthouse-keeper's cat: Discovery and extinction of the Stephens Island Wren (*Traversia lyalli*). *Notornis* **51**(4): 193–200.

Gehrt S. D. (2003): Raccoon and allies. *In:* Feldhamer G. A., Thompson B. C. & Chapman J. A. (eds.): *Wild mammals of North America. Biology, management, and conservation.* 2nd edition. The Johns Hopkins Press, Baltimore: 611–634.

Gehrt S. D. (2004): Ecology and management of Striped Skunks, Raccoons, and Coyotes in urban landscapes. *In:* Fascione N., Delach A. & Smith M. E. (eds.): *People and predators. From conflict to coexistence.* Island Press, Washington: 81–104.

Gehrt S. D. & Fritzell E. K. (1998): Duration of familial bonds and dispersal patterns for Raccoons in South Texas. *Journal of Mammalogy* **79**(3): 859–872.

Giannatos G. (2004): *Conservation Action Plan for the Golden Jackal Canis aureus L. in Greece.* WWF Greece, Athens.

Giannatos G., Marinos Y., Maragou P. & Catsadorakis G. (2005): The status of the Golden Jackal (*Canis aureus* L.) in Greece. *Belgian Journal of Zoology* **135**(2): 145–149.

Glen A. S., Dickman C. R., Soulé M. E. & Mackey B. G. (2007): Evaluating the role of the Dingo as a trophic regulator in Australian ecosystems. *Austral Ecology* **32**(5): 492–501.

Gosling L. M. (1981): Climatic determinants of spring littering by feral Coypus, *Myocastor coypus. Journal of Zoology* **195**(3): 281–288.

Gosling L. M. & Baker S. J. (1989): The eradication of Muskrats and Coypus from Britain. *Biological Journal of the Linnean Society* **38**(1): 39–51.

Görner M. & Hackethal H. (1987): *Säugetiere Europas.* Neumann Verlag, Radebeul – Leipzig.

Greenwood R. J. (1981): Foods of Prairie Raccoons during the waterfowl nesting season. *The Journal of Wildlife Management* **45**(3): 754–760.

Groó Z., Szenczi P., Bánszegi O. & Altbäcker V. (2013): Natal dispersal in two mice species with contrasting social systems. *Behavioural Ecology and Sociobiology* **67**(2): 235–242.

Groves C. P., Leslie D. M., Huffman B. A., Valdez R., Habibi K., Weinberg P. J., Burton J. A., Jarman P. J. & Robichaud W. G. (2011): Family Bovidae (Hollow-horned ruminants). *In:* Wilson D. E. & Mittermeier E. A. (eds.): *Handbook of the mammals of the world.* Volume 2. *Hoofed mammals.* Lynx Edicions, Barcelona: 444–779.

Guichón M. L., Benítez V. B., Abba A., Borgnia M. & Cassini M. H. (2003a): Foraging behaviour of Coypus *Myocastor coypus*: why do Coypus consume aquatic plants? *Acta Oecologica* **24**(5–6): 241–246.

Guichón M. L., Borgnia M., Fernández Righi C., Cassini G. H. & Cassini M. H. (2003b): Social behavior and group formation in the Coypu (*Myocastor coypus*) in the Argentinean pampas. *Journal of Mammalogy* **84**(1): 254–262.

Guichón M. L., Doncaster C. P. & Cassini M. H. (2003c): Population structure of Coypus (*Myocastor coypus*) in their region of origin and comparison with introduced populations. *Journal of Zoology* **261**(3): 265–272.

Harrington L. A., Harrington A. L., Moorhouse T., Gelling M., Bonesi L. & Macdonald D. W. (2009): American Mink control on inland rivers in southern England: An experimental test of a model strategy. *Biological Conservation* **142**(4): 839–849.

Hartman L. H., Gaston A. J. & Eastman D. S. (1997): Raccoon predation on Ancient Murrelets on East Limestone Island, British Columbia. *The Journal of Wildlife Management* **61**(2): 377–388.

Hayward M. W., Porter L., Lanszki J., Kamler J. F., Beck J. M., Kerley G. I. H., Macdonald D. M., Montgomery R. A., Parker D. M., Scott D. M., O'Brian J. & Yarnell R. W. (2017): Factors affecting the prey preferences of jackals (Canidae). *Mammalian Biology* **85**: 70–82.

Heidemann G. (1986): *Cervus dama* (Linnaeus, 1758) – Damhirsch. *In:* Niethammer J. & Krapp F. (Hrsg.): *Handbuch der Säugetiere Europas.* Band 2. *Paarhufer – Artiodactyla (Suidae, Cervidae, Bovidae).* AULA-Verlag, Wiesbaden: 142–160.

Helle E. & Kauhala K. (1993): Age structure, mortality, and sex ratio of the Raccoon Dog in Finland. *Journal of Mammalogy* **74**(4): 936–942.

Heltai M., Ćirović D., Szabó L., Penezić A., Nagyapáti N., Kurys A. & Lanszki J. (2013): Golden Jackal: opinions versus facts – experiences from Serbia and Hungary. *In:* Beuković M. (ed.): *Proceedings. „Modern Aspects of Sustainable Management of Game Population". 2nd International Symposium on Hunting. Novi Sad, Serbia, 17–20 October, 2013.* University of Novi Sad, Faculty of Agriculture, Novi Sad: 13–20.

Heltai M., Lanszki J., Szemethy L. & Tóth M. (szerk.) (2010): *Emlős ragadozók Magyarországon.* Mezőgazda Kiadó, Budapest.

Hoffmann M., Arnold J., Duckworth J. W., Jhala Y., Kamler J. F. & Krofel M. (2018): *Canis aureus. In: The IUCN Red List of Threatened Species 2018*: e.T118264161A163507876. – www.iucnredlist.org

Hohmann U. (2000): *Raumnutzung und Sozialsystem des Waschbären in Mitteldeutschland.* Infodienst Wildbiologie und Oekologie, Zürich.

Hohmann U. & Hupe K. (1999): Interspecific competition of the Raccoon (*Procyon lotor*) and the Wildcat (*Felis silvestris silvestris*) with regard to rest sites in Germany. *In:* Thomaidis C. & Kypridemos N. (eds.): *Agriculture forestry – game. Integrating wildlife in land management. International Union of Game Biologists XXIVth Congress, Thessaloniki – Greece, 20–24 September 1999. Proceedings.* Thessaloniki: 361–367.

Hohmann U., Gerhard R. & Kasper M. (2000): Home range size of adult Raccoons (*Procyon lotor*) in Germany. *Zeitschrift für Säugetierkunde* **65**(2): 124–127.

Horváth Gy. (2003): A vándorpatkány (*Rattus norvegicus* (Berkenhout, 1769)) mint inváziv emlősfaj természetvédelmi értékelése. *In:* Sallai Z. (szerk.): *Hazai inváziv gerincesek (halak és emlősök) elleni természetvédelmi stratégiát megalapozó tanulmány.* Hortobágyi Nemzeti Park Igazgatóság, Debrecen: 53–63.

Horváth Gy. (2007a): Házi patkány *Rattus rattus* (Linnaeus, 1758). *In:* Bihari Z., Csorba G. & Heltai M. (szerk.): *Magyarország emlőseinek atlasza.* Kossuth Kiadó, Budapest: 199–200.

Horváth Gy. (2007b): Vándorpatkány *Rattus norvegicus* (Berkenhout, 1769). *In:* Bihari Z., Csorba G. & Heltai M. (szerk.): *Magyarország emlőseinek atlasza.* Kossuth Kiadó, Budapest: 197–198

Howerth E. W., Reeves A. J., McElveen M. R. & Austin F. W. (1994): Survey for selected diseases in Nutria *(Myocastor coypus)* from Louisiana. *Journal of Wildlife Diseases* **30**(3): 450–453.

Hu Y., Hu S., Wang W., Wu X., Marshall F. B., Chen X., Hu L. & Wang C. (2014): Earliest evidence for commensal processes of cat domestication. *Proceedings of the National Academy of Sciences* **111**(1): 116–120.

Hubbard A. L., McOrist S., Jones T. W., Boid R., Scott R. & Easterbee N. (1992): Is survival of European Wildcats *Felis silvestris* in Britain threatened by interbreeding with Domestic Cats? *Biological Conservation* **61**(3): 203–208.

Hulme-Beaman A., Orton D. & Cucchi T. (2021): The origins of the domesticate Brown Rat (*Rattus norvegicus*) and its pathways to domestication. *Animal Frontiers* **11**(3): 78–86.

Ibarra J. T., Fasola L., Macdonald D. W., Rozzi R. & Bonacic C. N. (2009): Invasive American Mink *Mustela vison* in wetlands of the Cape Horn Biosphere Reserve, southern Chile: what are they eating? *Oryx* **43**(1): 87.

Ivanova G. I. (1962): Sravnitelnaya kharakteristika pitaniya lisitsy, barsuka i yenotovidnoy sobaki v Voronezhskom zapovednike. *Uchenye Zapiski Moskovskogo Gosudarstvennogo Pedagogicheskogo Instituta im. V. I. Lenina* **186**: 209–256.

Jabir H. A., Bajomi D. & Demeter A. (1985): New record of the Black Rat (*Rattus rattus* L.) from Hungary, and a review of its distribution in Central Europe (Mammalia). *Annales Historico-naturales Musei Nationalis Hungarici* **77**: 263–267.

Jablonowski J. (1927): A pézsmapocok hazai letelepedése és terjeszkedése. *Term*észettudományi Közlöny **59**(841): 120–130.

Jędrzejewska B. & Jędrzejewski W. (1998): *Predation in vertebrate communities. The Białowieża Primeval Forest as a case study.* Springer-Verlag, Berlin – Heidelberg. /Ecological Studies 135./

Jędrzejewska E., Bartoszewicz M., Okarma H. & Zalewski A. (2014): Plastyczność obcego inwazyjnego gatunku – szopa pracza (*Procyon lotor*) w Polsce. *In:* Jankow W., Ulbrych L., Wypychowski K. & Zalewski A. (red.): *Ekologia i wpływ na środowisko gatunków inwazyjnych. Publikacja pokonferencyjna konferencji „Znaczenie gatunków inwayjnych w ochronie ptaków wodnych oraz ich siedlisk". 7–10 maja 2014, Kostrzyn nad Odrą.* Park Narodowy Ujście Warty: 115–122.

Jhala Y. V. & Moehlman P. D. (2004): Golden Jackal *Canis aureus* Linnaeus, 1758. *In:* Sillero-Zubiri C., Hoffmann M. & Macdonald D. W. (eds.): *Canids: foxes, wolves, jackals and dogs. Status survey and Conservation Action Plan.* IUCN – SSC Canid Specialist Group, Gland – Cambridge: 156–161.

Kamler J. F., Ballard W. B. & Helliker B. R. & Stiver S. (2003): Range expansion of Raccoons in western Utah and central Nevada. *Western North American Naturalist* **63**(3): 406–408.

Kapota D., Dolev A., Bino G., Yosha D., Guter A., King R. & Saltz D. (2016): Determinants of emigration and their impact on survival during dispersal in fox and jackal populations. *Scientific Reports* **6**(1): 24021.

Katona K. & Altbäcker V. (2007): Üregi nyúl *Oryctolahus cuniculus* (Linnaeus, 1758). *In:* Bihari Z., Csorba G. & Heltai M. (szerk.): *Magyarország emlőseinek atlasza.* Kossuth Kiadó, Budapest: 132–134.

Katona K., Bíró Zs., Hahn I., Kertész M. & Altbäcker V. (2004): Competition between European Hare and European Rabbit in a lowland area, Hungary: a long-term ecological study in the period of Rabbit extinction. *Folia Zoologica* **53**(3): 255–268.

Kaufmann J. H. (1982): Raccoon and allies. *In:* Chapman J. A. & Feldhamer G. A. (eds.): *Wild mammals of North America: biology, management, and economics.* The Johns Hopkins University Press, Baltimore: 567–585.

Kauhala K. (1996): Introduced carnivores in Europe with special reference to central and northern Europe. *Wildlife Biology* **2**(1): 197–204.

Kauhala K. & Helle E. (1995): Population ecology of the Raccoon Dog in Finland – a synthesis. *Wildlife Biology* **1**(1): 3–9.

Kauhala K. & Kowalczyk R. (2011): Invasion of the Raccoon Dog *Nyctereutes procyonoides* in Europe: History of colonization, features behind its success, and threats to native fauna. *Current Zoology* **57**(5): 584–598.

Kauhala K. & Saeki M. (2004): Raccon Dogs: Finnish and Japanese Raccoon Dogs – on the road to speciation? *In:* Macdonald D. W. & Sillero-Zubiri C. (eds.): *Biology and conservation of wild canids.* Oxford University Press, Oxford: 217–226.

Kauhala K., Holmala K., Lammers W. & Schregel J. (2006): Home ranges and densities of medium-sized carnivores in south-east Finland, with special reference to rabies spread. *Acta Theriologica* **51**(1): 1–13.

Kauhala K., Holmala K. & Schregel J. (2007): Seasonal activity patterns and movements of the Raccoon Dog, a vector of diseases and parasites, in southern Finland. *Mammalian Biology* **72**(6): 342–353.

Kauhala K., Laukkanen P. & von Rége I. (1998): Summer food composition and food niche overlap of the Raccoon Dog, Red Fox and Badger in Finland. *Ecography* **21**(5): 457–463.

Kauhala K., Schregel J. & Auttila M. (2010): Habitat impact on Raccoon Dog *Nyctereutes procyonoides* home range size in southern Finland. *Acta Theriologica* **55**(4): 371–380.

Kézdy P., Csiszár Á., Korda M. & Bartha D. (2018): Inváziós fajok előfordulása és kezelése Magyarország védett és Natura 2000 területein, európai összehasonlítással. *Természetvédelmi Közlemények* **24**: 85–103.

Kilshaw K., Montgomery R. A., Campbell R. D., Hetherington D. A., Johnson P. J., Kitchener A. C., Macdonald D. W. & Millspaugh J. J. (2016): Mapping the spatial configuration of hybridization risk for an endangered population of the European Wildcat (*Felis silvestris silvestris*) in Scotland. *Mammal Research* **61**(1): 1–11.

Kitchener A. (1991): *The natural history of the wild cats.* Comstock Publishing Associates, Ithaka (New York).

Kleijn D., Kohler F., Báldi A., Batáry P., Concepción E. D., Clough Y., Díaz M., Gabriel D., Holzschuh A., Knop E., Kovács A., Marshall E. J. P., Tscharntke T. & Verhulst J. (2009): On the relationship between farmland biodiversity and land-use intensity in Europe. *Proceedings of the Royal Society* B *Biological Sciences* **276**(1658): 903–909.

Koepfli K.-P., Pollinger J., Godinho R., Robinson J., Lea A., Hendricks S., Schweizer R. M., Thalmann O., Silva P., Fan Z., Yurchenko A. A., Dobrynin P., Makunin A., Cahill J. A., Shapiro B., Álvares F., Brito J. C., Geffen E., Leonard J. A., Helgen K. M., Johnson W. E., O'Brian S. J., Van Valkenburgh B. & Wayne R. K. (2015): Genome-wide evidence reveals that African and Eurasian Golden Jackals are distinct species. *Current Biology* **25**(16): 2158–2165.

Kovács Zs. E. (2012): Dispersal history of an invasive rodent in Hungary – subfossil finds of *Rattus rattus*. *Acta Zoologica Academiae Scientiarum Hungaricae* **58**(4): 379–394.

Kovács Zs. E. (2014): *A kisemlősfauna holocén kori változásai Magyarországon – a házi patkány (Rattus rattus) megjelenése és terjedése.* Doktori értekezés. Debreceni Egyetem, Debrecen.

Krauze-Gryz D., Gryz J. & Żmihorski M. (2019): Cats kill millions of vertebrates in Polish farmland annually. *Global Ecology and Conservation* **17**: e00516.

Krofel M., Giannatos G., Ćirovič D., Stoyanov S. & Newsome T. M. (2017): Golden Jackal expansion in Europe: a case of mesopredator release triggered by continent-wide Wolf persecution? *Hystrix* **28**(1): 9–15.

Kryštufek B., Murariu D. & Kurtonur C. (1997): Present distribution of the Golden Jackal *Canis aureus* in the Balkans and adjacent regions. *Mammal Review* **27**(2): 109–114.

Lakatos K. (2022): Ritka találkozás – amerikai nyérc az objektív előtt. Állatvilág **9**(6): 28–29.

Lanszki J. (2012): *Ragadozó emlősök táplálkozási kapcsolatai.* Somogy Megyei Múzeumok Igazgatósága, Kaposvár. /Natura Somogyiensis 21./

Lanszki J. & Cserkész T. (2022): Amerikából érkezett. Állatvilág **9**(6): 30–31.

Lanszki J. & Gruber Á. (2021a): Az európai vadmacska (*Felis s. silvestris*) terepi és post mortem kutatása. *In: 21. Kolozsvári Biológus Napok, 2021. április 16–17, Kolozsvár. Konferencia kötet*: 40.

Lanszki J. & Gruber Á. (2021b): A veszélyeztetett vadmacska (*Felis silvestris silvestris*) állományhelyzete terepi és post mortem kutatás alapján. *In:* Tinya F. (szerk.): *12. Magyar Ökológus Kongresszus. Előadások és poszterek összefoglalói. 2021. augusztus 24–26., Vác.* Magyar Ökológusok Tudományos Egyesülete – Ökológiai Kutatóközpont, Vác: 179.

Lanszki J. & Heltai M. (2010): Food preferences of Golden Jackals and sympatric Red Foxes in European temperate climate agricultural area (Hungary). *Mammalia* **74**(3): 267–273.

Lanszki J., Giannatos G., Heltai M. & Legakis A. (2009): Diet composition of Golden Jackals during cub-rearing season in Mediterranean marshland in Greece. *Mammalian Biology* **74**(1): 72–75.

Lanszki J., Hayward M. W. & Nagyapáti N. (2018a): Feeding responses of the Golden Jackal after reduction of anthropogenic food subsidies. *PLoS ONE* **13**(12): e0208727.

Lanszki J., Hayward M., Ranc N. & Zalewski A. (2018b): Feeding ecology of the Golden Jackal: knowledge and limitations. *Hellenic Zoological Archives* **9**: 54–57.

Lanszki J., Heltai M. & Szabó L. (2006): Feeding habits and trophic niche overlap between sympatric Golden Jackal (*Canis aureus*) and Red Fox (*Vulpes vulpes*) in the Pannonian ecoregion (Hungary). *Canadian Journal of Zoology* **84**(11): 1647–1656.

Lanszki J., Kletečki E., Trócsányi B., Mužinić J., Széles G. L. & Purger J. J. (2016): Feeding habits of house and feral Cats (*Felis catus*) on small Adriatic islands (Croatia). *North-western Journal of Zoology* **12**(2): 336–348.

Lanszki J., Kurys A., Heltai M., Csányi S. & Ács K. (2015): Diet composition of the Golden Jackal in an area of intensive big game management. *Annales Zoologici Fennici* **52**(4): 243–255.

Lanszki J., Kurys A., Szabó L., Nagyapáti N., Porter L. B. & Heltai M. (2016): Diet composition of the Golden Jackal and the sympatric Red Fox in an agricultural area (Hungary). *Folia Zoologica* **65**(4): 310–322.

Lavrov N. P. (1971): Itogi introduktsii yenotovidnoy sobaki (*Nyctereutes procyonoides* Grey) v otdelnye oblasti SSSR. *Uchenye Zapiski Moskovskogo Gosudarstvennogo Pedagogicheskogo Instituta* **29**: 101–160.

LCIE (2021): Golden Jackal – *Canis aureus*. *In:* LCIE: *Large Carnivore Initiative for Europe.* IUCN/SSC Specialist Group. – www.lcie.org

Letnic M. & Koch F. (2010): Are Dingoes a trophic regulator in arid Australia? A comparison of mammal communities on either side of the dingo fence. *Austral Ecology* **35**(2): 167–175.

Lever C. (1985): *Naturalized mammals of the world.* Longman, New York.

Liberg O. (1984): Food habits and prey impact by feral and house-based Domestic Cats in a rural area in southern Sweden. *Journal of Mammalogy* **65**(3): 424–432.

Liberg O. & Sandell M. (1988): Spatial organisation and reproductive tactics in the Domestic Cat and other felids. *In:* Turner D. C. & Bateson P. (eds.): *The Domestic Cat. The biology of its behaviour.* Cambridge University Press, Cambridge: 83–98.

Linnell J. D. C., Odden J. & Kindberg J. (2021): *Første bekreftede observasjon av gullsjakal i Norge.* Norsk Institutt for Naturforskning, Trondheim. /NINA Rapport 1981./

Lohr M., Young L. C., VanderWerf E. A., Miller C. J. & Leong H. (2013): Dietary analysis of free-ranging cats at Ka‘ena Point, Hawai‘i. *Elepaio* **73**(3): 1–3.

Lorenz K. (1983): *Salamon király gyűrűje.* 3. kiadás. Gondolat Kiadó, Budapest.

Loss S. R., Will T. & Marra P. P. (2013): The impact of free-ranging Domestic Cats on wildlife of the United States. *Nature Communications* **4**: 1396.

Lowe S., Browne M., Boudjelas S. & De Poorter M. (2004): *100 of the world's worst invasive alien species. A selection from the Global Invasive Species Database.* Updated and reprinted version. The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), Auckland.

Loyd K. A. T., Hernandez S. M., Carroll J. P., Abernathy K. J. & Marshall G. J. (2013): Quantifying free-roaming Domestic Cat predation using animal-borne video cameras. *Biological Conservation* **160**: 183–189.

Lutz W. (1984): Die Verbreitung des Waschbären (*Procyon lotor*, Linné 1758) im mitteleuropäischen Raum. *Zeitschrift für Jagdwissenschaft* **30**(4): 218–228.

Lutz W. (1996): The introduced Raccoon *Procyon lotor* population in Germany. *Wildlife Biology* **2**(3): 228.

Macdonald D. W. (1979): The flexible social system of the Golden Jackal, *Canis aureus*. *Behavioral Ecology and Sociobiology* **5**(1): 17–38.

Macdonald D. W. (1983): The ecology of carnivore social behaviour. *Nature* **301**(5899): 379–384.

Macdonald D. W. (ed.) (1989): *The encyclopedia of mammals.* Unwin Hyman Ltd., London.

Macdonald D. & Barrett P. (1993): *Mammals of Britain and Europe.* Harper Collins Publishers, London. /Collins Field Guide/

Macdonald D. W. & Sillero-Zubiri C. (eds.) (2004): *Biology and conservation of wild canids.* Oxford University Press, Oxford.

Macdonald D. W., Barreto G. R., Ferreras P., Kirk B., Rushton S., Yamaguchi N. & Strachan R. (1999): The impact of American Mink, *Mustela vison*, as predators of native species in British freshwater systems. *In:* Cowand D. P. & Feare C. J. (eds.): *Advances in vertebrate pest management.* Filander Verlag, Furth: 5–24.

Macdonald D. W., Newman C. & Harrington L. A. (eds.). (2017): *Biology and conservation of musteloids.* Oxford University Press, Oxford.

Manabella Salcedo I., Fraschina J., Busch M., Guidobono J. S., Unzaga J. M., Dellarupe A., Farace M. I., Pini N. & León V. A. (2021): Role of *Mus musculus* in the transmission of several pathogens in poultry farms. *International Journal for Parasitology: Parasites and Wildlife* **14**: 130–136.

Maran T. & Henttonen H. (1995): Why is the European Mink (*Mustela lutreola*) disappearing? – A review of the process and hypotheses. *Annales Zoologici Fennici* **32**(1): 47–54.

Markó G., Ónodi G., Kertész M. & Altbäcker V. (2011): Rabbit grazing as the major source of intercanopy heterogeneity in a Juniper shrubland. *Arid Land Research and Management* **25**(2): 176–193.

Mattioli S. (2011): Family Cervidae (Deer). *In:* Wilson D. E. & Mittermeier R. A. (eds.): *Handbook of the mammals of the world.* Volume 2. *Hoofed mammals.* Lynx Edicions, Barcelona: 350–443.

Mezzetto D., Dartora F. & Mori E. (2021): Feeding plasticity and temporal behaviour of the alien American Mink in Europe. *Acta Oecologica* **110**: 103700.

Michler B. A., Michler F.-U., Rieger S. & Roth M. (2014): Effects of Raccoon settlement in Germany – a closer look at the ecology of an unfamiliar invasive species. *In:* Jankow W., Ulbrych L., Wypychowski K. & Zalewski A. (red.): *Ekologia i wpływ na środowisko gatunków inwazyjnych. Publikacja pokonferencyjna konferencji „Znaczenie gatunków inwayjnych w ochronie ptaków wodnych oraz ich siedlisk". 7–10 maja 2014, Kostrzyn nad Odrą.* Park Narodowy Ujście Warty: 69–71.

Mikkonen T., Haukisalmi V., Kauhala K. & Wihlman H. (1995): *Trichinella spiralis* in the Raccoon Dog (*Nyctereutes procyonoides*) in Finland. *Bulletin of the Scandinavian Society for Parasitology* **5**(2): 100.

Mitchell-Jones A. J., Amori G., Bogdanowicz W., Kryštufek B., Reijnders P. J. H., Spitzenberger F., Stubbe M., Thissen J. B. M., Vohralík V. & Zima J. (1999): *The Atlas of European mammals.* T & A D Poyser, London.

Moehlman P. D. (1987): Social organization in jackals. *American Scientist* **75**(4): 366–375.

Mori E., Andreoni A., Cecere F., Magi M. & Lazzeri L. (2020): Patterns of activity rhythms of invasive Coypus *Myocastor coypus* inferred through camera-trapping. *Mammalian Biology* **100**(6): 591–599.

Morris D. (1986): *Miért csinálja…? A macska. Nélkülözhetetlen útmutató a macskák viselkedéséhez.* Európa Könyvkiadó, Budapest.

Mulder J. L. (2012): A review of the ecology of the Raccoon Dog (*Nyctereutes procyonoides*) in Europe. *Lutra* **55**(2): 101–127.

Nagy G. G., Czirák Z., Demeter A., Dóka R., Fadel N., Jónás B., Riskó A., Schmidt A., Sulyán P., Váczi O. & Érdiné Szekeres R. (2020): *Az európai uniós jegyzéken szereplő idegenhonos inváziós fajok terjedési útvonalainak magyarországi átfogó elemzése és értékelése, valamint a terjedési útvonalak cselekvési tervei.* Fertő–Hanság Nemzeti Park Igazgatóság – Agrárminisztérium, Természetmegőrzési Főosztály, Sarród – Budapest.

Nagy I. (szerk.) (2018): *Erdei vadkárfelvételi és értékelési útmutató. Sine loco.*

Németh A., Bárány A., Csorba G., Magyari E., Pazonyi P. & Pálfy J. (2016): Holocene mammal extinctions in the Carpathian Basin: a review. *Mammal Review* **47**(1): 38–52.

Newsome T. M., Greenville A. C., Ćirović D., Dickman C. R., Johnson C. N., Krofel M., Letnic M., Ripple W. J., Ritchie E. G., Stoyanov S. & Wirsing A. J. (2017): Top predators constrain mesopredator distributions. *Nature Communications* **8**: 15469.

Nogales M., Martín A., Tershy B. R., Donlan C. J., Veitch D., Puerta N., Wood B. & Alonso J. (2004): A review of Feral Cat eradication on islands. *Conservation Biology* **18**(2): 310–319.

Nordström M., Högmander J., Laine J., Nummelin J., Laanetu N. & Korpimäki E. (2003): Effects of feral Mink removal on seabirds, waders and passerines on small islands in the Baltic Sea. *Biological Conservation* **109**(3): 359–368.

Ónodi G., Kertész M., Botta-Dukát Z. & Altbäcker V. (2008): Grazing effects on vegetation composition and on the spread of fire on open sand grasslands. *Arid Land Research and Management* **22**(4): 273–285.

Ortega-Pacheco A., Concha-Guillermo H., Segura-Correa J. & Jimenez-Coello M. (2012): Seasonal reproductive activity of Domestic Queens (*Felis catus*) in the tropics of Mexico. *Reproduction in Domestic Animals* **47** (Suppl. 6): 52–54.

Osowski S. L., Brewer L. W., Baker O. E. & Cobb G. P. (1995): The decline of Mink in Georgia, North Carolina, and South Carolina: the role of contaminants. *Archives of Environmental Contamination and Toxicology* **29**(3): 418–423.

Oswald C. (2012): *A világ gímszarvasai. Kialakulásuk, elterjedésük, alaki sokféleségük.* Vadászlap Kft., Budapest.

Ottoni C., Van Neer W., De Cupere B., Daligault J., Guimaraes S., Peters J., Spassov N., Prendergast M. E., Boivin N., Morales-Muñiz A., Bălăşescu A., Becker C., Benecke N., Boroneant A., Buitenhuis H., Chahoud J., Crowther A., Llorente L., Manaseryan N., Monchot H., Onar V., Osypińska M., Putelat O., Quintana Morales E. M., Studer J., Wierer U., Decorte R., Grange T. & Eva-Maria Geigl E.-M. (2017): The palaeogenetics of cat dispersal in the ancient world. *Nature Ecology and Evolution* **1**(7): 0139.

Ozella L., Cecchetti M. & Pessani D. (2016): Diet of feral cats during the Scopoli's Shearwater breeding season on Linosa Island, Mediterranean Sea. *Italian Journal of Zoology* **83**(4): 589–599.

Pascal M. (1980): Structure et dynamique de la population de chats harets de l'archipel des Kerguelen. *Mammalia* **44**(2): 161–182.

Pearre S. & Maass R. (1998): Trends in the prey size-based trophic niches of feral and House Cats *Felis catus* L. *Mammal Review* **28**(3): 125–139.

Pielowski Z., Kamieniarz R. & Panek M. (1993): *Raport o zwierzętach łownych w Polsce.* Biblioteka Monitoringu *Środowiska*; Warszawa.

Pierpaoli M., Biró Z. S., Herrmann M., Hupe K., Fernandes M., Ragni B., Szemethy L. & Randi E. (2003): Genetic distinction of Wildcat (*Felis silvestris*) populations in Europe, and hybridization with Domestic Cats in Hungary. *Molecular Ecology* **12**(10): 2585–2598.

Rakonczay Z. (szerk.) (1990): *Vörös Könyv. A Magyarországon kipusztult és veszélyeztetett növény- és állatfajok.* Akadémiai Kiadó, Budapest.

Ranc N., Alvares F., Banea O. C., Berce T., Cagnacci F., Červinka J., Ćirović D., Cosic N., Giannatos G., Hatlauf J., Heltai M., Ivanov G., Lanszki J., Lapini L., Maiorano L., Melovski D., Migli D., Mladenovič J., Pankov I. A., Penezić A., Petrova A., Šálek M., Selanec I., Selimovic A., Stojanov A., Szabó L., Trbojević I., Trbojević T. & Krofel M. (2018): The Golden Jackal (*Canis aureus*) in Europe: predicting habitat suitability of a rapidly establishing carnivore. *In:* Bro E. & Guillemain M. (eds.): *33rd International Union of Game Biologists Congress & 14th Perdix Symposium. Montpellier, France – 2017, August 22–25. Abstract book.* ONCFS, Paris: 320–322.

Randi E. & Ragni B. (1991): Genetic variability and biochemical systematics of Domestic and Wild Cat populations (*Felis silvestris*: Felidae). *Journal of Mammalogy* **72**(1): 79–88.

Ratnaswamy M. J. & Warren R. J. (1998): Removing Raccoons to protect sea turtle nests: are there implications for ecosystem management? *Wildlife Society Bulletin* **26**(4): 846–850.

Redford K. H. & Eisenberg J. F. (1992): *Mammals of the Neotropics.* Volume 2. *The southern cone. Chile, Argentina, Uruguay, Paraguay.* The University of Chicago Press, Chicago.

Reid F., Schiaffini M. & Schipper J. (2016): *Neovison vison. In: The IUCN Red List of Threatened Species 2016*: e.T41661A45214988. – www.iucnredlist.org

Robinson S. K., Thompson F. R., Donovan T. M., Whitehead D. R. & Faaborg J. (1995): Regional forest fragmentation and the nesting success of migratory birds. *Science* **267**(5206): 1987–1990.

Rochlitz I. (2005): A review of the housing requirements of Domestic Cats (*Felis silvestris catus*) kept in the home. *Applied Animal Behaviour Science* **93**(1–2): 97–109.

Rotem G., Berger H., King R. & Saltz D. (2011): The effect of anthropogenic resources on the space-use patterns of Golden Jackals. *Journal of Wildlife Management* **75**(1): 132–136.

Rotenko I. & Sidorovich V. (2017): *Badger Meles meles and Raccoon Dog Nyctereutes procyonoides in Belarus. Population studies with implication for the decline in Badgers.* Chatyry Chverci, Minsk.

Rothenburger J. L., Himsworth C. G., Treuting P. M. & Leighton F. A. (2015): Survey of cardiovascular pathology in wild urban *Rattus norvegicus* and *Rattus rattus. Veterinary Pathology* **52**(1): 201–208.

Röhrs M. (1986): *Ovis ammon mussimon* (Pallas, 1811) – Mufflon. *In:* Niethammer J. & Krapp F. (Hrsg.): *Handbuch der Säugetiere Europas.* Band 2. *Paarhufer – Artiodactyla (Suidae, Cervidae, Bovidae).* AULA-Verlag, Wiesbaden: 435–450.

Rueness E. K., Asmyhr M. G., Sillero-Zubiri C., Macdonald D. W., Bekele A., Atickem A. & Stenseth N. C. (2011): The cryptic African wolf: *Canis aureus lupaster* is not a Golden Jackal and is not endemic to Egypt. *PLoS ONE* **6**(1): e16385.

Russell J. C., Lecomte V., Dumont Y. & Le Corre M. (2009): Intraguild predation and mesopredator release effect on long-lived prey. *Ecological Modelling* **220**(8): 1098–1104.

Rutkowski R., Krofel M., Giannatos G., Ćirović D., Männil P., Volokh A. M., Lanszki J., Heltai M., Szabó L., Banea O. C., Yavruyan E., Hayrapetyan V., Kopaliani N., Miliou A., Tryfonopoulos G. A., Lymberakis P., Penezić A., Pakeltytė G., Suchecka E. & Bogdanowicz W. (2015): A European concern? Genetic structure and expansion of Golden Jackals (*Canis aureus*) in Europe and the Caucasus. *PLoS ONE* **10**(11): e0141236.

Ruxton G. D., Thomas S. & Wright J. W. (2002): Bells reduce predation of wildlife by Domestic Cats (*Felis catus*). *Journal of Zoology* **256**(1): 81–83.

Sadowski C. & Bowman J. (2021): Historical surveys reveal a long-term decline in Muskrat populations. *Ecology and Evolution* **11**(12): 7557–7568.

Šálek M., Červinka J., Banea O. C., Krofel M., Ćirović D., Selanec I., Penezić A. Grill S. & Riegert J. (2014): Population densities and habitat use of the Golden Jackal (*Canis aureus*) in farmlands across the Balkan Peninsula. *European Journal of Wildlife Research* **60**(2): 193–200.

Salgado I. (2018): Is the Raccoon (*Procyon lotor*) out of control in Europe? *Biodiversity and Conservation* **27**(9): 2243–2256.

Schertler A., Rabitsch W., Moser D., Wessely J. & Essl F. (2020): The potential current distribution of the Coypu (*Myocastor coypus*) in Europe and climate change induced shifts in the near future. *NeoBiota* **58**: 129–160.

Schuster R. K., Specht P. & Rieger S. (2021): On the helminth fauna of the Muskrat (*Ondatra zibethicus* (Linnaeus, 1766)) in the Barnim District of Brandenburg State/Germany. *Animals* **11**(8): 2444.

Sey O. (1966): Contributions to knowledge of the internal parasites of Muskrat (*Ondatra zibethica* L., 1766) living along the river Tisza. *Tiscia* **2**: 89–94.

Shiels A. B. & Pitt W. C. (2014): A review of invasive rodent (*Rattus* spp. and *Mus musculus*) diets on pacifiic islands. *In:* Timm R. M. & O'Brien J. M. (eds.): *Proceedings of the Twenty-Sixth Vertebrate Pest Conference. March 3–6, 2014. Waikoloa, Hawaii.* University of California, Davis: 161–165.

Shier C. J. & Boyce M. S. (2009): Mink prey diversity correlates with Mink–Muskrat dynamics. *Journal of Mammalogy* **90**(4): 897–905.

Stohl G. (1981): *Emlős háziállatok – Mammalia domestica.* Akadémiai Kiadó, Budapest. /Magyarország állatvilága – Fauna Hungariae XXII. kötet 5. füzet/

Stoyanov S. (2012): Golden Jackal (*Canis aureus*) in Bulgaria. Current status, distribution, demography and diet. *In: Đorđević* N. (ed.): *Proceedings. „Modern Aspects of Sustainable Management of Game Population". International Symposium on Hunting. Zemun-Belgrade, Serbia, 22–24 June, 2012.* University of Belgrade, Faculty of Agriculture, Zemun: 48–56.

Stronen A. V., Konec M., Boljte B., Bošković I., Gačić D., Galov A., Heltai M., Jelenčič M., Kljun F., Kos I., Kovačič T., Lanszki J. Pintur K., Pokorny B., Skrbinšek T., Suchentrunk F., Szabó L., Šprem N., Tomljanović K. & Potočnik H. (2021): Population genetic structure in a rapidly expanding mesocarnivore: Golden Jackals in the Dinaric-Pannonian region. *Global Ecology and Conservation* **28**: e01707.

Stubbe M. (1993): *Procyon lotor* (Linné, 1758) – Waschbär. *In:* Niethammer J. & Krapp F. (Hrsg.): *Handbuch der Säugetiere Europas.* Band 5/I. *Raubsäuger – Carnivora (Fissipedia). Teil I. Canidae, Ursidae, Procyonidae, Mustelidae 1.* AULA-Verlag, Wiesbaden: 331–364.

Sutor A., Kauhala K. & Ansorge H. (2010): Diet of the Raccoon Dog *Nyctereutes procyonoides* – a canid with an opportunistic foraging strategy. *Acta Theriologica* **55**(2): 165–176.

Suzuki H. (2020): Evolutionary history of the subgenus *Mus* in Eurasia with special emphasis on the House Mouse *Mus musculus*. *Records of the Australian Museum* **72**(5): 317–323.

Suzuki H., Nunome M., Kinoshita G., Aplin K. P., Vogel P., Kryukov A. P., Jin M.-L., Han S.-H., Maryanto I., Tsuchiya K., Ikeda H., Shiroishi T., Yonekawa H. & Moriwaki K. (2013): Evolutionary and dispersal history of Eurasian House Mice *Mus musculus* clarified by more extensive geographic sampling of mitochondrial DNA. *Heredity* **111**(5): 375–390.

Szabó L., Heltai M. & Lanszki J. (2010): Jackal versus livestock – is it a real problem? *Hungarian Agricultural Research* **19**(4): 4–10.

Széles G. L., Purger J. J., Molnár T. & Lanszki J. (2018): Comparative analysis of the diet of Feral and House Cats and Wildcat in Europe. *Mammal Research* **63**(1): 43–53.

Széll Z., Marucci G., Pozio E. & Sréter T. (2013): *Echinococcus multilocularis* and *Trichinella* *spiralis* in Golden Jackals (*Canis aureus*) of Hungary. *Veterinary Parasitology* **197**(1–2): 393–396.

Szunyoghy J. (1959): Honosított emlősök Magyarországon. *In:* Kocsis F. (szerk.): *Az Élet és Tudomány 1959. évi tudományos kalendáriuma.* Gondolat Kiadó, Budapest: 279–282.

Takács A., Szabó L., Juhász L., Takács A. A., Lanszki J., Takács P. T. & Heltai M. (2014): Data on the parasitological status of Golden Jackal (*Canis aureus* L, 1758) in Hungary. *Acta Veterinaria Hungarica* **62**(1): 33–41.

Taryannikov V. I. (1974): Pitaniye shakala (*Canis aureus aureus*) v basseyne Syrdaryi. *Zoologicheskiy Zhurnal* **53**(10): 1539–1547.

Tóth T., Krecsák L., Szűcs E., Heltai M. & Huszár Gy. (2009): Records of the Golden Jackal (*Canis aureus* Linnaeus, 1758) in Hungary from 1800th until 2007, based on a literature survey. *North-western Journal of Zoology* **5**(2): 386–405.

Trouwborst A., Krofel M. & Linnell J. D. C. (2015): Legal implications of range expansions in a terrestrial carnivore: the case of the Golden Jackal (*Canis aureus*) in Europe. *Biodiversity and Conservation* **24**(10): 2593–2610.

Tschanz B., Hegglin D., Gloor S. & Bontadina F. (2011): Hunters and non-hunters: skewed predation rate by Domestic Cats in a rural village. *European Journal of Wildlife Research* **57**(3): 597–602.

Turner D. C. & Bateson P. (eds.): *The Domestic Cat. The biology of its behaviour.* Cambridge University Press, Cambridge.

Turner D. C. & Meister O. (1988): Hunting behaviour of the Domestic Cat. *In:* Turner D. C. & Bateson P. (eds.): *The Domestic Cat. The biology of its behaviour.* Cambridge University Press, Cambridge: 111–121.

Urban D. (1970): Raccoon populations, movement patterns, and predation on a managed waterfowl marsh. *The Journal of Wildlife Management* **34**(2): 372–382.

Varga T. (2019): A kinigli múltja és jelene. *In: Magyar Mezőgazdaság.* – www.magyarmezogazdasag.hu

Villafuerte R. & Delibes-Mateos M. (2019): *Oryctolagus cuniculus* (errata version published in 2020). *In: The IUCN Red List of Threatened Species 2019*: e.T41291A170619657. – www.iucnredlist.org

Weissbrod L., Marshall F. B., Valla F. R., Khalaily H., Bar-Oz G., Auffray J.-C., Vigne J.-D. & Cucchi T. (2017): Origins of House Mice in ecological niches created by settled hunter-gatherers in the Levant 15,000 y ago. *Proceedings of the National Academy of Sciences* **114**(16): 4099–4104.

Woinarski J. C. Z., Murphy B. P., Legge S. M., Garnett S. T., Lawes M. J., Comer S., Dickman C. R., Doherty T. S., Edwards G., Nankiell A., Paton D., Palmer R. & Woolley L. A. (2017): How many birds are killed by cats in Australia? *Biological Conservation* **214**: 76–87.

Woods M., McDonald R. A. & Harris S. (2003): Predation of wildlife by Domestic Cats *Felis catus* in Great Britain. *Mammal Review* **33**: 174–188.

Yamaguchi N., Kitchener A., Driscoll C. & Nussberger B. (2015): *Felis silvestris*. *In: The IUCN Red List of Threatened Species 2015*: e.T60354712A50652361. – www.iucnredlist.org

Yom-Tov Y., Ashkenazi S. & Viner O. (1995): Cattle predation by the Golden Jackal *Canis aureus* in the Golan Heights, Israel. *Biological Conservation* **73**(1): 19–22.

Zalba S. M., Politi N. & de la Fuente G. (2001): Habitat quality for Coypu (*Myocastor coypus*) in a southern Argentinean agroecosystem. *Vida Silvestre Neotropical* **10**(1–2): 50–55.

Zalewski A. & Bartoszewicz M. (2012): Phenotypic variation of an alien species in a new environment: the body size and diet of American Mink over time and at local and continental scales. *Biological Journal of the Linnean Society* **105**(3): 681–693.

Zalewski A. & Brzeziński M. (2014): *Norka amerykańska. Biologia gatunku inwazyjnego.* Instytut Biologii Ssaków Polskiej Akademii Nauk, Białowieża.

Zalewski A., Szymura M., Kowalczyk R. & Brzeziński M. (2021): Low individual diet variation and high trophic niche overlap between the native Polecat and invasive American Mink. *Journal of Zoology* **314**(2): 151–161.

Zhang L., Zhang H. & Hua Y. (2020): Evolutionary status of the invasive Muskrat Ondatra zibethicus revealed by complete mitochondrial genome. *Mitochondrial DNA Part B* **5**(1): 980–981.

Zimmermann Á. & Zimmermann G. (1944): *A házi-macska.* Királyi Magyar Természettudományi Társulat, Budapest.

Published by:
Duna-Ipoly National Park Directorate
Address: 2509 Esztergom, Strázsa-hegy
Phone: +36 1 391 4010
E-mail: dinpi@dinpi.hu
www.dunaipoly.hu

Ministry of Foreign Affairs and Trade of Hungary
Address: 1027 Budapest Bem rakpart 47.
Phone: +36-1-458-1125
E-mail: vizdiplomacia@mfa.gov.hu
https://dunaregiostrategia.kormany.hu/

Typeset:
András Rozs

Printed by:
SÉD NYOMDA
Address: 7100 Szekszárd. Epreskert u. 10.
Phone.: +36 74 529 950
E-mail: kereskedelem@sednyomda.hu

Publisched in 150 copies

ISBN 978-615-5241-40-6

The seemingly unstoppable spread of invasive species is globally becoming more and more serious. So far, the problems caused by invasive alien plants have drawn some attention in Hungary. The first comprehensive book on this topic was published in 2004 by the Nature Conservation Office (and thereby, its responsible issuer was the then current head of the Office, László Haraszthy, the editor of the present volume). Since then, several books and other publications came to light about invasive plants. Practical experiences about their control methods were compiled in the 3rd volume of our handbook series 'Rosalia'.

Regarding invasive alien animal species, however, our knowledge is much less established and so far, the main sources of information were the internet and peer-reviewed journals. Despite the fact that the spatial expansion of invasive alien animal species is now a major threat to our aquatic and forest ecosystems, there has been no book that would have started to put even a species lists together, let alone gather all the knowledge available from researchers and experts concerning different taxa.

This taxonomically structured volume aims to fill this 20-year gap and to provide descriptions of every invasive animal species that have occurred in Hungary. This huge undertaking was carried out by the cooperation of 36 experts of different taxonomic groups. The book contains detailed descriptions for all 118 species that have already (or shall inevitably) occur in Hungarian territory, and also includes short notes on further 4 amphibian and 32 terrestrial snail species. A general conclusion of the present volume is that our natural waters are especially vulnerable as more than half of the species dealt with within the book occur in aquatic habitats.

On account of the previously experienced international interest in our earlier volume on invasive plants, this volume, too, shall be published in English as well as in Hungarian. Both versions are available online from the website of the Danube-Ipoly National Park Directorate (www.dunaipoly.hu).

Controlling invasive alien species is almost always a difficult task that requires significant financial and labour input, with more often than not, essentially species-specific methodologies. Invasive animals are lagging behind in this regard, too, as in most cases we have no means to control their spread and increase in numbers. This evidently hinders their control. The authors of the present volume attempt to present these species in a way that may well be the first step towards finding methodologies for fighting them. We warmly recommend this book to all those who keep a vigilant eye on the spread of invasive species and who also wish to contribute to the protection of our native ecosystems.

DANUBE REGION strategy
Prosperity through Diversity

The present publication was financed by
the Ministry of Foreign Affairs and
Trade of Hungary in accordance with the objectives of the EU Strategy for the Danube Region (Priority Area 6 - Biodiversity and Landscapes, Quality of Air and Soils)

9 786155 241406