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INVASIVE MOLLUSC, CRUSTACEAN, FISH AND REPTILE SPECIES ALONG THE HUNGARIAN STRETCH OF THE RIVER DANUBE AND SOME CONNECTED WATERS

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The River Danube, connected to the Rhine catchment via the Rhine–Main–Danube Canal, is part of a significant aquatic invasion corridor in Europe between the North Sea and the Black Sea. Among its aquatic fauna molluscs, crustaceans and fishes represent the most prominent groups of invaders in terms of species number and biomass. The listed reptile species is in the list of the 100 worst invasive species in the world. This paper reviews available information about the arrival time, way of introduction, distribution area, dominance in communities, ecosystem functions, and impact on the native fauna along the Hungarian stretch of the Danube of 43 non-indigenous species having arrived from several continents as Africa, Asia, Europe, North America, or New Zealand. Transport vectors that contribute to the introduction and the rapid spread of alien species are river shipping, deliberate crayfish and fish stocking, pet trade, release from aquaria, and food consumption. The invasions of the studied species have a potential to alter the structure and the function of Danubian ecosystems and create new biodiversity and economic problems. Due to the international importance of the River Danube, efforts should be made to prevent new invasions and manage the existing invaders along the whole river.

Key words: invasion, River Danube, mollusc, crustacean, fish, reptile

INTRODUCTION

Biological invasion is one of the most important issues in ecology since it plays a major role in almost 40% of species extinctions on a global scale leading to biological homogenization in ecosystems (ABRAMOVITZ 1996). Regarding their harmful impacts and difficulties in their eradication, the study of the establishment and the area expansion of invasive species are especially significant. All ecosystems are sensitive to biological invasion; moreover, aquatic ecosystems are especially vulnerable (SALA *et al.* 2000). In recent decades, the appearance and the quick expansion of non-native species in aquatic systems have greatly accelerated. This trend can be explained by the increasing intensity of ship traffic due to the globalization of international trade, increasing recreational activities, and the modification of natural water systems, which is connected with the degradation of native biota and the vacancy of habitats (COHEN & CARLTON 1998, EVERETT 2000). The River Danube is one of the most important shipping routes in Europe, providing excellent opportunities for the area expansion of non-indigenous aquatic species. The importance of the River Danube as an invasion corridor increased further after the opening of the Rhine–Main–Danube Canal (BIJ DE VAATE *et al.* 2002). Along the Danube, several non-native species arrived to Hungary both from northwestern and southeastern Europe (PUKY *et al.* 2008).

Species belonging to four taxonomical groups as molluscs, crustaceans, fishes and reptiles have a special role in invasion biology in regard to their conservation value and the high densities of non-indigenous species in several areas. Moreover, each group represented by species listed among the 100 worst invasive species (*Corbicula fluminea*, *Dreissena polymorpha* (molluscs); *Dikerogammarus villosus*, *Eriocheir sinensis* (crustaceans); *Neogobius melanostomus, Pseudorasbora parva* (fishes) and *Trachemys scripta* (reptile) (LOWE *et al.* 2000). In addition, many species from these groups were only detected at the end of the 20th century along the Danube but their rapid expansions have been described since (BORZA *et al.* 2011*b*, BÓDIS *et al.* 2011*b*).

The aim of the present study is to review the available information about the invasive mollusc, crustacean, fish and reptile species including arrival time, way of introduction (transport vectors and pathways), estimated area of recent distribution, dominance in communities, impact on the native fauna and role in ecosystem functions in the Hungarian stretch of the River Danube and some connected waters.

RESULTS

Molluscs

At present, eleven non-indigenous mollusc species (5 bivalves and 6 aquatic snails) occur along the Hungarian stretch of the Danube (Table 1).

Dominant invasive bivalve species deserve special attention as they can influence native species composition and environmental processes, leading to important changes in the structure and function of aquatic ecosystems (SOUSA *et al.* 2009). *Corbicula fluminea* invaded the River Rhine in 1987, where it became abundant very quickly (DEN HARTOG *et al.* 1992). After the opening of the Rhine–Main–Danube Canal, it expanded its range into the Danube basin. It was first recorded in the lower section of the Hungarian Danube in 1999 (CSÁNYI 1998–1999) but within a decade it became widespread and abundant (736 ind. m^{-2}) in the Hungarian stretch of the Danube (BÓDIS 2007) and also invaded the rivers Tisza, Ipoly and Rába. In European ecosystems, at least two *Corbicula* morphs are generally considered as separate species (*C. fluminea* and *C. fluminalis*). However, genetic analysis pointed out that the existence of two species is uncertain (RENARD *et al.*

2000, PFENNINGER *et al.* 2002). In a recent study, BÓDIS *et al.* (2011*a*) detected differences in their mitochondrial DNA sequence and reproductive biology, which indicates that the two morphs probably belong to distinct taxa. Nevertheless, the use of "*C. fluminalis*„ is premature, as its phylogenetic relationship with native *C. fluminalis* still requires confirmation. The first occurrence of *Corbicula* morph 2 was also detected in the lower section of the Hungarian Danube in 1999 (CSÁNYI 1998–1999), but this morph did not extend its range, and can be found in a small section of the Hungarian Danube (BÓDIS *et al.* 2011*b*).

Anodonta (Sinanodonta) woodiana was accidentally introduced to Europe along with Asian fish species (carrying their parasitic glochidium) and was first recorded in Hungary in fish ponds at Biharugra in the 1960s (PETRÓ 1984), then in the Hungarian stretch of the Danube in 1984 (POPA *et al.* 2007). Recently, this species has often been found along the Middle Danube, also colonizing side arms and tributaries.

Bivalves belonging to the Dreissenidae family can attach themselves to hard substrates by byssal threads and have planctonic larvae, which results in their rapid spread and great abundance. The Ponto-Caspian *Dreissena polymorpha* first occurred along the Hungarian stretch of the Danube in 1867 (TITTIZER 2006), and it has become one of the most widespread bivalve species in a short period of time. Several individuals of the similarly Ponto-Caspian *Dreissena rostriformis bugensis* were collected along the Hungarian stretch of the Danube while dredging the profundal regions of the river in 2008 (SZEKERES *et al.* 2008), and the rapid proliferation of this species has been detected since then.

Potamopyrgus antipodarum was introduced to Europe after the middle of 19th century (PONDER 1988), and its first occurrence in the Hungarian stretch of the Danube was reported in 1987 (FRANK *et al.* 1990, CSÁNYI 1994). This species can reproduce parthenogenetically and has a wide range of ecological tolerance, which contributes to its invasive success (ALONSO & CASTRO-DIÉZ 2008). In the Hungarian stretch of the Danube, its highest abundance was recorded in a side arm, where due to the regulation of the river the current velocity is constant throughout the year.

Theodoxus fluviatilis is native to the Rhine and the Lower Danube, from where it began to spread at the end of the 20th century (ČEJKA & HORSÁK 2002). First occurrence in the Hungarian stretch of the Danube was reported in 1987 (FRANK *et al.* 1990, CSÁNYI 1994). Nowadays *T. fluviatilis* is widespread in the entire Hungarian stretch of the Danube. This species is abundant at several sites of the main arm, whereas the native *Theodoxus* species (*T. danubialis* and *T. transversalis*) has become very rare.

Table 1. Characteristics of the studied invasive species.The area of recent distribution in the Danube and its main tributaries (River Rába, Ipoly, Mosoni Danube, Sió canal) was given as a proportion of inhabited 5 km × 5 km UTM squares in 5 size classes: <1%, 1–5%, 6–20%, 21–50% and >50% determined by POVŽ and ŠUMER (2005). ERD = Estimated area of recent distribution; DC = Dominance in communities; DA = Date of arrival.

		Family	Species	Origin	DA	Transport vectors, pathways	ERD	DC
Mollusca	Bivalvia	Corbiculidae	*Corbicula fluminea*	Asia	1999	ships	>50%	yes
		Corbiculidae	*"Corbicula fluminalis"*	Middle East, Africa	1999	ships	1%	yes
		Dreissenidae	*Dreissena polymorpha*	Ponto-Caspian region	ca. 1867	ships	>50%	yes
		Dreissenidae	*D. rostriformis bugensis*	Ponto-Caspian region	2008	ships	6–20%	no
		Unionidae	*Anodonta woodiana*	Asia	1984	aquaculture (fish carrying its parasitic larva)	6–20%	yes
	Gastropoda	Hydrobiidae	*Potamopyrgus antipodarum*	New Zealand	ca. 1987	ships	6–20%	yes
		Neritidae	*Theodoxus fluviatilis*	Lower Danube, Rhine	ca. 1987	ships / active expansion	>50%	yes
		Physidae	*Haitia acuta*	North America	ca. 1967	ships / release from aquaria	6–20%	yes
		Planorbidae	*Ferrissia fragilis*	North America	ca. 1967	ships	1–5%	no
		Melanopsidae	*Melanoides tuberculatus*	North Africa, S Asia	ca. 1960	release from aquaria	1%	no
		Lithoglyphidae	*Lithoglyphus naticoides*	Ponto-Caspian region	ca. 1950	ships / active expansion	>50%	yes
Crustacea	Decapoda	Cambaridae	*Orconectes limosus*	North America	1985	aquaculture	>50%	yes
		Varunidae	*Eriocheir sinensis*	Asia	2003	ships	1–5%	no
		Astacidae	*Pacifastacus leniusculus*	North America	1998 (tributary)	aquaculture	6–20%	yes
	Amphipoda	Corophidae	*Chelicorophium sowinskyi*	Ponto-Caspian region	1917	ships	>50%	yes
		Corophidae	*Chelicorophium curvispinum*	Ponto-Caspian region	1933	ships	>50%	yes
		Corophidae	*Chelicorophium robustum*	Ponto-Caspian region	2007	ships	>50%	yes
		Pontogammaridae	*Dikerogammarus bispinosus*	Ponto-Caspian region	1926	ships	>50%	yes
		Pontogammaridae	*Dikerogammarus haemobaphes*	Ponto-Caspian region	1926	ships	>50%	yes
		Pontogammaridae	*Dikerogammarus villosus*	Ponto-Caspian region	1975	ships	>50%	yes
		Gammaridae	*Echinogammarus ischnus*	Ponto-Caspian region	1926	ships	>50%	yes
		Gammaridae	*Echinogammarus trichiatus*	Ponto-Caspian region	2009	ships	one data	yes

		Family	Species	Origin	DA	Transport vectors, pathways	ERD	DC
		Pontogammaridae	*Obesogammarus obesus*	Ponto-Caspian region	1991	ships	>50%	yes
	Mysida	Mysidae	*Limnomysis benedeni*	Ponto-Caspian region	1946	ships	>50%	yes
		Mysidae	*Hemimysis anomala*	Ponto-Caspian region	1997	ships	>50%	yes
		Mysidae	*Katamysis warpachowskyi*	Ponto-Caspian region	2001	ships	>50%	yes
	Isopoda	Janiridae	*Jaera sarsi*	Ponto-Caspian region	1930	ships	>50%	yes
Pisces	Osteichthyes	Cyprinidae	*Ctenopharingodon idella*	Far East	ca. 1965	aquaculture / commercial, recreational reasons	>50%	no
		Cyprinidae	*Pseudorasbora parva*	Far East	1971	aquaculture	>50%	yes
		Cyprinidae	*Carassius gibelio*	Asia	ca. 1965	aquaculture / active expansion	>50%	yes
		Cyprinidae	*Hypophtalmichthys molitrix*	Far East	ca. 1965	aquaculture / commercial reasons	>50%	no
		Ictaluridae	*Ameiurus nebulosus*	North America	ca. 1920	aquaculture / recreational reasons	1–5%	no
		Ictaluridae	*Ameiurus melas*	North America	ca. 1985	aquaculture / recreational reasons	>50%	yes
		Salmonidae	*Oncorhynchus mykiss*	North America	1963	recreational reasons	1–5%	no
		Gasterosteidae	*Gasterosteus aculeatus*	Northeastern Europe	1956	release from aquaria / active expansion	21–50%	no
		Gasterosteidae	*Gasterosteus gymnurus*	Southwestern Europe	2010	release from aquaria / active expansion	21–50%	no
		Centrarchidae	*Lepomis gibbosus*	North America	1913	aquaculture / active expansion	>50%	yes
		Gobiidae	*Neogobius fluviatilis*	Ponto-Caspian region	1984	ships / active expansion	>50%	yes
		Gobiidae	*Neogobius gymnotrachelus*	Ponto-Caspian region	2004	ships / active expansion	21–50%	yes
		Gobiidae	*Neogobius kessleri*	Ponto-Caspian region	1996	ships / active expansion	>50%	yes
		Gobiidae	*Neogobius melanostomus*	Ponto-Caspian region	2001	ships / active expansion	>50%	yes
		Gobiidae	*Proterorhinus semilunaris*	Ponto-Caspian region	1872	ships / active expansion	>50%	yes
Reptilia	Testudines	Emydidae	*Trachemys scripta*	North America	1970s	pet trade	6–20%	yes

Haitia acuta was first recorded in Europe in 1805. At an early stage, it spread through the Mediterranean regions and later on colonized northern Europe, as well (ANDERSON 2003). This species has been present in the Hungarian stretch of the Danube since 1967 (FRANK *et al.* 1990, TITTIZER 2006). It can survive severe environmental conditions such as water pollution and extreme temperature (WETHINGTON 2004), and in the Hungarian stretch of the Danube, it occurs in high abundance in the tributaries and side arms.

Ferrissia fragilis is mentioned as *Ferrissia wautieri* in several studies. Recently it was described as originating from North America, with its first European appearance in 1949 (WALTHER *et al.* 2006). *Melanoides tuberculatus* was presumably introduced to Europe by release from aquaria. It carries a parasite species infecting native fish species (PINTO & DE MELO 2011). *Ferrissia fragilis* and *M. tuberculatus* have been present in the Hungarian stretch of the Danube since the 1960s (FRANK *et al.* 1990, TITTIZER 2006). Currently, these species can mainly be found in the side arms of the Hungarian Danube.

Lithoglyphus naticoides is native to the western part of the Black Sea, from where it colonised Europe in the second half of the 19th century (BIJ DE VAATE *et al.* 2002). It can infect the native fauna since it carries several parasites (TYUTIN & SLYNKO 2010). It was widespread in Europe in the Pliocene, but during the Pleistocene it was forced back to the Ponto-Caspian region. At the beginning of the Holocene its secondary area expansion was determined, which accelerated during the 19th century. It was registered from Holocene geological samples in Hungary (FÜKÖH 1995). Therefore it may be more accurate to consider this species as an "area reconquerer" or "spreading native species" in Hungary.

Peracarid crustaceans

At present 13 non-indigenous peracarid crustacean species occur in the Hungarian stretch of the Danube, representing 5 families of 3 orders (Table 1), all of them originating from the Ponto-Caspian region.

The order Mysida is represented only by non-native species in the country. Their number has recently risen from one to three. *Lymnomysis benedeni* has recently been accompanied by *Hemimysis anomala* and *Katamysis warpachowskyi* (BORZA *et al.* 2011*b*, WITTMANN 2002, 2007). Since their appearance around the millennium the two new species have colonized the entire river section and its connected waters (BORZA *et al*. 2011*b*). All three species reach their highest densities in man-made embayments (industrial ports, winter harbours). Mysids are generally regarded as a premium food source for fish, for which they have been deliberately introduced into several reservoirs and lakes, especially in the former Soviet

Union. There is also a Hungarian example because *L. benedeni* was stocked into Lake Balaton in 1950 (WOYNÁROVICH 1954), though the zooplankton consumption of mysids may entail unwanted consequences (e.g., KETELAARS *et al.* 1999).

Nine non-indigenous amphipod species occur in the Hungarian Danube. Native species are not present because they disappeared during the 20th century. Fortunately, they have found refuge in smaller tributaries of the river, into which the Ponto-Caspian species cannot intrude (NESEMANN *et al.* 1995). The invaders associated with the most considerable effects on the ecosystem, *Chelicorophium curvispinum* and *Dikerogammarus villosus*, colonized the river section several decades ago. The former is reported to have caused massive declines in *Dreissena polymorpha* populations in invaded waters (VAN DEN BRINK *et al.* 1993), while the latter is renowned for its predatory feeding habits, affecting other amphipod species (DICK & PLATVOET 2000). Since they are already integral parts of the fauna, further impact of comparable scale cannot be expected from future invasions. However, rearrangements in dominance among the Ponto-Caspian species are likely to occur as demonstrated by *Chelicorophium robustum*, which showed strong dominance over the earlier colonist *C. sowinskyi* and *C. curvispinum* at several sites of the Hungarian river section in 2009, only two years after it was first recorded (BORZA 2011*a*). The most recent invader, *Echinogammarus trichiatus* was found only at one site so far (BORZA 2009). Amphipods constitute a considerable proportion of the benthic invertebrate biomass, and hence play a central role in the benthic food web. They have been demonstrated to be one of the major food sources of gobiids, the most abundant fish species in the River Danube, Ponto-Caspian immigrants themselves (BORZA *et al.* 2009).

Isopods are represented by a sole non-native species, *Jaera sarsi*. This small-bodied crustacean is also an important food item of juvenile fish (BORZA *et al.* 2009).

Eucarid crustaceans

At present, two non-indigenous eucarid crustacean species occur along the Hungarian stretch of the Danube. A further species is spreading rapidly along a main tributary, the River Rába, towards the Danube, and is expected to reach it in the near future (Table 1).

Two of the species are of North-American origin; the third is native in eastern Asia. All three species were introduced to Europe, where they proved to be successful invasives. The spiny-cheek crayfish (*Orconectes limosus*) is native on the east coast of the United States. It has become predominant in parts of Europe such as northeastern Germany and northwestern Poland (SCHULZ & SMIETANA 2001).

Part of its successful invasion strategy is the fact that *O. limosus* can reproduce by parthenogenesis as well (BUŘIČ *et al.* 2011). THURÁNSZKY and FORRÓ (1987) first recorded this species in the wild in Hungary in a large secondary branch of the River Danube in 1985. Since then, abundant and spreading populations have been found in other side arms and tributaries of the river, such as the Sződrákos stream and the Sió canal (PUKY 2000, 2004). In the second half of the 2000s it also reached the River Tisza and a dead specimen was also found in Lake Balaton, while new populations originating from Croatia were also found in a stream west of the River Danube (HORVAI *et al.* 2010, SALLAI & PUKY 2008). Similarly to *Pacifastacus leniusculus*, it carries crayfish plaque, a fungal disease to which all native species are susceptible (KOZUBIKOVA *et al.* 2010).

The Chinese mitten crab (*Eriocheir sinensis*) is a catadromous species; the most recently found Decapoda species in the country (PUKY *et al.* 2005*a*). In its original distribution area, it has declined over large areas due to overfishing, water pollution and dam construction cutting off migration passages since 1982 (JIN *et al.* 2001). In North America and Europe, however, it is a successful invasive species. Even if it is listed among the 100 invasive species with the greatest impact, it is not expected to cause serious problems in Hungary as its reproduction areas are far away from the country.

The signal crayfish (*P. leniusculus*) is the most recent invasive in the Danubian watershed in Hungary. It is native to northwestern North America. It was first recorded in Hungary in 1998 (in the Gyöngyös stream at Kőszeg) (KOVÁCS *et al.* 2005). Since then it migrated downstream to the River Rába, a tributary of the River Danube.

Fishes

In the Hungarian stretch of the Danube, 15 invasive fish species have been recorded since the second half of the 19th century (Table 1).

Tubenose goby (*Proterorhinus semilunaris*), the first representative of gobies in Central Europe, was discovered at Budapest in 1872 (KRIESCH 1873).

The Brown bullhead (*Ameiurus nebulosus*) was introduced to Hungary in 1902 and rapidly spread in natural waters because of stockings for recreational reasons. Its population in the Danube started to decline in the 1950s. Nowadays it is rare; its isolated populations can be found in some disconnected backwaters (PINTÉR 2002).

The rainbow trout (*Oncorhynchus mykiss*) was introduced to Hungary in 1885. Small, self-sustaining populations occur only in creeks and it is a rare accidental species in the Danube and its tributaries. Pumpkinseed (*Lepomis gibbosus*) was introduced to a pond farm in Hungary in 1895 and spontaneously spread along the Danube. In the first half of the 20th century, it was mentioned in Hungarian literature as a "dangerous pest" which should be eradicated (PINTÉr 2002). Nowadays, it is regarded as a harmless species (PINTÉR 1980) and common in slow flowing sections and backwaters of the Danube.

Gibel carp (*Carassius gibelio*) was introduced from Bulgaria to a fish culture in eastern Hungary in 1954, and introductions for recreational reasons played important role in its rapid spread (PINTÉR 1980). However, some data indicates its occurrence in the 19th century, but it likely to have reached Hungary by natural expansion, too. Its dense stocks developed along the Danube from the 1960s, but its abundance started to decline from the 1990s (TÓTH 1977, TÓTH *et al*. 2005).

The first record of three-spined stickleback *(Gasterosteus aculeatus*) in Hungary was noted in 1956 in the Danube at Budapest (STERBETZ 1957). Specimens of *G. a. f. trachurus* and *G. a. f. leiurus* were found at several locations along the Hungarian stretch in the second half of the 20th century. *Gasterosteus aculeatus f. leiurus* can be regarded as a distinct species (KOTTELAT & FREIHOF 2007) and presumably, the *G. aculeatus* spread from the direction of the Black Sea, conversely the *G. gymnurus* arrived from the Upper Danube and its tributaries (HARKA & SZEPESI 2010).

Chinese carp, grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypophtalmichthis molitrix*) were introduced to Hungary in 1963 and successfully propagated during in the 1960s. Grass carp were stocked to natural waters for recreational reasons and sometimes are used for biological control of water weeds (PINTÉR 1980). It is a common species in the Danube, but its natural reproduction was only observed in the River Tisza. Silver carp were stocked in disconnected side arms of the Danube and Lake Balaton for fishery utilization and escaped specimens from hatcheries can contribute to the development of populations in natural waters. Its spawning in large rivers has been observed several times since the 1970s and its stocks in the Danube and Tisza rivers can be regarded self-sustaining (PINTÉR 2002, HARKA *et al*. 2009).

The topmouth gudgeon (*Pseudorasbora parva*) was unintentionally stocked with Chinese carps introduced from Far East in the 1960s, and quickly spread in natural waters in Hungary. It is abundant in several backwaters of the Danube (GOZLAN *et al.* 2010).

Black bullhead (*Ameiurus melas*) was introduced to a western Hungarian fish culture in the beginning of the 1980s, and escaped specimens spread rapidly along the Danube (PINTÉR 2002). Abundant stocks have developed in most of the backwaters along the Danube.

Four gobiid species (*Neogobius fluviatilis*, *N. kessleri*, *N. melanostomus*, *N. gymnotrachelus*) have appeared in the Hungarian stretch of the River Danube since the beginning of the 1980s and most of them became very abundant at the beginning of the 21st century (ERŐS & GUTI 1997, GUTI *et al.* 2003, GUTI 2006, HARKA & BÍRÓ 2007).

Remarkable change in the fish fauna has been reported in the Hungarian stretch of the Danube since the end of the 19th century, as the number of observed invasive fish species increased over time. The most significant impact of the invasive fishes, which affected native species of the Danube, is competition mainly for resources, such as food and habitats. Competition causes the displacement and reduction of abundance of native species (LENHARDT *et al.* 2011). Another important impact of non-native fish is disturbance and alteration of the ecosystem, which is reflected in changes in water quality, depletion of vegetation, eutrophication, modification of substrate and macrophytes (PINO-DEL-CARPIO *et al.* 2010). Invasive species as parasite transfer contributed to the spread of several new parasite species across Europe (SCHOLZ 1999, MOLNÁR & SZÉKELY 2004). Gibel carp as a reproductive parasite had a significant negative impact on the indigenous crussian carp (*C. carassius*) and tench (*Tinca tinca*), because triploid females of gibel carp use males of other cyprinid fishes for their reproduction (LUSK *et al.* 2010). The interspecific hybridisation of gibel carp could also be the reason for population decrease of common carp (KOŠČO *et al.* 2010).

Reptiles

At present, one non-indigenous reptile exists along the Hungarian stretch of the Danube (Table 1). *Trachemys scripta* is native to North America, from where it was introduced to all over Europe as a pet. This species is the most popular turtle in the pet trade, with more than 5 million exported from the United States annually (TELECKY 2001). In Hungary, it is known in the wild since the 1970s. In the floodplain of the River Danube, it has been recorded since the 1990s (PUKY *et al.* 2005*b*). Since 2000 it has been spreading rapidly in the country with indication of reproduction south of Lake Balaton (pers. comm. of the Balaton National Park Directorate staff).

DISCUSSION

In recent decades, the number of non-indigenous species has increased in the Hungarian stretch of the Danube, and several species have become dominant (Fig. 1).

Corbicula fluminea became one of the most abundant bivalves in less than a decade. Certain groups, such as mysids and amphipods, are only represented by invasive species. Alien decapods are much more abundant than the indigenous ones. Among fish, gobiids are characterized by the most spectacular dispersion.

The major vectors that contribute to the introduction and the rapid spread of alien species are river shipping, deliberate crayfish and fish stocking for economic reasons and pet trade for reptiles. Further possibilities for introductions involve release from aquaria, deliberate stocking for sport fishing, or even food consumption.

The introduction of non-indigenous species with good invasive and competitive abilities induces serious danger for the biodiversity and the ecosystem functions (KOLAR & LODGE 2001). Due to their dominant position, certain species could have considerable negative impacts on the Danubian ecosystem. The invaders in all the studied groups exert a competitive pressure on the native fauna for food. *Corbicula fluminea* competes with native bivalves due to its high filtration abilities (STRAYER 1999). *Hemimysis anomala* is a zooplankton consumer, which may imply competition with juvenile fish. In addition, competition can take place for habitat and among fish for spawning sites, as well. Invasive decapods and fish species can increase predatory pressure since several species feed on juvenile native fish. Some fish species have negative effects on the native fauna due to their special methods of reproduction (*C. gibelio*, LUSK *et al.* 2010). The introduction of diseases and parasites is also a great problem. Some aquatic gastropods (*M. tuberculatus*, *L. naticoides*) can act as an interhost for larvae of trematodes, which infect

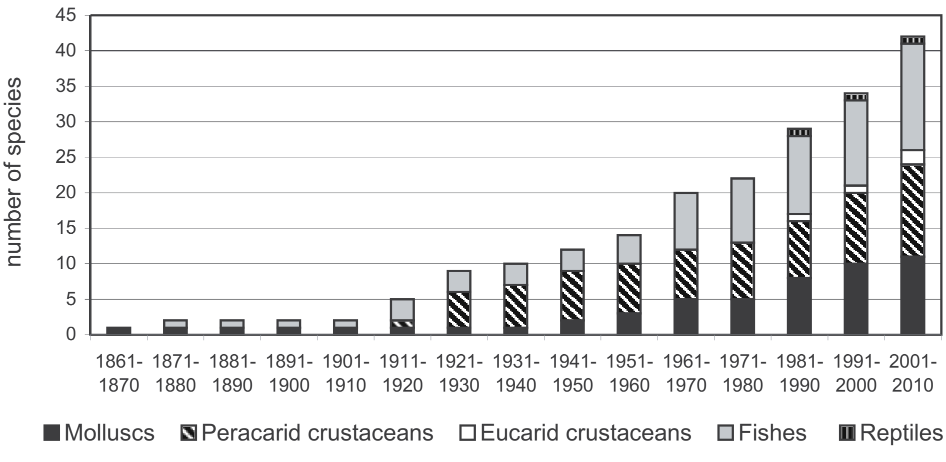

Fig. 1. Increasing number of invasive species in the Hungarian Danube stretch according to the studied taxonomical groups

fish species. Signal crayfish and spiny-cheek crayfish carry crayfish plaque, which is lethal for indigenous decapodes. Several new parasite species have spread in Europe as a consequence of fish transfers (SCHOLZ 1999, MOLNÁR & SZÉKELY 2004). In addition, *C. fluminea* and *D. polymorpha* can cause serious economic problems by biofouling the water channels of factories and power plants (DARRIGRAN 2002).

On the other hand, invaders can have positive effects on the ecosystem, as well. The great biomass of *C. fluminea* provides new food resources and their empty shells offer habitats and shelter for other aquatic organisms (GUTIÉRREZ *et al.* 2003). Moreover, due to its high filtration activity, *C. fluminea* can decrease turbidity (PHELPS 1994). Amphipods comprise a considerable proportion of the benthic invertebrate biomass, and hence play a central role in the benthic food web. *Jaera sarsi* is an important food item of juvenile fish (BORZA *et al.* 2009). Some abundant non-native fish species, as gobiids or topmouth gudgeon, provide significant food source for native predator fish (*Lota lota*, *Silurus glanis*, *Sander lucioperca*) (LENHARDT *et al.* 2011).

In conclusion, the invasions of the examined species have the potential to alter the structure and the function of Danubian ecosystems and even raise new biodiversity and economic problems in the Pannonian Biogeographical Region. For this reason, the regular monitoring of their area expansion and abundance is essential to estimating and predicting their impacts on native fauna and the whole ecosystem. In addition, established research data are required to provide information to risk assessment and conservation management strategies. Due to the international importance of the River Danube as an aquatic corridor, efforts should be made to prevent new invasions and mitigate the negative impacts of existing invaders along the whole river.

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