

ALIEN FISHES IN EUROPEAN WATERS

Nepůvodní druhy ryb v evropských vodách

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Abstract: The paper summarized published data on alien and alien invasive fishes (Actinopterygii) having been found in Europe and its adjacent waters since the 18th century to the present. At least 109 exotic freshwater fish species belonging to 29 families introduced there are documented. Successful introductions (established or acclimatized species at least in some parts of Europe) of non – native freshwater fishes include at least 38 species (mostly of them originate from Asia and North America, lesser from Middle, South America or Africa). Within European waters, some alien fishes can be considered invasive alien ones. A total of 160 sea alien (invasive) fish species have been reported from the Black Sea – Mediterranean Basin. Negative influences of invasive alien species to native ichthyofauna are discussed by the authors.

Key words: alien fishes, invasive alien fishes, Lessepsian migrations, Europe

Introduction

Invasive alien species are key drivers of human – caused global environmental change (PEJCHAR & MONEY 2009, SECRETARIAT OF THE CONVENTION ON BIOLOGICAL DIVERSITY 2010, SIMBERLOFF & REJMÁNEK 2011). The past two decades have seen an explosion of research interest on human – mediated invasions. It should be stressed that there is an important distinction between alien species in general – which are introduced outside their natural ranges by humans, but which in many cases are harmless and even more, support natural processes in ecosystems as well as human well – being, and invasive alien species, which

by the definition adopted by the Convention on Biological Diversity not only are introduced outside their ranges but also through introduction and/or spread outside their natural past or present distribution threaten biological diversity at all its main levels (genes/individuals, species, communities/ecosystems/landscapes, SECRETARIAT OF THE CONVENTION ON BIOLOGICAL DIVERSITY 2002). In addition, some of the invasive alien species cause substantial harm to human health and economy (KETTUNEN et al. 2009, MACK & SMITH 2011).

The studied European territory together with adjacent seas are in detail described by the paper published by HANEL, PLÍŠTIL & NOVÁK (2009). The increase in the fish species distribution range can be caused by naturally dispersing, invasive dispersing or introductions. Introductions of alien fish species have had a longstanding tradition, both worldwide and in Europe. They begun in the 18th century, intensified after the mid – 19th century and continued during the 20th century. They are existing two basic ways for introductions of alien fishes, i.e. unintentional (undeliberate) introductions (e.g. *Pseudorasbora parva*) and intentional (deliberate) introductions (most of the introduced fishes, e.g. *Oncorhynchus mykiss*, *Salvelinus fontinalis*, *Ctenopharyngodon idella*). PIAZZINI et al. (2010) recognize also the category of para – autochthonous fishes. The term describes species introduced and naturalized before 1500 AD (GENOVESI 2007).

COPP et al. (2006) summarized the historical data on human activities with respect to fish introductions to Europe. During the 20th century a wide range of human activities became responsible for animal alien species expansion arising from extensive fish culture and sport fishing, intensive aquaculture, for improvement of wild stocks, followed by the passive transportation by vessels, ornamental use (with introduction to lakes on private estates, small garden ponds, and indoor aquaria) and dispersal through canals. In many cases fish introductions have been carried out for various reasons at the same time. The only taxon to be imported for biological control were *Gambusia* spp. which has since then spread to many warmwater systems.

Both local and continental reviews of introduction activities present, in addition to lists of alien fish species, examples of either the risk or confirmed influence of such species on local (native) ichthyofauna, and their contribution to devastating the native populations (e.g. LEVER (1977), DE GROOT (1985), WITKOWSKI (1989, 1996, 2002), HOLČÍK (1991), WELCOMME (1988); CRIVELLI (1995), GOLANI (1998), KEITH & ALLARDI (1998), GARCÍA-BERTHOU & MORENO – AMICH (2000), ELVIRA (2001), ELVIRA & ALMÓDOVAR (2001), BOGUTSKAYA & NASEKA (2006); FREYHOF (2003); LUSK et al. (2004), CASAL (2006), CLAVERO, BLANCO – GARRIDO & PRENDA (2004); COPP et al. (2005), NICO, WILLIAMS & JELKS (2005), COPP, STAKENAS & DAVISON (2006); CUCHEROUSET et al. (2006); GOLLASCH & LEPPÄKOSKI (2007), KAPUSTA, BOGACKA – KAPUSTA & CZARNECKI (2008); KORSU, HUUSKO & MUOTKA (2008, 2010), LUSK, LUSKOVÁ & HANEL (2008, 2010, 2010a); RIBEIRO, COLLARES – PEREIRA & MOYLE (2008), KOŠČO et al. (2010), MARR et al. (2010).

Introduced fishes may directly impact on native fishes by predation, resource competition, interference with reproduction, changing habitats inhabited by native species and/or the introduction of parasites and diseases. The occurrence of invasive alien fishes can be used for evaluation of fish community conservation status (BIANCO 1990, KENNARD et al. 2005). Some related information about fish introductions is presented also BOMFORD, BARRY & LAWRENCE (2010).

Alien invasive fishes with evident negative impact on native biodiversity are sometimes included in the so-called Black lists of non-native species (e.g. NEHRING ET AL. 2010, LUSK, LUSKOVÁ & HANEL 2011).

Parasite invasions together with introductions of non – native fishes to Europe are documented by various authors, e.g. MORAVEC, WOLTER & KÖRTING (1999), UZUNOVA & ZLATANOVA (2007), KOŠUTHOVÁ et al. (2009). For example, the introduction of *Ctenopharyngodon idella* to the Czech Republic was accompanied by the introduction of the tapeworm species, *Bothriocephalus gowkongensis*, which subsequently caused heavy losses in *Cyprinus carpio* farmed stocks (ZAJÍČEK 1987). MÜHLEGGGER et al. (2008) found during parasitological studies of the invasive Round goby fish species (*Neogobius melanostomus*) from the Danube River in 2007 the digenean *Bucephalus polymorphus*. The parasite was recorded for the first time in Austria. The parasite nematode *Anguillicoloides crassus* is a natural parasite of the Japanese eel in its native range. This nematode was introduced in the 1980s to the Europe and it is considered to be one of the key threats to the European eel (*Anguilla anguilla*) in Europe, cf. e.g., KIRK (2003).

The species *Pseudorasbora parva* has been recently identified as a vector of disease caused by rosette – like agent (closely related to *Sphaerothecum destruens*) dangerous for European cyprinids (GOZLAN et al. 2005). HOLČÍK & ŽITŇAN (1978) found *Carassius auratus* (= *gibelio*) as a host of two monogenic helminths: *Gyrodactylus shulmani* and *Gyrodactylus sprostonae* originating from Far East and now having been present in the Danube basin.

The first occurrence of striped red mullet (*Mullus surmulentus*), tub gurnard (*Chelidonichthys lucerna*) and Atlantic horse mackerel (*Trachurus trachurus*) off the Western coast of Poland (Baltic Sea) described WIECZASZEK et al. (2011). Their expansion is probably due to increased sea temperatures resulting from climate change, as well as the inflow of saline water. The „visitors“ hosted eight pathogens from four taxonomic groups: Protozoa, Nematoda, Acanthocephala and Mollusca. Mostly of the parasite species were new for the hosts.

RODRÍGUEZ (2006) summarized the available information about ornamental fishes and their economic, ecological and health implications for the trade. Influence of ornamental fishes on native ichthyofauna was studied in many countries (e. g., CORFIELD et al. 2008). Various ornamental or aquarium fishes can escape from closed fish cultures or in open waters, they can be introduced by irresponsible aquarists. Their long – term appearance in colder parts of Europe is limited due to their different ecological requirements, particularly for temperature. DUGGAN, RIXON & MACISAAC (2006) discuss how the popularity of aquarium fish species can influence their import and introductions. It has not been known how many aquarists are in the Europe. In any case the aquaristic activities (particularly keeping of water animals) is one of the most popular and therefore common hobby, particularly in cities and towns (our unpublished data from the Czech Republic).

Very popular at present is keeping colour or shape fish varieties. They are used in aquarium tanks and garden or park ponds. For example, Czech fish farms produce „koi“ carps (*Cyprinus carpio*, nishikigoi) in various colours and their combination, „gold“ or „orange“ varieties of *Leuciscus idus*, *Tinca tinca*, *Carassius auratus* or *Silurus glanis*. Coloured huge carps are sometimes angled, e. g. specimens weighed about ten kilograms are known from Czechian waters (HANEL & LUSK 2005). In fish ponds, water reservoirs and rivers in

the Czech Republic, also angled albino or xanthophoric wels (*Silurus glanis*) were angled, see HANEL (2003). The huge albino wels was angled in the Rhône in France in 2003 (214 cm, 75 kg, see <http://xvella.free.fr/photos/photo-eng.php?sub=21&item=572>). The albino sterlet sturgeon (*Acipenser ruthenus*) is at present put on the market for garden ponds in the Czech Republic.

During preparing the list of alien species presented here we have often faced a problem of sufficient data needed. Not always sufficient evidence on fish introduction activities is available. Some species are introduced primarily as aquarium and ornamental fishes, but they can sometimes eventually survive in open waters when released and may possess undesirable negative effects on native abiotic environment and biota. For example, two species, the Chinese lake gudgeon, *Sarcocheilichthys sinensis* (family Cyprinidae) and the Chinese sucker, *Myxocyprinus asiaticus* (Family Catostomidae), are believed to have been illegally imported into the United Kingdom in the past under tropical fish import licences. Both species possess a risk to environment at the site if released into the wild (CLARK 2006). Consequently, we can anticipate unexpected findings of other fish species in open European waters in the future.

It is evident, that some of historical short notes about introductions of alien fishes are anecdotal and insufficient, without any further information about the further development of the imported specimens. The survey of introduced alien fish species of the ichthyofauna in Europe (forming naturalized, casual, feral populations, recorded only as accidental angled specimens or introduced to fish farms) is presented below.

Results

• Sturgeons (Acipenseridae)

GHERARDI et al. (2007) mentioned introductions of the White sturgeon (*Acipenser transmontanus*), native along Eastern Pacific seaside of Northern America. Consequently, the species was recorded in rivers and estuaries of the Baltic and North Seas (ARNDT et al. (2000). The species was introduced also to Italy (1987, see HOLČÍK (1991) and now is cultured in some European fish farms (WILLIOT et al. 2001). The Siberian sturgeon (*Acipenser baerii*) was introduced and now is bred in fish farms in France, Germany, Italy, Belgium, Hungary, Austria, Spain, the Czech Republic and Russia. It completes its life in freshwater and therefore, it is commonly kept in captivity for meat or for caviar. It is occasionally found in the wild – fish sporadically escape from breeding facilities, angling ponds, or are released when they become too large for private aquaria (ELVIRA & ALMODÓVAR 2001). MASÁR et al. (2006) reported the first record of the the Siberian sturgeon in the Slovak – Hungarian stretch of the Danube River. It was found also in the estuary of the Odra River (CZERNIEJEWSKI, KESZKA & RYBCZYK 2008). Sometimes hybrids are also bred in captivity, e.g. *A.baerii* x *A.gueldenstaedtii* and *A.baerii* x *A.ruthenus* (<http://www.cites.org/eng/com/ac/16/16-7-2a1.pdf>). The first evidence of the *Acipenser ruthenus* and *Acipenser baerii* hybrid in the Danube River was documented by LUDWIG et al. (2009). The Lake Sturgeon (*Acipenser fulvescens*), originating from North America, was introduced to former U.S.S.R. in 1969 and has been used in aquaculture with artificial reproduction only (see HOLČÍK 1991).

● Paddlefishes (Polyodontidae)

The Mississippi Paddlefish (*Polyodon spathula*) is cultivated in several European countries in fish farms, but sometimes can escape to the wild. For the first time, the species was introduced to Russia (RESHETNIKOV et al. 1997) and Hungary (HOLČÍK 1991) in 1974. REINARTZ (2002) reported that paddlefish were originally imported from the U.S.A. to Romania for acclimatization and breeding in fish farms. Paddlefish are at present currently bred in fish farms in Germany, Austria, Romania, Hungary, Greece, the Czech Republic and Bulgaria (BOGUTSKAYA & NASEKA 2006, PROKEŠ, BARUŠ & PEŇÁZ 2000, HUBENOVA, ZAIKOV & VASILEVA 2005). Adult paddlefish were caught in the Bulgarian part of the Danube River (KUTSAROV 2005). SIMONVIĆ, MARIĆ & NIKOLIĆ (2006) mentioned several paddlefish caught by local fisherman using a drifting trammel netting in the Serbian part of the Danube River. VASSILEV & PEHLIVANOV (2005) reported juvenile paddlefish being found in the lower Danube River, which indicates that paddlefish have already acclimatized there (establishing breeding populations?). HOLČÍK & ÁČ (2006) mentioned finding of the paddlefish in Slovakian open waters. In Russia the Mississippi paddlefish has been released in several water bodies where it is occasionally caught (KOTTELAT & FREYHOF 2007). CZERNIEJWSKI, KESZKA & RYBCZYK (2008) noted its occurrence in the estuary of the Odra River.

● Gars (Lepisosteidae)

SALNIKOV (2010) describes the first finding of the gar *Atractosteus* sp. in the Caspian Sea near the coast of Turkmenistan. The caught individual was not precisely determined; however, it was probably the Alligator gar (*Atractosteus spatula*). Gars are chiefly freshwater, living in brackish water only occasionally; they are very rarely inhabiting marine environment. Their homeland is eastern North America to the Mesoamerica.

● Freshwater eels (Anguillidae)

GHERARDI et al. (2009) informed about the American eel (*Anguilla rostrata*) introduction to Europe. TRAUTNER (2006) notes that in European aquaculture, mainly the European eel (*Anguilla anguilla*) is used for production. As the price for glass eels has risen up to 1,000 Euro per kilogram, the American glass eel, available for a much lower price, has been increasingly imported and used for stocking in aquaculture. The consequences of massive stocking with *A. rostrata* in European waters can only be assumed. FRANKOWSKI et al. (2009) assessed the occurrence of *A. rostrata* in fish farms and in open waters too. The life stages of American eels identified from several German waters draining to either the Baltic Sea and the North Sea ranged from elver to silver eels. ALBERT, JÓNSSON & BERNATCHEZ (2006) found natural hybrids in both eels *Anguilla anguilla* and *Anguilla rostrata* on Iceland (the life cycle of both the species begins in the Sargasso Sea). BUCHMANN, MELLERGAARD & KOIE (1987) and MOROZIŃSKA – GOGOL (2009) informed about introduction of the Japanese eel (*Anguilla japonica*) to European fish farms. WELCOMME (1988) reports that the Short – finned eel (*Anguilla australis*) was introduced from New Zealand to Italy in 1975 (however, no more details are available; the species has probably disappeared from the latter country).

● Minnows or carps (Cyprinidae)

The Grass carp (*Ctenopharyngodon idella*), native to East Asia, was introduced to Europe in 1950 to improve fish production and to control the aquatic and littoral vegetation (van Zon 1977, CUDMORE & MANDRAK 2004, SAVINI et al. 2010). The species have established feral populations in 15 European countries (SAVINI et al. 2010). The Asian species, the Bighead carp (*Hypophthalmichthys nobilis*) and Silver carp (*Hypophthalmichthys molitrix*) were introduced to Europe in 1940 as primarily filter feeders for so called “top – down control” for improving the water quality. They can consume phyto – and zooplankton and detritus. The Silver carp in 15 and the Bighead carp in 10 European countries established feral populations (SAVINI et al. 2010). Neither of both the species have established self – sustaining populations in European waters and consequently persist only by stocking there.

The Black carp, *Mylopharyngodon piceus*, native to the Far East, was introduced in 1950 to Europe for biological control of populations of molluscan vectors of fish and human parasites (COLLINS 1996). Its population is known from the Bulgarian Ovcharitza reservoir (UZUNOVA & ZLATANOVA 2007). By now it has been the only feral population of the species recorded in Europe (SAVINI et al. 2010).

GHERARDI et al. (2009) mentioned the White Amur bream (*Parabramis pekinensis*) as having been introduced to Europe, but without details. There are reports about introduction of the species to Greece (FAO 1997) and Russia (BOGUTSKAYA & NASEKA 2006). SHUMKA, PAPANISTO & GRAZHDANI (2008) and DHORA (2010) report the species' occurrence in Albania but they do not mention more details needed. HOLČÍK (1991) informed on introduction of the species to Hungary in 1963.

DHORA (2010) informed about the Black Amur bream (*Megalobrama terminalis*) and SHUMKA, PAPANISTO & GRAZHDANI (2008) cited the introduction of the Wuchang bream (*Megalobrama amblycephala*) to Albania and discussed their using in fisheries. HOLČÍK (1991) mentioned the introduction of the Wuchang bream also to Hungary and former Yugoslavia.

More detailed information about the Asian Topmouth gudgeon (*Pseudorasbora parva*) is presented in the chapter „Invasive species“. At present, the fish has been known from 23 European countries (FROESE & PAULY 2011).

The Asian Tinfoil barb (*Barbodes schwanefeldii*) was introduced to Italy in the past and have disappeared (HOLČÍK 1991). GANTE et al. (2008) described the first finding of the barb in the Iberian Peninsula.

Asian species, the Catla (*Catla catla*), the Mrigal carp (*Cirrhinus mrigala*) and the Roho labeo (*Labeo rohita*) were introduced to former U.S.S.R. in 1966 (HOLČÍK 1991) and probably have been used in the aquaculture.

The *Carassius auratus* has established feral populations in 29 European countries (SAVINI et al. 2010). Its taxonomic status has been debated and history of its introduction to Europe is disputable and unclear due to lack of reliable information (KOTTELAT 1997). Some authors suggest that *Carassius auratus* is in the fact a complex comprising a number of forms of the different taxonomic status (*C. auratus auratus*, *C. auratus gibelio*, *C. auratus langsdorfii*), considered as valid species by other authors (for more details, see e.g. LUSKOVÁ et al. 2010). Its invasiveness is discussed in the chapter „Invasive species“.

The Asian species, the Sharpbelly (*Hemiculter leucisculus*) is known from Romania and the former U.S.S.R. (FROESE & PAULY 2011).

The Fathead minnow (*Primephales promelas*) is native to North America. Locally the species was found in open flowing Belgian waters (ANSEEUW, GAETHOFS & LOUETTE 2005), it is known also from France (KEITH & ALLARDI 1998). It was introduced in the past also to Germany (HOLČÍK 1991). As a predator of eggs and larvae of other fish species, the Fathead minnow is considered as a potential pest. It is also responsible for the introduction of *Yersinia ruckeri*, the agent of the enteric redmouth disease. An introduction pathway of the pathogen to France was only shown in 1986 (MICHEL, FAIVRE & DE KINKELIN 1986). The above authors described a clinical case of the bacteriosis in Fathead minnows that had been imported from the United States at least since 1981 for live – bait fishing. ZIĘBA et al. (2010) mentioned a finding of the Fathead minnow in the United Kingdom.

• Suckers (Catostomidae)

Three species from the North American family Catostomidae (namely *Ictiobus niger*, *Ictiobus bubalus*, *Ictiobus cyprinellus*) were introduced to several European countries. Successful establishing of all mentioned catostomids is known only from Bulgaria (UZUNOVA & ZLATANOVA 2007). The Longnose sucker (*Catostomus catostomus*), native to North America and Arctic basin of in Russia, was introduced from Siberia to the Kopore, Neva and Kovashi drainages in Russia in 1978. It was probably locally established in streams draining to the Gulf of Finland, but there is no recent evidence that it has been present there yet (LEPPÄKOSKI 1984, KOTTELAT & FREYHOF 2007). The North American White sucker (*Catostomus commersonii*) was introduced from U.S.A. to the United Kingdom (FAO 1997), no more details are available. COPP, VAUGHAN & WHEELER (1993) later informed on the first finding of the species in U.K. The Chinese sucker (*Myxocyprinus asiaticus*) is newly put on official market for garden ponds in the Czech Republic. Its occurrence in open waters has not been known yet there.

• Loaches (Cobitidae)

ZIĘBA et al. (2010) in their paper about recent releases and dispersal of non – native fishes in England and Wales also mentioned the species *Misgurnus mizolepis*. Its homeland is China, Taiwan and Korea. Asian weather loach (*Misgurnus anguillicaudatus*) was introduced to several sites in Rhine (Germany) and Ticino (Italy), see RAZZETTI et al. (2001), FREYHOF & KORTE (2005). The species *Paramisgurnus dabryanus* was regularly imported from southern China as ornamental species for European garden ponds (KOTTELAT & FREYHOF 2007).

• Characins (Characidae)

HENSEL (2004) described the first capture of non predatory piranha parapatanga (*Piaractus brachypomus*) in Slovakian waters. GHERARDI et al. (2009) mentioned introduction of species *Piaractus brachypomus*, *P. mesopotamicus* and *Pygocentrus nattereri* to Europe without providing any detailed information. ELLIS (2006) mentioned finding of *Pygocentrus (nattereri?)* in waters in U.K. The Red – bellied pacu (*Colossoma macrostomum*) was

found in the Torridge river in Devon (the United Kingdom), see ZIEBA et al. (2010). Four angled piranha specimens were also described from Czech waters but precise determination is unfortunately not known (HANEL & LUSK 2005, own data). The occurrences of „piranhas“ in European open waters are evidently due to irresponsible aquarists' activities.

● **Flannel – mouth characiforms (Prochilodontidae)**

BARTLEY (2006) reports introduction of the Streaked prochilod *Prochilodus lineatus* to Albania. No later observations are available. The fish originates from South America (Paraná – Paraguay and Paraíba do Sul River basins) and can grow up to 80 cm.

● **North American freshwater catfishes (Ictaluridae)**

For the first time, North American catfishes were imported to Europe to France in 1871 (see CVIJANOVIĆ, LENHARDT & HEGEDIŠ 2005), then to Germany in 1885. The Brown bullhead (*Ameiurus nebulosus*) is widely distributed in European waters: the fish has established feral populations in 19 European countries (SAVINI et al. 2010). In Europe its viable populations were recorded from the Ebro and Tagus drainages (in the Iberian Peninsula), most drainages in France, locally in Italy, the Netherlands and Germany (KOTTELAT & FREYHOF 2007). Some established populations are known also from the Czech Republic and Slovakia (HANEL 2001, HANEL & LUSK 2005).

HOLČÍK (1991) summarises that the Black bullhead (*Ameiurus melas*) was introduced to Belgium, France, Hungary, Ireland (?), Italy, the Netherlands, Norway, Switzerland, Spain and United Kingdom. ZIEBA (2010) refers that the Black bullhead expanded from Hungary to Slovakia (KOŠČO & KOŠUTH 2002, KOŠČO et al. 2004) and have established naturalized populations there. ELVIRA (1984) and DE LOMAS et al. (2009) present the first record of the Black bullhead in the Guadalquivir Estuary in southern Spain. CVIJANOVIĆ, LENHARDT & HEGEDIŠ (2005) informed about the first finding of the species in Serbian waters. GANTE & SANTOS (2002) and RIBEIRO et al. (2006) found the fish in Portugal, WILHELM (1998) and POPA et al. (2006) in the Romanian section of the Danube River, from the Czech Republic it is referred by HARTVICH & LUSK (2006) and MUSIL et al. (2008). Life-history traits of non-native Black bullhead from an oxbow of the Váh River (near the town of Komárno), located in the middle Danube reaches (Slovakia) were studied by NOVOMESKÁ & KOVÁČ (2009). According to SAVINI et al. (2010), the Black bullhead has established feral populations in 15 European countries.

BRITTON & DAVIES (2006) and ZIEBA (2010) inform about first record of the White catfish (*Ameiurus catus*) in the United Kingdom, later the fish was found also in Polish waters (NOWAK et al. 2008, 2010). HOLČÍK (1991) and GANDOLFI et al. (1991) informed about the occurrence of the Yellow catfish (*Ameiurus natalis*) in Italy. The Channel catfish (*Ictalurus punctatus*) was introduced to Belgium, Cyprus, the former Czechoslovakia, France, Hungary, Italy, the United Kingdom, the former U.S.S.R. and former Yugoslavia (HOLČÍK 1991, KOŠČO et al. 2004) and it has established feral populations in 4 European countries (SAVINI et al. 2010). Viable populations were recorded in the lower Ebro (Spain), River Oglio and Pavia Province (northern Italy), and in the lower Kuban and Don drainages (DOADRIO 2002, KOTTELAT & FREYHOF 2007, HERMOSO, BLANCO – GARRIDO & PRENDA 2008).

● **Airbreathing catfishes (Clariidae)**

The North African catfish (*Clarias gariepinus*) was introduced to Cyprus, the former Czechoslovakia and the Netherlands (HOLČÍK 1991). The most recent information about the new introductions of the North African catfish to Bulgaria is provided by UZUNOVA & ZLATANOVA (2007). The species was introduced in European aquaculture in 1974, first in Cyprus, and later on in the Czech Republic, Slovakia, the Netherlands (GAVRILOAIE & CHIŞAMERA 2005) and Poland. ZIĘBA et al. (2010) refer in their paper about recent releases and dispersal of non – native fishes in England and Wales the Philippine catfish (*Clarias batrachus*) which was introduced only in the United Kingdom (GAVRILOAIE & CHIŞAMERA 2005). The first occurrence of the Blunt toothed African catfish (*Clarias ngamensis*) in Romania (a lake in the Titan Park in Bucharest) is reported by mentioned GAVRILOAIE & CHIŞAMERA (2005). The Philippine catfish (*Clarias batrachus*) was caught in the river Thames (London) in 2009 (ZIĘBA et al. 2010).

● **Callichthyid armored catfishes (Callichthyidae)**

The South American catfish *Megalechis thoracata* was in the past found dead in the Vltava River in Prague (HANEL 2003). It is not known whether the specimens were released alive to the river.

● **Armored catfishes (Loricariidae)**

In a small stream in southern Tuscany (Fossa Calda), fed by hot springs, the exotic aquarium fish, the Amazon sailfin catfish (*Pterygoplichthys pardalis*) was recorded, see PIAZZINI et al. (2010) Several specimens of the Armoured suckermouth catfish (*Hypostomus plecostomus*) were caught in the United Kingdom in 2000 – 2009 (ZIĘBA et al. 2010), see also BARTLEY 2006).

● **Mudminnows (Umbridae)**

The North American Eastern mudminnow (*Umbra pygmaea*) was introduced to Central and West Europe (France, Belgium, the Netherlands, Germany, Denmark, Poland), see WITKOWSKI, KUSZNIERZ & KOTUSZ (1995), GUIDOU & KEITH (2005), KOTTELAT & FREYHOF (2007), VERREYCKEN et al. (2010). In Europe is usually found in small isolated ponds and peat bogs.

● **Salmonids (Salmonidae)**

Some North American salmonid species were introduced to European waters to supply fisheries or/and angling. The Rainbow trout (*Oncorhynchus mykiss*) is the most important salmonid species in European aquaculture. It had been sent to Germany from Michigan in 1882 and then dispersed to various hatcheries. From Germany it was distributed to Sweden, Denmark, Finland, Poland, the Czech territory by the 1900 and later to other European countries (JONSSON 2006). Up to now, the species present has been established in 28 European countries where are its feral populations have been known (SAVINI et al. 2010).

The Coho salmon (*Oncorhynchus kisutch*) came to Europe in the 1970s, when it was deliberately introduced into France. In 1974 50,000 yearlings escaped from a fish farm

into the river Varenne in Normandy. Between 1975 and 1979 similar incidents occurred in other parts of France. In 1975 – 1977, adult fish were caught in various rivers of northern France and in the English Channel. The species was introduced to Cyprus in 1988 (DILL 1990). Records of Coho salmon have also been reported from Belgium and the Netherlands.

According to FishBase (FROESE & PAULY 2011), the Coho salmon also occurs as an introduced species in the Mediterranean and further countries (Israel, Cyprus, Greece, former Yugoslavia, France, the Netherlands and Italy). OLENIN et al. (2008) present its introduction to Spain. It has been apparently farmed in Spain and individuals escape from aquaculture (KOTTELAT & FREYHOF 2007, SALONEN & MUTIA 2007). There are reports of the species being stocked in the eastern Baltic in the 1970s. It was observed in German waters in 1974 and in Latvian ones in 1980. Records have also been reported from Estonia (http://www.frammandearter.se/0/2english/pdf/Onchorhynchus_kisutch.pdf). SAVINI et al. (2010) summarise that the Coho salmon has established in feral populations 3 European countries.

Some farms in Sweden and perhaps elsewhere apparently have bred also the Cutthroat trout (*Oncorhynchus clarkii*) and the species is listed among Swedish freshwater fishes (KOTTELAT & FREYHOF 2007). COWX (1997) mentioned experiments with the fish in Denmark. In Cyprus many exotic fish have been introduced, experiments with the Cutthroat trout were carried out there in the 1960s (HOLČÍK 1991) and in 1980 (DILL 1990). MUSIL et al. (2008) reported its introduction to the Czech Republic in 1905, but without any supplementary information.

The Chum salmon (*Oncorhynchus keta*) was introduced to Norway and Finland (see WELCOMME 1988, LEVER 1996) and former the U.S.S.R. (HOLČÍK 1991), no more detailed information is available.

The Chinook salmon (*Oncorhynchus tshawytscha*) was introduced to Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands and the United Kingdom (WELCOMME 1988, HOLČÍK 1991).

The Pink salmon (*Oncorhynchus gorbuscha*) was introduced to Finland, Ireland, Norway, the United Kingdom, Poland and the former U.S.S.R. in the past (WELCOMME 1988, HOLČÍK 1991).

Another salmonid, the Sockeye salmon (*Oncorhynchus nerka*), was introduced from U.S.A. to Finland, Sweden and Denmark in 1933 – 1960 (WELCOMME 1988, FAO 1997).

FAO (1997) and WELCOMME (1988) report that the salmon *Oncorhynchus rhodurus* (originally endemic to the Japanese lake Biwa) was introduced from Japan to Germany in 1976, but it has not established there.

The Brook charr (*Salvelinus fontinalis*) is native to North America. The fish was firstly introduced to Europe in the the United Kingdom as early as in 1869 (LEHTONEN 2002), and nowadays, it is present in some twenty countries; from Spain in the south to Norway. Established or acclimatized populations are documented from high altitude lakes and streams e.g., in Corsica, Italy, the Czech Republic, Germany (KOTTELAT & FREYHOF 2007, JANSSON 2008). The Brook charr established feral populations in 23 European countries (SAVINI et al. 2010). Its influence on native salmonids is discussed by KORSU, HUUSKO & MUOTKA (2008).

The Lake trout (*Salvelinus namaycush*) was introduced from North America to Europe in 1881. It is established particularly in high altitude lakes in France, Italy, Sweden and Finland (DILL 1990, FREYHOF 2008, KOTTELAT & FREYHOF 2007). There are data available about its introduction also to former Czechoslovakia, Denmark, Germany, Spain, Switzerland and the United Kingdom (HOLČÍK 1991).

The Whitespotted charr (*Salvelinus leucomaenis*) was introduced from Japan to Germany in 1977 (WELCOMME 1988), but similarly to some other cases, no details are known.

WELCOMME (1988) and LEVER (1977) summarise that the Lake whitefish (*Coregonus clupeaformis*) has been introduced from the U.S.A. to France, Germany, United Kingdom, Italy (?), Switzerland, the Netherland in 1980s, but unsuccessfully (no more details available). LEPPÄKOSKI (1984) informed about the species' rare occurrence in the Gulf of Finland within the Baltic Sea.

The Black Baikal grayling (*Thymallus baicalensis*) was introduced to former Czechoslovakia and Poland in the late 1950s (HOLČÍK 1991). In the former country, the grayling was bred in the riverine lake Dobšiná (Slovakia). The first specimen had been caught there in 1961, and mass spawning migrations were documented in spring 1962. By 1975, the grayling occurred regularly there, but its population was declining. After 1975, the species disappeared entirely (BARUŠ & OLIVA 1995).

The species of *Coregonus migratorius* was introduced to Latvia (PLIKSS 2002, see FROESE & PAULY 2011), introduction of *Coregonus baunti* to USSR is mentioned by HOLČÍK (1991) and BOGUTSKAYA & NASEKA (2002).

The presented review on salmonids may not be entirely complete due to limited and unclear records of species introductions (e.g., the Blaufelchen *Coregonus wartmanni*, the Féra *Coregonus fera*, the Zubatak *Salmo dentex*), see LUSK, LUSKOVÁ & HANEL (2010a), GRABOWSKA, KOTUSZ & WITKOWSKI (2010).

● Neotropical silversides (Atherinopsidae)

The La Plata silverside (*Odontheistes bonariensis*) had been introduced to the Italian Lake Nemi in 1974 (KOTTELAT & FREYHOF 2007) and established there. It grows upto 50 cm.

● Ricefishes (Adrianichthyidae)

In 1974, the Chinese medaka (*Oryzias sinensis*) was intentionally introduced for mosquito control in 1974 to the lower Kuban drainage (Sea of Azov basin) and to lakes of Anapka drainage (Black Sea basin), see ABDILDAYEV & DUBITSKYI (1974).

● Topminnows and killifishes (Fundulidae)

The American Mummihog (*Fundulus heteroclitus*) was introduced to southern Portugal and south – western Spain (BERNARDI et al. 1995, GUTIERREZ – ESTRADA et al. 1998, DOADRIO 2002, GISBERT & LÓPEZ (2007), having established viable populations there.

● **Poeciliids (Poeciliidae)**

The American Eastern mosquitofish (*Gambusia holbrooki*) has been established throughout southern Europe. Its first introductions to Europe were carried out in Spain (1921) by human health care authorities, hoping that it would control mosquitoes (vectors of various diseases). For more details, see DOADRIO (2002) and OSOZ, MIRANDA & LEUNDA (2008). The fish was also recorded in a small stream in southern Tuscany (Fossa Calda), fed by hot springs (PIAZZINI et al. 2010). VIDAL et al. (2009) analyzed the origin of the mosquitofish populations in Europe (Portugal, Spain, France, Greece, Hungary).

The Mosquitofish (*Gambusia affinis*) established feral populations in 13 European countries (SAVINI et al. 2010).

The American Guppy (*Poecilia reticulata*), one of the most popular aquarium fishes, was successfully established in the Mijares drainage in Spain. Its viable populations have also become established in many hot springs or warm effluents of power plants in lot of countries (e.g., Albania, Slovakia, the Czech Republic, Romania, Hungary, the United Kingdom, the Netherlands, Germany, Russia), see e.g. HENSEL & BRTEK (1971), FAO (1997), WELCOMME (1983), RESHETNIKOV et al. (1997), MÁJSKY (2000), FROESE & PAULY (2011). Further poeciliids introduced to warmer European waters are the Molly (*Poecilia sphenops*) and the Green swordtail (*Xiphophorus helleri*), KOTTELAT & FREYHOF (2007), but probably they have not established (see also MÁJSKY 2000). In a small stream in southern Italian Tuscany (Fossa Calda), fed by hot springs, the Molly was recorded (PIAZZINI et al. 2010). In the thermal brook Teplý potok in southern Slovakia the following fishes often bred by aquarists have been found: *Poecilia reticulata*, *P. sphenops* and *Xiphophorus helleri* (HENSEL & BRTEK 1971).

● **Sticklebacks and tubenouts (Gasterosteidae)**

The American Brook stickleback (*Culaea inconstans*) was introduced to upper Inn drainage in Bavaria (Germany) and accidentally to southern Finland in the 1960s, where it has established in the Lake Lohjanjärvi (WOLTER & RÖHR 2010, KOLI 2001).

● **Mullets (Mugilidae)**

The So – iuy mullet (*Liza haematocheilus*) was introduced from Asia to the former U.S.S.R. (KOTTELAT & FREYHOF 2007). In the Azov Sea, it is now the most abundant mugilid species. Along shores of the Black Sea, its expansion reflects a sharp decline in native mullet species, which it apparently replaces.

● **Perches (Percidae)**

According to HOLČÍK (1991), the North American Walleye (*Sander vitreus*) was introduced to the United Kingdom in 1925 and it has disappeared from there.

● **Temperate basses (Moronidae)**

The striped bass (*Morone saxatilis*) was introduced to former USSR and Latvia (PLIKSS 2002, see FROESE & PAULY 2011). It has also been introduced into Russia, France, and

Portugal (<http://ccesuffolk.org/assets/galleries/Marine/Fisheries – Management/striped – bass.pdf>). This euryhaline species originates from Western Atlantic area (North and Middle America).

• Sunfishes (Centrarchidae)

Six species of North American sunfishes are reported as introduced in European waters. In the fact, only three are established. The Rock bass (*Ambloplites rupestris*) had been introduced to France, England and Germany in the 1880 – 1910s but did not become established, except for two populations in middle Loire drainage near Digoïn and Décize in France (KEITH & ALLARDI 1998). According to HOLČÍK (1991) the species was also introduced to the United Kingdom.

The Pumpkinseed (*Lepomis gibbosus*) was introduced to Europe in the 1880s as a pond and aquarium fish. Now it is quite widespread throughout Europe, from Portugal to southern Ukraine, eastward to the Dniepr River. It is particularly abundant in Mediterranean countries. The Pumpkinseed established feral populations in 10 European countries (SAVINI et al. 2010). External morphology of a Slovenian population of Pumpkinseed from habitat with extreme thermal conditions is described by ŠUMER et al. (2005). The comparison of external morphology between native (Canadian) and non-native (Slovak) Pumpkinseed populations is presented by TOMEČEK et al. (2005). The data about biological flexibility of the Pumpkinseed in European waters are summarized by TOMEČEK et al. (2007).

WELCOMME (1988) also mentioned introductions of the Green sunfish (*Lepomis cyanellus*) to Germany, and the Redbreast sunfish (*Lepomis auritus*) to Germany and Italy, but without any further information.

The Largemouth bass (*Micropterus salmoides*) was introduced in 1883 to England, Scotland, Germany and the Netherlands, but it is also widespread in Mediterranean countries as Portugal, Spain (including Mallorca) and in the Adriatic basin from Slovenia to Albania. It is also known from Slovenian Danube drainage and Carynthian lakes (Austria). The Largemouth bass established feral populations in 15 European countries (SAVINI et al. 2010).

The related species, the Smallmouth bass (*Micropterus dolomieu*) was also in the past introduced to Europe (e. g. Austria, Germany, Belgium, Denmark, Finland, France, Norway, Sweden, the United Kingdom and former Czechoslovakia), but probably it has not been established there (WELCOMME 1988, HOLČÍK 1991, HANEL & LUSK 2005).

• Cichlids (Cichlidae)

One of South American species, the Chameleon cichlid „Chanchito“ (*Australoheros facetus*), has been introduced to the Iberian Peninsula. First it was recorded in the Mira drainage in 1940, later invaded the Guadiana and Sando drainages (Portugal and Spain), see ALMACA (1995), DOADRIO (2002).

The Rainbow cichlid (*Archocentrus multispinosus*, = *Herotilapia multispinosa*) was found in 1991 in the hot spring at Hévíz (Balaton, Hungary) where it is established (BIRO 1977). Central America is its native distribution range.

One of the authors (J. Novák) confirmed the occurrence of the Convict cichlid (*Amatitlania nigrofasciata*) in the largest European thermal lake at Hévíz (Hungary) in 1984.

The species, originating from Central America, was also recorded in a small stream in southern Tuscany (Fossa Calda), fed by hot springs (PIAZZINI et al. 2010).

HOLČÍK (1991) cited the introduction of the Oscar (*Astronotus ocellatus*) to Italy. Its homeland is South America. SOLARZ (2005) reported introduction of the species to Poland.

DHORA (2010) describes the occurrence of the South American Black acara (*Cichlasoma bimaculatum*) in Albania.

Two African species (*Hemichromis fasciatus*, *Hemichromis guttatus*) were established in a hot spring near Austrian Villach around 1970 and another one (*Oreochromis niloticus*) in Greece (hot springs of Thermophyles near Lamia and the Kremasta Reservoir within the Acheloos drainage) and northern Italy in a canal with warm industrial effluent (ECONOMIDIS et al. 2000). GHERARDI et al. (2009) also noticed the Jewel fish (*Hemichromis letourneauxi*) as having been introduced to Europe, but without details.

Some African cichlids are bred as food fishes in warm aquacultures throughout Europe (*Oreochromis niloticus*, *O. aureus*, *O. mossambicus*, *O. urolepis*, *Tilapia zilli*) and they can sometimes escape from the fish farms. There two notes about angled tilapias *Oreochromis niloticus* in Czech open waters (HANEL 2001). SCORDELLA et al. (2003) described the first presence of the established population of the Nile tilapia (*Oreochromis niloticus*) in the Lesina lagoon (eastern Italian coast). The Nile tilapia was also recorded in the Ruda River in Poland (KOTUSZ, KUSZNIERZ & WITKOWSKI 2000). DHORA (2010) presents the occurrence of the Nile tilapia in Albania.

According to HOLČÍK (1991) and FAO (1997) the Blue tilapia (*Oreochromis aureus*) has been introduced to United Kingdom, Cyprus, former U.S.S.R. and the former Czechoslovakia. The Mozambique tilapia (*Oreochromis mossambicus*), the Redbelly tilapia (*Tilapia zilli*) and the Longfin tilapia (*Oreochromis macrochir*) were introduced in 1958 to France (see ARRIGNON 1962). LEVER (1977) found a refuge of the Redbelly tilapia (*Tilapia zillii*) in thermally – enhanced waters downstream of a power station in England. The Mozambique tilapia was introduced also to Malta, the former Czechoslovakia, the former U.S.S.R and the United Kingdom (WELCOMME 1988, HOLČÍK 1991). MÁJSKY (2007) describes the record of the Mozambique tilapia in Slovakia.

According to HOLČÍK (1991) there also is information on introductions of the Black chin tilapia (*Sarotherodon melanotherodon*), the Guinean tilapia (*Tilapia guineensis*) and the Spotted tilapia (*Tilapia mariae*) to the former U.S.S.R.

● Freshwater sleepers (Odontobutidae)

The Amur sleeper (*Perccottus glenii*) is native to the Pacific basin of East Asia from the Tugur drainage (the Sea of Okhotsk) to northeastern Korea. It was introduced to Russia at the beginning of the 20th century as a ornamental fish. More information is given in the chapter „Invasive fishes“. The another species *Micropercops swinhonis* is sometimes reported to have been introduced from East Asia to Eastern Europe (KOTTELAT & FREYHOF 2007).

● Lates perches (Latidae)

The Barramundi, *Lates calcarifer*, was reported from Bulgaria (UZUNOVA & ZLATANOVA 2007) without more details.

• Gouramies (Osphronemidae)

The Giant goramy (*Osphronemus gorami*) was introduced to France in the 19th century (FAO 1977) and to Italy (HOLČIK 1991) without knowledge of the year of introduction. More information is lacking.

• Damselfishes (Pomacentridae)

The Indo – pacific seargant (*Abudefduf vaigensis*) was introduced to Italy (GOLANI et al. 2002).

• Snakeheads (Channidae)

ZIĘBA et al. (2010) mentioned two finding of the Giant snakehead (*Channa micropeltes*) in the United Kingdom in 2008 – 2009. The Ocellated snake head (*Channa argus*), originating from the Russian Far East was imported into former Czechoslovakia in 1956 and 1960. Acclimatization was unsuccessful, because during the severe winter 1962/63 under the tick ice cover, almost all fish perished in protected small experimental ponds in Central Bohemia (FRANK 1970).

It is necessary to improve the evidence on introductions of alien fishes within Europe. The evidence would be provided not only in single countries but also at the pan – European scale. We suppose that illegal introductions and releasing alien fishes to European open waters are carried out much more often than it would be supposed.

Invasive alien fishes in freshwaters

Invasive alien fishes are characterized by the following basic features: a rapid and successful reproduction with high reproduction rate, high dispersal ability, phenotypic plasticity, tolerance to a wide range of various environmental conditions (= generalists), ability feed themselves on various food (= generalists). There are not sharp differences between wildlife natural spreading and invasions and sometimes it is difficult to categorize respective species. Conceptually, invasions depend both on the receiving environment (invasiveness) and on the ability to reach these new areas (propagule pressure), see LEUNG & MANDRAK (2007). For more details about biological invasion terminology see e. g. COLAUTTI & MACISAAC (2004) and BLACKBURN et al. (2001). GENOVESI & SHINE (2002) drafted the European Strategy on Invasive Alien Species approved by the Bern Convention Standing Committee. The European Union legislation on invasive alien species is scheduled for 2012. HULME et al. (2008) presented some aspects of the knowledge raised during the invasive alien species inventory in Europe. Some alien fish species can display as invasive only under the specific environmental conditions. Some authors discussed the issue of European invasive alien fishes, e.g. WELCOMME (1988), LEPPÄKOSKI, GOLLASCH & OLENIN (2002), GARCÍA – BERTHOU et al. (2005), VILA – GISPERT, ALCARAZ & GARCÍA – BERTHOU (2005), BRITTON & BRAZIER (2006), KOVÁČ et al. (2007), CAFFREY et al. (2008), RIBEIRO et al. (2008).

Examples of some invasive freshwater fish species in Europe are presented in the text below. The species *Carassius auratus* is a characteristic invasive species. In 1611, goldfish

were introduced to Portugal and from there to other parts of Europe. During the 1620s, the goldfish were highly regarded in southern Europe because of their metallic scales, and symbolized good luck and fortune (<http://en.wikipedia.org/wiki/Goldfish>). Of the former, *Carassius auratus* „form“ *gibelio* can be described as evidently invasive. It grows rapidly, reproduces efficiently, and competes with native fishes for food and space. In some parts of Central Europe it has affected the range of other, native and commercially more valuable fish species. Invasiveness level of the species within Europe is discussed in some papers, e. g. HOLČÍK & ŽITŇAN (1978)], HOLČÍK (1980), HALAČKA, LUSKOVÁ & LUSK (2003), LORENZONI et al. (2010), LUSKOVÁ et al. (2010).

The Amur sleeper (*Perccottus glenii*) was introduced to St. Petersburg as an ornamental fish in 1916, now it is widely distributed around and in the Gulf of Finland, in the Baltic basin, in Kaliningrad and is also common in the Vistula River drainage in Poland and Ukraine. In 1950, it was released by aquarium hobbyists into lakes near Moscow. Now it is very abundant throughout the upper and middle Volga and Kama Rivers. It was also introduced and now is abundant in the upper Dniestr River drainage and locally established in the Dniepr and Don River drainages. It has been spreading and abundant in northern Russia, Belarus and Ukraine. Local record is known from Slovakia (the Danube River), already is abundant in the Tisza drainage (Hungary). It spreads actively via navigation canals and has been introduced with stocked fish (DIRIPASKO 1996, HARKA & FARKAS (1997), KAUTMAN (1999). Native species (particularly mud minnow, *Umbra krameri*), with the some habitat preference as the Amur sleeper (*Perccottus glenii*), are getting into very complicated situation in Slovakia (KOŠČO et al. 2010). Further information about invasiveness of the Amur sleeper is presented also by RESHETNIKOV (2003, 2004), KOŠČO at al. (2003, 2008), ČALETA et al. (2010), SIMONOVIĆ, MARIĆ & NIKOLIĆ (2006B), POPA et al. (2006), NOWAK, POPEK & EPLER (2008). UZUNOVA & ZLATANOVA (2007) evaluated species *Perccottus glenii* as invasive in Bulgarian open waters. According SAVINI et al. (2010), the Amur sleeper has established feral populations in 6 European countries, at many sites has been naturalized.

The example of unintentional introductions can be the small cyprinid species, the Topmouth gudgeon (*Pseudorasbora parva*), which had been firstly introduced from the Far East with fry of phytophagous and planktonophagous fishes to Europe in 1961 (BANARESCU 1999) and later colonised most of Europe, either by active invasions, a stocked or released bait, or accidentally mixed with fingerling of other species (KOTTELAT & FREYHOFF (2007), GOZLAN et al. (2010). Usually it is not too abundant in flowing (running) waters, on the other hand it reaches extremely high abundance in many stagnant waters. High phenotypic plasticity in fitness related traits such as growth, early maturity, fecundity, reproductive behaviour (paternal care) and the ability to cope with novel pathogens has predisposed the Topmouth gudgeon to being a strong invader. It is not only an important competitor but also the species is known with its facultative parasitism (scale or even muscle damage in mature carp or other cyprinids), see LIBOSVÁRSKÝ, BARUŠ & ŠTERBA (1990) and ADÁMEK et al. (1996). Morphological variability in the Topmouth gudgeon among samples from Slovak, Romanian, English and French populations was also studied (ZÁHORSKÁ et al. 2009). Age and growth in a newly-established invasive population of the Topmouth gudgeon from Šúr pond near Bratislava (Slovakia) were studied by ZÁHORSKÁ et al. (2010). Reproductive parameters of the Topmouth gudgeon from Slovakia were examined

by ZÁHORSKÁ & KOVÁČ (2009). BRITTON, DAVIES & HARROD (2010) and BRITTON, DAVIES & BRAZIER (2010) discussed its negative impact on the native foodweb. The authors report also about in details a control programme of the invasive Asian cyprinid fish in the United Kingdom.

There is also further information about invasiveness of some alien freshwater fishes, particularly in the specific habitats, e. g. *Gambusia holbrooki* (ALCATRAZ & GARCÍA – BERTHOUS (2007), BENEJAM et al. (2009), *Lepomis gibbosus* (PRZYBYLSKI 2006, UZUNOVA & ZLATANOVA (2007), VAN KLEEF (2008). CUCHEROUSSET et al. (2009) report potential invasiveness in *Lepomis gibbosus* in northwestern Europe. FRANCH et al. (2008) concluded that the spread of the Dojo loach (= Asian weather loach) (*Misgurnus anguillicaudatus*) in Spain and Portugal cause the decline in native fish in the rivers and wetlands.

CUCHEROUSSET et al. (2006) examined the distribution and habitat selection in the invasive Black bullhead (*Ameiurus melas*) in the ditches and surrounded temporary flooded habitats in an artificial wetland in western France. The natural expansion of the Brown bullhead (*Ameiurus nebulosus*) was assisted by intentional introductions carried out by angling associations, fish pond's owners, accidental admixture to the stocking material of the other species and using it as alive bait (WITKOWSKI 2002).

At present, five gobiid species originating from the Black Sea basin are considered as invasive in Europe. KOVÁČ, COPP & SOUSA (2009) informed about invasion of the Bighead goby (*Ponticola* /= *Neogobius kessleri*) in the Danube River. Invasive dispersion against water flow is also described in the Monkey goby (*Neogobius fluviatilis*). The species inhabits the Azov a Black Seas, but it was caught in the middle Vistula River in Poland in 1997, which it reached from the Dniepr River via a navigation canal. In the Danube River it entered to Hungary, in the Dniepr has been distributed up to Belarus (AHNELT et al. (1998), DANILKIEWICZ (1998). VAN KESSEL, DORENBOSCH & SPIKMANS (2009) reported the species' invasion in the Dutch stretch of the Rhine. BIRÓ (1997) considered the *Neogobius fluviatilis* as new species in Central Europe, JURAIDA et al. (2005) in the Slovak section of the Danube River. Age and growth of the Monkey goby in the River Ipeľ (Slovakia) were studied by PLACHÁ et al. (2010).

The Round goby (*Neogobius melanostomus*) is reported by SAPOTA (2004) and CZUGALA & WOŹNICZKA (2010) from the Baltic Sea area. In Central Europe, the species was for the first time found by LUSK et al. (2008) in the Czech Republic.

DANILKIEWICZ (1998) informed about first finding of the Racer goby (*Neogobius gymnotrachelus*) in the Baltic Sea drainage, KAUTMAN (2001) mentioned the species' occurrence in the Slovak waters. OHAYON & STEPIEN (2007) analyzed genetic and biogeographic relationships of the Racer goby at its introduced and native Eurasian locations.

Following the opening of the Rhine – Main – Danube waterway in 1992 the invasive gobiid *Proterorhinus marmoratus* started to colonize the Main River and the Rhine River (VON LANDWÜST 2006). The expansion of the Tubenose goby (*Proterorhinus marmoratus*) in the Morava River basin was described by PRÁŠEK & JURAIDA (2005). GRABOWSKA, PIETRASZEWSKI & ONDRAČKOVÁ (2008) informed about its occurrence in the Wisla River basin, RIZEVSKY et al. (2007) in the Pripyat River (Belarus). It is worth mentioning new morphological and molecular data about the genus *Proterorhinus*. According to new opinions the species *Proterorhinus semilunaris* inhabits the Black Sea basin and the Danube River. It is invasive in Danube and Rhine rivers. The species *Proterorhinus marmoratus* does not

enter pure freshwaters, it inhabits brackish waters in Sevastopol, Crimea (KOTTELAT & FREYHOF 2007). NOLTE et al. (2005) analyse in the Rhine River system rapid upriver invasion of a freshwater sculpin of the genus *Cottus*.

In this paper translocations of native species within various tributaries in within their natural distribution ranges in Europe continent are not discussed. Nevertheless, some of these translocated fishes are remarkable due to their invasive effects, e. g. *Rutilus rutilus*, *Leuciscus cephalus* and *L. leuciscus* in Ireland (STOKES, O'NEILL & McDONALD (2006), CAFFREY, HAYDEN & WALSH (2007), CAFFREY et al. (2008) or the Roach (*Rutilus rutilus*) and the Ruffe (*Gymnocephalus cernua*) in some lakes in the United Kingdom (WINFIELD, FLETCHER & JAMES (2010). BENEJAM et al. (2007) published data on the Wels catfish (*Silurus glanis*) invasiveness.

It is probably that in the future invasive behaviour (to various extent) in some other alien fishes introduced to European waters will appear.

Sea invasive alien fishes and Lessepsian migrations

The Mediterranean Sea is technically a part of the Atlantic Ocean, although it is usually identified as a completely separate body of water. Lessepsian migration (also called Erythrean invasion) is the ongoing migration of marine species across the Suez Canal usually from the Red Sea to the Mediterranean Sea, more rarely in the opposite direction. It is named after Frenchman Ferdinand de Lesseps (1805 – 1894), the engineer in charge of the canal's construction. Invasive fishes originated from the Red Sea and immigrated the Mediterranean by the construction of the canal have become a major component of the Mediterranean ecosystem and can influence of the native ichthyofauna. Summary of "Lessepsian" fishes are pointed out e. g. by ANONYMUS (2007), findings of newly appeared species were published in many papers, e.g. POR (1978), ORSI (1990), PAPACONSTANTINOU (1990), GOLANI (1998), OTERO, GALEOTE & ARIAS (1998), SPANIER (2000), BUCCIARELLI et al. (2002), CIESM (2002), CORSINI, KONDILATOS & ECONOMIDIS (2002), DULČIĆ AND LIPEJ (2002), GALIL & ZENETOS (2002), GOLANI (2002), GOLANI et al. (2002), GOLANI & FINE (2002), STEVENTS et al. (2004), AKYOL et al. (2005), BARICHE & SAAD (2005), BILECENOGLU & KAYA (2006), CORSINI et al. (2002), HARMELIN – VIVIEN et al. (2005), DE MADDALENA & DELLA ROVERE (2005), ÇINAR et al. (2006), CORSINI et al. (2006), ERYILMAZ & DALYAN (2006), GOLANI, GÖKOGLU & GÜVEN (2002)], GOLANI & SONIN (2006), GOREN & GALIL (2006), GALIL (2007), GOLANI, APPELBAUM – GOLANI & GON (2008), LELLI et al. (2008) MAVRUK & AVSAR (2008), GOREN et al. (2010, 2010a).

Mediterranean Sea ichthyofauna can be enriched by the species emigrating from the Indo – Pacific region or the Atlantic region. Only those exotic species of the Indo – Pacific origin that have been recorded since 1920 and of the Atlantic origin since after 1960 are considered. Over hundred species in 29 families of cartilaginous fishes and bony fishes were found there (CIESM 2002). The first registered „lessepsian“ fish was *Atherinomorus lacunosus* found in 1902 (MAVRUK & AVSAR 2008).

GOLANI et al. (1998) summarized records of new fish species having been recently found in the Mediterranean Sea. Since the publication of the Fish Atlas (CIESM 2002), 18 new exotic fish species have been recorded, reaching a total of 108 representing 61 families, of which 37 were new to the Mediterranean ichthyofauna. This is an increase by

20% within only four years. In addition, many established species extended their distribution range. The most substantial range extensions were observed for *Etrumeus teres*, *Sphyrna flavicauda*, *Petroscirtes ancyloдон*, *Callionymus filamentosus* and *Lagocephalus suezensis* from Rhodes, *Upeneus pori* and *Scomberomorus commerson* from Tunis, *Fistularia commersonii* (see KALOGIROU (2007) and *Siganus luridus* from the Tyrrhenian Sea; *Pseudupeneus prayensis* progressed to the northwestern Mediterranean while *Seriola fasciata* reached the eastern Mediterranean due to the shallow Bay of Suez. The general pattern of population growth in invasive fish species in the Mediterranean is characterized by a small founder group that gradually expands its population. However, there have been some examples of invasive fish species experiencing a population explosion shortly after invasion initiated. Two distinct periods of the population explosion were observed. Between 1977 and 1982 four species, *Pempheris vanicolensis*, *Sillago sihama*, *Oxyurichthys petersi* and *Sphoeroides pachygaster* expanded their populations rapidly. Another wave of the population explosion occurred between 2000 – 2005 regarding the species *Fistularia commersonii*, *Plotosus lineatus*, *Hippocampus fuscus*, *Lagocephalus sceleratus* and *Decapterus russelli*.

A total of 160 alien fish species have been reported from the Black Sea – Mediterranean Basin. There are 67 species introduced from the Atlantic Ocean via the Gibraltar, three species of which are originated from the Boreal Atlantic, 86 species introduced from the Red Sea via the Suez Canal, four species of which are originated from the Pacific Ocean. The number of alien fish species increased 68.42% between years 2002 – 2010. Regionally, there are 40 species of the Aegean Sea, 3 species from the Marmara Sea, 5 species from the Black Sea, 96 species from the eastern Mediterranean Sea, 26 species from the Ionian Sea, 36 species from the Tyrrhenian Sea, 14 species from the Algerian coasts, 43 species from the Alboran Sea, 21 species from the Adriatic Sea, 6 species from the Ligurian Sea, 10 species from the Gulf of Lion and 10 species from the Tunisian coasts were reported (see ORAL 2011).

Tropical Atlantic origin in the Mediterranean Sea is known in the following species, e.g. *Carcharhinus altimus*, *C. falciformis*, *Galeocerdo cuvier*, *Rhizoprionodon acutus* (Carcharhinidae), *Sphyrna mokarran* (Sphyrnidae), *Enchelycore anatina* (Muraenidae), *Pisodonophis semicinctus* (Ophichthyidae), *Halosaurus ovenii* (Halosauridae), *Arius parkii* (Ariidae), *Chaunax suttkusi* (Chaunacidae), *Cheilopogon furcatus* (Exocoetidae), *Fistularia petimba* (Fistulariidae), *Gephyroberyx darwini* (Trachichthyidae), *Beryx splendens* (Berycidae), *Scorpaena stephanica*, *Trachyscorpia cristulata echinata* (Scorpaenidae), *Seriola fasciata*, *S. carpenteri*, *S. rivoliana* (Carangidae), *Pseudupeneus prayensis* (Mullidae), *Diplodus bellottii*, *Pagellus bellottii* (Sparidae), *Pinguipes brasilianus* (Pinguipedidae), *Psenes pellucidus* (Nomeidae), *Acanthurus monroviae* (Acanthuridae), *Microchirus boscanion*, *M. azevia*, *Solea senegalensis*, *Synaptura lusitanica* (Soleidae), *Sphoeroides pachygaster* (Tetraodontidae), *Diodon hystrix* (Diodontidae).

Indo – Pacific origin is known in the following species, e.g. *Himantura uarnak* (Dasyatidae), *Dussumieria elopoides*, *Etrumeus teres*, *Herklotsichthys punctatus*, *Spratelloides delicatulus* (Clupeidae), *Rhynchoconger trewavasae* (Congridae), *Muraenesox cinereus* (Muraenesocidae), *Plotosus lineatus* (Plotosidae), *Saurida undosquamis* (Synodontidae), *Parexocoetus mento* (Exocoetidae), *Tylosurus choram* (Belonidae), *Hyporhamphus affinis* (Hemirhamphidae), *Fistularia commersonii* (Fistularidae), *Hippocampus fuscus* (Syngna-

thidae), *Sargocentron rubrum* (Holocentridae), *Pterois miles* (Scorpaenidae), *Papillolociceps longiceps*, *Platycephalus indicus*, *Sorsogona prionota* (Platycephalidae), *Epinephelus coioides*, *E. malabaricus* (Serranidae), *Pelates quadrilineatus*, *Terapon puta* (Teraponidae), *Apogon pharaonis* (Apogonidae), *Synagrops japonicus* (Acropomatidae), *Sillago sihama* (Sillaginidae), *Rachycentron canadum* (Rachycentridae), *Alepes djedaba* (Carangidae), *Leiognathus klutzingeri* (Leiognathidae), *Lutjanus argentimaculatus* (Lutjanidae), *Upeneus moluccensis*, *U. pori* (Mullidae), *Pomadasystridens* (Haemulidae), *Crenidens crenidens*, *Rhabdosargus haffara* (Sparidae), *Pempheris vanicolensis* (Pempheridae), *Abudefduf vaigensis* (Pomacentridae), *Heniochus intermedium* (Chaetodontidae), *Liza carinata*, *L. haematocheila* (Mugillidae), *Sphyræna chrysotaenia*, *S. flavicauda* (Sphyrænidae), *Pteragogus pelycus* (Labridae), *Scarus ghobban* (Scaridae), *Omobranchus punctatus*, *Petroscirtes ancyloдон* (Blennidae), *Corygaloops ocheticus*, *Oxyurichthys petersenii*, *Silhouettea aegyptia* (Gobiidae), *Callionymus filamentosus* (Callionymidae), *Siganus luridus*, *S. rivulatus* (Siganidae), *Rastrelliger kanagurta*, *Scomberomorus commerson* (Scombridae), *Makaira indica* (Istiophoridae), *Cynoglossus simsarabici* (Cynoglossidae), *Stephanolepis diaspros* (Monacanthidae), *Tetrosomus gibbosus* (Ostraciidae), *Lagocephalus sceleratus*, *L. spadiceus*, *L. suzensis*, *Torquigener flavimaculosus* (Tetraodontidae), *Cylichthys spilostylus* (Diodontidae).

Boreo – Atlantic species are found in the Mediterranean Sea only rarely, e. g. *Syngnathus rostellatus* (Syngnathidae), *Centrolabrus exoletus* (Labridae) or *Gymnammodytes semisquamatus* (Ammodytidae).

LIPEJ, MAVRIĆ & BONACA (2009) introduced the term „meridionalisation“ – this is a temperature related factor, which affects the changes in fish species distribution. Some warm water fish species were recorded to spread from southern to northern areas. Such changes in species distribution due to temperature fluctuations were reported for different parts of the Mediterranean (see FRANCOUR et al. 1994) and also in the Adriatic Sea (DULČIĆ et al. 1999), LIPEJ & DULČIĆ (2004). Within exotic fishes invaded to the Mediterranean Sea or to European continent thermophilous species dominated: the fact can be related to climatic changes (see DULČIĆ & GRBEC 2000). Climate changes are modifying fish distribution and the productivity of marine and freshwater species and could also reduce catch in developing countries (CHEUNG et al. 2009, FICKE, MYRICK & HANSEN (2007), BRAND (2007) FAO (2009, 2009A), MCNEELY AND MAINKA (2009), HOEGH – GULDBERG AND BRUNO (2010), SECRETARIAT OF THE CONVENTION ON BIOLOGICAL DIVERSITY (2010), TEN BRINK et al. (2010). LIPEJ, MAVRIĆ & BONACA (2009) used also the term „bioinvasion“ – a recent process, which could be related to different factors. It refers to a (non – indigenous) newcomer species, which originates from other biogeographical province, and when the area of species distribution is disjunct. One of the main factors (although not the only one) is again the temperature.

Anticipated repeated invasions of Lessepsian migrants from the Red Sea to new habitats in the Mediterranean Sea can result in the course of time into the origin of cryptic species which are morphologically identical but highly genetically distinct (found in the Hardyhead silverside, *Atherinomorus lacunosus*, see BUCCIARELLI, GOLANI & BERNARDI (2002). Its Mediterranean population showed high levels of genetic diversity and did not share haplotypes with the northern Red Sea population. Lessepsian invasion by the Hardyhead silverside probably occurred repeatedly and is likely continuing.

Summary

The list presenting alien fishes in European waters includes following families (number of by man introduced species given in brackets): Acipenseridae (3), Polyodontidae (1), Lepisosteidae (1), Anguillidae (3), Cyprinidae (14), Catostomidae (6), Cobitidae (2), Characidae (4), Prochilodontidae (1), Ictaluridae (5), Clariidae (3), Callichthyidae (1), Loricariidae (2), Umbridae (1), Salmonidae (18), Atherinopsidae (1), Adrianichthyidae (1), Fundulidae (1), Poeliidae (5), Gasterosteidae (1), Percidae (1), Moronidae (1), Centrarchidae (6), Cichlidae (14), Odontobutidae (2), Latidae (1), Mugilidae (1), Osphromenidae (1), Channidae (2). Successful introductions (established or acclimatized species at least in some parts of Europe) of non – native freshwater or euryhaline species include at least following 38 species (mostly of them originate from Asia /As/ and North America /NA/, lesser from Middle /MA/, South America /SA/ or Africa /Af/): *Acipenser baerii* /As/, *Carassius auratus* /As/, *Ctenopharyngodon idella* /As/, *Hemiculter leucisculus* /As/, *Hypophthalmichthys molitrix* /As/, *Hypophthalmichthys nobilis* /As/, *Pimephales promelas* /NA/, *Pseudorasbora parva* /As/, *Ictiobus cyprinellus* /NA/, *Ictiobus niger* /NA/, *Misgurnus anguillicaudatus* /As/, *Ameiurus melas* /NA/, *Ameiurus natalis* /NA/, *Ameiurus nebulosus* /NA/, *Ictalurus punctatus* /NA/, *Oncorhynchus gorbuscha* /NA/, *Oncorhynchus mykiss* /NA/, *Salvelinus fontinalis* /NA/, *Salvelinus namaycush* /NA/, *Umbra pygmaea* /NA/, *Liza haematocheilus* /As/, *Odonesthes bonariensis* /SA/, *Oryzias sinensis* /As/, *Gambusia affinis* /NA + MA/, *Gambusia holbrooki* /NA/, *Poecilia reticulata* /SA/, *Xiphophorus helleri* /NA + MA/, *Poecilia sphenops* /MA + SA/, *Culaea inconstans* /NA/, *Ambloplites rupestris* /NA/, *Lepomis gibbosus* /NA/, *Micropterus salmoides* /NA/, *Australoheros facetus* /SA/, *Hemichromis fasciatus* /Af/, *Hemichromis guttatus* /Af/, *Archocentrus multispinosus* /SA/, *Oreochromis niloticus* /Af/, *Perccottus glenii* /As/.

The Rainbow trout (*Oncorhynchus mykiss*), the Grass carp (*Ctenopharyngodon idella*), and the Brook trout (*Salvelinus fontinalis*) are most distributed alien fishes within European countries, these species are also important for angling and fisheries.

Among typical invasive species belong e.g. *Carassius auratus* (resp. *Carassius auratus* „form“ gibelio) and *Pseudorasbora parva*, both occurring in large part of European continent.

A total of 160 sea alien (invasive) fish species (including Leseptians migrants) have been reported from the Black Sea – Mediterranean Basin.

More detailed information about consolidated list of European species of fishes and fish – like vertebrates and their taxonomy, nomenclature, distribution, maximum length and additional literary sources are stated in web pages: <http://aquatab.net/europe>.

Shrnutí

V článku jsou shrnuty publikované údaje o nepůvodních druzích ryb (Actinopterygii) potvrzených na evropském kontinentu a v přilehlých mořích v období od 18. století do současnosti. Za toto období bylo ve sledovaném regionu evidováno minimálně 109 člověkem introdukovaných exotických rybích druhů náležejících do 29 čeledí. Úspěšná introdukce člověkem s dokončenou aklimatizací a naturalizací (alepoň v některých lokalitách evropského kontinentu) byla zaznamenána přinejmenším u 38 sladkovodních druhů

(většinou pocházejících z Asie a Severní Ameriky, méně ze Střední a Jižní Ameriky nebo Afriky). Několik nepůvodních sladkovodních druhů lze klasifikovat jako invazivní, příkladem může být karas stříbrný či střevlička východní. Zmíněna je i lessepsiánská migrace a pronikání nových druhů ryb do k Evropě přilehlých moří. Aktuální informace o evropských rybách a rybovitých obratlovcích lze nalézt na webové stránce: <http://aquatab.net/europe>.

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