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Alien fish species in the Czech Republic and their impact on the native fish fauna

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A b s t r a c t. Over the past 150 years, the waters of the Czech Republic were experimentally stocked or invaded by a total of 41 alien (non-native) fish species. The following species have become fully naturalized and produced self-sustained populations: *Carassius gibelio*, *Pseudorasbora parva, Ameiurus nebulosus* and *Gasterosteus aculeatus,* which produced stable populations in several spatially limited localities. In some cases *Oncorhynchus mykiss, Salvelinus fontinalis* and *Coregonus maraena* will produce instable temporary populations based on released material obtained from fish farms and ponds. The occurrence of the remaining acclimatized alien species *(Coregonus peled, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Aristichthys nobilis)* in natural ecosystems and fishponds depends on stocking fish obtained from artificial spawning and cultures. The documented annual average production of alien species fit for human consumption amounts to around 2 000 tonnes, i.e. 8.2 % of the annual average production of marketable fish cultures in the Czech Republic. A significant negative impact of the introduced species on native ichthyofauna has been ascertained as regards its ecological, biological properties, biodiversity and health. Considered a typical invasive alien species, *Carassius gibelio* heavily depressed the occurrence and numbers of indigenous *Carassius carassius* populations and also contributed to the decreased numbers of *Tinca tinca, Leucaspius delineatus* and other native cyprinid fish. *P. parva* and *A. nebulosus* show a much weaker and limited impact. The introduction of *C. idella* was accompanied by the introduction of the tapeworm species, *Bothriocephalus gowkongensis,* which subsequently caused heavy losses in cultures of *Cyprinus carpio.* In 2008, *Neogobius melanostomus* was recorded for the first time in this country at the confluence of the Morava and Dyje rivers.

Key words: introduction, translocation, invasion

Introduction

Introductions of alien fish species are an important part of human activities concerning aquatic ecosystems. At present, such species are considered one of the major causes of erosion or devastation of the native fish biodiversity in freshwater ecosystems (e.g. Miller et al. 1989, Moyle & Light 1996, Cowx 1997, Gido & Brown 1999, Elvira & Almodóvar 2001, Riberio et al. 2008), even if there occasionally occur more cautious opinions on the consequences of the introductions (Cowx & Gerdeaux 2004, Gurevitch & Padilla 2004). Most of the intentional introductions aimed to bring benefits to fishery management, aquaculture and fishpond production or in the case of natural ecosystems, by a need to fill vacant niches, to increase production of forage fish for predators, and to provide new objects for sport fishing and ornamental fish (for a review see Welcomme 1988, Holčík 1991, Elvira 2001, Copp et al. 2005). In the past no heed was paid to the risks of introductions or the latter were not thoroughly premeditated, often because the negative impacts of the alien fish species became apparent only some time after the alien species had been introduced and established in the ecosystem. The studies reviewing fish introductions and, at the same time, attempting to evaluate the positive and negative consequences of such activities already attain the order of magnitude of thousands both on a wider and a regional scale (e.g. Welcomme 1988, Allendorf 1991, Crossman 1991, Cowx 1997, Keith & Allardi 1997, Efford et al. 1997, Elvira & Almodóvar 2001, Bogutskaya & Naseka 2002, Kolar & Lodge 2002, Witkowski 2002, Marchetti et al. 2004, Copp et al. 2005, Riberio et al. 2008, Grabowska et al. 2010).

In connection with the problem of conserving and protecting the biodiversity of native ichthyofaunas on a European scale, specific attention has been paid to the impact of alien taxa on native fish species (e.g. Witkowski 1989, Holčík 1991, Almaça 1995, Elvira 1995, Crivelli 1995, Lelek 1996). The introduction of alien fishes, connected with the aspect of biological invasion, is among other grave topics in a number of papers (e.g. Moyle & Light 1996, Rainbow 1998, Elvira & Almodóvar 2001, Lusk et al. 2004b, Garcia-Berthou et al. 2005, Garcia-Berthou 2007). The problem of alien species has become one of global importance, particularly as a result of the direct or indirect connection of previously separate hydrological systems by artificial channels, as well as in connection with shipping.

Recently, researchers have been focussing on the global aspects and evaluations of introducing alien species, analysing and attempting to define the causes of their success or failure, studying their invasions and ways of introduction (e.g. Kerr et al. 2005, Moyle & Marchetti 2006, Riberio et al. 2008). Based on such analyses, one can predict, with considerable safety, the successful invasions of naturalized alien species, yet it is still impracticable to control or stop them (Moyle & Marchetti 2006, Riberio et al. 2008). Vigorous measures, effective in spatially limited areas only (Meronek et al. 1996), are not permissible in view of the present aspects of nature conservation. The so-called biological control (predation, infestation with parasites and/or pathogens) of established alien species is problematical (Thresher 2008). Therefore, the rather negative attitude towards alien species is accompanied by a sceptical attitude towards possibly successful measures to be taken against established alien species (Garcia-Berthou et al. 2005, Thresher 2008). Nor is there a uniform opinion on the approach towards introduced species (denoted as "neozoans") that have become permanent components of regional ichthyofaunas, in view of the system of nature protection (Lelek 1996). This has its reflections even in legislation, there no longer being attempts to separate the long established alien species as "alien" species (Copp et al. 2005).

Even in the Czech Republic the introductions of non-indigenous fish species have been important both in their positive and negative consequences for fishery management as well as for the native components of the ichthyofauna of natural ecosystems. Several summarizing papers have been published on the introduction of fishes into the waters of the Czech Republic (e.g. Čihař 1968, Kálal 1987, Baruš & Oliva 1995, Adámek & Kouřil 1996, Lusk et al. 1998a). However, they are mainly aimed at evaluations of the success of the particular attempts. In the present contribution we attempt at an overall assessment of introductions of non-native fish species in the Czech Republic.

Methods

In this paper, the term "introduction" is used to denote a release of an alien fish taxon outside its native geographic region (e.g. Holčík 1991). This term does not apply to releasing a fish species within its distribution range but belonging to a different population, even if there are certain identical biological aspects as regards population genetics (Ferguson 1990, Garcia-Marin et al. 1999). The hydrographic network in the territory of the Czech Republic (78 864 km^2) belongs to the drainage areas of three seas: the Black Sea (25.4%), the Baltic Sea (9.4%), and the North Sea (65.2%), Hanel & Lusk (2005). The native occurrence of some of our fish species is limited to a particular sea drainage area only. In this paper, the term "translocation" is used to denote the transfer, within the Czech Republic, of a fish species from one sea drainage area to another, and these activities are not considered as introductions. We consider an alien taxon to be naturalized when it has established self-sustained and successfully reproducing populations independent of additional human activities. A taxon is denoted as acclimatized whose permanent or temporary presence in natural habitats is dependent on human activities (artificial reproduction, rearing, stocking). In deciding whether or not an alien species is invasive, we adhered to the definition in the "European Strategy on Invasive Alien Species, Council of Europe" (Genovesi & Shine 2003). Those alien species whose introduction, naturalisation and dispersal endanger the native diversity are considered to be invasive. Denoting a native species that in certain cycles can pass a population explosion connected with incidental marked dispersal is quite incorrectly denoted as invasive. We have thoroughly considered denoting a species as an invasive alien species in view of additional possible limiting measures that would follow from the legislative norm for alien invasive species in preparation.

The present review paper is based, partly on published papers quoted but mainly on our own published and unpublished data obtained from ichthyological research on the waters in the Czech Republic, implemented over the past forty or more years (Hanel 2003, Lusk et al. 2004a, Lusk & Lusková 2005). Since there is no central register of introductions and some of the individual attempts have been registered insufficiently or not at all, their total number may not be final. Occasional cases of aquarium fishes released in free nature are not considered attempts at introduction.

The complete scientific names of species have been unified according to FishBase (Froese & Pauly 2009) and Eschmeyer (2010), higher taxa (families) according to Nelson (2006).

Abandoning the use of the "subspecies" category in fish taxonomy resulted in taxonomic instability in the case of certain species, as exemplified by the originally specific taxon, *Carassius auratus*. At present, the originally subspecific taxa, *Carassius auratus auratus* and *Carassius auratus gibelio* (Pelz 1987, Szczerbowski 2001) are now considered to be two independent species, *C. auratus* and *C. gibelio* (Kottelat & Freyhof 2007). Besides, there is a group of Japanese silver crucian carp taxa some of which are given the taxonomic status of independent species (e.g. *Carassius cuvieri),* while others are presented as subspecies, forms, or biotypes within *Carassius auratus (C.a. buergeri, C. a. grandoculis, C. a. langsdorfii,* see (Murakami et al. 2001, Iguchi et al. 2003, among others). Genetical analyses of "silver crucian carps", occurring in the natural conditions of the Czech Republic, have revealed the occurrence of three forms which, however, cannot be separated on the basis of morphological characters (Vetešník et al. 2007, Papoušek 2008). These forms are *C. auratus, C. gibelio,* and *C. langsdorfii,* also considered to be separate species (Kottelat 1997, Kalous et al. 2007). All these three species/forms are non-indigenous to central Europe including the Czech Republic.

Results and Discussion

Most of the attempts at introducing non-native species did not take place until 150 years ago, usually following introductions on an international scale. In all, we obtained records and information on attempted introductions of some 41 non-native fish species (Table l). Information is available on the course and results of introductions for most species introduced into the Czech Republic and released in fishponds or directly in natural habitats. Around 1976, *C. gibelio* invaded the area of confluence of the Morava and Dyje (Thaya) rivers by natural migration from the Danube through the Slovakia – Austria section of the Morava River. A similar situation was repeated 30 years later, when we recorded, in that area, the first occurrence of *N. melanostomus*, which had immigrated from the Danube. Mere short notes on occasional, short-lived and unsuccessful attempts at introductions, dating from the late 19th and early 20th centuries that do not permit any more detailed evaluation, are available on several additional species *(Salmo*

Table 1. List of introduced fishes in the Czech Republic (Purpose: P - Production, B - Bioamelioration, C - Catch anglers, E - Experiment. Results of introduction: A - Acclimatisation, R - Dependent on artificial reproduction, N - Unsuccessful).

Species	Year of first introduction	Purpose of introduction	Results of introduction
ACIPENSERIDAE			
1. *Acipenser stellatus* Pallas, 1771	1993	E	
2. *Acipenser gueldenstaedtii* Brandt & Ratzeburg, 1833	1994	E	
3. *Acipenser baerii* Brandt,1869	1982	E	
4. *Acipenser nudiventris* Lovetsky, 1828	1994	E	
POLYODONTIDAE			
1. *Polyodon spathula* (Walbaum, 1792)	1995	E	
SALMONIDAE			
1. *Oncorhynchus mykiss* (Walbaum, 1792)	1880	P, C	A, R
2. *Salmo dentex* (Heckel, 1851)	1901 (?)	E	N
3. *Salvelinus alpinus* (Linnaeus, 1758)	1759	P	N
4. *Salvelinus fontinalis* Mitchill, 1815	1880	P, C	A, R
5. *Salvelinus namaycush* (Walbaum, 1792)	1972	C, B	N
6. *Coregonus albula* (Linnaeus, 1758)	1889 (?)	C	N
7. *Coregonus maraena* (Bloch, 1779)	1882	P	A, R
8. *Coregonus peled* (Gmelin, 1789)	1970	P	A, R
9. *Coregonus autumnalis* (Pallas, 1776)	1959	P	N
10. *Coregonus fera* Jurine, 1825	1889 (?)	E	N
11. *Coregonus wartmanni* (Bloch, 1784)	1893	E	N
12. *Thymallus arcticus baicalensis* (Dybowski, 1874)	1959	C	N
CATOSTOMIDAE			
1. *Ictiobus cyprinellus* (Valenciennes, 1844)	1985	E	
2. *Ictiobus niger* (Rafinesque, 1819)	1985	E	
CYPRINIDAE			
1. *Ctenopharyngodon idella* (Valenciennes, 1844)	1961	P, B	R
2. *Pseudorasbora parva* (Temminck & Schlegel, 1842)	1976		A
3. *Carassius gibelio* *	1975		A
4. *Hypophthalmichthys molitrix* (Valenciennes, 1844)	1961	B, P	A, R
5. *Aristichthys nobilis* (Richardson, 1845)	1964	B, P	A, R
6. *Mylopharyngodon piceus* (Richardson, 1846)	2000	B	
ICTALURIDAE			
1. *Ameiurus nebulosus* (Lesueur, 1819)	1890	P, C	A
2. *Ameiurus melas* (Rafinesque, 1820)	2003		
3. *Ictalurus punctatus* (Rafinesque, 1818)	1985	C	N
CLARIIDAE			
1. *Clarias gariepinus* (Burchell, 1822)	1985	P	
GASTEROSTEIDAE			
1. *Gasterosteus aculeatus* Linnaeus, 1758	1915		A
CHANNIDAE			
1. *Channa argus* (Cantor, 1842)	1956	E	N
CENTRARCHIDAE			
1. *Micropterus dolomieu* Lacépède, 1802	1889	P, C	N
2. *Micropterus salmoides* Lacépède, 1802	1889	P, C	N
3. *Lepomis gibbosus* (Linnaeus, 1758)	1929	C	C
4. *Lepomis auritus* (Linnaeus, 1758)	1913 (?)	E	N
5. *Ambloplites rupestris* (Rafinesque, 1817)	1892 (?)	E	N
CICHLIDAE			
1. *Oreochromis aureus* (Steindachner, 1864)	?	E	
2. *Oreochromis mossambicus* (Peters, 1852)	?	E	
3. *Oreochromis niloticus* (Linnaeus, 1758)	1985	E	
4. *Oreochromis urolepis hornorum* (Trewavas, 1966)	?	E	
GOBIIDAE			
1. *Neogobius melanostomus* (Pallas, 1814)	2008		

Explanations

(?) The year of introduction is not known even approximately 1889 (?); the given year indicates when a report on the introduction was published, the introduction having probably taken place a year before.

* Occasionally, *C. auratus* and *C. langsdorfii* also occur in *Carassius gibelio* populations.

dentex, Coregonus wartmanni, Coregonus fera, Lepomis auritus, Ambloplites rupestris (Hanel 2003). In that period the introduction mostly followed those of imported alien species native in North America, in most cases through Germany. Another period, richest in introduction activities, followed after 1950 (see Table l). In the first part of that period, alien species were imported from the former Soviet Union where large-scale introductions were carried out. The introductions of these alien species in the Czech Republic were mainly motivated by production reasons and utilisation of excess food supply in fishponds *(Coregonus peled, C. idella, H. molitrix, A. nobilis)*. In the past 20 years, attempts at introducing alien species have been based on no rational reasons; in most cases they are imports of "research objects" without any wider utilisation (species of the genera *Oreochromis, Acipenser, Ictiobus,* and *Polyodon spathula,* see Table l). Recently, the mollusc-eating species, *Mylopharyngodon piceus,* was imported in this country but has not been used so far beyond research objects in view of its possible undesirable effect on protected mollusc species.

Several alien species were unintentionally introduced as admixtures to imported stock fish. Thus, *Lepomis gibbosus* was imported with carp stock from former Yugoslavia in 1929. After 1980, *P. parva* was imported with stocks of *C. idella, H. molitrix* and *A. nobilis* from Hungary and released in various places. Quite recently, evidence was obtained on unintentional introduction of *Ameiurus melas* with carp stock from Croatia to the fishponds in the Třeboň district in 2003 (Koščo et al. 2004). A special case is that of *C. gibelio,* which migrated from the Danube to the confluence of the Morava and Dyje rivers. Its subsequent dispersal was connected, apart from its own migration activity, with intentional as well as unintentional transfer of this species, mostly due to admixture to, or mistake for, stocks of *C. carpio* (Lusk 1986).

At present, 49 native fish species occur in the waters of the Czech Republic (Lusk et al. 2004, 2006). Besides, there occur, in various extents, 11 alien species that are either quite naturalized (4 spp.) or acclimatized (7 spp.). Their permanent or temporary occurrence depends on artificial reproduction and stocking from cultures. Thus, there appears a quite logical question of the success of attempts at introducing alien species. Moyle & Light (1996) consider abiotic conditions to be decisive for the successful establishment of alien species. In some cases, biotic factors may also play a part. Thus, e.g. Holčík (1980) considers a heavy drop in the numbers of predatory fish in the lower part of Danube drainage area to be an important circumstance in the invasion of the alien *Carassius gibelio.*

Of the 41 recorded attempts at introducing alien species in the Czech Republic, only four species (*C. gibelio, P. parva, A. nebulosus, G. aculeatus*) were established and naturalized. Another seven alien species became acclimatized but either they do not spawn in natural conditions *(C. idella, H. molitrix, A. nobilis),* or they do spawn but the establishment of their populations is short-lived *(C. maraena, C. peled, O. mykiss, S. fontinalis).* The group of acclimatized species is utilised for production in aquacultures and fishponds. Quite new is the recently observed occurrence of *N. melanostomus* in the area of confluence of the Morava and Dyje rivers in 2008 (Lusk et al. 2008). Several specimens were ascertained in the streams of the rivers Dyje (r. km 26.7) and Morava (r. km 74.1) below weirs acting as migration barriers. The species occurred there as a result of upstream migration from the Danube through its Slovakia – Austria section, 70 km in length, lacking migration barriers (Lusk & Holčík 1998). The species belongs to the species group of the genus *Neogobius* and *Apollonia* which, in recent years, have gradually invaded and occupied river systems of eastern and central Europe. In the Danube, at the mouth of the Hron River, *N. melanostomus* was first recorded in 2003 (Stráňai & Andreji 2004). Presumably, the species will become permanently established at the confluence of the Morava and Dyje rivers and will preferably populate sections with reinforced banks. At present, this habitat is populated by *Proterorhinus semilunaris* (according to taxonomic opinions published by Kottelat & Freyhof 2007, Freyhof & Naseka 2008). In view of the hitherto observations in the Danube, one may presume that *N. melanostomus* will gradually replace *P. semilunaris* in that microhabitat. The spontaneous upstream migration of this alien species along the two rivers is impeded by a number of weirs, even if fish ladders have been constructed in the Dyje River. Like other gobies in Slovakia, *N. melanostomus* is evaluated as an invasive alien species (Kováč et al. 2007).

What is the success of introductions in the Czech Republic? We consider that human factors (experience, interest, single-mindedness) were decisive in determining the success or failure of alien fish introductions. For instance, the selection of *Channa argus, Salvelinus namaycush* or *Ictalurus punctatus* for introductions in natural habitats was quite unsuitable and professionally wrong. The extent and systematic nature of endeavours at a successful introduction (repeated import, number of individuals, artificial culture) also plays an important part. Of objective environmental influences, this is primarily the small territorial size of the Czech Republic, with most of the river network consisting of the headwater sections of rivers (mostly of the Ist to IVth order), as all streams flow away from the territory. Only such major rivers as the Labe (Elbe), Odra (Oder), and Morava could present rather important water ways for incidental immigration of new species. This, however, is impeded or complicated by various kinds of migration barriers. Such barriers are only absent from the lower reaches of the Morava River, which allowed various fish species to migrate upstream from the Danube (Lusk & Holčík 1998). This was the way used by the alien species, *C. gibelio* and recently also *N. melanostomus.* Also, the water temperature regime in the course of the year (0-2 °C in winter, max. 25 °C in summer) excludes the presence of a number of alien species or prevents them from reproducing and becoming established. Acclimatized alien species are maintained only because they are the object of artificial cultures and subsequently utilised for production in fishponds or artificial reservoirs. This situation is very favourable as regards native ichthyofauna. If, however, the alien species fails to yield effects expected in fishponds its further maintenance is ceased. This was the case of fishpond cultures of *Micropterus salmoides* and *A. nebulosus.* The two species were also widely released in natural habitats. Only *A. nebulosus* became established in the lower reaches of the Labe River. *M. salmoides* has only been preserved in research objects, only very rarely is caught in open waters (in the wake of fade-out from closed fish cultures, see Hanel 2001).

At present the zoogeographic integrity coefficient (ZIC, i.e. the number of native species divided by the total number of species present in the system, Bianco 1990) for the Czech Republic attains the value of 0.82 when naturalised and acclimatized species are included. This indicates a slight improvement from the situation a decade ago when the ZIC value was 0.78 (Lusk et al. 1998). The major cause of this improvement is seen in the recently renewed occurrence of some of the native species (Lusk et al. 2006). If only the naturalized species are included in the evaluation, the resulting ZIC value is 0.92. Distinctly higher shares of alien species are found in extensive regions lacking marked temperature limits. Elvira (1995) found similar ZIC values for Spain (ZIC = 0.63) and Portugal (ZIC = 0.65). Data for Italy (ZIC = 0.56) indicate considerably higher degree of disturbance (Bianco 1990). The high value of this coefficient for Greece (ZIC = 0.88) is also due to the rather high share (78) of native species (Economidis 1991). The value of ZIC computed from the data stated by Keith & Allardi (1997) is 0.69.

Evaluation of introductions of most important alien species

Only the following fish species have become well-established in the Czech Republic: *C. gibelio* (an East Asian form, first immigrants ascertained in 1976, Lusk et al. 1977), *P. parva* (unintentionally introduced in 1981-1982, Šebela & Wohlgemuth 1984)), and *A. nebulosus* (introduced in 1890). These three species have become a permanent part of the ichthyofauna of this country and are no longer dependent on human activities. As regards impact on native biodiversity, *C. gibelio* has shown unequivocally negative effects and has therefore been evaluated as invasive. The other two species can only be classified as "alien invasive species" with some limitation. At present, *A. nebulosus* occurs only locally, without showing any tendency towards spreading. Rather large numbers of *P. parva* occur only as a result of fishpond draining. *G. aculeatus* has established permanent population in a few localities only, without any marked impact on either ecosystems or biodiversity. Below are analysed in greater detail the problems of three important naturalised alien species that show various degrees of direct or indirect negative influence on native biodiversity.

Carassius gibelio

According to the FAO database, this "taxon" – *C. auratus* and *C. gibelio* – are among the 10 most frequently introduced subjects, showing the highest degree of success (92.3%) (Garcia-Berthou et al. 2005). In the Czech Republic, *C. auratus* is solely the object of rearing for ornamental purpose (aquariums, garden pools). Occasionally, it occurs in free nature as a result of releasing. Contrary to western Europe, the species has not established independent populations (Oliva & Hruška 1955, Collares-Pereira & Moreira da Costa 1999, Balon 2004, Hänfling et al. 2005). The Japanese form, *C. langsdorfii,* was occasionally found in this country after 2000 and established an independent population in single case (Kalous et al. 2007, Vetešník et al. 2007). The presence of this Japanese taxon in this country has not been clarified. *C. gibelio* is the dominant taxon in central and eastern Europe incl. the waters of the Czech Republic (Lusková et al. 2004). At present, the species is spreading into western Europe where only *C. auratus* has hitherto occurred (Verreycken et al. 2007).

The first occurrence of *C. gibelio* in the waters of the Czech Republic was ascertained in the area of confluence of the Dyje and Morava rivers after 1975. It penetrated here migrating through the lower section of the Morava River from the Danube. In subsequent years, it gradually expanded, also with the help of humans, into most waters all over the Czech Republic (Lusk et al. 1977, Lusk 1986). Initially, it was a monosexual population that consisted of females showing triploid karyotype (Peňáz et al. 1979) and reproduced gynogenetically. After 1990, males began gradually occurring in the population and at the same time there occurred diploid individuals besides triploid ones. Besides the gynogenetical way, the population gradually began reproducing bisexually. At present the populations are mixed as to their ploidy status and as regards reproduction. *C. gibelio* has become a permanent and important component of our fish communities, particularly in lowland regions (Lusková et al. 2004).

In view of its biological properties and requirements, *C. gibelio* is a competitor for a number of cyprinid fish species. Having penetrated into fishponds, it yields production of substantially lower marketable value to the detriment of *C. carpio,* the main productive species. Thus, for example in some of the fishponds situated in the floodplain of the Dyje River, the financial losses attained up to 200 – 300 EUR per hectare, owing to the excessive occurrence of *C. gibelio* in 1999. Our observations show that in natural aquatic habitats in the floodplain along the lower section of the Dyje River the number and biomass of *C. gibelio* amount to 2 500 individuals and 390 kg biomass per hectare of water surface. This situation results in enormous competition for food and space and the drop in numbers or even the vanish of characteristic native fish species, such as *C. carassius, T. tinca, L. delineatus,* and *Scardinius erythrophthalmus.* Besides, we have observed mass sexual parasitism of triploid female *C. gibelio*, spawning with male *C. carpio* and *Abramis brama,* less frequently even *C. carassius, Rutilus rutilus, Abramis bjoerkna*, and *T. tinca* (Lusk et al. 1998b, unpublished data). Hybridization with *C. gibelio* exerts a negative impact even on the initial status of populations of *C. carassius* (Papoušek et al. 2008). A similar observation is the undesirable hybridization between *C. carassius* and *C. uratus* in England (Hänfling et al. 2005).

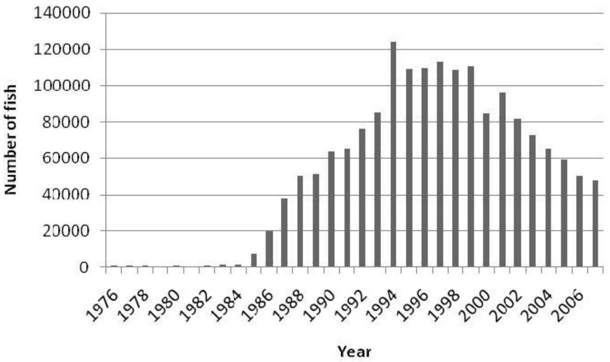

Fig. 1. Catch of *Carassius gibelio* obtained by anglers in the Czech Republic between 1976 and 2007.

At present, *C. gibelio* is the dominant fish species in lenitic and slowly running aquatic habitats in the floodplains of major rivers, particularly in the drainage areas of the Morava and Dyje rivers. As a part of fishery management, it has also been released with water during fishpond draining. It is an important object of angling. The bags of *C. gibelio* attained maximum sizes around 1995 (cf. Fig. 1). There is evidence of the gradual expansion of the species, however, the bag sizes have been dropping in recent years because of decreased interest of anglers for this species.

Pseudorasbora parva

The native range of this species lies in eastern Asia. From that region, the species dispersed in 1960-1970, with imported stocks of various fish species into Russia and several European countries lying along the Danube (Romania, Hungary, etc.) (Witkowski 2006). In 1981 and 1982, it was introduced all over the Czech Republic with stocks of *C. idella, A. nobilis* and *H. molitrix* imported from Hungary (Šebela & Wohlgemuth 1984, Libosvárský et al. 1990). The species found suitable environmental conditions especially in fishponds and adjacent channels, besides minor aquatic habitats such as various pools. In case of mass reproduction, this species will become a serious food competitor for other plankton feeding fish (above all, young of the year) and also exert a negative influence on the environment (Adámek & Sukop 2000). In streams this species occurs primarily with waters drained from fishponds, sometimes in large numbers. Permanent more numerous populations are exceptionally produced outside fishponds and their adjacent channels, however. The spread of *P. parva* in Slovakia has affected native species in a negative way (Žitňan & Holčík 1976). The mass occurrence of *P. parva* in fishponds is sometimes thought to be the reason why *L. delineatus,* a small native fish species, has vanished. In the past, this native species occurred in great numbers, mainly in extensively managed small ponds. *L. delineatus* became scarce after the intensity of carp cultures (higher stocks, annual fishpond draining) was markedly increased before introduction of *P. parva*. In the ponds the introduced *P. parva* occupied the trophic niche "vacated" by the already vanished *L. delineatus. P. parva* has also been associated with the introduction and transmission of the pathogen called the "rosette-like agents" as well as with a marked competition pressure (Gozlan et al. 2005, 2006). *L. delineatus* currently occurs in the few sparse populations in the floodplains of major rivers in the Czech Republic, hence it is classified as endangered in the Red List (Lusk et al. 2004a).

Ameiurus nebulosus

In the late 19th century, this species was repeatedly imported into Europe from North America. In 1890, it was imported into the present Czech Republic for the purpose of fishpond cultures. Subsequently, *A. nebulosus* was also released in streams and reservoirs all over the territory. The culture of this species in fishponds gradually died out because of its slow growth rate. The species produced permanent populations in the lower reaches of major rivers and the water bodies of their adjacent floodplains. Still around 1950, it was found in a number of localities in the Czech Republic (Vostradovský 1958). At present it only occurs in the lower sections of the Labe (Elbe) and Vltava (Moldau) rivers and in the pools of their adjacent floodplains and river branches, and in an isolated place near Kroměříž in the Morava River drainage area (Koščo et al. 2004). Inconsistent opinions have been published on the negative influence of *A. nebulosus* on native fish species. Our own observations implemented on the Labe River, where *A. nebulosus* was very numerous in sections with rugged banks (2-7 ind. per 1 m of bank), other species *(Gobio gobio, Perca fluviatilis, Barbatula barbatula, Leuciscus cephalus)* occurred only occasionally. Presumably, its competitive pressure may be apparent in its requirements for space and shelter, yet it may even compete for food and become a predator on fish larvae and small individuals, cf. Wohlgemuth (1987). The negative impact of *A. nebulosus* is considerably limited due to its local occurrence and heavily decreased numbers.

Specific groups of alien species

Optimum subjects are included in the group of introduced alien species: *C. maraena, C. peled, S. fontinalis, O. mykiss, C. idella, H. molitrix* and *A. nobilis,* the existence and occurrence of which depends on artificial reproduction, rearing and releasing stock fish. They are capable of living in natural aquatic habitats in the Czech Republic, yet they have not established stable populations. If natural reproduction of these species does occur in some localities the resultant populations are short-lived *(S. fontinalis, O. mykiss, C. maraena).* These species are either utilised for production purposes or released in natural habitats for the purpose of sport fishing. To a limited extent they may be utilised in bio-amelioration. The species *O. mykiss, C. idella, H. molitrix* and *A. nobilis* are most important as regards biomass production. Together with the widely distributed *C. gibelio* and *P. parva,* releasing these alien species markedly increases the original natural species richness in the individual mapping quadrats of the Czech Republic (Krojerová-Prokešová et al. 2008).

A specific group comprises species native in subtropical and tropical regions, which cannot permanently survive all year round in the natural habitats in the Czech Republic owing to temperature conditions. Alien species of this group, imported as part of experimental introductions, include *Oreochromis aureus, O. mosambicus, O. niloticus, O. urolepis,* and *Clarias gariepinus.* In warm water aquaculture, these species can assert themselves to a limited extent, and their importance in the Czech Republic is negligible. Of similar purpose and importance are the experimental introductions of selected species of sturgeon (Table l). This group also comprises some of the species kept in aquarium cultures. These species can survive for a short time in stream sections into which warm sewage waters are drained (e.g., *Poecilia sphenops, Poecilia reticulata,* and *Xiphophorus helleri*). *G. aculeatus* is the only alien species that had originated in aquarium cultures and has established permanent populations in a few localities. A number of additional species (Table l), each of which were imported only once or in a limited number of attempts, failed to find any important niche in habitats of the Czech Republic.

Apparently due to aquarists who tend to recklessly release some of their breeds into free waters, some exotic species have rarely been registered in our waters, such as the catch of a piranha (family Characidae, species not determined exactly) on hook and line in the Olše River (Hanel 2001). Apparently owing to escapes from aquacultures, sport anglers could record catches of *O. niloticus, Ictiobius niger,* and *Huso huso* in our free waters.

In order to have a full picture, we include here species that are not considered alien in the Czech Republic but were translocated into the waters belonging to different sea drainage areas. In the 12th to 14th centuries, *C. carpio* and later also *Sander lucioperca* were translocated from the drainage area of the Morava River (Black Sea river network) into that of the Labe River (North Sea network) and the Odra River (Baltic Sea network). Unsuccessful transfers of *H. hucho* were implemented from the Morava River drainage area into that of the Labe River. In recent decades, successful experimental transfers of *Chondrostoma nasus* were implemented from the Morava River basin into the drainage areas of the Labe and Vltava Rivers (North Sea network). *Anguilla anguilla,* a species not indigenous in the drainage area of the Morava River, has been repeatedly released in that river.

Production assets

During 2001 to 2006, the alien species have only yielded a small part (8.15%, i.e. 2 001.8 tonnes) of annual total fish production fit for human consumption, which averages 24 570 tonnes in the Czech Republic. Most of that total is produced by carp, *C. carpio.* The average annual production of the individual alien species is: *H. molitrix* and *A. nobilis* 742.4 tonnes, *C. idella* 384.3 t, *O. mykiss* 695 t, *S. fontinalis* 115.6 t, *C. maraena* and *C. peled* 33 t, and *C. gibelio* 31.5 t. Most of the above production is obtained in fishponds and intensive aquacultures. Only a smaller part is obtained from some species caught with hook and line in free waters: *C. gibelio* (100%), *C. idella* (21.8%), and *O. mykiss* (7.2%) (Ženíšková & Gall 2007). In the past, *M. salmoides* and *A. nebulosus* were also raised in fishponds for the purpose of obtaining their production. With increasing fishpond management intensity their culture was ceased due to their slow growth. *A. nebulosus* locally produced numerous natural populations in the lower and middle section of the Labe River. For some time after 1950, it was among the important objects of sport fishing in that area; for instance in 1957, the total bag size of that species was 66 000 individual fish, totalling 6.3 tonnes. At present only small numbers are bagged in that area and the bags are not specifically recorded in the statistics (Vostradovský 1958, Koščo et al. 2004).

Negative impact

The first and most significant consequences of introduction of an alien fish species become apparent in the impaired health condition of the native species. The function of introduced fish species as hosts of various parasites and diseases, followed by losses among native fish species, is well documented (e.g. Stewart 1991, Keith & Allardi 1997). In the Czech Republic, the introduction of *C. idella* was accompanied by the introduction of the tapeworm, *Bothriocephalus gowkonensis.* This parasite then infested *C. carpio* and caused, in 1970-1980, considerable losses in carp fishpond cultures, especially among fish up to 1.5 years of age. In addition to direct losses caused by carp mortality, considerable sums of money had to be paid for the treatment of the infested carp (Zajíček 1987). Converted to the present costs, they amounted to 0.5 – 0.8 million EUR annually. Import of stocks of *Anguilla anguilla* from Italy in 1991, which were subsequently released in streams and reservoirs in the Morava River drainage area (in which eel are not native), caused the introduction of the nematode, *Anguillicola crassus.* Subsequent infestation with this nematode caused local mortality of eel. For instance, in 1954 over 3.5 tonnes of eel died in the Vranov Reservoir and the total bag size dropped markedly in subsequent years (Baruš et al. 1999). Also known are health problems in intensive cultures of salmonid fishes in connection with transportation of stocks (e.g. ulceral dermal necrosis), temporarily occurring even in populations of *Salmo trutta* living in streams. As a rule, however, most of the infections pass from the explosive outbreak to an inhibitory phase.

Ecological and biological risks are mainly caused by alien species that have become fully established and acclimatized in natural ecosystems and show natural reproduction. In suitable conditions, such species produce abundant populations, as stated above for *C. gibelio* in the Czech Republic, with subsequent depressive impact on native taxa. A similar influence of *C. gibelio* on native species in the Danube Delta was indicated by Navodaru et al. (2000). Introduction of alien species presents high risks to genetics on both specific and intraspecific levels. A high degree of hybridization between *S. trutta* and *S. marmoratus* in natural conditions has been reported from Slovenia (Povž et al. 1996, Meldgaard et al. 2007). In the Czech Republic, extensive hybridization took place between introduced *C. maraena* and *C. peled,* resulting in distinctly decreased fitness of the hybrids, associated with high mortality rate among both juveniles and adults. The enlarged range of *Chondrostoma nasus* has been connected with the depression of native species, *C. toxostoma* (Nelva 1997) and *C. soeta* (Povž 1983) in their natural environments.

Introduced alien species also show negative influence on the quality of aquatic environments, especially if producing abundant populations. A dense population of *C. gibelio* distinctly increases water turbidity, decreasing its transparency in minor pools and fishponds. In separated river branches populated by this species at biomass around 100 kg or more per hectare (Lusková et al. 2002), we found water transparency less than 20 cm throughout the growing season (April to September, unpublished observations in the floodplain or Dyje River). It was caused by physical particles raised from the bottom. Similar observations were described by Crivelli (1995). The impact of *P. parva* populations upon pond environmental determinants is illustrated by Adámek & Sukop (2000). Well known are the devastation effects of *C. idella* on aquatic vegetation, with subsequent negative impact on the reproduction of phytophilic fish species. At the same, eutrophication of the aquatic environment takes place (Holčík 1984, Crivelli 1995).

Endeavours to limit introductions of alien species, and thus also their incidental negative impacts on native fish biodiversity, is inevitably connected with legislation (for a review see Copp et al. 2005). In the Czech Republic, the introduction of alien species was bound on an approval process within the valid legal regulations. After 1989, the discipline in importing and releasing alien species began to slacken gradually. According to Law no. 114/1992, it is possible to intentionally introduce geographically alien species into free range only with the permission of nature protection authorities. Unfortunately, the subsequent limitation is not as unequivocal as that, as the *geographically alien species* is defined as *a species that is not a part of the natural community of a particular region*. This gives rise to the possibility of disregarding as alien those species which have already been occurring in a given region for decades (cf. also Lelek 1996). Likewise, the legislature concerning fishing is very benevolent. In relation to a fishing ground, species are considered alien only if they have occurred in it for less than three successive generations (Law no. 99/2004). Thus for example, *C. gibelio,* a classical invasive alien species in the Czech Republic, is now no longer considered to be alien. In connection with the national legislative norm (now in preparation), which should prevent and limit the activities of alien invasive species, it will be inevitable to retain the classification of fish species as "alien", regardless of the time after which they have become acclimatized and naturalised. In the cases of fish taxa considered as "alien invasive species", it will be first necessary, to prevent their translocation beyond the area of their present occurrence, invalidate the fishing limits, and prevent them "being released" from fishponds into open waters.

Various alien species of the family Acipenseridae have been occurring in various minor reservoirs and ponds managed outside the Anglers Unions, serving as objects of sport fishing. It is expected that in future there may occur more cases of ornamental aquarium and garden fishes introduced into natural ecosystems, such as reported e.g. from England by Copp et al. (2006). Besides, it is expected that problems of new alien species may occur due to the weakened efficiency of legislative norms, connected with the conception of absolute democracy and freedom.

Concluding considerations

It can be accepted, without any stimulation that introducing non-native (alien) forms and species of fishes present grave risks to the native species, including their genetic characteristics, as well as to other aquatic biota (Allendorf 1991, Crivelli 1995, Elvira 2001). In connection with the risks associated with such introductions, various systems of directions, legislative rules and procedures are compiled to limit or perhaps exclude the risks. Unfortunately, basing on our own experience and the evaluation of information contained in the literature, we have to state that the most effective way to prevent the negative impacts of such introduction is not to realise them (Kerr et al. 2005). In fact, no reports are available on a case in which an alien species that was fully established and naturalised was successfully limited or even completely removed from its new range. There may be a thoroughly elaborated system of limitations available, and yet one cannot hinder, over some time, an introduced element from getting into free nature. This is evidenced by occasional catches of various species of sturgeon and tilapia which, although very rarely so far, have been captured in natural habitats in the Czech Republic. At the same time, these species were exclusively reared in closed systems. The escape of alien species from closed experimental cultures into free waters can also be caused by catastrophic events, such as the extreme floods that occurred in southern Bohemia in August 2002. A further potential possibility of introducing alien fish species into natural ecosystems are the uncontrolled activities of aquarists, as evidence, e.g., by the case of *G. aculeatus* or *Perccottus glenii* (Koščo et al. 2003). The occasional occurrence of *L. gibbosus* is connected with the activities of aquaculturists. One cannot exclude the possible establishment of stable populations of this species in some localities, as suggested by the recent observations in the branches of the River Labe and in the sand pits near Tovačov in the Morava drainage area (Švanyga et al. 2008, P. Jurajda, pers.comm.).

In Europe most of the hydrological systems are permanently or temporarily connected. That is why any introduction of an alien taxon into any of the regions, countries, or drainage areas will result in its gradual spontaneous dispersal into further regions and drainage areas, provided that the introduced taxon can find suitable environmental conditions. In most cases this dispersal is intentionally or unintentionally aided by man. Recent persuasive examples include the expansion of *C. gibelio, P. parva, P. glenii,* or *A. melas,* indicating that there may arise grave problems concerning alien species which will spread without any intentional introduction. Even the unintentional introduction of *A. melas* with carp stocks into the Czech Republic is evidence that it is illusory to believe in abiding with principles and measures preventing unintentional import or spreading of alien species. It should be realised that in the conditions of central Europe, any introduction of alien species has international dimensions and ceases to be the matter of any individual country.

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