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Non-native freshwater fishes in Poland: an overview

Michał Nowak, Paweł Szczerbik, Krzysztof Tatoj, and Włodzimierz Popek

Department of Ichthyobiology and Fisheries, Univeristy of Agriculture in Kraków, ul. T. Spiczakowa 6, 30-199 Kraków, Poland, EU. Corresponding author: M. Nowak, e-mail: mikhael.nowak@gmail.com

Abstract. The number of non-native fish species in Poland has already passed 30, and has being still growing consecutively from the end of 19th century. It is rather difficult to assess impact of all these introductions on native fauna, however it seems reasonable to say that most of them have rather negatively affected indigenous biocenoses. Due to increase of number of new alien fishes found in Polish inland waters observed in the last years, some regulations regarding limitations of introductions should be applied.
Key Words: biodiversity, conservation, ichthyofauna, non-native fishes, Poland.

Streszczenie. Liczba gatunków obcych w polskiej ichtiofaunie rośnie sukcesywnie od końca XIX w. i aktualnie przekroczyła już granicę 30. Wpływ wszystkich tych introdukcji jest trudny do oszacowania, jednak wydaje się, że większość z nich miała zasadniczo negatywne skutki dla rodzimej fauny. Z uwagi na, widoczny zwłaszcza w ostatnich latach, wzrost ilości nowych gatunków znajdywanych w wodach śródlądowych Polski, wydaje się, że niezbędne są zasadnicze działania na rzecz ograniczenia przyszłych introdukcji.
Key Words: bioróżnorodność, gatunki obce, ichtiofauna, ochrona przyrody, Polska.

Rezumat. Numărul speciilor străine de peşti din Polonia a trecut de 30, crescând constant de la sfârşitul secolului al XIX-lea. Impactul acestor introduceri asupra faunei native este destul de dificil de estimat, fiind rezonabil să conchidem că cele mai multe afectează mai degrabă negativ biocenozele autohtone. Datorită faptului că au fost semnalate din ce în mai multe specii străine noi de peşti în apele interioare ale Poloniei în ultimul an, este necesară aplicarea unor reglementări privind limitarea introducerilor.
Cuvinte cheie: biodiversitate, conservare, ihtiofaună, specii străine de peşti, Polonia.

Introduction. Non-native species pose a serious problem in modern conservation of biodiversity. Their potential commercial value, magnitude of introductions and translocations, uncertain origin and taxonomic position of some species, wide spectrum of influence of exotic taxa on native biocenoses and many other reasons (listed by Copp et al 2005) cause the debate about alien species probably endless. For the present moment at least two scientific journals, *Biological Invasions* and *Aquatic Invasions*, are regarding mainly this topic. The number of papers published on this subject is exceptionally high, and it is still arising. It has already exceeded the number of 20 000 (Casal 2006; Rosenthal 2008).

List of non-native fish species in Poland has increased with time, and new species are presently being added. Before 19th century there were probably only two species, in the beginning of 21st century the list consist of about 35 fishes. Staff (1950) listed 57 freshwater species (including lampreys and excluding fishes from outside of the current territory of Poland) among which 6 were non-native (ca. 11%). The same number of alien species was given by Gąsowska (1962), however her key to fishes and lampreys consist of 62 freshwater taxa. In the fundamental *The freshwater fishes of Poland* (Brylińska 1986) 15 non-native fishes were considered. In the revised edition of this book (Brylińska 2000) the list was much longer and consisted of 29 (including some taxa not recognised as alien by authors of that book) of the total number of 84 taxa included (almost 35%). For the present moment the most comprehensive studies on alien fish

species in Poland were performed by Witkowski (1989, 1996a,b, 2002). Nevertheless, they are somehow out-of-date now, and there is an urgent need for some additions and corrections. Finely, this author considered as more as 31 fish species to be non-native to Polish ichthyofauna (Witkowski 1996a,b, 2002).

The issue of fish introductions seems an urgent matter. Dynamics of changes in number of non-native species (Fig. 1) shows a radical increase of new invasions (or sometimes just of new findings), especially during the last decade. In this paper we reviewed current status of, as far as we know, all alien fish species that have ever been introduced into Polish fresh waters. However, the review is rather not definite, and probably it cannot never be, due to continuous efforts of professional fishermen, sport anglers, and irresponsible aquarists, who one by one, are trying to import and acclimatize new fishes.

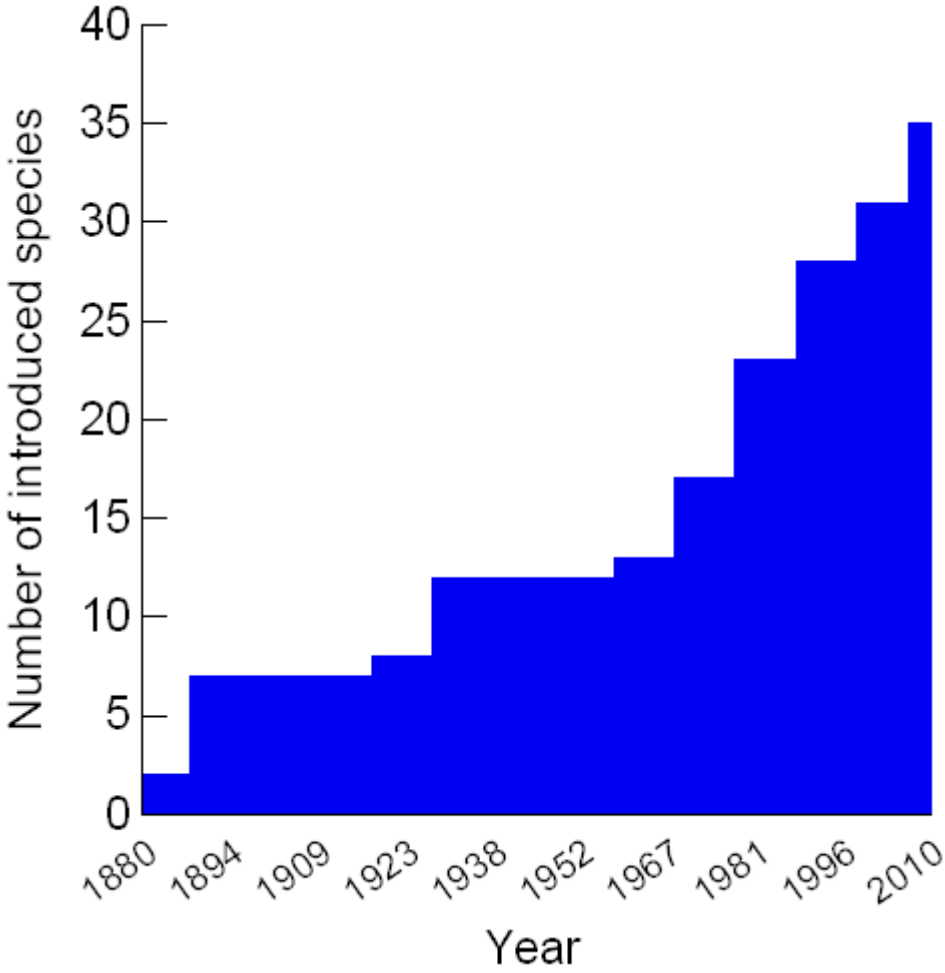

Figure 1. Dynamics of changes in number of non-native fishes in Polish ichthyofauna in following decades. See Table 1 for more details.

Background. The terms "non-indigenous", "non-native", "alien" or "exotic" are used herein exchangeable. Their definition follows that of Copp et al (2005), i.e. they are ones that does not occur in the given geographical area without, direct or indirect, intentional or unintentional, human activity. All species that have colonised since the Neolithic (6000 BP) are considered non-native. In contrary, "native" or "indigenous" species were present in the area before Neolithic (Copp et al 2005). All other terms, derived from these, are rather intuitional, and they follow Copp et al (2005) too. A taxon, equally native or not, is considered to be "invasive" if it spreads and reproduces on high rate, and its occurrence causes significant alterations in natural native ecosystems (cf. Copp et al 2005).

The territory of Poland is split into three sea basins, i.e. Baltic (99.7% of the territory), Black (0.2%), and North Sea (0.1%). Within the largest one, the Baltic Sea basin, four drainages are distinguished, i.e. of Vistula (55.7%), Odra (Oder) (33.9%), Niemen River (0.8%), and the drainage of coastal rivers (9.3%). Only short parts of four rivers are draining to Black Sea, i.e. Czarna Orawa River and Czedaczka Stream, via the Danube River drainage, and Strwiąż River and Mszanka Stream, via the Dniestr (Dniester) River drainage. Only a few small rivers (e.g. Izera and Dzika Orlica) are draining to North Sea, via the Laba River drainage (Fig. 2). This distinction must to be stressed, because the definition of non-native species refers to a "geographical area", not a country.

The ichthyofauna of Poland consists of more than 80 freshwater fishes. The number cannot be given definitely due to some ambiguities in cases of certain species complexes (e.g. *Carassius* "*gibelio*", *Gobio gobio* complex or *Cobitis taenia* complex; cf. for example Nowak et al 2008a). At least 25 species are non-native (Witkowski 1996a,b; Copp et al 2005; Grabowska et al 2008; Nowak et al 2008c and in press), and it is more than 30% of the total number.

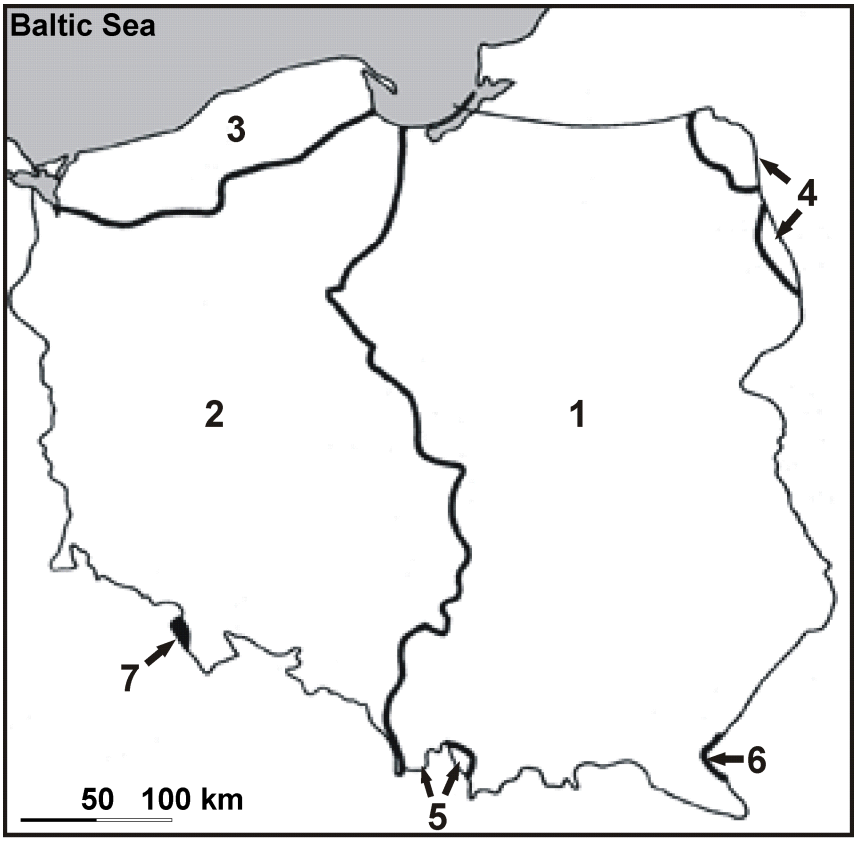

Figure 2. Drainages of Poland. 1, the Vistula River drainage; 2, the Odra (Oder) River drainage; 3, rivers draining direct to Baltic Sea; 4, the Niemen River drainage; 5, the Danube River drainage; 6, the Dniestr (Dniester) River drainage; 7, the Laba River drainage.

Main patterns of introductions. The first introduction in the history of Polish fresh waters was associated with domestication of the common carp *Cyprinus carpio*. The most probably the first introductions took place about 12th or 13th century (Balon & Hoffmann 1995; Wojda 2004; Balon 2004). Since that time the common carp achieved exclusive place in the fisheries of Poland. Its production in pond cultures reached about 24 500 tons/year in mid-1990s, and now is consecutively depressing, flirting about the value of 16-17 000 tons/year (Wojda 2004; Lirski & Myszkowski 2008a,b). It makes Poland 1st or 2nd (after Czech Republic, depending on year) producer of the common carp in Europe.

Surprisingly, the newest molecular investigations showed that another alien species was imported together with *C. carpio*, the European bitterling *Rhodeus amarus*, species widely considered to be a native one throughout Europe (Van Damme et al 2007; Kottelat & Freyhof 2007). It was probably introduced in 12th or 13th century and widespread together with increase of carp cultures during the next eight centuries (Van Damme et al 2007). For many years *R. amarus* was considered to be a native fish, and is currently even protected by national legislation in Poland (Ministry of Agriculture and Rural Development 2003).

In the end of 19th century angling and fishery associations intensified their efforts to make the native ichthyofauna "more attractive". In that period mainly North American species were tried to introduce.

One of them was the rainbow trout *Oncorhynchus mykiss.* This species is native to the Pacific drainages of western North America and Kamchatkan Peninsula (Englund & Polhemus 2001; Crawford & Muir 2008). The first introduction into fresh water of Poland took place between 1882 and 1889 (Goryczko 2000a). In 1904 eyed eggs of *O. mykiss* were imported from Sweden to the hatchery Złoty Potok and this year was considered the beginning of pond culture of *O. mykiss* in Poland (Goryczko 2000a). Now this species has a great commercial importance. Its production in 2007 reached almost 17 000 tons (Bontemps 2008). Rainbow trout is present (usually as single specimens, however sometimes mass escapes from cultures take place) in about 20% of Polish rivers (Witkowski 1996a,b). Its presence in natural environment is mainly an effect of escapes from ponds. Although the rainbow trout seems to be very adaptable to new environments, there are no self-sustaining populations in Poland. It is probably due to the lack of suitable spawning grounds (MacCrimmon 1971) or maladaptive adaptation (caused by domestication), which can prevent fish from establishing naturally reproducing stocks (Saegrov et al 1996; Landergren 1999). On the other hand, self-sustaining populations were reported from other European countries: Sweden, Norway, Denmark, and Czech Republic (Svardson & Nilson 1985; Frier et al 1995; Saegrov et al 1996). Although the rainbow trout competes for food and territorial space with native brown trout *Salmo trutta*, its negative impact is rather low because of usually limited number of specimens in open waters. Due to different terms of spawning they do not hybridize with *S. trutta*.

Meanwhile, another fish was acclimatized, the brown bullhead *Ameiurus nebulosus*. Probably the first introduction took place in 1885 in Barnówek, near Szczecin (Horoszewicz 1971; Nowak et al, in press). Contrary to the rainbow trout, brown bullhead fully acclimatized in Poland (as in the whole Europe, in fact), and in short time became a successful invader (Kornijów 2001; Bryliński & Chybowski 2000; Nowak et al, in press).

The most probably in 1890 another North American salmonid was introduced, the brook trout *Salvelinus fontinalis*. After the World War II this species was released in degraded parts of rivers in southern part of the Vistula River drainage (Staff 1950). It was probably introduced to some rivers of the Odra River drainage (Gąsowska 1962). Also initially fishless Tatra Mountains Lakes were stocked with *S. fontinalis* (Witkowski 1996a; Goryczko 2000b) and probably it contributed to extinction of relic crustacean circumpolar fairy shrimp *Branchinecta paludosa* (Gliwicz 1963; Smagowicz & Dyduch 1980). *S. fontinalis* is known to be more acid-tolerant then the brown trout *S. trutta*, and the purpose of its introduction was also to compensate the loss of *S. trutta* in acidified waters (Larsen et al 2007). Currently, only a few trout farms in southern Poland breed the brook trout, and refugees from these places are consecutively being record in open waters (Szczerbik, pers. observ.).

A few years later, in the beginning of 20th century, two centrarchid species were introduced. Probably in 1912 the largemouth bass *Micropterus salmoides*, and in 1926 the pumpkinseed *Lepomis gibbosus* were tried to acclimatize in some water bodies (Staff 1950; Rolik & Rembiszewski 1987; Witkowski 1996a,b; Copp et al 2005; Przybylski 2006). In the 1950s and 1960s *M. salmoides* was bred in some farms in central and southern Poland (Terlecki 2000). The basses generally failed to acclimatize, and only the second one, *L. gibbosus*, forms established populations in isolated sites of heated waters

from power plants in the Odra River drainage (Rolik & Rembiszewski 1987; Terlecki 2000; Przybylski 2006).

In 1920s (Pax 1921; Kulmatycki 1926) and 1967 (Ejsmont & Słoniewski 1969) an endangered endemic species of the Danube River drainage, the European mudminnow *Umbra krameri*, was recorded. However, only in the last record taxonomic identity of the specimens was definitely confirmed, and there is a possibility that it was *U. pygmea* instead of *U. krameri* in these two others (Witkowski et al 1995; Kostrzewa 1998; Bryliński 2000; Kostrzewa et al 2004). It was probably introduced accidentally, with transports of stocking fish, e.g. *C. carpio* (Witkowski et al 1995; Witkowski 1996a; Kostrzewa 1998; Bryliński 2000).

The Prussian carp *Carassius* "*gibelio*" was recorded and identified in Poland for the first time in the early 1930s (Gąsowska 1934, 1936; Staff 1950). During the 20th century it has expanded within the territory of whole Poland, and now is one of the most abundant fish species, as well as one of the most popular in aquaculture (Szczerbowski & Szczerbowski 1996). Initially recognised as distinct species *C. gibelio* (Gąsowska 1934), subsequently treated as a subspecies of the goldfish *C. auratus gibelio* (e.g. Gąsowska 1936, 1962; Staff 1950; Rolik & Rembiszewski 1987; Szczerbowski & Szczerbowski 1996), and recently again reconsidered as distinct species *C. gibelio* (Kottelat 2006; Kottelat & Freyhof 2007), however, due to complex system of reproduction, dozens of years of confusions with *C. auratus* or even *C. carassius*, and low quality of most part of older literature data, its taxonomic status is still rather unclear (cf. Kottelat 2006; Kottelat & Freyhof 2007; Kalous & Bohlen 2002; Kalous et al 2007a,b), so we applied the specific name in parentheses, *C.* "*gibelio*". Despite those, the Prussian carp is invasive throughout Europe and established in most of the European countries (Kottelat & Freyhof 2007).

Mentioned above species of *Carassius*, the goldfish *C. auratus*, is also present in the open water bodies of Poland. However, it seems rather impossible to estimate when it appeared in Poland for the first time. In Europe it is present the most probably from the 17th century. The goldfish is often abundant in ornamental garden ponds, as well as in aquarium cultures, and refugees from those places sometimes appear in open fresh waters (Szczerbowski & Szczerbowski 1996; Kottelat & Freyhof 2007; Szczerbik & Nowak, pers. observ.).

The next four species were introduced in mid-1960s. The first one, grass carp *Ctenopharyngodon idella*, in 1964. The next two, the bighead carp *Hypophthalmichthys molitrix*, and the silver carp *Hypophthalmichthys nobilis*, in 1965 (Krzywosz 2000a,b). In the next year a coregonid native to Siberia, the peled *Coregonus peled*, was imported from USSR (Szczerbowski 2000). *C. idella* and *Hypophthalmichthys* spp. were imported mainly for the reason of aquaculture. Additionally they were thought to be a solution for increasing eutrophication, as potentially herbivorous fishes (Rolik & Rembiszewski 1987; Krzywosz 2000a,b). However, they all failed to compete the eutrophication, and there was found that they cannot reproduce in the climate of Poland (Krzywosz 2000a,b). It is contrary to the *C. peled*, which successfully acclimatized in the lakes of northern Poland, where it hybridized with native *C. maraena* (often treated as *C. lavaretus* s. lato; for the taxonomic considerations on this issue see Kottelat & Freyhof 2007). Contrary to the many other coregonids, the peled is relatively resistant to the low oxygen concentration and high temperatures of water. For these reasons some hopes were putted to its commercial use in the aquaculture however its production in pond cultures is rather of minimal importance (Szczerbowski 2000). Nevertheless, according to Mamcarz (1992), by 1983 *C. peled* has been introduced to 254 lakes in Poland, with about 42% of successful acclimatization.

In the same period, in mid-1960s, an action of so-called "translocation" of the huchen *Hucho hucho* took place. The only native populations of this species lived in the Czarna Orawa River system (Black Sea basin), and depressed due to degradation of the ecosystem, and building a dam reservoir on the border with Slovakia (former Czechoslovakia). The last adult specimens were caught in the river in 1963, and since then successive action of introduction of *H. hucho* to certain rivers within the drainages of Vistula and Oder River (Baltic Sea basin) is being conducted. It is quite successful, and

this species established in these new ecosystems very well (Witkowski 1996c, 2001; Witkowski et al 2007).

In 1973 the second Pacific salmon, *Oncorhynchus gorbuscha*, was release to Vindava River (former USSR), and in the autumn 1974 one specimen was caught in the, Bukowo Lake (a coastal lake connected directly with Baltic Sea) within the territory of Poland. As far as the authors are aware, no more specimens of this species have ever been recorded in the country. Also in the 1970s another salmonid fish, *Salvelinus alpinus*, was tried to introduce into water bodies of southern Poland, fortunately, without any results (Rolik & Rembiszewski 1987).

In the same time, as speculated by Rolik & Rembiszewski (1987), and Witkowski (1996a,b, 2000), the Baikal black grayling *Thymallus baicalensis* might appeared in the Nysa Kłodzka River system. According to these authors, *T. baicalensis* was stocked in some dam reservoirs in Slovakia, and especially in one farm on the Štenava River (Czech Republic, the Nysa Kłodzka River system, the Odra River drainage), from where it escaped due to a flood. Some anglers reported occurrence of strange-coloured graylings in the mid-1970s (Witkowski 2000). However, not a single record has ever been confirmed. Moreover, according to data from the Czech Republic (Hanel & Lusk 2005; Lusk, pers. comm.) and Slovakia (Oliva et al 1968; Holčik 1998; Koščo, pers. comm.) published documentation of the introductions of *T. baicalensis* to the water bodies of former Czechoslovakia is so incomplete and fragmented, that possible occurrence of that species in Polish waters is of rather low probability. Moreover, during the newly conducted investigations (Jurczyk & Brzuzan 2003, 2004) any mtDNA sequences of *T. baicalensis* were found in the grayling samples from southern Poland.

Meanwhile, in 1970s, some species of sturgeons were introduced for the reasons of aquaculture. These were the Siberian sturgeon *Acipenser baerii*, the Russian sturgeon *A. gueldenstaedtii*, the Starry sturgeon *A. stellatus*, and cross-hybrid of *A. ruthenus* and *H. huso*, called bester (Kolman 2000). It is fairly probable that some other species may be involved, as well as hybrids of these ones. For the present moment sturgeons aquaculture is a growing up branch of inland fisheries in Poland (Kolman 2000, 2006). Since the time of start of sturgeon aquaculture in Poland some specimens have been recorded in Baltic Sea, and Vistula and Odra River drainage (e.g. Keszka & Stepanowska 1997).

In 1984-1985 the next coregonid species, the muksun *Coregonus muksun*, was tried to acclimatize in Mazurian Lakes, the most probably without any positive results (Szczerbowski 2000).

For the reason of commercial usage of heated water from power plants, two exotic species were introduced in 1989 and 1990, the black buffalo *Ictiobus niger* and the sharptooth catfish *Clarias gariepinus* (Adamek 1993; Witkowski 1996a,b; Kotusz 2000a). Experiments with the first one were quit in relatively short time, and now only one farm in Poland breeds *I. niger* (Kottelat & Freyhof 2007). Just the opposite the second species, *C. gariepinus*, which very well filled into the niche in market, and its importance has consecutively grown during the last years (Adamek 1993; Chybowski 2000).

Also in 1990 another warm-water exotic species was imported. In the experimental unit of the Polish Academy of Sciences in Gołysz were conducted experiments with the Nile tilapia *Oreochromis niloticus* as a potentially commercial fish in heated water of power plants. In the following years it was introduced to some heated water bodies, among others to Rybnik Reservoir on Ruda River (the Odra River drainage). In 2000 the Nile tilapia was recorded from that river below the dam (Kotusz 2000b; Kotusz et al 2000). In such water bodies, with an appropriate water temperature, *O. niloticus* forms well established populations (Nowak, Tatoj & Szczerbik, pers. observ.).

A few years after these introductions the next exotic fish was imported, this time from North America. The American paddlefish *Polyodon spathula* was thought to be cultured in carp farms. Currently it is of rather low interest however it is stocked in some farms in Poland (Kolman 2000).

In the end of 20th and begining of 21st century invasions of small-sized fishes is being observed. First was the round goby *Apollonia melanostoma* (taxonomic status of the round and monkey gobies is under still running debate; we applied the newest

nomenclature, considering molecular data of Brown & Stepien (2008), and placing these two species in the genus *Apollonia*, whereas the racer goby remains in the genus *Neogobius*), which was recorded for the first time in Baltic Sea near Hel (Skóra & Stolarski 1993). During the following years it has colonized whole southern coastal of Baltic Sea, and is inserting the lower parts of Vistula River (Kostrzewa & Grabowski 2002; Kostrzewa et al 2004; Grabowska et al 2008).

Figure 3. The Chinese sleeper *Perccottus glenii* (carp ponds in Kraków-Mydlniki, Poland, by P. Szczerbik, 2008).

The next invader was recorded one year after. In the carp ponds in Gołysz a cyprinid fish, the stone moroko *Pseudorasbora parva* was found (Witkowski 1991). Irrespective, its distribution and density of populations suggested that this species was introduced somehow earlier, probably in the late 1980s (Witkowski 1991; Kotusz & Witkowski 1998). For the present moment the stone moroko inhabits numerous small water bodies, mainly commercial carp ponds and heated lakes in south-western and central Poland (Kotusz & Witkowski 1998; Kapusta et al 2008; Nowak et al 2008a).

In 1993 (Antychowicz 1994) and 1994 (Terlecki 1995) another alien species was caught in the middle stretch of Vistula River, the Chinese sleeper *Perccottus glenii* (Fig. 3). Number of its localities increased with every year, and reached the number of 15 (officially confirmed; Nowak et al 2008b; Nowak & Popek 2008), however a real number is without any doubts much higher, probably even over 100 (most of them reported by anglers; Witkowski 2002, 2003; Nowak, Szczerbik & Tatoj, pers. observ.).

During the next four years another two Ponto-Caspian gobies has joined the previous one (the round goby), i.e. the racer goby *Neogobius gymnotrachelus* in 1995 (Danilkiewicz 1996) and the monkey goby *Apollonia fluviatilis* (see the remarks on *A. melanostoma*, above) in 1997 (Danilkiewicz 1998). Both were recorded for the first time in Western Bug River (the Vistula River drainage). Not surprisingly, both were found in Vistula River itself a few years later (Kostrzewa & Grabowski 2001, 2002, 2003; Kostrzewa et al 2004; Grabowska et al 2008). In 2008 the fourth Ponto-Caspian goby appeared in Vistula River, the tubenose goby *Proterorhinus semilunaris* (Grabowska et al 2008; the name *Proterorhinus marmoratus*, traditionally considered to be the name of the tubenose goby that is currently invading central Europe, is restricted to marine populations within the Caspian Sea basin; cf. Kottelat & Freyhof 2007).

In the end of 1990s (Witkowski et al 1995; Kostrzewa 1998) two isolated sites of exotic eastern mudminnow *Umbra pygmea* were found in the Odra River drainage. The specimens were probably released from aquaria however it was not definitely concluded (Witkowski et al 1995; Kostrzewa 1998; Witkowski & Kotusz 2000; Kostrzewa et al 2004).

From 2000 some occasional records of single specimens of the pirapitinga *Piaractus brachypomus* have been noted (Boeger et al 2002; Witkowski 2002; Witkowski & Kotusz

2003; Więcaszek et al 2007). This fish is reported by anglers from different water bodies from time to time. All these specimens are definitely released by aquarists.

In addition, in 2007 a second ictalurid species was found, the black bullhead *Ameiurus melas* (Nowak et al 2008c and in press). However it has not been definitely established yet whether it has spread from adjacent countries during last years, or was intentionally introduced in 1885, together with *A. nebulosus* (cf. Nowak et al, in press). It seems possible that the black bullhead remained confused with the brown bullhead for over 100 years. Their very high morphological resemblance might cause such misidentifications (see Fig. 4).

Beside of all these records described above, Witkowski (2002) reported also some findings of *Astronotus ocellatus*, *Serrasalmus* sp., *Poecilia* sp., and *Xiphophorus* sp. from heated water bodies. However these were not accompanied with any detailed description (cf. Tab. 1).

Figure 4. The black bullhead *Ameiurus melas* (Latorica River, Slovakia, by M. Nowak, 2008). This species was found in Poland for the first time in the summer 2007.

Consequences of introductions and additional problems. One of the better known consequences of introductions is the phenomenon of non-native parasites and pathogens that are translocated together with host species. This problem was discussed for many times, and in various aspects (e.g. Czeczuga et al 2002; Witkowski 2002; Košuthová et al 2004; Gozlan et al 2005, 2006; Uzunova & Zlatanova 2007). There are many examples of parasites and pathogens brought to Poland with non-native fishes. Two of them, that are better known, are *Khawia sinensis* and *Bothriocephalus acheilognathi*, tapeworms introduced most probably with *H. molitrix*, *H. nobilis* and *C. idella* from Far East (Pańczyk & Żelazny 1974). Since the first records in 1973 (Pańczyk & Żelazny 1974) they have successfully spread within the territory of Poland, where they live off native cyprinid fishes (Łozińska-Gabska 1981).

In the last years a special attention was given to Cyprinid Herpesvirus, CyHV-3 (Koi Herpesvirus, KHV), which has been brought with ornamental carps (nishigikoi *C. carpio*) from Far East due to completely unregulated translocations among countries. For the present moment it poses a serious risk to the carp aquaculture (e.g. Ruszczyk 2004; Antychowicz 2007). As many as 20 other herpesviruses have been recognized in Poland so far (Siwicki et al 2006).

A similar problem is of accidental introductions of small fish imported together with stocking material, or by ballast waters of ships. These are particularly *P. glenii*, *P. parva*, and the Ponto-Caspian gobies (*Apollonia*, *Neogobius* and *Proterorhinus*). They might be very dangerous to native biocenoses. Especially well-documented is the first species, the Chinese sleeper. It is established that in small water bodies it can strongly depress populations of native fishes, often additionally declining for other reasons, like the whetherfish *Misgurnus fossilis* or the lake minnow *Rhinchocypris percnurus* (called in the literature *Phoxinus*, *Morocco*, or *Eupalasella percnurus* or *pereunurus*; according to

recent molecular investigations of Sakai et al (2006) it is placed in the genus *Rhinchocypris*), as well as macroinvertebrates and amphibians (Reshetnikov 2003, 2008; Koščo et al 2003; Nowak et al 2008b). Numerous studies were conducted to assess the role and threats that are induced by these small invaders (beside of the works cited above, e.g. Simonović et al 2001; Kostrzewa & Grabowski 2003; Kostrzewa et al 2004; Gozlan et al 2005; and many others). These fishes, i.e. *P. glenii*, *P. parva*, and the Ponto-Caspian gobies, are considered fully invasive, what means that they can disrupt and negatively alter native biocenoses.

The Atlantic salmon *Salmo salar* disappeared from the territory of Poland in the mid-1980s and its last spawning area was Drawa River (Wiśniewolski et al 2004). The restoration program for the Atlantic salmon in Polish rivers started in 1985 and it is based on material obtained from Daugava River (Latvia), because Latvian population of *S. salar* was the most similar to extinct Polish salmon (Bartel 2002). Eyed eggs were imported from Latvia in 1985 and in 1989 the first part of stocking material was released into some Polish rivers. Beside of the effects of that action, the question is: is it still restitution/reintroduction or rather introduction/translocation of very similar but not exactly the same fish?

Additional problem connected with the Atlantic salmon stocking are refugees from open marine salmon farms, which can negatively affect native (or restituted) populations of this species (Fiske 2006). It is rather not possible to these refugees to spawn with native salmons in the conditions of Poland, however such cases were reported a few times, so such possibility cannot be definitively excluded (Fleming et al 2000; Garant et al 2003). Nevertheless, their impact may be significant even without successful reproduction (Young et al 2008; Perry et al 2008).

The endemic population of the lake trout *Salmo trutta* (most often referred to as "morpha *lacustris*"), occurs naturally only in Lake Wdzydze and some neighboring lakes. However, it was introduced into different dam reservoirs (Wajdowicz 1972, 1976; Bartel & Prokuski 1992; Bartel et al. 1996), rivers (Jakubowski & Penczak 1976; Bartel & Zieliński 1978) and even the Baltic Sea (Backiel & Bartel 1967). The question is: is it still native species or an alien one, if stocked into these new ecosystems? The similar question occurs in a case of the brown trout translocations between different river drainages. It seems that release of fish taken from one drainage into another may cause the disturbance of genetic integrity of autochthonous populations and even their extinction.

As it was already mentioned, alien species can often successfully hybridize with native fishes, and produce fertile or infertile offspring. In the context of Poland the very examples of that process are *S. fontinalis* which hybridize with the native brown trout *S. trutta* producing infertile so-called "tiger trouts", and non-native *Coregonus* spp. that extremely easy hybridize with native coregonids (*C. albula*, *C. maraena*), and these hybrids ale fully fertile. Hybridization of *Carassius* spp. was conducted in artificial conditions (Smartt 2007). For the present moment there is no evidence that it takes place in Poland. Nevertheless, it probably occurs, and tends to be one of the reasons of decline of native *C. carassius*. In fact such cases of hybridization have already been reported from adjacent Czech Republic (Papoušek et al 2008). However, the problem is much more complex, regarding various levels of ploidy of *C. auratus* complex (*auratus*, *gibelio*, and *langsdorfii*; the last one was found in Czech Republic in 2000; Kalous et al 2007a), their complex system of reproduction, and ambiguities in identification of these species themselves and their hybrids (Szczerbowski & Szczerbowski 1996; Kalous et al 2007a; Kottelat & Freyhof 2007; Papoušek et al 2008).

During last years another interesting phenomenon is being observed. In those water bodies where *A. nebulosus* were introduced earlier than *A. melas*, the second one is successfully replacing the previous invader (Koščo & Pekárik 2008). It is not clear whether it is due to higher potential "invasivness" of the black bullhead, or to changing environmental conditions (i.e. the global warming effect; Koščo & Pekárik 2008).

From time to time there are still some voices for introduction of the next species to the Polish fresh waters. Following the case of *H. hucho* translocated from the Czarna Orawa River system to some rivers in southern part of the Vistula and Odra River

drainage (Witkowski et al 2007), and mentioned above translocations of *S. salar* and *S. trutta*, an introduction (called "translocation" too) of *A. ruthenus* was postulated (Kolman 1996). However, ongoing action of restitution of the native sturgeon, *Acipenser oxyrinchus*/*sturio*, may dismiss further such inventions. In fact, restitution of the Baltic sturgeon is in some way questionable itself, because there are no living native populations of sturgeons in the Baltic Sea, at least as far as we know. For the present moment the last self-sustaining natural populations of *A. sturio* live only in the Gironde River drainage (France) and Rioni River drainage (Georgia) (Kolman 1996). These drainages are nearly completely disconnected from the Baltic Sea basin. *A. oxyrinchus* lives in Atlantic drainages of North America from Labrador to Florida (Popovic et al 2008). Fry of *A. oxyrinchus* for the restitution was imported from St. John River (Canada) (Kolman 2008). The case is additionally complicated due to ambiguities in identification of these extinct sturgeons. It is still unclear which species inhabited the Baltic Sea basin. For the many years it was considered, that the only one native species was *A. sturio* (e.g. Kolman 1996, 2000), but the analysis of ancient DNA showed that rather *A. oxyrinchus* was the prevalent species. There are strong evidence that *A. oxyrinchus* colonized the Baltic Sea during the Medieval Little Ice Age (or earlier) and replaced *A. sturio* there (Birstein et al 1998; Ludwig et al 2002; Popovic et al 2008). On the other hand, analyzes of ancient mtDNA showed that the most of samples from archeological excavations and museums in Poland revealed *A. oxyrinchus* haplotype but *A.sturio* haplotype was also present (Stankovic et al 2007; Popovic et al 2008). Recent molecular investigations showed that the case is much more complex. Tiedemann et al (2007) suggest that *A. oxyrinchus* did not replace native sturgeon in the Baltic Sea but it introgressed with *A. sturio* population, thus the extinct Baltic sturgeon had a hybrid nature.

For all these reasons, sturgeons released to Baltic Sea seem to be not the same that had lived there for ages and evolved in disconnection both from European populations of *A. sturio* and American populations of *A. oxyrinchus*, and they are completely different fish. The question is same as in the case of restitution of *S. salar* (and probably any other further restitution action): is it restitution of a native species, or introduction of an alien one? If Baltic sturgeon is definitely extinct, there is no possibility to restore it. In this context sturgeons imported from Canada are non-native fish. Irrespective, it does not dismissed the question, what is better to do, accept the extinction of Baltic sturgeon (what particularly is a fact), or introduce non-native sturgeons from Canada.

Conclusions. Summarizing, one should answer the question: are all of these introductions bad (cf. Gozlan 2008)? Main stream of considerations presented in this paper were focused on negative aspects of presence of non-native fishes in Poland. Nevertheless, it must be said, that some benefits also are achieved. Probably the most important are these of aquaculture, especially of the common carp and the rainbow trout production, which are the most valuable branches of Polish inland fisheries (cf. Wojda 2004; Lirski & Myszkowski 2008a; Bontemps 2008). In details these consequences, both benefits and negative effects, were discussed by numerous authors, in Poland especially by Witkowski (1989, 1996a, 2002) and Kostrzewa et al. (2004), and dozens of direct investigations on certain species.

It should be also stressed that aquaculture without alien species is not possible for the present moment, and probably it cannot be possible anyway (Gozlan 2008). Fish species have been translocated for ages, they are being translocated now, and most probably they will be translocated in future. It is not only due to reason of aquaculture. Cases of *H. hucho* transferred from one drainage to another (even from one sea basin to another) within the territory of one country, or *S. salar* brought to Poland from adjacent Latvia (however within one sea basin) were of conservational significance. Some questions stated above in the previous section show our concerns of this matter. We consider that introductions should be omitted and avoided as much as it is possible, and should be processed only in special cases, after thorough analyses of risk, impact and

profits. Also it is very important to educate people about possible consequences of seemingly innocent releasing exotic fish to open waters (cf. Elvira & Almodovar 2001).

When take a look on Figure 1 and Table 1, and when assess a number of introduced species, even only those that have established in open fresh waters, it may seems astonishing how many new non-native species were found in last 20 years. If then one compare this number with the, anyhow incomplete, review of their impacts, it should be clear why the authors are so preoccupied by the issue of introductions.

After all, we would like to cite a significant thought of Holčik (1991) that "one fact remains certain: only few species are generally accepted as having been beneficial introductions".

Table 1

Checklist of non-native fishes that occur in the fresh waters of Poland

Species	Year of introduction	Reason of introduction	Main reference
	Acipenseridae		
Acipenser ruthenus	1890s, 1970s	Aquaculture	Kolman 2000
Acipenser baerii	1970s	Aquaculture	Kolman 2000
Acipenser gueldenstaedtii	1970s	Aquaculture	Kolman 2000
Acipenser stellatus	1970s	Aquaculture	Kolman 2006
A. ruthenus x *Huso huso*	1970s	Aquaculture	Kolman 2000
	Polyodontidae		
Polyodon spathula	mid-1990s	Aquaculture	Kolman 2000
	Cyprinidae		
Cyprinus carpio	ca. 1200	Aquaculture	Balon & Hoffmann 1995
*Rhodeus amarus**	ca. 1200	Accidental	Van Damme et al 2007
Carassius auratus	ca. 1930 (?)	Ornamental	Szczerbowski & Szczerbowski 1996
*Carassius gibelio**	ca. 1930 (?)	Unknown / accidental	Szczerbowski & Szczerbowski 1996
Ctenopharyngodon idella	1964	Aquaculture	Krzywosz 2000a
Hypophthalmichthys molitrix	1965	Aquaculture	Krzywosz 2000b
Hypophthalmichthys nobilis	1965	Aquaculture	Krzywosz 2000b
*Pseudorasbora parva**	late 1980s	Accidental	Witkowski 1991
	Catostomidae		
Ictiobus niger	1989	Aquaculture	Kotusz 2000a
	Salmonidae		
Oncorhynchus mykiss	1881-1889	Aquaculture	Goryczko 2000a
Oncorhynchus gorbuscha	1973-1974	Aquaculture	Rolik & Rembiszewski 1987
*Salvelinus fontinalis**	1890	Aquaculture	Goryczko 2000b
Salvelinus alpinus	1970s	Angling	Rolik & Rembiszewski 1987
Hucho hucho[1,]*	1955	Conservation, angling	Witkowski et al 2007
	Thymallidae		
Thymallus baicalensis	1973-1974	Accidental	Witkowski 2000

Table 1 (cont.)

Species	Year of introduction	Reason of introduction	Main reference
	Coregonidae		
Coregonus peled[2]	1966	Aquaculture	Szczerbowski 2000
Coregonus muksun	1984-1985	Aquaculture	Szczerbowski 2000
	Odontobutidae		
*Perccottus glenii**	1990s	Accidental	Nowak et al 2008b
	Ictaluridae		
*Ameiurus nebulosus**	1885	Aquaculture	Bryliński & Chybowski 2000
*Ameiurus melas**	1885 (?)	Aquaculture (?)	Nowak et al, in press
	Clariidae		
Clarias gariepinus	1990	Aquaculture	Chybowski 2000
	Loricariidae		
Pterygoplichthys gibbiceps	2006	Aquarium release	Keszka et al 2008
	Cichlidae		
Oreochromis niloticus(*)	1990	Aquaculture	Kotusz 2000b
Astronotus ocellatus	2000s	Aquarium release	Witkowski 2002
	Centrarchidae		
Micropterus salmoides	1912 (?)	Aquaculture, angling	Staff 1950; Terlecki 2000
*Lepomis gibbosus**	1927 (?)	Aquaculture, ornamental	Przybylski 2006
	Serrasalmidae		
Piaractus prachypomus	2000	Aquarium release	Witkowski & Kotusz 2003
Serrasalmus sp.	ca. 2000	Aquarium release	Witkowski 2002
	Gobiidae		
Apollonia melanostoma[3]	1990	Natural spreading	Skóra & Stolarski 1993
*Neogobius gymnotrachelus**	1995	Natural spreading	Danilkiewicz 1996
*Apollonia fluviatilis**	1997	Natural spreading	Danilkiewicz 1998
*Proterorhinus semilunaris**	2008	Natural spreading	Grabowska et al 2008
	Umbridae		
Umbra krameri	1921, 1967	Accidental	Kostrzewa et al 2004
Umbra pygmea	1990s	Releasing from aquaria	Witkowski & Kotusz 2000

[1] Native in the Polish part of Czarna Orawa River and Czedaczka Stream, introduced in some rivers within southern part of the Vistula and Oder River drainage
[2] *C. peled* hybridised with native *C. maraena*
[3] This species was record for the first time in 2007, so data are lacking; however, it probably forms established population, or will do it in the next years
* Species forms established populations
(*) Species forms established populations only in heated water bodies (e.g. power plants)

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Authors:
Michał Nowak, Department of Ichthyobiology and Fisheries, University of Agriculture in Kraków, ul. T. Spiczakowa 6, 30-199 Kraków, Poland, EU, e-mail: mikhael.nowak@gmail.com
Paweł Szczerbik, Department of Ichthyobiology and Fisheries, University of Agriculture in Kraków, ul. T. Spiczakowa 6, 30-199 Kraków, Poland, EU, e-mail: rzbienia@cyf-kr.edu.pl
Krzysztof Tatoj, Department of Ichthyobiology and Fisheries, University of Agriculture in Kraków, ul. T. Spiczakowa 6, 30-199 Kraków, Poland, EU, e-mail: krzysztof@akwarium.org
Włodzimierz Popek, Department of Ichthyobiology and Fisheries, University of Agriculture in Kraków, ul. T. Spiczakowa 6, 30-199 Kraków, Poland, EU, e-mail: rzpopek@cyf-kr.edu.pl
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