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INTRODUCTION OF FISHES INTO POLAND: BENEFACTION OR PLAGUE?

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"Introduction of fish species into waters that are foreign is a highly controversial practice...", "...one fact remains certain: only a few species are generally accepted as having been beneficial introductions..." (Holčík 1991)

"...There is no other branch of zoology where introducing and relocating species is as widespread and is carried out on such a large scale, as in the case of fishes. A "man with a bucket" is the curse of the last century, bringing about profound disturbances in freshwater ichthyofauna, not sparing from his intervention even the communities of endemic fauna of enormous value to human knowledge..." (Głowaciński 2001)

Abstract: *Cyprinus carpio* was the first fish introduced into Polish waters – as early as in the Meadieval times. Up until the present day, 30 more species have been introduced, either intentionally or unintentionally, most of them after World War II. At present the zoogeographic integrity coefficient (*ZIC*) of the freshwater ichthyofauna of Poland is 0.70. Several of the species (*Pseudorasbora parva, Carassius auratus, Lepomis gibbosus, Ictalurus nebulosus, Perccottus glenii, Neogobius gymnotrachelus, N. fluviatilis, N. melanostomus*) dispersed quickly in open waters and still demonstrate great potential for expansion. The introduction of fishes caused a number of adverse changes in the aquatic environment and autochtonic fish communities, contributing to: increased eutrophication, a decrease in the number and disappearance of native species of fishes and invertebrates, and the introduction of exotic parasites and diseases. Some of the introduced species (*Coregonus peled, C. muksun*) entered into reproductive interactions with native species so affecting their genotypes. A successful outcome of the introductions was noted only for a mere two species (*C. carpio, Oncorhynchus mykiss*) bred in aquaculture.

Key words: freshwater ichthyofauna, introductions, exotic species, invasions, threats, Poland.

INTRODUCTION

Untill quite recently it has been presumed that regulation projects (collection systems, draining wetlands, hydro-engineering structures erected on water courses, e.g. weirs, river bars, or impoundments), water pollution (industrial waste water and sewage) and overexploitation have a decisive effect on modifying the structure of species composition and numbers in ichthyofauna communities (Backiel 1985; Cooper and Wheatley 1981; Elvira et al. 1998; Holčik 2001; Jungwirth et al. 1998; Jurajda 1995; Jurajda et al. 1998; Nielsen et al. 1986; Penczak 1972, 1995; Penczak and Mann 1993; Penczak et al. 1992; Peter 1998; Petts 1984; Ward and Stanford 1979; Włodek 1978; Wolter and Vilcinskas 1997).

In recent years it is increasingly the case that the adverse effects of other factors on the native ichthyofauna are also noted. These are elements of "biological contamination": fish species either introduced intentionally or brought in accidentally. The essential nature of this problem is underscored by numerous symposia and conferences and an abundant body of scientific literature, pertaining to both general and special aspects of introduction and acclimatisation of fishes and other aquatic organisms in various regions of the world (e.g. Allardi 1984; Arthington 1991; Billington and Herbert 1991; Burmakin 1961; Crossman 1991; Delmastro 1986; De Silva 1989; Drake et al. 1989; Dryagin 1954; Elvira 2001; Fernando 1991; Fernando and Holčik 1991; Fitzmaurice 1984; Holčik 1984, 1991; Kapuscinski and Hallerman 1991; Karpevič 1975; Krueger and May 1991; Loftus 1968; Lusk 1988; Maitland 1987; Molnar

1984; Mooney and Drake 1986; Nilsson 1984; Rosenthal 1976; Sindermann et al. 1992; Welcomme 1981, 1988, 1991; Žitnan 1974).

In Poland, the issue of fish introduction, and particularly its effect on the native ichthyofauna and water environment has recently attracted an increasing level of attention (Hesse 1997; Kostrzewa and Grabowski 2003; Krzywosz et al. 1980; Mamcarz 1992; Mastyński et al. 1987; Opuszyński 1972, 1987, 1989, 1997; Radziej and Krzywosz 1979; Wilkońska 1988; Witkowski 1989, 1992, 1996a,b, 1998).

The data of Welcomme (1981, 1988) indicate that since the 1980s, there were ca. 1,350 documented introductions of 237 species of fish (Table 1). Before that period, into the territories of 29 European countries (except Andorra, Monaco, San Marino and the Vatican) out of 33 existing at the time, 134 species of 34 families were introduced, including as many as 74 species from outside the continent. At that time the USSR was (also) *"the super power in this respect, as it introduced to, and transferred on its European territory, 70 species including 40 exotic and 30 native, i.e. slightly more than half of the total number of fish species received by all other European countries"* (Holčik 1991). Regrettably, at that time, Poland with 23 exotic species occupied a high (4th) place in Europe while the zoogeographic integrity coefficient (*ZIC*) of the freshwater ichthyofauna of Poland was 0.70 (Fig. 1) (Witkowski 1996a, b).

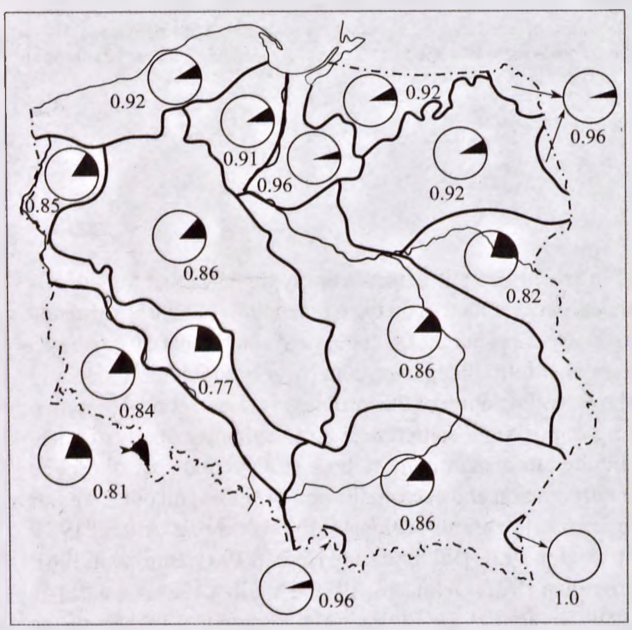

Fig. 1. The zoogeographic integrity coefficient (*ZIC*) of the freshwater ichthyofauna of Poland in principal parts of major river catchments (black portions indicate the percentage share of introduced species; after Witkowski 1996b)

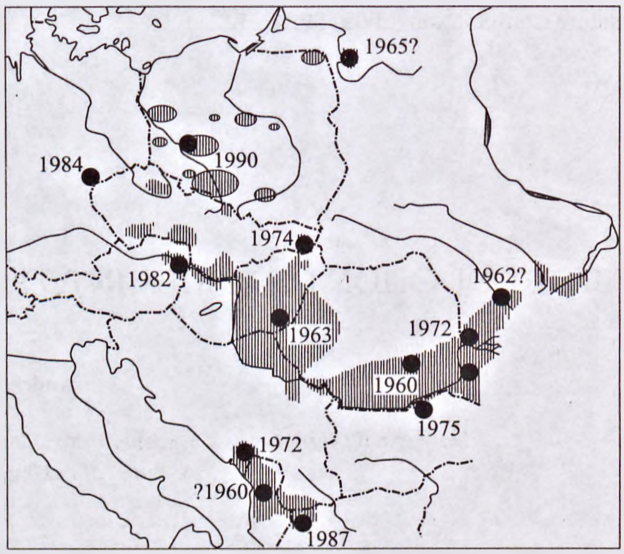

Fig. 2. The expansion of the stone moroco *Pseudorasbora parva* in Europe (after Wohlgemuth, Šebela 1987, Witkowski 1991; supplemented)

HISTORY OF THE INTRODUCTION OF FISH INTO POLISH INLAND WATERS

Over the period of the past 800 years, many attempts at introducing exotic fish species into the Polish national territory have been made. The intensity of these practices was evidently dependant on the degree of mastering the breeding techniques, the ability to transport fish over long distances as well as of the fashion for exotic species. This period can be divided into three stages: I – from the early Meadieval times, till the end of the first half of the 19th century; II – from the second half of the 19th century till the second half of the 20th century; III – from the second half of the 20th century till its end (Table 2).

In the first period, several attempts at introducing new fish species were made, and the first and also successful one was the introduction of carp (*Cyprinus carpio*). It is likely that it was brought by the Cistercian monks from the area of Bohemia and Moravia in the 12-13th century, because it was then already bred in many ponds at monasteries (Balon 1974), and that the first fish pond farming operations started in the Silesia and Małopolska regions (Rudziński 1962, 1963a,b). The 19th-century attempts to introduce four more species (*Salvelinus alpinus, Acipenser ruthenus, Coregonus nasus, Oncorhynchus kisutsch*) were not successful (Daszkiewicz 2000; Leśniewski 1837; Weigel 1806; Zawadzki 1840).

In the second period some 10 exotic fish species appeared in the territory of Poland. Out of this number only 6 (*Oncorhynchus mykiss, Ictalurus nebulosus, Salvelinus fontinalis,*

Table 1. Number of species introduced into different continents by decade (after Welcomme 1988)

Decades	Africa	Asia	Europe	Near East	North America	Oceania	South America	Total
Ancient times – Meadieval times	-	1	4	-	1	1	-	7
before 1850	-	4	9	-	-	-	-	13
1850	2	-	-	-	-	-	2	4
1860	1	-	2	-	-	5	1	9
1870	-	3	9	-	-	6	2	20
1880	-	2	27	-	3	-	1	33
1890	2	1	27	-	4	-	4	38
1900	3	6	14	-	1	10	17	59
1910	6	11	5	-	1	-	5	28
1920	19	6	14	1	2	9	8	59
1930	16	11	14	1	1	5	17	65
1940	12	10	4	1	-	5	21	53
1950	67	21	11	1	9	13	44	166
1960	44	37	40	7	10	21	41	200
1970	35	20	43	1	2	3	71	175
1980	1	7	14	-	1	2	37	62
Subtotal	208	140	237	12	35	80	271	983
Unknown	48	45	57	4	54	80	72	360
Total	256	185	294	16	89	160	343	1343

Lepomis gibbosus, *Micropterus salmoides*, *Carassius auratus*) have acclimatised themselves and they are found in open waters to the present day (Witkowski 1989).

In the last 50 years, as many as 17 species have been introduced either intentionally or accidentally, which constitutes more than 50% of all the fish species introduced to date (Witkowski 1989, 1996a,b,c). This number must be increased by 4 more species of the "sturgeon group" (*Acipenser ruthenus*, *A. baeri*, *A. gueldenstaedti*, *Polyodon spathula*) and their hybrids (*A. baeri* x *A. gueldenstaedti*, *Huso huso* x *A. ruthenus* and other) because they appear fairly often in many fish pond farms (Kolman 1999). Unfortunately, we do not have data yet on their presence in our rivers (Arndt et al. 2000).

The main motivations for introducing fishes into Poland, as it was throughout the world (Welcomme 1988), included: aquaculture, spinning/angling, control of undesired organisms, as well as 'improving' the initial species composition aimed at increasing the biodiversity of natural aquatic communities and others listed in Table 3. Unfortunately, in addition to 'large species' purposely introduced and kept under control, there was also a group of approximately ten species brought in accidentally, that were not wanted at all (Table 4). Most of them due to their small size, great adaptation capabilities, and – above all – *insufficient knowledge of their biology among people*, spread rapidly over significant parts of Poland, invading various aquatic ecosystems so that now they elude any control measures.

EXAMPLES OF INVASIONS BY FISH SPECIES OF POLISH NATIONAL TERRITORY

Several cases reported from Poland indicate that species both introduced (for breeding purposes) and accidentally brought into the area, rapidly succeeded in getting out of control and colonising large areas of the country.

Brown bullhead *Ictalurus nebulosus* introduced in 1885 from the eastern parts of the United States into what was then Germany (ponds near Barnówek in western Pomeranian province), in a mere couple of years succeeded in penetrating into open waters (Horoszewicz 1971). In a similarly short time

Table 2. Introduction of fishes into Poland (names of species whose introductions have proven successful are given in bold italics)

Year	Species
1200-1300?	***Cyprinus carpio* Linnaeus, 1758**
1603?, 1840	*Salvelinus alpinus* (Linnaeus, 1758)
1837	*Acipenser ruthenus* (Linnaeus, 1758)
1858-1862	*Coregonus nasus (=C. fera)* (Pallas, 1776)
1859	*Oncorhynchus kisutsch* Walbaum, 1792
1881-1889	***Oncorhynchus mykiss* Walbaum, 1792**
1885	***Ictalurus nebulosus* (Le Sueur, 1819)**
1889	*Oncorhynchus tschawytscha* Walbaum, 1792
1890	***Salvelinus fontinalis* (Mitchill, 1815)**
1912?	***Micropterus salmoides* (Lecepede, 1802)**
1921, 1967	***Umbra krameri* Walbaum, 1792**
1927	***Lepomis gibbosus* Linnaeus, 1758**
1930-1933	***Carassius auratus* (Bloch, 1783)**
1964	***Ctenopharyngodon idella* (Vallenciennes, 1844)**
1965	***Hypophthalmichthys molitrix* (Vallenciennes, 1844)** ***Aristichthys nobilis* Richardson, 1836**
1966	***Coregonus peled* Gmelin, 1788**
1973	*Thymallus baicalensis* Dybowski, 1874
1973-1975	*Oncorhynchus gorbuscha* Walbaum, 1792
1974	*Huso huso* (L.) x *Acipenser ruthenus* (L.)
1984	***Coregonus muksun* (Pallas, 1814)**
1989	***Ictiobus niger* Rafinesque, 1820**
1990	***Clarias gariepinus* (Burchell, 1922)** ***Pseudorasbora parva* (Schlegel, 1842)**
1993	***Perccottus glenii* Dybowski, 1877**
1994	***Oreochromis niloticus* (Linnaeus, 1758)**
1995	***Umbra pygmaea* (De Kay, 1842)** ***Neogobius gymnotrachelus* (Kessler, 1857)**
1997	***Neogobius fluviatilis* (Pallas, 1811)**
2002	***Neogobius melanostomus* (Pallas, 1811)**

it invaded most of the European inland waters (except the Italian, Iberian and Scandinavian penninsulas). In Poland, over several decades (particularly after World War II) it became a common and numerous species. At present it is distributed throughout the Pomeranian lake district, Wielkopolska, Kujawy, Mazowsze, Silesia, Małopolska and Podlasie regions. The rapid expansion of brown bullhead was caused mainly by accidental admixture to the stocking material of other species, escapees from fish farms to rivers and canals linking various bodies of water. The habitat preferences of this species are limited to eutrophic lakes, lower courses of lowland rivers, oxbow lakes and small bodies of water. In these types of ecosystems, the species grew rapidly into numerous populations evidently limiting the numbers of native species (Adamczyk 1975). According to Kornijów (2001) there are several characteristics contributing to the colonisation success of this species: a/ high resistance to pollution and temporary deficits of oxygen, b/ modest requirements as to the quality of food taken, c/ parental care over spawn and the young, d/ adverse effect on native species (e.g. by feeding on their spawn and fry), e/ great resistance to parasites, and f/ low attractiveness for predators.

Particularly well known is the expansion in Europe of stone moroco (*Pseudorasbora parva*). The homeland of this small (maximum size of 9-11 cm) species is East Asia (Russia – the catchment of the Amur river, China – the catchments of the Yang-tze and Huang-ho, Taiwan, Japan, Korea) (Berg 1949). It was unintentionally brought to the continent of Europe within the stocking material of herbivorous fishes (*Ctenopharyngodon idella, Aristichthys noblis, Hypophathalmichthys molitrix*). This species was found in 1960 in southern Romania (Nucet fish-farm in Dimbovita river catchment) (Bănărescu and Nalbant 1965) and probably also in Albania (Knezevič et al. 1978). From there it spread either naturally or with the stocking material of other species. At the end of 1960s it was found in many regions and river systems of Romania, including the Danube delta. Spreading along the Danube, as early as in 1963, stone moroco was recorded in Hungary. It is not unlikely that *P. parva* got there also with the fry of grass carp, silver carp and bighead carp imported by several fish-farms in the same year. In a couple of years it was found in most fish ponds and in open waters, including Lake Balaton (Biró 1972). In 1972, stone moroco was recorded in the European part of the then USSR – the Danube delta, and in the Dniester (Kozlov 1974). At the same time it was found in Lake Skardar (former Yugoslavia). The species also passed into the area of what was then Czechoslovakia, probably from Hungary. It was reported for the first time in 1974 from the Tisza river catchment area (Žitnan and Holčik 1976). In subsequent years, the presence of *P. parva* was found in more than 20 sites, several of them near the border with Poland (Karvina district) (Wohlgemuth and Šebela 1987). In Bulgaria, stone moroco appeared in 1975, brought in with the stocks of herbivorous fishes from the USSR. In 1982 and later, the species was recorded in Austria (for the first time – in the March river) (Weber 1984). In 1984, it was found in Germany in the Weisse Elster river (near Gera in former DDR) (Arnold 1985), and in 1987 in northern Greece in lake Mikroprespa and the Aliakmaon river (Bianco 1988).

In the territory of Poland, *P. parva* was reported first in 1990 in the State Fish Farm in Stawno near Milicz, where it arrived most likely in the 1980s with stocking material, probably imported from Hungary (Witkowski 1991). In the following year the species was reported in a neighbouring fish farm at Ruda Sułowska as well as in the Barycz river and its tributaries (Błachuta et al. 1993). It is probably from these places that stone moroco began its rapid expansion throughout most of Poland, mainly within the stocking material of other species (Fig. 2). Before the end of the 1990s it was found in other regions of Silesia (in the Jelenia Góra and Legnica areas, in Wielkopolska (Środa Wielkopolska, Sieraków, Miłosław, Lu-

Fig. 3. The expansion of the Amur sleeper *Perccottus glenii* in the Wisła basin (after Terlecki and Palka 1999; supplemented)

tom, Osieczno, Zgnilice), Małopolska (Brzesk, Pławowice), and Mazowsze (Żabieniec) (Kotusz and Witkowski 1998). In recent years, the species has been found in the Kozienicka Primeval Forest (Zagożdżonka), Łódź upland (Ner), and in the Podlasie region (Knyszyn), as well as in the tributaries of the upper Odra river: Osobłoga, Stradunia, Olza, Psina, and Ruda (Kusznierz et al. 2002; Lojkasek et al. 2000; Witkowski et al. 2000).

This species owes its colonisation success to its small size and its biological features: life style (it hides in densely overgrown parts of bodies of water, high reproductive rate (spawning several times a year) and taking care of its spawn. Quite independently, it also benefited from human actions aimed at introducing fish species into open waters or waters intensively exploited for fish. Unfortunately, its spread was also aided by amateurs of bait-fishing because this small fish is often used as a live-bait for predatory fish.

In recent years, some exotic species have appeared in our waters: Amur sleeper (*Perccottus glenii*), taking a route which has not been identified so far. The natural distribution area of this species spans from the southern coasts of the Sea of Okhotsk to Korea peninsula and Yellow Sea as well as in the middle and lower Amur river, Tumyen-ala, and Tugur (Berg 1949). The first documented information on the introduction of this species into Europe (into park ponds in St. Petersburg) dates back to 1914. From there, Amur sleeper spread to nearby lakes and the Gulf of Finland. In 1982 it was found near Kaliningrad. From 1950-1970 there were fish stocking operations carried out in lakes around Moscow, and unintentional introductions into the fish-farms of Nizhny Novgorod from where the species spread widely in the Volga and Kamna river systems. It is presupposed that this species got also through to the catchment areas of the Dnieper and Don rivers (Terlecki 2000). On the Polish territory, *P. glenii* was recorded first in 1993 in the Wisła ox-bow lake near Dęblin (Antychowicz 1994). In 1996, its presence was reported from the Wisła river and its ox-bow lakes between the Solec locality and the mouth of the Wieprz river (Terlecki and Pałka 1999); in 1997 – near Otwock, Łomianki, Wyszogród, and in Warsaw (Woźniewski 1997); in 1998 – in the Włocławek reservoir (Kakareko 1999); and very recently – even below the Tczew locality (Wiśniewolski et al. 2001). In the 6-7 years following its discovery, the species succeeded in entering the middle and lower stretches of the Wisła river over a total length of nearly 600 kilometres. Additionally, it was recorded on a stretch of the Bug river between the Hrubieszów and Zabuże localities, in the Pacynka river (a tributary of the Radomka river) and in Zwolenka (a tributary of the Wisła river near Kozienice) (dr. J. Kotusz, pers. comm.) (Fig. 3). Amur sleeper owes the rapid success of its colonisation to its extraordinary resistance to oxygen deficits, major fluctuations in water temperature and to the freezing and drying of bodies of water. This last factor in particular, does not threaten the survival of Amur sleepers, as the species has this extraordinary feature of being able to winter directly in ice (Sokolov 2001). The high survival rates also result from some other features of its biology, like high reproduction rate (multi-spawning) and taking care of laid spawn.

Linking the catchments of the Wisła and Dnieper rivers resulting from the construction of the Królewski (Royal) Canal which connected tributaries of the Bug and Prypet' rivers was

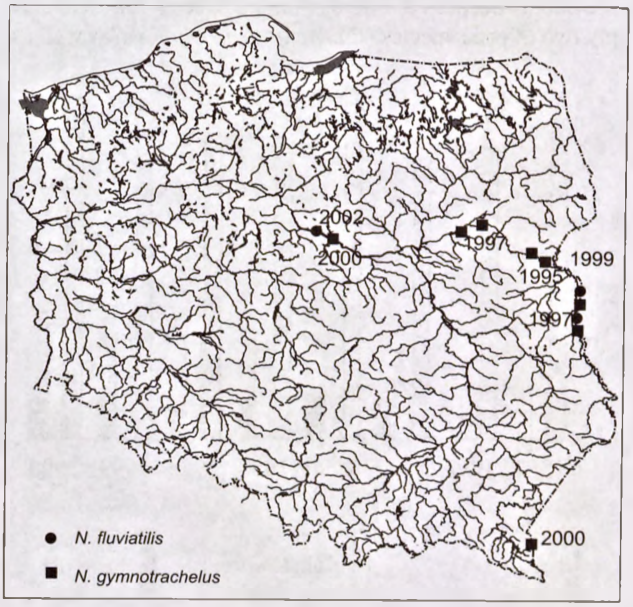

Fig. 4. The expansion of the racer goby *Neogobius gymnotrachelus* and monkey goby *N. fluviatilis* in the Wisła basin (after Kostrzewa and Grabowski 2003; supplemented)

a likely cause behind the appearance in Polish territory of two species of gobies (*Gobiidae* family): – racer goby (*Neogobius gymnotrachelus*) and monkey goby (*N. fluviatilis*). Their natural distribution area includes brackish bays of the Black and Azov seas, and lower stages of the Danube, Dniester, Boh, Dnieper and Don rivers (Berg 1949). Both species were found in the middle Bug: *N. gymnotrachelus* in 1995, on the Terespol-Drohiczyn section and in 1997 also on the Hanna-Kamieńczyk stretch, wheras *N. fluviatilis* in 1997, near Janów Podlaski (Danilkiewicz 1996, 1998). These two species probably occur along the whole stretch of the Bug river in Poland, including the Zegrzyński reservoir as well as in the middle Wisła, because in 2000 *N. gymnotrachelus* and in 2002 *N. fluviatilis* were caught in the Włocławek reservoir (Kostrzewa and Grabowski 2001). Outside the Wisła R. basin *N. gymnotrachelus* was recorded in 2000 from the Strwiąż R. (Dniester basin) (dr. J. Kusznierz – pers. comm.)(Fig. 4). In the same year, another species – *N. melanostomus* – was found in the lower section of the Wisła (Kostrzewa and Grabowski 2003), and earlier (1990 r.) had been caught in the Baltic Sea near the harbour in Hel (Skóra and Stolarski 1993).

It is common belief that fish species from subtropical and tropical zones are not able to live for any long time in open waters in our climatic zone. It turned out, however, that several of these species have been recorded already outside the breeding centres. In 1999, several individuals of Nile tilapia (*Oreochromis niloticus*) were found in the Ruda river (a right-side tributary of the upper Odra river) below the Rybnik reservoir (Kotusz et al. 2000). Several years earlier, the species was introduced for breeding in the reservoir (Kuczyński et al. 1997). Also reported are some single individuals of the velvet cichlid (*Astronotus ocellatus*), one of piranha species (*Serrasalmus* sp.), two of pacu species (*Piaractus brachypomus*) as well as species of *Poecilia* and *Xiphophorus* genera - probably released from aquarium breeding (Anonymous 2001). It appears that some of these can successfully survive in our region through winter.

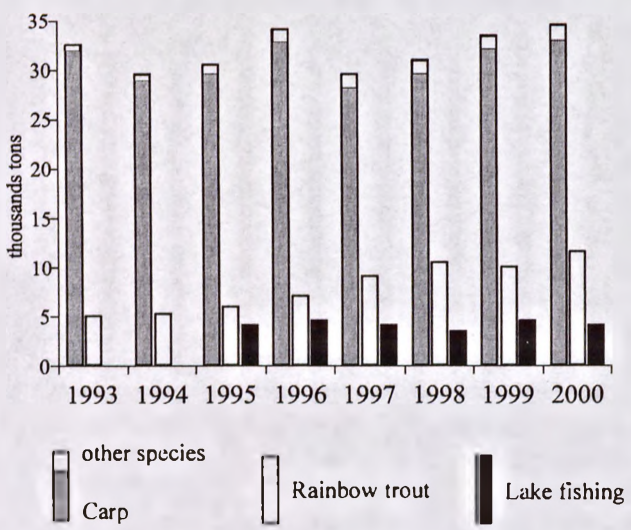

Fig. 5. The production of carp and other species, rainbow trout and lake fishing in Poland figures in 1993-2000 (after Bontemps 2001)

Table 3. Purposes for which species have been introduced (after Welcomme 1988)

Motivations	Number of introductions
Aquaculture	**495**
Sport fishing/ angling	**191**
Improvement in species composition	**165**
-- developing new resources for fishing	45
-- filling in 'free niches'	33
-- stocking open waters	28
--food for predators	21
--'reconstruction' of fish communities	24
--management of 'dwarfing' species/populations	2
Accidental	**139**
--escapes or releases from aquaria	73
-- penetration through canals	20
-- escape or release of live fish bait	11
-- introduction together with other species	11
-- unknown in detail	10
-- escapes from fish-farms	9
-- discharging with ballast water	4
-- transportation of fish for consumption	1
Decorative species	**130**
Control of undesirable organisms	**82**
-- vascular plants	36
-- mosquitoes	35
-- molluscs	5
--algal blooms	5
-- other fishes	2
Diet considerations	**1**
Unknown (including introductions by private individuals)	**312**

ADVANTAGES AND DISADAVANTAGES OF THE INTRODUCTION OF NON-NATIVE (ALIEN) FISH INTO POLAND

The presence in Poland of species, either introduced or simply brought in accidentally have resulted in many adverse changes in aquatic ecosystems. They are now noted with increasing attention but full assessment of the effects is not always possible. Here are several examples:

Brook trout (*Salvelinus fontinalis*) introduced into the waters where the native brown trout (*Salmo trutta* m. *fario*) lived, contributed to the drop in numbers of the latter. These two species spawn at the same time and quite often interact in reproduction giving sterile offspring. The same species introduced into lakes in the Tatra mountains (Witkowski 1996c) has caused adverse changes in the crustacean plankton com-

munities (Dawidowicz and Gliwicz 1983; Gliwicz 1963), and have also possibly contributed to the disappearance of a relict phyllopodan species, *Branchinecta paludosa* (Smagowicz and Dyduch 1980).

Introducing peled (*Coregonus peled*) into lakes with native whitefish (*C. lavaretus*) has resulted in an extremely high degree of hybridisation. Mamcarz (1986, 1992) reported the presence of hybrids in as many as 70 % of the Masurian lakes. It is practically very hard to find genetically pure populations of native forms of the whitefish. This process intensifies because of the strong migratory instinct of peled, colonising increasing numbers of lakes.

Introducing great numbers of herbivorous fishes brought about many adverse changes in lacustrine ecosystems. Particularly harmful was the introduction of grass carp (*Ctenopharyngodon idella*), which – by intensive feeding on both soft and hard vegetation – eliminated the spawning grounds of phytophilous fishes, as well as sites where they grew and fed. According to Mastyński et al. (1987) in some lakes of the Wielkopolska region, only a few years after introducing grass carp, the catches of pike-perch (*Sander lucioperca*), pike (*Esox lucius*), tench (*Tinca tinca*), bream (*Abramis brama*), roach (*Rutilus rutilus*), white bream (*A. bjoerkna*) and Eurasian perch (*Perca fluviatilis*) (Krzywosz et al. 1980, Radziej and Krzywosz 1979), were reduced and there was also an evident decline in the species composition of bird fauna of these lakes. Species such as coot (*Fulica atra*) and swan (*Cygnus* sp.), feeding on tender vegetation, have all but left these bodies of water.

As in the case of grass carp, the farming of silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys noblis*) necessitates controlled actions. In some cases, the breeding of these species can bring down the overall production in lakes and create a danger to the populations of the most valuable native species. In his studies on the effect of stocking carp ponds with silver carp and bighead carp, on the environmental and biocoenotic conditions there, Opuszyński (1978, 1979, 1987, 1988, 1989, 1997) found that in some cases they can even accelerate the eutrophication process. The two introduced species feed more on detritus than on unicellular algae and eliminate zooplanctonic filtrators. By this process they accelerate the turnover of essential biogens; phosphorus and nitrogen.

Introduction of brown bullhead had an evident impact on the ichthyofauna of some lakes and small bodies of water. According to Adamczyk (1975), Danilkiewicz (1973) and Kornijów (2001) it is soon able to become dominant, because it feeds on the eggs and fry of other fish species.

With regard to other introduced species (e.g. *Lepomis gibbosus, Pseudorasbora parva, Perccottus glenii, Neogobius gymnotrachelus, N. fluviatilis, N. melanostomus*), which have recently colonised significant portions of the country, there are no literature data available to-date detailing their effects on the autochtonic ichthyofauna. They probably compete for food and feed on eggs and early forms of native fish species. The data avalaible from other parts of Europe indicate that the appearance of these species evidently contributed to the gradual disappearance of some native fishes (Arnold 1985; Balon 1957; Cakić 1987; Jankowić 1985; Kautman 1999; Stein and Hertl 1986; Žitnan and Holčik 1976).

Together with introduced herbivorous fish, *Bothriocephalus acheilognathi* (= *B. gowkongensis*) and *Khawia sinensis*, tapeworms were brought into our waters where they cause significant loss among the fry of native cyprinid species (Pańczyk and Żelezny 1974; Pojmańska 1993). Also, with the translocation of Danube salmon (*Hucho hucho*) from the catchment of the Czarna Orawa river to the Dunajec and Poprad rivers, a species of parasitic crustacean *Basanistes huchonis* was brought to the system of the Wisła river for which it was a new species (Witkowski and Błachuta 1980; Witkowski and Kowalewski 1989).

Only with respect to a few introduced species, has the breeding in controlled conditions resulted in significant economic effects in the form of increased numbers of fish available for consumption. Traditionally, for many years the major contri-

Table 4. Motivations for introducing fish species into Poland (A - aquaculture, B -sport/angling, C - 'improving' original species composition, D - aquarium keeping, E - controlling other aquatic organisms, F - accidental)

A	B	C	D	E	F
C. carpio	*S. fontinalis*	*C. peled*	*L. gibbosus*	*M. salmoides*	*L. gibbosus*
O. mykiss	*O. mykiss*	*C. muksun*	*U. pygmaea*	*C. idella*	*U. krameri*
I. niger		*O. gorbuscha*		*H. molitrix*	*U. pygmaea*
C. gariepinus		*I. nebulosus*		*A. nobilis*	*C. auratus*
O. niloticus					*T. baicalensis*
					P. parva
					P. glenii
					N. gymnotrachelus
					N. fluviatilis
					N. melanostomus

bution has come from the breeding of carp (*Cyprinus carpio*), whose annual production figures have been regularly 30-33 thousand tonnes and rainbow trout (*Oncorhynchus mykiss*) – climbing rapidly in the last decade, with production currently at 11 thousand tonnes (Bontemps 2001) (Fig. 5). Because these species do not reproduce naturally in the climatic conditions prevailing in Poland they can be regarded as relatively harmless towards the native ichthyofauna.

Fish farming of the thermophilous species: African walking catfish (*Clarias gariepinus*), Nile tilapia (*Oreochromis niloticus*), buffalo (*Ictiobus niger*) and sturgeons (*Acipenseridae*) are still at an experimental stage, whereas catches of herbivorous fishes and peled (*Coregonus peled*) and muksun (*C. muksun*) from lakes are fairly low only totalling a mere several hundred tonnes a year (Szczerbowski 1985).

In the concluding part of this article there is a question to ponder: Do the economic gains from introducing exotic species of fish compensate for losses in the aquatic environment and native fish fauna? The adverse effect of introductions on native hydrobionts and aquatic environment in open waters is more and more noticeable but currently still difficult to evaluate fully. It is likely that the effects of introducing fish may manifest themselves strongly only after many years but then the damage incurred could be irreversible.

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REFERENCES

Adamczyk L. 1975. Sumik karłowaty, *Ictalurus nebulosus* (Le Sueur, 1819) w biocenozie jeziora (*Ictalurus nebulosus* (Le Sueur, 1819) in a lake biocenosis). Przegl. Zool. 19: 71-73 (in Polish with an English summary).

Allardi J. 1984. Introduction et acclimatation de poissons d'eau douce en France: historique et bilan. EIFAC Tech. Pap. 42 (suppl.): 247-447.

Anonymus. 2001. Pirania na Suwalszczyźnie (A piranha in the region of Suwałki). Wędkarz Polski 12: 12 (in Polish).

Anonymus. 2003. Fałszywa pirania (A false piranha). Wędkarz Polski 3, 145: 12 (in Polish).

Antychowicz J. 1994. *Perccottus glehni* w naszych wodach (*Perccottus glehni* in our waters). Kom. Ryb. 2: 21-22 (in Polish).

Arndt G. M., Gessner J., Andreas E., Spratte S., Filipiak J., Debus L., Skora K. 2000. Predominance of exotic and introduced species among sturgeons captured from the Baltic and North Seas and their watersheds, 1891-1999. Bol. Inst. Esp. Oceanogr. 16: 29-36.

Arnold A. 1985. *Pseudorasbora parva* (Schlegel 1842) nun auch in der DDR! Z. Binnenfisch. DDR 32: 182-183.

Arthington A. H. 1991. Ecological and genetic impacts of introduced and translocated freshwater fishes in Australia. Can. J. Fish. Aquat. Sci. 48 (suppl.): 33-43.

Backiel T. 1985. Fall of migratory fish populations and changes in commercial fisheries in impoundment rivers in Poland. In: J. S. Alabaster (ed.). Habitat Modification and Freshwater Fisheries Proceedings of a Symposium of the European Inland Fisheries Advisory Commission, FAO, London, Butterworths, pp. 28-41.

Balon E. 1957. Neres *Lepomis gibbosus* (Linné, 1758), aklimatizowanej v bočnych vodach Dunaja, a jej vývoj počas embrionalnej periody (Spawning of *Lepomis gibbosus* (Linné, 1758) acclimatized in the back-waters of the Danube and its development during the embryonic period). Vest. Česk. Zool. Spol. 23: 1-22 (in Czech with an English summary).

Balon E. K. 1974. Domestification of the carp *Cyprinus carpio* L. Royal Ont. Mus., Toronto, Life Sci. Misc. Publ. pp. 37.

Bănărescu P., Nalbant T. 1965. Studies on the systematics of *Gobioninae* (*Pisces: Cyprinidae*). Rev. Roum. de Biol. Ser. de Zoologie 10: 219-229.

Berg L. S. 1949. Ryby presnych vod SSSR i sopredelnych stran. 2. pp. 477-925. Izd. AN SSSR, Moskva-Leningrad.

Bianco P. J. 1988. Occurrence of Asiatic gobionid *Pseudorasbora parva* (Temmnick and Schlegel) in south-eastern Europe. J. Fish Biol. 32: 973-974.

Billington M. M., Herbert P. D. N. 1991. The ecological and genetic implications of fish introductions. Can. J. Fish. Aquat. Sci. 48: 1-181.

Biró P. 1972. *Pseurorasbora parva* a Balatondon. Halaszat 18: 11-13.

Błachuta J., Kuszewski J., Kusznierz J., Witkowski A. 1993. Ichtiofauna dorzecza Baryczy (Ichthyofauna of the Barycz River basin). Rocz. Nauk. PZW 6: 19-48 (in Polish with an English summary).

Bontemps S. 2001. Analiza produkcji i sprzedaży pstrągów tęczowych w 2000 r. In: K. Goryczko (ed.). Aktualne problemy pstrągarstwa polskiego (Current problems of trout farming in Poland). pp. 3-30. Wyd. IRS, Olsztyn (in Polish)

Burmakin E. V. 1961. Nekotorye voprosy teorii akklimatizacji ryb v SSSR (Some problems of fish acclimatization theory in the USRR). Zool. Žurn. 40: 385-395 (in Russian with an English summary).

Cakić P. 1987. *Pseudorasbora parva* (Schlegel, 1842): Neue Fischart im jugoslawischen Donauteil. 26 Arbeitstagung IAD, Passau, Wiss. Kurzref., pp. 252-256.

Cooper M. J., Wheatley G. A. 1981. An examination of the fish population in the River Trent, Nottinghamshire using angler catches. J. Fish Biol. 19: 539-556.

Crossman E. J. 1991. Introduced Freshwater Fishes: A review of the North American perspective with emphasis on Canada. Can. J. Fish. Aquat. Sci. 48 (suppl.): 46-57.

Danilkiewicz Z. 1973. Ichtiofauna dorzeczy Tyśmienicy i Włodawki (Die Ichthyofauna der Flussgebiete von Tyśmien-

ica und Włodawka). Fragm. Faun. 19: 121-147 (in Polish with a German summary).

Danilkiewicz Z. 1996. Babka łysa (gołogłowa), *Neogobius gymnotrachelus* (Kessler, 1857) *Perciformes, Gobiidae* – nowy gatunek w ichtiofaunie zlewiska Morza Bałtyckiego *[Neogobius gymnotrachelus* (Kessler, 1857) *Perciformes, Gobiidae* – a new ichthyofauna species in the Baltic Sea basin]. Kom. Ryb. 2: 27-29 (in Polish).

Danilkiewicz Z. 1998. Babka szczupła, *Neogobius fluviatilis* (Pallas, 1811), *Perciformes, Gobiidae* – nowy, pontyjski element w ichtiofaunie zlewiska Morza Bałtyckiego [*Neogobius fluviatilis* (Pallas, 1811) a Pontic element new to the ichthyofauna of the Baltic basin is reported occurring in the River Bug (Poland)]. Fragm. Faun. 41: 269-277 (in Polish with an English summary).

Daszkiewicz P. 2000. Mało znany dokument dotyczący historii introdukcji ryb w wodach Polski (A little known document concerning the introduction of fish in Polish waters). Przegl. Zool. 45: 71-74 (in Polish with an English summary).

Dawidowicz P., Gliwicz M. 1983. Food of brook charr in extreme oligotrophic conditions of an alpine lake. Env. Biol. Fish. 8: 55-60.

Delmastro G. B. 1986. Problemi relativi all'introduzione di specie esotiche di pesci nelle acque dolci italiane. Quaderni E.T.P. – Udine 14: 85-96.

De Silva S. S. (ed.) 1989. Exotic aquatic organisms in Asia. Proceedings of the workshop on introduction of exotic aquatic organisms in Asia. Asian Fish. Soc. Spec. Publ. 3: 1-54.

Drakej A., Mooney H. A., Di Castri F., Groves R. H., Krueger F. J., Rejmanek M., Williamson M. (eds.) 1989. Biological invasions a global perspective. J. Wiley & Sons, New York.

Dryagin P. A. 1954. Teoretičeskije osnovy i plan akklimatizacji ryb vo vnutriennych vodojemach SSSR. Tr. Sov. Ichtiol. Kom. AN SSSR 3: 9-20.

Elvira B. 2001. An overview of freshwater fish introductions in Europe. 10th Europ. Congress of Ichthyol., Prague.

Elvira B., Almodovar A., Nicola G. G. 1998. Fish communities of the middle-upper Tagus River (Central Spain): a story of river regulation and exotic introductions. Pol. Arch. Hydrobiol. 45: 165-171.

Fernando C. H. 1991. Impacts of fish introductions in tropical Asia and America. Can. J. Fish. Aquat. Sci. 48 (suppl.): 24-32.

Fernando C. H., Holčik J. 1991. Some impact of fish introductions into tropical freshwaters. In: P. S. Ramakrishnan (ed.). Ecology of biological invasion in the tropics. pp. 103-129.

Fitzmaurice P. 1984. The effects of freshwater fish introductions into Ireland. EIFAC Tech. Pap. 42 (suppl.): 449-457.

Gliwicz M. 1963. Wpływ zarybiania na biocenozy jezior tatrzańskich (The influence of the stocking of the Tatra lakes with fish upon their biocenoses). Chrońmy Przyr. Ojcz. 19: 27-35 (in Polish with an English summary).

Głowaciński Z. (ed.) 2001. Polska Czerwona Księga Zwierząt. Kręgowce. (Polish Red Data Book of Animals. Vertebrates). PWRiL, Warszwa (in Polish with an English summary).

Hesse T. 1997. Wpływ introdukcji egzotycznych gatunków ryb na biocenozy polskich jezior (Effect of exotic fish introduction on the Polish lakes biocenoses). In: A. Choiński (ed). Mat. Konf. Nauk "Wpływ antropopresji na jeziora". Uniw. A. Mickiewicza w Poznaniu, pp. 25-31 (in Polish).

Holčik J. 1984. Some considerations on the role of introduced species of fish in the management of inland fisheries. EIFAC Tech. Pap. 42 (suppl.) 2: 488-495.

Holčik J. 1991. Fish introduction in Europe with particular reference to its central and eastern part. Can. J. Fish. Aquat. Sci. 48: 13-23.

Holčik J. 2001. The impact of stream regulation upon the fish fauna and measures to prevent it. Ekologia (Bratislava) 20: 250-262.

Horoszewicz L. 1971. Sum (Sheatfish). PWRiL, Warszawa.

Jankowić D. 1985. Extension of *Pseudorasbora parva* (Schlegel) 1842 in Serbia, taxonomic characteristics of this fish species from Moravica River (South Morava river basin) and its possible role and significance for ichthyofauna of the open waters and fish ponds. Ichthyologia 17: 1-12.

Jungwirth M., Schmutz S., Weiss S. 1998. Fish migration and fish bypasses. Fishing News Books, Oxford, pp. 440.

Jurajda P. 1995. Effect of channelization and regulation on fish recruitment in a floodplain. Regulated Rivers: Research and Management 10: 207-215.

Jurajda P., Hohausova E., Gelnar M. 1998. Seasonal dynamics of fish abundance below a migration barrier in the lower regulated River Morava. Folia Zool. 47: 215-223.

Kakareko T. 1999. *Perccottus glenii* (*Odontobutidae*) – nowy gatunek ryby w Zbiorniku Włocławskim na Dolnej Wiśle [*Perccottus glenii* Dybowski, 1877 (*Odontobutidae*) in the Włocławek Dam Reservoir on the lower Vistula River]. Przegl. Zool. 42: 107-110 (in Polish with an English summary).

Kapuscinski A. R., Hallerman E. M. 1991. Implications of introduction of transgenic fish into natural ecosystems. Can. J. Fish. Aquat. Sci. 48 (suppl.): 99-107.

Karpevič A. F. 1975. Teoria i praktika akklimatizacji vodnych organizmov. Pišč. Promysl. Moskva.

Kautman J. 1999. *Perccottus glenii* Dybowski, 1877 vo vodach vychodneho Slovenska. Ochran. Uzem. Slovenska 40: 20-22.

Knezević B., Vuković T., Kavarić M. 1978. *Pseudorasbora parva* (Schlegel). Nova vrsta za ihtiofaunu Jugoslavie. Rib. Jugosl. 33: 140-142.

Kolman R. 1999. Jesiotry (Sturgeons). Wyd. IRS, Olsztyn.

Kornijów R. 2001. Przyczyny sukcesu kolonizacyjnego sumika karłowatego *Ictalurus nebulosus* Le Sueur, 1819 w ekosystemach wodnych Polski (Reasons for successful

colonisation of Polish waters by brown bullhead *Ictalurus nebulosus* Le Sueur, 1819). Przegl. Zool. 55: 113-119 (in Polish with an English summary).

KOSTRZEWA J., GRABOWSKI M. 2001. Babka łysa (gołogłowa), *Neogobius gymnotrachelus* (Kessler, 1857) *Gobiidae, Perciformes* – nowy gatunek ryby w Wiśle [Racer (goad) goby, *Neogobius gymnotrachelus* (Kessler, 1857) *Gobidae, Perciformes* – a new fish species in the Vistula River]. Przegl. Zool. 45: 101-102 (in Polish with an English summary).

KOSTRZEWA J., GRABOWSKI J. 2003. Opportunistic feeding strategy as a factor promoting the expansion of racer goby (*Neogobius gymnotrachelus* Kessler, 1857) in the Vistula basin. Lauterbornia 48, 91-100.

KOTUSZ J., WITKOWSKI A. 1998. Morphometrics of *Pseudorasbora parva* (Schlegel, 1842) (*Cyprinidae: Gobioninae*), a species introduced into the Polish waters. Acta Ichthyol. et Piscat. 28: 3-14.

KOTUSZ J., KUSZNIERZ J., WITKOWSKI A. 2000. Tilapia nilowa *Oreochromis niloticus* (L.)(*Osteichthyes: Cichlidae*) w wodach otwartych Polski (rzeka Ruda, prawy dopływ górnej Odry) [Nile tilapia *Oreochromis niloticus* (L.)(*Osteichthyes: Cichlidae*) in the open waters of Poland (the Ruda River, right affluent of the upper Odra River)]. Przegl. Zool. 44: 85-87 (in Polish with an English summary).

KOZLOV V. I. 1974. Amurskij čebačok - *Pseudorasbora parva* (Schl.) – novyj vid ichtiofauny bassejna Dnestra [The Amur Pseudorasbora *Pseudorasbora parva* (Schl.), a new species in the ichthyofauna of the Dnestr River basin]. Vest. Zool. 1: 77-78 (in Russian with an English summary).

KRUEGER C. C., MAY B. 1991. Ecological and genetic effects of salmonid introductions in North America. Can. J. Fish. Aquat. Sci. 48 (suppl.): 66-77.

KRZYWOSZ T., KRZYWOSZ W., RADZIEJ J. 1980. The effect of grass carp, *Ctenopharyngodon idella* (Val.) on aquatic vegetation and ichthyofauna of lake Dgał Wielki. Ecol. Pol. 28: 433-450.

KUCZYŃSKI M., RONCHETTI R., WYMYSŁO K. 1997. Tilapia nilowa – nowy gatunek w zbiorniku "Rybnik" (Nile tilapia – a new species in the Rybnik reservoir). Mat. XVII Zjazdu Hydrobiol. Pol. p. 191, Poznań.

KUSZNIERZ J., KOTUSZ J., POPIOŁEK M., WITKOWSKI A. 2002. Ichtiofauna górnego dorzecza Odry (część polska) [The ichthyofauna of the upper Odra basin (Polish part)]. Rocz. Nauk. PZW 15 (in press) (in Polish with English summary).

LEŚNIEWSKI P. E. 1837. Rybactwo Krajowe czyli Historyja Naturalna Ryb Krajowych. (Domestic fishing that is the natural history of indigenous fishes). Warszawa (in Polish).

LOFTUS K. H. (ed.) 1968. A symposium on introductions of exotic species. Ontario Dept. of Land and Forests, Research Branch. Res. Repr. 82.

LOJKASEK B., LUSK S., HALAČKA K., LUSKOVA V. 2000. Fish communities in the drainage area of the Osoblaha River and effect of the 1997 flood. Czech. J. Anim. Sci. 45: 229-236.

LUSK S. 1988. Stav a vyhledy introdukce ryb v Československu. Zpravy USEB 1988: 171-174 (in Czech with an English summary).

MAITLAND P. S. 1987. Fish introductions and translocations – their impact in the British Isles. In: P. S. Maitland, A. K. Turner (eds.). Angling and Wildlife in Freshwaters, ITE Symposium 19: 51-56.

MAMCARZ A. 1986. Gospodarka pelugą (Management of peluga). Gosp. Ryb. 5: 17-19.

MAMCARZ A. 1992. Effect of introductions of *Coregonus peled* Gmel. on native *C. lavaretus* L. stocks in Poland. Pol. Arch. Hydrobiol. 3: 847-852.

MASTYŃSKI J., MAŁECKI J., IWASZKIEWICZ M. 1987. Ryby roślinożerne w jeziorach – perspektywa czy niebezpieczeństwo (Plant-eating fishes in lakes – prospects or danger). Gosp. Ryb. 1: 9-11.

MOLNAR K. 1984. Parasite range extension by introduction of fish to Hungary. EIFAC Tech. Pap. 42 (suppl.): 534-540.

MOONEY H. A., DRAKE J. (eds.) 1986. Biological invasions in North America and Hawaii. Springer Verl., New York.

NIELSEN L. A., SHEEHAN R. J., ORTH D. J. 1986. Impacts of navigation on riverine fish production in the United States. Pol. Arch. Hydrobiol. 33: 277-294.

NILSSON N. A. 1984. The niche concept and the introduction of exotics. EIFAC Tech. Pap. 42 (suppl.): 496-505.

OPUSZYŃSKI K. 1972. Wykorzystanie ryb roślinożernych do zwalczania roślin wodnych (The utilization of phytophagous fish for aquatic weeds control). Wiad. Ekol. 18: 111-124 (in Polish with English summary).

OPUSZYŃSKI K. 1978. Wpływ tołpygi białej (*Hypophthalmichthys molitrix* Val.) na eutrofizację stawów karpiowych Cz. VII. Podsumowanie [The influence of the silver carp (*Hypophthalmichthys molitrix* Val.) on the eutrophication of the environment of carp ponds. Part VII. Recapitulation]. Rocz. Nauk Roln. H 99: 127-151 (in Polish with English summary).

OPUSZYŃSKI K. 1979. Azjatyckie ryby roślinożerne – czy niespełnione nadzieje? (Asiatic herbovorous fishes: shattered hopes?). Gosp. Ryb. 6: 6-9 (in Polish).

OPUSZYŃSKI K. 1987. Sprzężenie zwrotne między procesem eutrofizacji a zmianami zespołu ryb. Teoria ichtioeutrofizacji (The feed-back dependence between the eutrophication process and changes in the fish community. The theory of ichthyoeutrophication). Wiad. Ekol. 33: 22-30 (in Polish with English summary).

OPUSZYŃSKI K. 1988. Rola gospodarki rybackiej w przeciwdziałaniu eutrofizacji wód (The role of fish economy in actions against water eutrophication). Gosp. Ryb. 11: 3-5 (in Polish).

OPUSZYŃSKI K. 1989. Azjatyckie ryby roślinożerne wsiedlone do wód Polski (Asiatic herbivorous fish introduced into Polish waters). Przegl. Zool. 28: 109-123 (in Polish with English summary).

Opuszyński K. 1997. Wpływ gospodarki rybackiej, szczególnie ryb roślinożernych, na jakość wody w jeziorach (Effect of fish economy, especially plant-eating ones, on the quality of water in lakes). Bibl. Monitoringu Środowiska, Wyd. PIOŚ, Warszawa.

Pańczyk J., Żelezny J. 1974. Kawioza i botriocephaloza karpi – nowe choroby pasożytnicze stwierdzone w Polsce (New parasitic diseases of carps in Poland). Gosp. Ryb. 6: 10-13 (in Polish).

Penczak T. 1972. Wpływ ścieków Częstochowy i Radomska na strukturę zgrupowań ryb w Warcie (The effect of the sewage discharged from the towns Częstochowa and Radomsko on the structure of fish community in the Warta River). Ochr. Przyr. 37: 345-360 (in Polish with English summary).

Penczak T. 1995. Effects of removal and regeneration of bankside on fish population dynamics in the Warta River, Poland. Hydrobiologia 303: 207-210.

Penczak T., Koszaliński H., Galicka W. 1992. Wpływ regulacji i zanieczyszczenia wody na populacje ryb w Gwdzie i jej dopływach (Impact of river bed regulation and water pollution on fish populations in the Gwda River d its tributaries). Rocz. Nauk. PZW 5: 173-181 (in Polish with English summary).

Penczak T., Mann R. H. K. 1993. A preliminary evaluation of the effect of human activity on the fish populations of the Pilica River, Central Poland. Pol. Arch. Hydrobiol. 40: 101-115.

Peter A. 1998. Interruption of the river continuum by barriers and the consequences for migratory fish. In: M. Jungwirth, S. Schmutz, S. Weiss (eds.). Fish migration and fish bypases. Fishing News Books, Oxford, pp. 99-112.

Petts G. E. 1984. Impounded rivers: perspectives for ecological management. J. Wiley & Sons, Chichester, pp. 326.

Pojmanska T. 1993. Możliwość transferu pasożytów między rodzimymi a aklimatyzowanymi rybami karpiowatymi w hodowli stawowej (A chance of transferring parasites between native and acclimatised *Cyprinidae* in pond culture). Kom. Ryb. 1: 6-8 (in Polish).

Radziej J., Krzywosz W. 1979. Wpływ amura białego na biomasę i skład gatunkowy roślin oraz ichtiofaunę jeziora Dgał Wielki (An impact of grass carp on the biomass and species composition of the ichthyofauna in the Dgał Wielki Lake). Gosp. Ryb. 9: 6-8 (in Polish).

Rosenthal H. 1976. Bibliography on transplantation of aquatic organisms and its consequences on aquaculture and ecosystems. Spec. Publ. Eur. Maricul. Soc. 3: 1-46.

Rudziński E. 1962. Fragmenty historii europejskiego karpia hodowlanego (Selected fragments of the history of carp-farming in Europe). Gosp. Ryb. 9: 3-5 (in Polish).

Rudziński E. 1963a. Karp w Polsce (Carp in Poland). Gosp. Ryb. 1: 6-8 (in Polish).

Rudziński E. 1963b. Karp w Polsce (Carp in Poland). Gosp. Ryb. 2: 16-17 (in Polish).

Sindermann C. J., Steinmetz B., Hershberger W. K. (eds.) 1992. Symposium on introductions and transfers of aquatic species. ICES Marine Science Symposia. Inter. Council for the Explor. of the Sea, Paris.

Skóra K., Stolarski J. 1993. New fish species in the Gulf of Gdańsk, *Neogobius melanostomus* (Pallas, 1811). Bull. Sea Fish. Inst. Gdynia, 1: 83.

Smagowicz K., Dyduch A. 1980. Skrzelopływka bagienna *Branchinecta paludosa* w Tatrach (*Branchinecta paludosa* in the Polish Tatra Mts.). Chrońmy Przyr. Ojcz. 3: 45-49 (in Polish with English summary).

Sokolov L. I. 2001. On wintering of *Perccottus glenii* in the water-bodies of the Amur River. Vopr. Ichtiol. 41: 572-573.

Stein H., Hertl O. 1986. *Pseudorasbora parva* – eine neue Art der mitteleuropäischen Fischfauna. Der Fischwirt. Z. Binnenfisch. 36: 1-2.

Terlecki J., Pałka R. 1999. Occurrence of *Perccottus glenii* Dybowski, 1877 (*Perciformes, Odontobutidae*) in the middle stretch of the Vistula River, Poland. Arch. Ryb. Pol. 7: 141-150.

Terlecki J. 2000. *Perccottus gleni* Dybowski, 1877. In: M. Brylińska (ed.). Ryby Słodkowodne Polski (Freshwater fishes of Poland). PWN, Warszawa, pp. 476-479 (in Polish).

Ward J. V., Stanford J. A. (eds.). 1979. The ecology of regulated streams. Proceedings 1st International Symposium on Regulated Streams. Eric, Pennsylwania. Plenum Press, New York, pp. 398.

Weber E. 1984. Die Ausbreitung der Pseudokeilfleckenbarben in im Donauraum. Österr. Fisch. 33: 63-65.

Weigel J. A. V. 1806. Faune silesiace prodromus. In: Geographische, naturhistorische und technologische Beschreibung des souveräinen Herzogthmus Schlesien. Berlin.

Welcomme R. L. 1981. Register of international transfers of inland fish species. FAO Fish. Tech. Pap. 213: 1-120.

Welcomme R. L. 1988. International introductions of inland aquatic species. FAO Fish. Tech. Pap. 294: 1-318.

Welcomme R. L. 1991. International introduction of freshwater fish species into Europe. Finn. Fish. Res. 12: 11-18.

Wilkońska H. 1988. The effect of the introduction of herbivorous fish in the heated Lake Gosławickie (Poland) on the fry of local ichthyofauna. Ecol. Pol. 36: 275-281.

Wisniewolski W., Borzęcka I., Buras P., Szlakowski J., Woźniewski M. 2001. Ichtiofauna dolnej i środkowej Wisły – stan i zagrożenia (Fish fauna of the lower and middle Vistula River – present state and threats). Rocz. Nauk. PZW 14 (suppl.): 137-155 (in Polish with English summary).

Witkowski A. 1989. Introdukowane ryby w polskich wodach i ich wpływ na środowisko (Fishes introduced to Polish waters and their impact on environment). Przegl. Zool. 33: 583-598 (in Polish with English summary).

Witkowski A. 1991. *Pseudorasbora parva* (Schlegel, 1842) (*Cyprinidae, Gobioninae*) nowy gatunek w polskiej ichtiofaunie [*Pseudorasbora parva* (Schlegel, 1842) (*Cyprinidae, Gobioninae*) a new component of the Polish ichthyofauna].

Przegl. Zool. 35: 323-331 (in Polish with English summary).

Witkowski A. 1992. Threats and protection of freshwater fishes in Poland. Neth. J. Zool. 42: 43-259.

Witkowski A. 1996a. Introduced fish species in Poland: pros and cons. Arch. Ryb. Pol. 4: 101-112.

Witkowski A. 1996b. Changes in the ichthyofauna of the Polish rivers: native and introduced species. Zool. Pol. 41 (suppl.): 29-40.

Witkowski A. 1996c. Ryby (Fishes). In: Z. Mirek, Z. Głowaciński, K. Klimek, H. Piękoś-Mirkowa (eds.). Przyroda Tatrzańskiego Parku Narodowego (Nature of the Tatra National Park). Wyd. Tatrzański Park Narodowy, Zakopane-Kraków, pp.485-492 (in Polish with English summary).

Witkowski A. 1998. Niebezpieczne wzbogacanie (Dangerous enrichment). Wędkarz Polski 12: 22-24 (in Polish).

Witkowski A., Błachuta J. 1980. Występowanie *Basanistes huchonis* (Schrank, 1786) (*Copepoda parasitica, Lernaeopodidae*) na głowacicy *Hucho hucho* L. w Dunajcu [Occurrence of *Basanistes huchonis* (Schrank, 1786) (*Copepoda parasitica, Lernaeopodidae*) on the Danube salmon *Hucho hucho* (L.) in the Dunajec river]. Przegl. Zool. 24: 464-467 (in Polish with English summary).

Witkowski A., Kowalewski M. 1989. Biologiczna charakterystyka głowacicy *Hucho hucho* (L.) introdukowanej do dorzecza Dunajca (Biological characteristics of the Danube salmon *Hucho hucho* (L.) introduced into the Dunajec River drainage basin). Rocz. Nauk. PZW 2: 15-44 (in Polish with English summary).

Witkowski A., Błachuta J., Kotusz J., Kusznierz J. 2000. Lampreys and fishes of the upper and middle Odra basin (Silesia, SW Poland) – The present situation. Acta Hydrobiol. 42: 283-303.

Włodek J. M. 1978. Studies on the influence of man (angling) on freshwater fish populations in southern Poland. Verch. Internat. Verein. Limnol. 20: 2142-2145.

Wohlgemuth E., Šebela M. 1987. Střevlička východni, nový prvek evropské ichtyofauny. Živa 35: 25-27 (in Czech).

Wolter C., Vilcinskas A. 1997. Perch (*Perca fluviatilis*) as an indicator species for structural degradation in regulated rivers and canals in the lowlands of Germany. Ecol. of Freshw. Fish. 6: 174-181.

Woźniewski M. 1997. Trawianka – nowy gatunek ryby w Wiśle (*Percottus glenii* - a new fish species in the Vistula River). Wiad. Wędk. 12: 69 (in Polish).

Zawadzki A. 1840. Fauna der galizisch-bukowinischen Wirbelthiere. Eine systematische Uebersicht der in diesen Provinzen mit vorkommenden Säugethiere, Vögel, Amphibien und Fische, mit Rücksicht auf ihre Lebensweise und Verbreitung. Stuttgart.

Žitnan R. 1974. Acclimatization of fish in the Carpathian Region of Czechoslovakia and the role of helminths in this process. Ichthyologia 6: 143-155.

Žitnan R., Holčik J. 1976. On the first find of *Pseudorasbora parva* in Czechoslovakia. Zool. Listy 25: 91-95.