Rev Fish Biol Fisheries
DOI 10.1007/s11160-010-9180-8

REVIEWS

Non-native and translocated fish species in Serbia and their impact on the native ichthyofauna

Mirjana Lenhardt · Goran Markovic · Aleksandar Hegedis · Stevan Maletin · Miroslav Cirkovic · Zoran Markovic

Received: 1 March 2010 / Accepted: 18 October 2010

Abstract A total of 22 fish species have been introduced into the inland waters of Serbia, either intentionally or accidentally. This paper provides a summary of data concerning time and reason of introduction, mode of expansion, degree of acclimatization, impact on native fish and estimated area of recent distribution. Four of the non-native fish species currently occupy more than 51% of Serbian territory while 5 of them occupy between 21–50% of territory. This paper reviews impacts of introduced freshwater fish in Serbia based on collected data.

M. Lenhardt (✉)
Institute for Biological Research,
Bul Despota Stefana 142, 11000 Belgrade, Serbia
e-mail: lenhardt@ibiss.bg.ac.rs

G. Markovic
Faculty of Agronomy, Cara Dusana 34,
32000 Cacak, Serbia

A. Hegedis
Institute for Multidisciplinary Research,
Kneza Viseslava 1, 11000 Belgrade, Serbia

S. Maletin · M. Cirkovic
Faculty of Agriculture, Trg D. Obradovica 8,
21000 Novi Sad, Serbia

Z. Markovic
Faculty of Agriculture, Nemanjina 6,
10080 Belgrade, Serbia

Keywords Allochthonous fish · Ecological risk · Economic benefit · Inland waters

Introduction

The introduction of allochthonous fishes into drainages outside their natural range has occurred for centuries (Leonardos et al. 2008), and it may be traced back to the beginning of the first century A.D. (Holcik 1991).

Freshwater aquaculture is a major driver of freshwater fish introductions. In many regions of the world, non-native species have been intentionally introduced for aquaculture purposes and have contributed significantly to the expansion of the industry (Wellcome 1992). The occurrence of non-native fish species in natural waters is associated with escapes from aquaculture facilities, stocking for sport fisheries, careless release of live specimens from home aquaria, dumping of unused bait fish, negligent transfer of fertilized eggs of unknown species during stocking, struggle against macrophyte and plankton eutrophication, opening connective channels with introduced fish to native habitats or simply undocumented stocking (Cowx 1998; Innal and Erk'akan 2006; Vitule et al. 2009).

Non-native fish may have ecological impact which has been defined as 'quantifiable negative effect' on the recipient environment and has been measured using the existing body of scientific reports and

Published online: 03 November 2010

publications on a particular species introduction (Innal and Erk'akan 2006; Gozlan 2008; Leonardos et al. 2008). Predicting the impact that non-native species will have on habitat structure and, as a consequence, existing food webs and community composition is inherently difficult (Cook et al. 2008). Many links of negative effects of introduction have never been clearly established and sometimes some introductions have positive outcomes. Ecological risk associated with freshwater fish introduction is also fairly variable across families of fish (Gozlan 2008). Therefore, ecologically sustainable development seeks a balance between the benefits and costs (environmental, economic, social) of an activity related to the introduction of new fish species (Cook et al. 2008).

The government's responsibility for inland fisheries and its management in Serbia is vested in the Ministry of Environment and Spatial Planning while Ministry of Agriculture, Forestry and Water Management is responsible for aquaculture. Introduction of new species is regulated by The Law on Fishery (Anonymous 2009) prohibiting the importation of non-native fish into natural waters. Since 2000, stocking of open waters with existing non-native species and any introduction of new species have been rejected.

Hydroecological conditions in Serbia have caused a high diversity of its ichthyofauna including 94 permanent or occasional fish species of 26 families recorded in Serbian watercourses, with 22 of them belonging to 10 families non-native to the ichthyofauna of Serbia (Jankovic and Krpo-Cetkovic 1995; Simonovic and Nikolic 1997; Lenhardt et al. 2006a, b; Simonovic et al. 2006). Earlier introductions of allochthonous species into Serbian waters were made primarily in order to increase ichthyoproduction for purposes of weed control and sport fishing, and also incidentally (Maletin et al. 1997)

This review attempts to describe the situation in Serbia, which has not been thoroughly covered until nowadays. The objective of the present study was to review the information on societal benefits and ecological impacts of non-native fish in Serbia.

Materials and methods

The data on aquaculture and open water catches were obtained from the Statistical Office of the Republic of Serbia, Serbian Fisheries District Managers, and through field investigations conducted by the authors of the present study.

The degree of acclimatization was assessed using the following categories: unknown, failure, acclimatization of adults only, satisfactory and very good. Suspected impacts on native species were categorized as: unknown, established existence without apparent impact, suspected competition with native fish for resources and 'causal' (Copp et al. 2005) existence with suspected strong impact on native fish and 'causal' existence with no suspected impact. The mode of recent expansion was categorized as: continuous stocking for sport fishing, escapes from fish farms and fish ponds, uncontrolled self reproduction and drift. The area of recent distribution was estimated as a proportion of the total area of Serbia, covering 883 km^2, using the UTM Grid zones of the world, converted to classes: <1, 1–5, 6–20, 21–50 and >51%. The categorization is in accordance with categories established by Povz and Sumer (2005).

Fish introductions into Serbia and their use in aquaculture

The majority of non-native fish in Serbia are North American (representatives of the *Ictaluridae, Centrarchidae, Acipenseridae* families, rainbow trout *Oncorhynchus mykiss,* brook trout *Salvelinus fontinalis* species of the *Salmonidae* family), Asian—primarily the Amur river basin (fam. *Cyprinidae* and *Odontobutidae*) as well as Ponto-Caspian ones (fam. *Gobiidae*). There are 22 non-native species in Serbia (Table 1). The area of recent distribution of pumpkinseed *Lepomis gibbosus*, brown bullhead *Ameiurus nebulosus* and black bullhead *A. melas* as well as of Prussian carp *Carassius gibelio* covers more than 50% of the total Serbian area. Grass carp *Ctenopharyngodon idella*, bighead carp *Arystichthys nobilis*, and silver carp *Hypophthalmichthys molitrix* occupy 37.5, 24.6, and 35.1% of the total Serbian area, respectively, with two of them showing only acclimatization of adults (Table 1). Gobiids are currently distributed within 11.3–14.2% of the total Serbian area while other non-native species account for only few percent of the total Serbian area.

Among the 22 non-native species, only three cyprinids, including bighead carp, silver carp and

Table 1 List of non-native fish species recorded in Serbia

Species	Time of introduction or first record	Reason of introduction	Mode of expansion	Degree of acclimatization	Impact on native fish	Area of recent distribution (% of Serbian total area)
Hypophthalmichthys nobilis	1963	Aquaculture, To fill	Self reproduction	Very good	Impact on water quality	***24.6***
Hypophthalmichthys molitrix	1963	Vacant niche	Escapes from farm	Acclim of adults	"Casual" with no	***35.1***
Ctenopharyngodon idella	1963	Aquaculture, weed control	Escapes from farm	Acclim of adults	Suspected impact	***37.5***
Carassius gibelio	1960	Accidental	Self reproduction	Very good	Competition with native fish	**52.1**
Pseudorasbora parva	1978	Accidental	Self reproduction	Very good	Competition with native fish	***43.6***
Oncorhynchus mykiss	Between first and second world war	Aquaculture, sportfishing	Escapes from farm	Acclim of adults	Without apparent impact	***29.0***
Salvelinus alpinus		Sportfishing, fill vacant niche	Self reproduction	Satisfactory	Without apparent impact	*1.3*
Salvelinus fontinalis		Sport fishing	Self reproduction	Satisfactory	Without apparent impact	0.6
Coregonus peled	1991		Self reproduction	Satisfactory	Without apparent impact	0.2
Ameiurus nebulosus	1930	Aquaculture	Self reproduction	Very good	Competition with native fish	**53.2**
Ameiurus melas	2005	Aquaculture	Self reproduction	Very good	Competition with native fish	**53.2**
Lepomis gibbosus	1930	Ornamental fish	Self reproduction	Very good	Competition with native fish	**51.2**
Micropterus salmoides	1984	Sportfishing	Self reproduction	Satisfactory		*2.3*
Syngnathus abaster	1998	Expanded distribution	Self reproduction	Satisfactory	Without apparent impact	*3.4*
Neogobius fluviatilis	1977	Expanded distribution	Self reproduction	Very good	Competition existing mainly among these five gobiids species relating to food and area of distribution. They have positive impact as a food for economically important native fish species	14.2
Neogobius gymnotrachelus	1991	Expanded distribution	Self reproduction	Very good		12.51
Neogobius kessleri	1977	Expanded distribution	Self reproduction	Very good		11.3
Neogobius melanostomus	1998	Expanded distribution	Self reproduction	Very good		11.3
Proterorhinus marmoratus	Nineteenth century	Expand ed distribution	Self reproduction	Very good		11.3
Gasterosteus aculeatus	1995	Ornamental fish	Self reproduction	Satisfactory	Without apparent impact	*3.4*
Perccottus glenii	2004	Accidental	Self reproduction	Satisfactory	Unknown	0.6

Table 1 continued

Species	Time of introduction or first record	Reason of introduction	Mode of expansion	Degree of acclimatization	Impact on native fish	Area of recent distribution (% of Serbian total area)
Polyodon spathula	2006	Accidental	Escapes from fish farm	Failure	Unknown	0.2

The mode of recent expansion was categorized as: continuous stocking for sportfishing, escapes from fish farm and fish ponds, uncontrolled self reproduction and drift

The degree of acclimatization was assessed using the following categories: unknown, failure, acclimatization of adults only, satisfactory and very good

Suspected impacts on native species were categorized as: unknown, established existence without apparent impact, suspected competition with native fish for resources and 'causal' (Copp et al. 2005) existence with suspected strong impact on native fish and causal existence with no suspected impact

The area of recent distribution was estimated as a proportion of the total area of Serbia, covering 883 km^2, using the UTM Grid zones of the world, converted to classes: <1% (regular font), 1–5% (italic), 6–20% (underlined), 21–50% (bold italic) and >51% (bold underlined)

grass carp, and one salmonid species rainbow trout are reared in Serbian aquaculture. They are mainly reared in fishponds (over 95% of the total fish produced), and a considerably lower-scale ichthyoproduction is practiced in cages and partitioned open water sections (reservoirs, channels). Fishponds in Serbia cover between 13,500 and 14,000 ha, 99.9 and 0.1 % of which are cyprinid and salmonid ones, respectively. In recent years, the total fish production has ranged from 10,000–15,000 t, with the dominant carp farming exceeding 80% of the total production (Markovic et al. 2009).

Patterns of fish introductions and dispersal

Non-native fish species, including Chinese carps, the Prussian carp, the topmouth gudgeon, brown and black bullhead, mainly spread throughout Serbia via the Danube and Tisza rivers from Romania and Hungary, while the Mississippi paddlefish *Polyodon spathula* came from the Romanian part of the Danube and probably escaped from Romanian fish ponds during floods in 2006 (Fig. 1). E–W invasions included the dispersal of gobiids along the Danube, short-snouted pipefish *Syngnathus abaster* from the Black Sea and the Amur sleeper *Perccottus glenii* from the upper parts of the Tisza River (Fig. 1). The rainbow trout mostly occurs in open waters due to escapes from fish farms. The other two salmonid species and the peled are found only at individual locations where they were previously introduced, and do not spread any further. The largemouth bass spreads mostly throughout the canal network in northern Serbia. As for the three-spined stickleback, only individual findings in Serbia have been reported and no sufficient data are available as to the spread of the species.

Cyprinidae

Chinese carps

The introduction of the so-called 'Chinese carps' (grass carp, silver carp, bighead carp) into the European waters (Danube Basin) was conducted in the 1960s to produce their polyculture in carp fishponds and stock open waters in order to increase total ichthyoproduction at the expense of food resources available in plankton form.

The contribution of grass, silver and bighead carp to the total fish catch from the Danube in Serbia increased steadily during the 1980s and accounted for approximately 10% of total catch at the beginning of the 1990s (Maletin et al. 1994). The annual catch of grass, bighead and silver carp varied between 450 and 16,444 kg during 1979–1997 in the particular section of the Danube River in Serbia (section rkm 991–rkm 846), the ratio being 1:1.7:8.1 for grass, bighead and silver

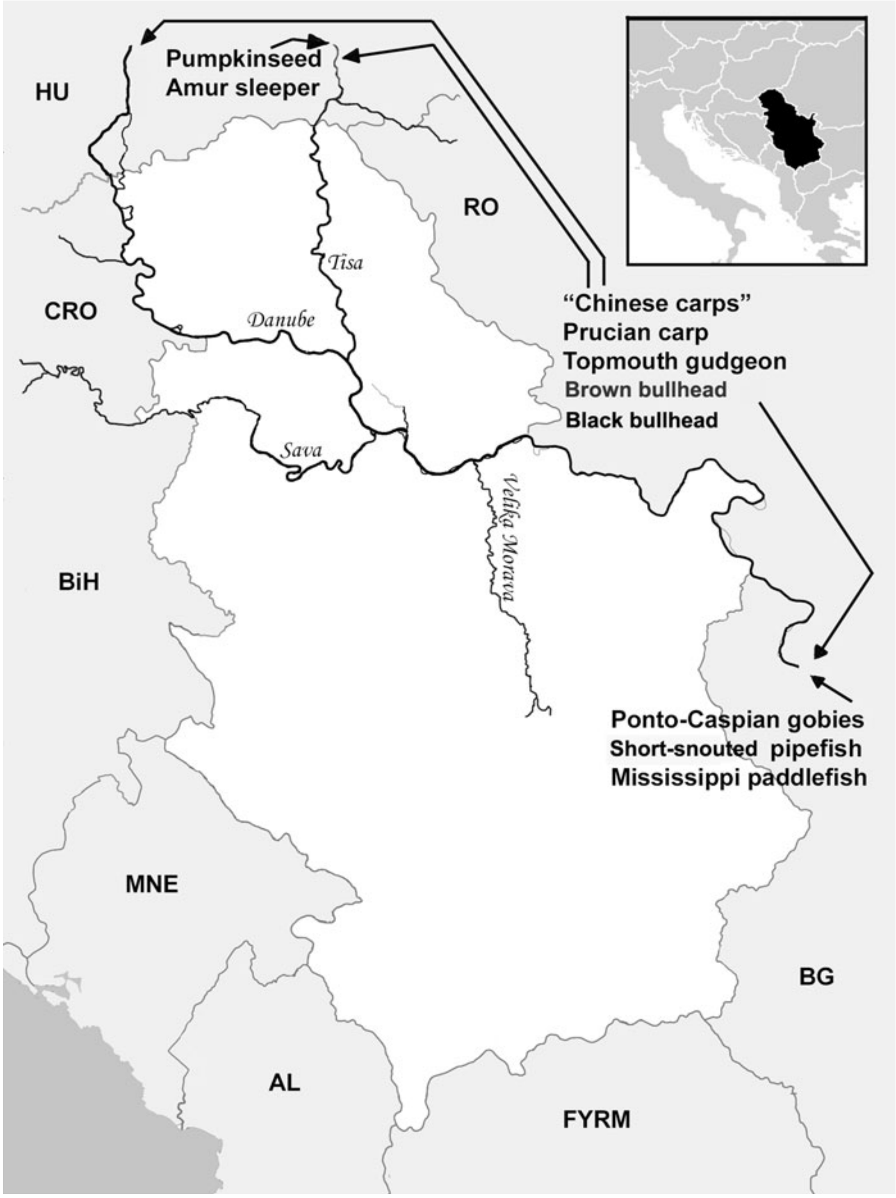

Fig. 1 Patterns of fish introductions and dispersal. Non-native fish species spreaded mainly by the Danube and Tisza River from Romania and Hungary

carp, respectively (Lenhardt et al. 2004). The current ratio of the three Chinese carps in the commercial fishery catch in Serbia remained unchanged. Bighead and silver carp account for 10–40% of the fish catch in the Tisza River (Petrovic-Gegic et al. 2006).

Due to the large size that bighead and silver carp reach in Serbian waters, fishermen prefer to catch these species and use nets of larger mesh size, thereby reducing, however, the catch of many other native species. Nowadays, silver and bighead carp are among the commonly consumed fish species in Serbia. However, notwithstanding their high economic importance, stocking open waters with these species is prohibited as they are non-native fish.

Grass, silver and bighead carp are farmed nowadays in polyculture with the carp, their proportion being up to 20%. Rational farming of these species in polyculture has provided judicious exploitation of productive fishpond features as these species are generally not nutrient competitors to the benthophagous carp. However, the grass carp has a low food conversion efficiency and a large part of the plant material introduced (up to 70%) is being ejected with the intestinal flora, additionally loading the watercourse with degradable organic matter. This results in increased sediment production and oxygen regime deterioration (Leslie et al. 1983; Mitrovic-Tutundzic et al. 1996).

The import of the Chinese complex is cited as a reason for the decrease in tench (*Tinca tinca*) populations due to competition for food (Cirkovic et al. 2009).

Grass carp (*Ctenopharyngodon idella* Vallenciennes, 1844)

The macrophyte feeder grass carp was introduced into Serbia in 1963 to utilize available food resources of a carp fishpond and to control the growth of macrophytic vegetation mainly in smaller closed water basins. It was introduced into the fish pond near Belgrade (Jankovic 1998) and, subsequently, into the canal system to control aquatic weeds (Hristic 1977; Maletin et al. 1994). The spread into the Danube Basin was also a result of free entrance into the streams from Hungary (Toth 1971, 1984) and Romania (Bacalbasa-Dobrovici 1982).

There is only one record of one-year-old grass carp individuals in the Danube River (Djerdap reservoir) in 1991 which was identified as successful acclimatization and as the possibility of natural spawning of this species under Serbian environmental conditions (Jankovic 1998). However, as there were no further records of the natural spawning of grass carp in Serbian waters, the grass carp was assumed to have shown only acclimatization of adults.

A number of new studies on the use of grass carp for ameliorative purposes indicate that it can also have negative effects similar to those of the other non-native fish species. Some studies suggest that grass carp enhancement, along with the enhancement of silver, bighead and Prussian carp, exerted pressure on certain autochthonous species, especially the Danube carp (Simic and Simic 2004). Jankovic (1998) reported that aquatic-plant-based nutrition of grass carp resulted in a reduction in spawning areas for carp as a phytophilic species.

Bighead carp (*Hypophthalmichthys nobilis* Richardson, 1845)

The bighead carp was introduced into Serbian fishponds in 1963 (Ristic 1968). It appeared in the open waters of Serbia along with the silver carp in 1969 (Toth 1971). It is reared in polyculture with carp. Stocking of open waters was aimed at increasing the total fish biomass at the expense of using plankton as a food source.

It is used to solve the problem of accelerated eutrophication, but variable results are obtained. It has a positive influence on autochthonous ichthyofauna and the ecosystem in general, contributing to the increase in total ichthyoproduction and maintenance of the biological balance in accordance with the capacity of a given habitat (Maletin et al. 1997).

The negative effects of bighead carp importation into Serbian waters are illustrated by findings of a new parasite in Serbian waters and by the negative effect on native fish species. The parasitic copepod *Sinergasilus polycolpus* was identified on the gills of the bighead carp in the Serbian part of the Danube River (Cakic et al. 2004a, b), indicating the introduction of the new parasite in Serbian waters which is species-specific for two Chinese carps, the bighead carp and the silver carp.

Silver carp (*Hypophthalmichthys molitrix* Vallenciennes, 1844)

The first finding of the silver carp in the open waters of Serbia was in 1969 (Toth 1971). During the 1980s, the process of silver carp acclimatization was underway, as natural spawning could not be accomplished due to the collision between the gonadal maturation period and water level increase, being the most significant stimulus to reproduction besides temperature (Maletin and Kostic 1988; Maletin 1989; Maletin and Pujin 1989). Nowadays, the silver carp exhibits a fair degree of acclimatization in Serbia, as manifested through its excellent total growth gain, maturity results and regular spawning in natural waters (Hegedis, unpublished data). There are reports of juvenile silver carp (0.5–17 g) findings in Serbian rivers, testifying to the fact that this species is likely to become a regular member of fish fauna in many natural waters in Serbia (Hegedis et al. 2008). Its introduction into a part of its wider distribution area has increased the total ichthyoproduction in the open waters, concurrently establishing and maintaining the ecological balance based on the previous estimation of habitat capacity (Maletin et al. 1997).

Prussian carp (*Carassius gibelio* Bloch, 1782)

The Prussian carp was introduced into the European part of the USSR in 1948 (Maletin et al. 1981) and recorded in Hungary in 1954 (Toth et al. 2005), with only female individuals being detected in the Danube River Basin thereafter (Csakany 1958). In the Serbian part of the Danube River, the Prussian carp appeared at the beginning of the 1960s (Plancic 1967), first in the east part of the Danube, spreading from Romania (Maletin et al. 1987) and resulting in its expansion after 1975 (Maletin and Budakov 1982). An analysis of Prussian carp populations from the Danube, Sava and Tisza rivers during 1976–1982 showed that all of the specimens caught were females. An investigation of an old meander of the Sava River in 1982 revealed 2 males in a sample of 85 individuals, this finding being due to the deterioration of abiotic and biotic factors (Budakov and Maletin 1984). The acclimatization of this species was rapid, resulting in a complete adaptation in Serbia. Nowadays, it is found in nearly all waters in Serbia. The Prussian carp is also a part of the ichthyofauna of mountain rivers at 1,100 m above sea level in the trout zone. The Prussian carp is an economically important fish species (a large number of specimens can reach a weight of 400–500 g) in Serbia but mainly due to its low price. It is especially popular during the spring fasting period when there is a ban on catching other fish species due to spawning. During the period, commercial fishery is allowed only if surface drifting nets are used to catch 'Chinese carps' and Prussian carp.

The negative effect of the Prussian carp is reflected in a remarkable competition over reproduction and food with other native species, primarily Crucian Carp *Carassius carassius,* tench and common carp *Cyprinus carpio* (Maletin et al. 1997). Oligochaeta, Cladocera and Copepoda have the highest incidence in Prussian carp diet if the biomass is taken into consideration (Pujin and Maletin 1987). An experiment performed by Demeny et al. (2009) showed that Prussian carp, especially juveniles, considerably influenced the survival and growth of Crucian carp and tench.

Topmouth gudgeon (*Pseudorasbora parva* Temnick and Schlegel, 1846)

Topmouth gudgeons colonized continental Europe from the east to the west and were also recorded in southern Algeria (Gozlan et al. 2002). The first record of this species in Serbia was noted in 1978 (Karaman 1983). Having been unintentionally introduced into the Serbian part of the Danube River, the populations expanded into the entire river catchment (Cakic et al. 2004a, b). This species has no economic value and it is only used by sport fishermen as bait fish. The practice of dumping unused bait fish is still one way they spread in Serbia. Another persistent problem is poor control of the stocking procedure in Serbian waters. Apart from the small carp, some amount of black bullhead, pumpkinseed and topmouth gudgeon are always found in the stocking material. Thus, many Serbian waters are still being unintentionally stocked with non-native fish.

The topmouth gudgeon most likely has negative effects on the native fish fauna with regard to predation, competition for food and other resources as well as to the introduction of new pathogens. However, no studies have been conducted in Serbia related to its impacts on native fish fauna.

Salmonidae

Rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792)

The rainbow trout is of highest commercial significance in Serbia. The first introduction of rainbow trout in Europe occurred in 1882 (Holcik 1991). It was introduced into Serbian fishponds between the First and Second World Wars (data are lacking on the exact date of their introduction). The rainbow trout has been currently bred in 13–14 ha fishponds with the annual production of about 1–2,000 t recorded (about 15% of the total consumable fish production in Serbia). The yields are highly variable (ranging from 10 to over 50 kg m^{-3}), depending on different production characteristics of fish farms (water amount and quality, fish fry and food quality). Apart from fish farming, there have been cage farming efforts with an average yield of 15 kg m^{-3} produced. In general, the rainbow trout production is not sufficient to satisfy market demands in Serbia despite the favourable hydroenvironmental upland growing conditions.

There is no established population of rainbow trout in Serbian natural waters, its populations being associated with escapes from fish farms. Natural spawning is not documented in Serbian open waters.

There is some evidence that rainbow trout introductions led to the extinction of or a decrease in the population numbers of the autochthonous salmonid brown trout (*Salmo trutta m. fario)*.

Arctic char (*Salvelinus alpinus* Linnaeus, 1758)

This species was introduced into the former Yugoslavia from Alpine lakes in 1943 and translocated thereafter into many other waters in Serbia. The Arctic char currently occurs only in two reservoirs. The Kokin Brod reservoir has a stabilized population of all age classes and shows evidence of regular natural spawning. As for the second reservoir, Vlasina Lake, there is only a record of Arctic char found in it (Simonovic 2001). This species is of interest to sport fishery and there are no confirmed negative effects of it on native fish populations.

Brook trout (*Salvelinus fontinalis* Mitchill, 1814)

The first introduction of brook trout into Europe occurred in 1869 (Holcik 1991). The brook trout was introduced between the First and Second World Wars in Serbia. It was introduced into some reservoirs (Vlasina and Lisina Lakes) and successfully reared in the Vrla fishpond—Surdulica (Simonovic 2001). The main reason for its introduction includes sport fishery but the current area of distribution of this species is very low −0.6% (Table 1).

Coregonidae

Peled (*Coregonus peled* Gmelin, 1789)

In the Balkan waters, the peled was introduced for the first time into the Perucac reservoir (Habekovic 1980) to increase the total ichthyopruduction utilizing available food resources of relatively unloaded niche. The first finding of peled in the Serbian part of the Danube River was at 1,282 rkm (Maletin and Djukic 1991). This species has a relatively narrow distribution in Serbia and no economic value. It is unknown whether it still exists in Serbian waters.

Ictaluridae

Brown bullhead (*Ameiurus nebulosus* Lesueur, 1819)

The first introduction of brown bullhead in Europe occurred in 1885 (Holcik 1991). The brown bullhead reached the Danube Basin in Serbia through introduction into warm-water fishponds and via free migration along the Danube and its tributaries from neighbouring countries (Vukovic and Ivanovic 1971). There was a population "explosion" in the 1940s and 1950s that gradually subsided during the 1980s and 1990s (Maletin et al. 1997). In this part of its wider distribution area, notwithstanding its smaller size, the rapid adaptation of the fish has induced its successful reproduction under natural conditions (Sotirov 1968).

It has negative effects on native fish species by feeding on the bottom fauna, small fishes, fish larvae, and roe (Pujin and Sotirov 1966).

Black bullhead (*Ameiurus melas* Rafinesque, 1820)

The first introduction of brown bullhead in Europe occurred in 1871 (Holcik 1991). The first record of the black bullhead in Serbian waters was in 2005 (Cvijanovic et al. 2005). Studies conducted in the last few years have revealed the dominant presence of black bullhead in Serbian waters.

There is only one fish farm in Serbia that rears black bullheads. It has an annual production of 20 t. The fish are exported after 3 years spent in fish ponds when they reach an approximate weight of 200 g. On the other hand, mass removals of black bullhead were organized in some small reservoirs in Serbia for the purpose of removing the species on grounds of being an undesirable pest (approximately 3–6 t of black bullhead were removed from each reservoir).

Epizootic haematopoietic necrosis was observed in 0^+ and 1^+ old black bullhead reared in polyculture with carp. The disease induced mortality of 6 tons of this species over a one-month period (from mid-August to mid-September), whereas no mortality in carp was recorded at the time nor any sign of the disease in 1^+ old carp reared in the same pond (Jeremic and Radosavljevic 2009).

Acipenseridae

Mississippi paddlefish (*Polyodon spathula* Walbaum, 1792)

The first introduction of the North American fish species Mississippi paddlefish into Europe occurred in 1974, when hatched larvae, originating from Missouri (USA), were imported into the former USSR for aquaculture rearing purposes. Thence the paddlefish was exported to Romania and other European countries. The paddlefish that appeared during 2006 in the Serbian part of the Danube River were most likely the specimens that escaped from Romanian fish ponds during floods (Lenhardt et al. 2006a, b). The occurrence of paddlefish in Serbia should be closely monitored as paddlefish are assumed to have established natural populations in Russia. Simonovic et al. (2006) reported that paddlefish can have a negative impact on the already endangered natural sturgeon population residing in the Danube, whereas Holcik (2006) suggested the improbability of paddlefish naturalization in the Danube.

Centrarchidae

Pumpkinseed (*Lepomis gibbosus* Linnaeus, 1758)

The pumpkinseed was introduced into Europe as an aquarium fish at the end of the nineteenth century. It was first recorded in Serbia in the 1930s in the Tisza river (Ristic 1940). The species currently inhabits almost the entire region of the Black Sea Basin in Serbia, but it has no economic value.

The pumpkinseed feeds on bottom fauna, small fishes, fish roe and young fish, which coupled with competition for habitat and spawning sites can have a negative effect on native species (Markovic and Simovic 1997).

Largemouth bass (*Micropterus salmoides* Lacepede, 1802)

The largemouth bass was introduced along with pumpkinseed into Europe at the end of the nineteenth century. In 1883, it was imported into Germany and, then, into Czechoslovakia, with the first record in the open waters of the Danube dating back to 1957. The first record of the largemouth bass in Serbia was in 1984 by Maletin (1988) in the Jegricka river (Danube Basin). Other findings of different specimens of this species (different age characterized by exceptional length, weight gain and overall condition) indicated that this species underwent all the acclimatization phases and that its adaptation to new living conditions terminated successfully (Maletin et al. 1992). It is now distributed throughout the Danube-Tisza-Danube canal system and is of interest to anglers. Further propagation of the largemouth bass towards the west and south is likely to occur mostly through the canal net (Maletin 1992).

Markovic et al. (1996) reported that the largemouth bass as a predatory species can become a food competitor for autochthonous predators like pike (*Esox lucius* L.)

Syngnathidae

Short-snouted pipefish (*Syngnathus abaster* Risso, 1827)

The short-snouted pipefish is native to the Mediterranean and Black Sea, and the Atlantic coast northward to southern Biscay. The occurrence of freshwater short-snouted pipefish populations in the Danube (900 km from the river mouth) probably resulted from their introduction through ships' ballast water originating from the Black Sea (Cakic et al. 2002). The first official record of the short-snouted pipefish in Serbia was in 1998 by Sekulic et al. (1998). This species has no economic value in Serbia.

A study on the fish communities of the Danube River (Djerdap resevoir) during 1994, 1995 and 2000 revealed an increase in abundance of short-snouted pipefish in grassy litoral habitats (Simic and Simic 2004).

Gobiidae

Monkey goby (*Neogobius fluviatilis* Pallas, 1814)
Racer goby (*Neogobius gymnotrachelus* Kessler, 1857)
Bighead goby (*Neogobius kessleri* Günther, 1861)

Round goby (*Neogobius melanostomus* Pallas, 1814)

Tubenose goby (*Proterorhinus marmoratus* Pallas, 1814)

Many gobiids extended their geographical distribution well beyond their native range (Black and Caspian Seas and the lowermost reaches of some tributary rivers). Data on the presence of the tubenose goby *Proterorhinus marmoratus* in Serbia were first recorded in the nineteenth century. During the 1970s, the monkey goby *Neogobius fluviatilis* was distributed only downstream of the Danube rkm 988, whereas the bighead goby *Neogobius kessleri* was distributed up to the rkm 1,214 (Ristic 1977). Other *Neogobius* spp. began to appear in the 1990s. The first record of the racer goby *Neogobius gymnotrachelus* was in 1991 (Hegedis et al. 1991) and that of the round goby *Neogobius melanosatomus* in 1998 (Simonovic et al. 1998). Gobiids have expanded their distribution in Serbia, and nowadays they can be found in the Danube, Tisza, Sava and Velika Morava Rivers (Fig. 1).

These species have no economic value but they serve as favorable food for economically important fish species (catfish *Silurus glanis*, pike-perch *Stizostedion lucioperca*). The increase in the commercial catch of pike-perch in the last few years in Serbia has been likely due in part to an increase in the amount of gobiids found in the food consumed by pike-perch. Anglers also use these species as a good bait for catfish and pike-perch.

Gasterosteidae

Three-spined stickleback (*Gasterosteus aculeatus* Linnaeus, 1758)

The first record of the three-spined stickleback in Serbia was in 1995 (Cakic et al. 2000), but there are unverified earlier data on the existence of this species. Specimens of the species were recorded in July close to the riverbank of the Danube River at rkm 927. Several authors have published records of this species in the Danube delta (Banarescu 1964), in the Danube near Budapest (Berinkey 1960) and near Bratislava (Balon 1967; Bastl 1976). Balon (1967), Ahnelt et al. (1998) reported that aquarists were responsible for the introduction and spread of the three-spined stickleback.

The calculated area of recent distribution of this species in Serbia is 3.4 % (Table 1). The species has no economic value. Its negative effects on native fish species have not been investigated.

Odontobutidae

Amur sleeper (*Perccottus glenii* Dybowski, 1877)

The amur sleeper was intentionally introduced during 1912 into the waters of St. Petersburg, European Russia (Reshetnikov 2004). Then, it dispersed to the Vistula and Odra basins and appeared in the Danube basin (Hegedis et al. 2007). The first record in Serbia was in 2004 (Gergely and Tucakov 2004). It came via the Tisza river from Hungary. The Amur sleeper has been recorded in the Serbian part of the Danube and Tisza Rivers in the regions having strong commercial fishery activities, which could be adversely affected by this pest species.

This species is an example of a careless release of live specimens from home aquaria being distributed very rapidly by high water events in rivers. There are some records of the negative effects of this species in other countries, but no thorough research on this species has been conducted in Serbia.

Discussion

Only four species (3 species of ‘Chinese carps’ and rainbow trout) of 22 non-native fish species in Serbia have a large economic value. However, notwithstanding the fact that these species are also reared in aquaculture facilities in Serbia, the common carp is still a dominant species, accounting for approximately 80% of the total fish production. The bighead carp is gaining importance in commercial fishery in Serbia, making up 10–40% of the total fish catch in the Danube and Tisza rivers.

‘Chinese carps’ are still being used for biomanipulation in small reservoirs and channels in Serbia despite the fact that the use of filter-feeding silver carp as a biomanipulation tool to reduce phytoplankton biomass in lakes and reservoirs remains controversial (Radke and Kahl 2002). Grass carps may have a strong effect on plant growth and are currently used in many parts of the world to reduce macrophyte abundance, but a shift to a turbo state may be caused by overstocking (Perrow and Davy 2002). The method should therefore be used with caution, but it is not the case in Serbia where there is a management problem and a frequent change of holders of fishing rights in waterbodies, which places greater importance on making immediate profit than on taking care of the future process in the reservoir.

Similarly to Serbia, an importation of East Asian herbivorous carps in the mid-1960s also occurred in Bulgaria, Romania and Hungary. This activity was closely related to the state policy during the period, which was directed to the aquaculture industry (Uzunova and Zlatanova 2007). Uzunova and Zlatanova (2007) reported that following the introduction of East Asian herbivorous carps, more than twelve parasites were transferred, and soon afterwards, the common carp became also infected. In Serbia, only the parasitic copepod *S. polycolpus* was identified on the gills of the bighead carp, being species-specific for bighead and silver carps (Cakic et al. 2004a, b).

The ratio of non-native species to total fish species in the country is similar for Romania (23.1%), Hungary (23.4%) and Serbia (23.4%). The main route of fish introductions into Serbia was via the Danube and Tisza rivers from Romania and Hungary. Data on the negative effect of non-native fish species on native species are reported in many papers dealing with allochthonous species in Serbia. Furthermore, there are many records (personal comm.), but a detailed study is still lacking. A similar situation is observed in Bulgaria where potential effects of introduced fishes on native fish biodiversity reduction are still unknown (Uzunova and Zlatanova 2007). Gozlan (2008) shows that the ecological risk associated with freshwater fish introduction is fairly variable across families of fish. The risk is fairly low for Acipenseridae, Syngnathidae and Gasterosteidae, low for Cyprinidae and Salmonidae, high for Centrarchidae and highly variable for Ictaluridae.

The problem with brown and black bullheads manifests itself through difficulties to identify *Ameiurus* species. The brown and black bullheads are pest species found in many angling waters in Serbia that can degrade recreational fisheries by proliferating at the expense of native fish and dominating the catch. Another report showed that the black bullhead was found in the artificial spawning nest of the pike-perch where it consumed all eggs from the nest (Hegedis, unpublished data).

Many salmonid species have been introduced into worldwide watercourses, primarily for recreational fishing purposes (Fausch 1988). The rainbow trout has thence been introduced into a number of upland watercourses and reservoirs in Serbia where it has been highly acclimated to existing environmental conditions (Simonovic and Nikolic 1995). However, non-native salmonid introductions often lead to interspecific competition with native species through different interspecific interactions (Moyle and Light 1996; Hasegawa and Maekawa 2006). Rainbow trout introductions, coupled with water quality deterioration, stream course regulation and excessive catches (Fausch 2007) have most likely led to the extinction of or a decrease in the population numbers of the autochthonous salmonid brown trout (*Salmo trutta m. fario)*.

In recent years, the introduction of some of the tilapia species -*Tilapia (Oreochromis) nilotica* and *T. mossambicus* into aquaculture has become the focus of scientific attention. Serbia abounds in unutilized thermal waters which could be used for tilapia breeding (some regions of Vojvodina, Western and Southern Serbia). A successful experimental spawning attained in the aquarium of the Faculty of Sciences in Kragujevac as well as the polyculture breeding with carp in the fishpond in the village of Moshorin (Vojvodina) confirm the possibility of introducing tilapia into the aquaculture of Serbia (Maletin et al. 2008).

Ruesnik (2005) underlines that many opportunities for reducing global biotic homogenization occur at a national level. It is for that reason that a fair, feasible and risk-based comprehensive screening system aimed at evaluating first-time intentional introductions of non-native species is necessary. The results of such risk assessments could then be reflected in trade policies and customs inspections, with national borders being often biogeographically irrelevant. It is imperative that caution be practiced in introducing exotic species to any country because biological invasions are considered to be the second most important cause of species extinction after habitat destruction (Casal 2006). Precautionary approaches to species introduction are necessary since, according to FAO (1996), in terms of aquaculture, experience has shown that animals will usually escape the confines of a facility. Non-native species used in aquaculture often escape from facilities into open waters. Hence, the premise behind the precautionary approach in evaluating non-native species for aquaculture is that, ultimately, species will escape into the wild.

Gozlan's (2008) statement that the majority of freshwater fish introductions on the global scale were not identified as having an ecological impact while having great social benefits gave rise to a number of reactions, ranging from moderate (Leprieur et al. 2009) to quite opposite (Vitule et al. 2009). Leprieur et al. (2009) stated that very little is actually known about the ecological impacts associated with fish introductions and that it was inappropriate to equate a lack of data with a conclusion of "no impact", whereas Vitule et al. (2009) strongly disagreed with this statement demonstrating that many real-word examples of freshwater fish introductions had catastrophic ecological consequences.

The introduction of new fish species into Serbia is prohibited by The Law on Fishery (Anonymous 2009). However, private aquaculture companies push for further introductions of new species for aquaculture purposes. Hence, increased international regulation structured around sound risk assessment tools would be a major step forward in regulating future fish introductions (Gozlan 2008). The thing to bear also in mind is that some non-native fish species reach Serbian open waters via international rivers from countries where introductions of new fish species are not prohibited.

Acknowledgments This study was financially supported by the Ministry of Science and Technological Development of Serbia (Project No. 20107 and Project No. 143045).

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