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Non-native Freshwater Fishes in Slovenia

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Abstract: Since 1891, 20 fish species have been introduced to the inland waters of Slovenia, either intentionally or unintentionally, beginning with the introduction of the rainbow trout, *Oncorhynchus mykiss.* In this paper we summarise the information on the introduction of all non-native fish species, with specifying the year of introduction to this country, the pathways of introduction, the pattern of spread, the degree of acclimatisation, the potential impact on native fishes, and the area of recent distribution.

Key words: Alien freshwater fishes, distribution, acclimatisation, impact, Slovenia

Introduction

A total of 95 fish species inhabit Slovenian inland waters. Among them, 75 species are indigenous, while 20 have been introduced (Povž & Ocvirk 1988, Šumer et al. 2003, Piria et al. 2016). Records of fish introductions to the area currently encompassing Slovenia began in 1891, when the occurrence of the rainbow trout, *Oncorhynchus mykiss,* was mentioned for the first time (Franke 1913a). The introductions were performed mainly by fishermen who introduced non-native fish species either intentionally for angling and aquaculture, or unintentionally while restocking rivers with native species. Many introductions in Slovenia have been carried out on a repeated basis (Povž & Ocvirk 1988).

The impacts of most introductions are completely unknown, although such introductions are governed by legislation with precisely defined limitations (Copp et al. 2005). Protection of fishes in Slovenia is provided under the National Freshwater Fisheries Act, Nature Conservation Act and related decrees. Conservation measures include among others the banning of introductions of non-native organisms without proper permission. No measures to control the introductions are active, and there have been no studies that have followed a particular invasion from the very beginning. Escapee fishes from fish farms, ponds, etc., are common and probably responsible for the large number of specimens of rainbow trout, Alpine charr, *Salvelinus umbla,* and brook charr, *Salvelinus fontinalis*, which are found downstream of the fish farm outlets (M. Povž, personal observation). In most cases, escapee fishes are not reported.

The aim of this paper was to make a review of the information on introduction of all non-native fish species in Slovenia and to analyse this informaiton in terms of year of introduction, pathways of introduction, pattern of spread, degree of acclimatisation, potential impact on the native fishes, and area of recent distribution.

Materials and Methods

In this study we used historical and recent data from various published and 'grey' literature sources (e.g. books and manuscripts). The acquired information about the non-native fish species in Slovenia included the year and pathway of introduction, the degree of acclimatisation (Copp et al. 2005), potential impact on native fishes, the pattern of recent spread, and estimation of the area of recent distribution as a proportion of the total area of Slovenia.

The degree of acclimatisation was assessed by using evidence of natural reproduction and recruitment, with respective division into the following categories: (i) unknown, (ii) failure, (iii) acclimatisation of adults only, (iv) satisfactory,

and (v) very good. The potential impact on the native species was categorised as: (i) unknown; (ii) established existence without apparent impact; (iii) potential competition with native fishes for resources (e.g. habitat and food); (iv) 'casual' existence (for definition, see Copp et al. 2005) with potential strong impact on native fishes; and (v) casual existence with no potential impact. The pattern of recent spread was assessed as: (i) continuous stockings for sport fishing, (ii) escapes from fish farms and fish ponds, (iii) uncontrolled reproduction, and (iv) drift. The area of recent distribution was estimated as a proportion of the total area of Slovenia, divided into 266 squares (Krystufek et al. 2001), using the UTM Grid zones of the world. Five classes were separated under this index: (i) <1%, (ii) 1–5%, (iii) 6–20%, (iv) 21–50%, and (v) >51%.

Results and Discussion

Five alien fish species (i.e. nearly 30% of all registered releases) were introduced in Slovenia at the end of the 19th century (Table 1). The second peak of the introductions was between 1960 and 1969, when another four species were released (Povž 1986). After 2000, two introductions of the largemouth bass, *Micropterus salmoides,* were recorded: in the Drava River and in oxbows of the Mura River (Šumer et al. 2003). By the end of 2015, a total of 20 alien fish species were recorded in Slovenia. These species belong to nine families: Salmonidae (five species), Centrarchidae (two species), Ictaluridae (two species), Poecilidae (one species), Cyprinidae (six species), Clariidae (one species), Cichlidae (one species), Polyodontidae (one species), and Gobiidae (one species). Most of the introduced fishes originated in North America (9 species), followed by Asian species (six species), three species from Europe and two species from Africa (Table 1). Of these 20 species introduced, 18 species are still present in Slovenia. Only the North African catfish *(Clarias* sp.) and coho salmon *Oncorhynchus kisutch* disappeared, the former within one year and the latter within 10 years of their introduction (Povž & Sket 1990). All other introduced salmonids (rainbow trout, Alpine charr, brook charr) have successfully established self-sustaining populations.

The common whitefish, *Coregonus lavaretus,* naturally entered Slovenia via downstream movement from the Austrian part of the Drava River (Kristofič 1992). On the other hand, the Chinese grass carp, *Ctenopharyngodon idella*, silver carp, *Hypophthalmichthys molitrix*, and bighead carp, *H. nobilis,* are reared artificially at the fish farms for human consumption and for sport fishing. The grass carp was also released by fishermen into many ponds in order to control the dense aquatic vegetation (Šumer et al. 2003). Many non-native fish species were introduced twice or even three times. For example, the Alpine charr was first introduced in 1928 into Bohinj Lake (Simončič 1948), and then in 1998 into the alpine Dvojno Lake (Brancelj et al. 1995, Brancelj 1997).

The North American catfish, brown bullhead, *Ameiurus nebulosus*, was first introduced in 1935 for sport fishing and aquaculture (Table 1). It has reached high population densities, especially in oxbows, gravel pits and backwaters (Šumer et al. 2003). The exact date of introduction and recent distibution of the black bullhead, *Ameiurus melas,* are unknown. The Prussian (gibel) carp, *Carassius gibelio,* entered Slovenia in 1962 (Povž 1982). Following its initial, unsuccessful introduction at the end of the 19th century (Munda 1924), the largemouth bass, *M. salmoides,* was released in some reservoirs in different parts of Slovenia in 1993, and in the Drava and Mura river basins from 2000 onwards. Currently, the species is present in the rivers and reservoirs of the Adriatic and Danube basins.

The major motive for the introduction of non-native fishes to Slovenian inland waters was sport fishing (Table 1). These introductions were designed for filling perceived vacant niches or introducing exotic elements to the water bodies (Franke 1913b). Thus, the goldfish, *Carassius auratus,* was introduced for ornamental purposes, and its distribution is restricted to many ponds and small lakes not connected with the running waters. On the other hand, the introduction of the mosquitofish, *Gambusia holbrooki,* was for the purposes of biocontrol. The grass carp, silver carp and bighead carp were introduced for aquaculture (Kristofič, pers. comm.), but subsequently the first two species were used for sport fishing (Povž & Ocvirk 1988), as well as in order to control the aquatic macrophytes (Shireman & Smith 1983) and blooms of phytoplankton in natural waters (Spataru & Gophen 1985, Welcomme 1988, Anonymous 1999). The reasons for some fish introductions remain unknown (Šumer et al. 2003). Some introductions, such as that of the topmouth gudgeon, *Pseudorasbora parva,* are considered accidental, possibly as a contaminant in imported consignments of the Chinese carp larvae, as is the case elsewhere in Europe (Copp et al. 2005). The mentioned species was first registered in open waters in 1986 (Povž 1987). Currently, it occurs in many standing and slow-running waters throughout Slovenia (Šumer et al. 2003). Ten fish species were

Table 1. List of alien fish species recorded in Slovenia, with specified the native range, time of introduction, pathways of introdution, and pattern of spread in the country

Fish species	Native range	Time of introduction	Pathway of introduction	Pattern of spread
Salvelinus fontinalis	North America	1892	Sport fishing	Release for sport fishing, self-reproduction, escapement from aquaculture
Salvelinus umbla	Europe	1928, 1943, 1998	To fill vacant niche, sport fishing	Release for sport fishing, self-reproduction, escapement from aquaculture
Oncorhynchus mykiss	North America	1891	Sport fishing, aquaculture	Release for sport fishing, self-reproduction, escapement from aquaculture
Oncorhynchus kisutch	North America	1977	Sport fishing, aquaculture	Disappeared after 10 years of introduction
Coregonus lavaretus	Europe	Every year	Independentdownstream spreading	Drift
Micropterus salmoides	North America	1892, 1993	Sport fishing	Release for sport fishing, self-reproduction
Lepomis gibbosus	North America	End of 19th century	Ornamental fish	Self-reproduction, escapement from aquaculture
Ameiurus nebulosus	North America	1935	Sport fishing, aquaculture	Release for sport fishing, self-reproduction, escapement from aquaculture
Ameiurus melas	North America	Unknown	Sport fishing, aquaculture	Self-reproduction
Gambusia holbrooki	North America	1927	Mosquito control	Self-reproduction
Hypophthalmichthys molitrix	Asia	1963	Aquaculture, sport fishing	Escapement from aquaculture, sport fishing
Hypophthalmichthys nobilis	Asia	1963	Aquaculture, sport fishing	Escapement from aquaculture, sport fishing
Ctenopharyngodon idella	Asia	1963	Aquaculture, sport fishing, weed control	Escapement from aquaculture, sport fishing
Pseudorasbora parva	Asia	1986	Accidental introduction	Self-reproduction, escapement from aquaculture
Carassius gibelio	Asia	1962	Accidental introduction, sport fishing	Release for sport fishing, self-reproduction, escapement from aquaculture
Carassius auratus	Asia	In the 19th century	Ornamental fish	From aquaria, self-reproduction
Clarias sp.	Africa	1997	Sport fishing	Release for sport fishing (disappeared?)
Oreochromis niloticus	Africa	2008	Aquaculture	Self-reproduction in hot springs, escapement from aquaculture
Polyodon spathula	North America	2013	Aquaculture	Not yet present in the rivers and lakes
Neogobius kessleri	Europe	2015	Independent upstream spreading	Independent upstream spreading

introduced by continuous stockings for sport fishing, namely: the rainbow trout, brook charr, Alpine charr, largemouth bass, North African catfish, the brown and black bullheads, Prussian carp, grass carp, silver carp, and bighead carp (Table 1). Of these species, all, with the exception of the Alpine charr and the North African catfish, are also thought to have escaped from fish farms. The pumpkinseed, *Lepomis gibbosus,* and topmouth gudgeon are also among the escapee fish species. Of the ten species listed above, only rainbow trout, brook charr, grass carp, silver carp, and bighead carp are reared for human consumption, the other

Table 2. The alien fish species in Slovenia, with specified the degree of acclimatisation, impact on native species, pattern of recent spread, and size of the area of recent distribution in % of the territory of Slovenia and number of UTM squares (in the brackets). For more details on different categories see Materials and Methods

Fish species	Degree of acclimatisation	Impact on native species	Pattern of recent spread	Size of recent distribution
Salvelinus fontinalis	(v) very good	(i) unknown	(i) continuous stockings for sport fishing	(iii) 6-20% (54)
Salvelinus umbla	(v) very good	(i) unknown		(ii) 1-5% (5)
Oncorhynchus mykiss	(v) very good	(iii) competition for resources	(i) continuous stockings for sport fishing; (ii) escapees from fish farms	(v) > 58% (163)
Oncorhynchus kisutch	(i) unknown	(i) unknown	unknown	(i) < 1% (1)
Coregonus lavaretus	(ii) failure	(i) unknown	(iv) drift	(ii) 1-5% (6)
Micropterus salmoides	(iv) satisfactory	(i) unknown	(iii) uncontrolled self-reproduction	(iii) 6-20% (19)
Lepomis gibbosus	(iv) satisfactory	(i) unknown	(iii) uncontrolled self-reproduction	(iv) 21-50% (71)
Ameiurus nebulosus	(iv) satisfactory	(i) unknown	(iii) uncontrolled self-reproduction	(iii) 6-20% (39)
Ameiurus melas	(iv) satisfactory	(i) unknown	(iii) uncontrolled self-reproduction	(iii) 6-20% (19)
Gambusia holbrooki	(v) very good	(i) unknown	(iii) uncontrolled self-reproduction	(i) < 1% (2)
Hypophthalmichthss molitrix	(iii) acclimatisation of adults only	(i) unknown	(i) continuous stockings for sport fishing	(iii) 6-20% (31)
Hypophthalmichthys nobilis	(iii) acclimatisation of adults only	(i) unknown	(i) continuous stockings for sport fishing	(ii) 1-5% (21)
Ctenopharyngodon idella	(iii) acclimatisation of adults only	(i) unknown	(i) continuous stockings for sport fishing	(iv) 21-50% (73)
Pseudorasbora parva	(v) very good	(i) unknown	(iii) uncontrolled self-reproduction	(ii) 1-5% (38)
Carassius gibelio	(v) very good	(i) unknown	(iii) uncontrolled self-reproduction	(iv) 21-50% (62)
Carassius auratus	(v) very good	(i) unknown	(iii) uncontrolled self-reproduction	(iii) 6-20% (40)
Clarias sp.	(ii) failure	(i) unknown		(i) < 1% (1)
Oreochromis niloticus	(i) unknown	(i) unknown	(iii) uncontrolled self-reproduction	(i) < 1% (1)
Polyodon spathula	(i) unknown	(i) unknown	unknown	(i) < 1% 1)
Neogobius kessleri	(i) unknown	(i) unknown	(iii) uncontrolled self-reproduction	(i) < 1% (1)

being by-products of cyprinid fish culture.

Eleven of the introduced species: the goldfish, rainbow trout, brook charr, Alpine charr, largemouth bass, brown bullhead, Prussian carp, pumpkinseed, topmouth gudgeon, mosquitofish, and the Nile tilapia, *Oreochromis niloticus,* have established self-sustaining populations in nature (Table 1). On the other hand, the common whitefish, which drifts from Austria, is casual species, with no natural reproduction in Slovenia (Povž & Sket 1990). The coho salmon and North African catfish did not succeed in maintaining themselves in this country, and they disappeared soon after their introduction. The reason for the failed acclimatisation in the coho salmon is unclear, whereas the North African catfish probably disappeared because of the low water temperatures in winter (Gertjan De Graaf & Janssen 1996). The grass carp, silver carp, and bighead carp acclimated as adults but were unable to reproduce because of the too low water temperatures. Another reason for

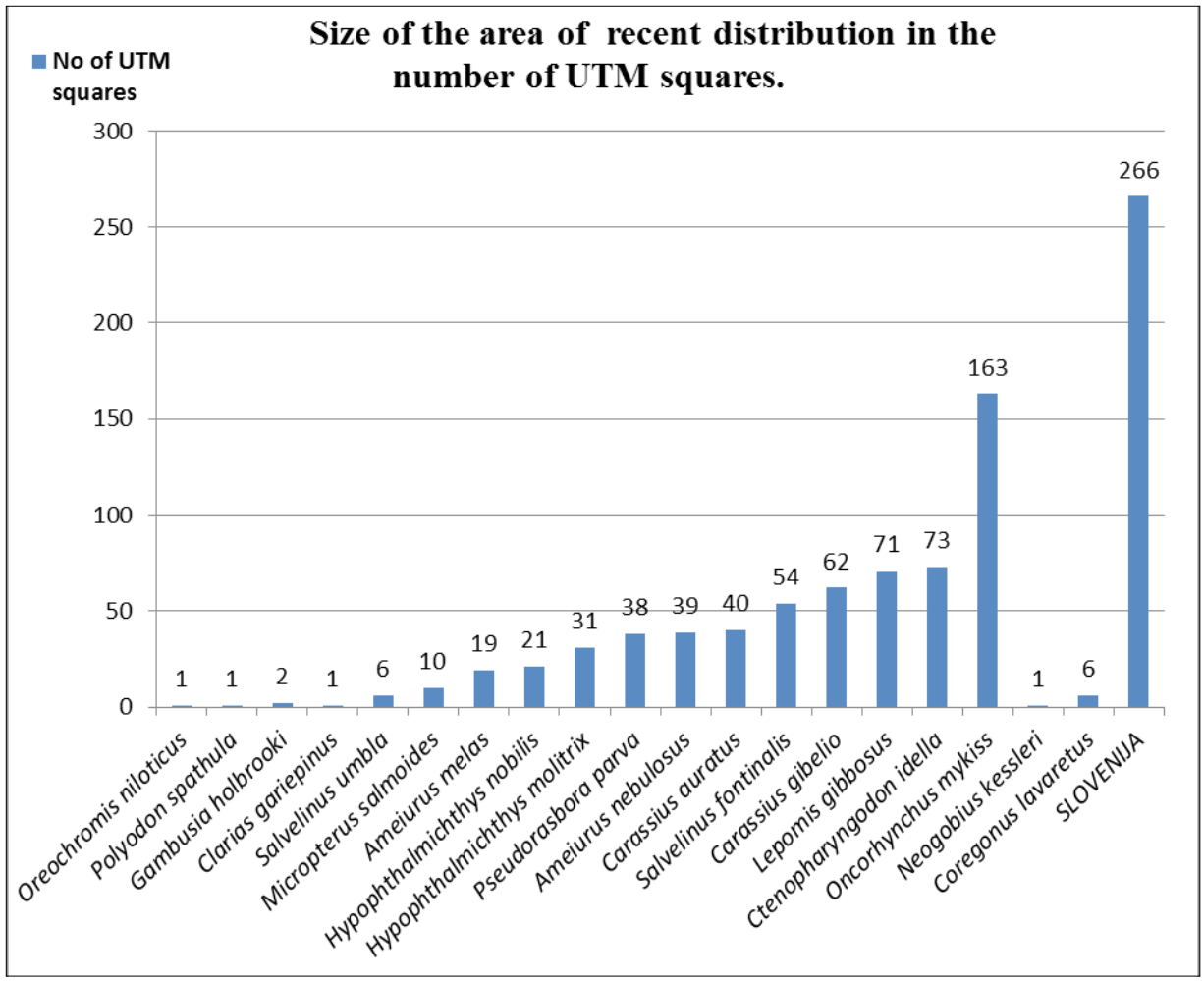

Fig. 1. The size of the area of recent distribution of alien fish species in Slovenia based on the number of UTM squares covered

the failed acclimatisation is that these species require long, unregulated river stretches for their pelagic eggs to develop.

Little is known of the impact of the introduced fishes on the native fishes, with the influence of the mosquitofish, North African catfish and common whitefish being fully unknown (Table 2). Goldfish is not known to have some impact in Slovenia, contrary to the reports elsewhere (Copp et al. 2005). Eight introduced species: rainbow trout, brook charr, Alpine charr, largemouth bass, pumpkinseed, topmouth gudgeon, brown bullhead, and Prussian carp are believed to compete with the native fish species for habitat, food and other resources, mainly because of their wide distribution (e.g. rainbow trout), their high abundance in some locations, and their trophic role as obligate or facultative piscivores (e.g. salmonids, pumpkinseed, largemouth bass) (Copp et al. 2010). In addition, some species, e.g. topmouth gudgeon and brown bullhead, may predate on the eggs and young of native fish species (Povž & Sket 1990). The silver and bighead carps feed on zooplankton and phytoplankton, and are reported to compete for food with the native planctivorous fishes elsewhere (Nico & Fuller 2005), but it remains unknown whether this is the case in Slovenia.

Assessment of the proportional area of recent distribution (Table 2, Fig. 1) revealed that six species: the coho salmon, mosquitofish, North African catfish, bighead goby, *Neogobius kessleri,* Nile tilapia, and the American paddlefish, *Polyodon spathula,* each cover <1% of the Slovenian territory. Four species: the Alpine charr, common whitefish, bighead carp, and topmouth gudgeon, cover 1-5% of the area (i.e. 6-38 UTM squares). Six species: the largemouth bass, brook charr, brown and black bullheads, silver carp, and goldfish inhabit 6-20% (i.e. 19-54 UTM squares). Three species: the pumpkinseed, grass carp, and Prussian carp inhabit 21-50% (i.e. 62-73 UTM squares). The most abundant and most widely spread rainbow trout occupies 58% of Slovenian territory (163 UTM squares), and thus may be considered as

a widely distributed species (Kryštufek et al. 2001), with nearly 30% of the locations of its distribution area being recorded after 1995 (Table 2, Fig. 1). In contrast to some other parts of the world (Fausch et al. 2001), the rainbow trout is extremely successful in Slovenia, with spawning in the majority of running waters in the Danube River and Adriatic Sea basins (Bertok & Budihna 1999). In conclusion, the future research should concentrate on assessing and mitigating the impact of the non-native species.

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