A brief overview of the long-term changes of fish fauna in the Slovak-Hungarian section of the Danube River

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Abstract. Description of the fish fauna was completed by way of literary review, field experience, and some rare species have been found in the catches of commercial fishermen. Suitable publications and reports are available from the 18th century. The upper part of the Slovak-Hungarian section of the Danube is aggrading and anabranching, while its lower part is a wandering sinuous channel. The native fish fauna includes 54 species, while the alien fish fauna contains 23 species, 11 of which are exotic in Europe. Two species, *Huso huso* and *Acipenser stellatus* are practically extinct from the Middle Danube region. This river stretch is heavily modified, and the historical changes of the fish fauna were evaluated in conjunction with human impacts.

Keywords. historical fish fauna, invasive species, endangered fish, large river, Žitný Ostrov, Szigetköz, Middle Danube.

INTRODUCTION

The fish fauna of the Slovak-Hungarian Danube and its changes from the 19th century is evaluated, based on literature data and results of recent observations from the 1990s. Regarding Danubian river fisheries located on the Rye Island (Žitný Ostrov) and Szigetköz floodplain – the left and right side of the Danube's alluvial cone between Bratislva and Komarom – numerous archival documents can be found from the 13th century (Takáts 1902, Alapy 1933). The fishery colony of 'Wöniki' (Vének) was already mentioned in a document dating from 1093 (Méry 1874), however, information on the region's fish populations is scarce in these early records. In terms of the fish fauna, initial publications can be evaluated from the 18th century (Marsigli 1726, Kramer 1756, Bél 1767, Grossinger 1794, Reinsinger 1830, Heckel 1847, Heckel & Kner 1858, Méry 1874, Herman 1887, Ortvay 1902, Vutskits 1904, 1918). More detailed data were taken from ichthyological studies published from the 1960s in Slovakia (Balon 1967, Holčík *et al*. 1981, 1989, Holčík 2003, Černý 2006, Kováč 2015) and in Hungary (Berinkey 1960, 1966, Tóth 1970, Jancsó & Tóth 1987, Guti 1993, 1997, Sallai 2001, 2003, Györe & Józsa 2005, Sallai & Vida 2010).

The description of the fish fauna was completed by updating the scientific names of the species, according to the current nomenclature.

The Slovak-Hungarian section of the Danube

The natural system

The 172 km long Slovak-Hungarian section of the Danube is located in the upper part of the Middle Danube (r.km 1880–1708), stretching from the mouth of the Morava River to the confluence with the Ipeľ (Ipoly) River. Its mean annual discharge is 2024 m^3s^{-1} at Bratislava (Holčík *et al.* 1981), and its natural bed formation has foothill and lowland features and is characterised by a progressively decreasing slope and a finer load in downstream direction. Discharge and water regime are mainly determined by precipitation and snow and glacier melt water from the 131,000 km^2 water catchment area of the northern Alps and the Alps' foothills.

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The water regime is basically stochastic; however, from spring to the middle of summer, generally several flood pulses arrive consecutively. The melting of the Alps' snow cover and glaciers, and the simultaneous significant quantity of precipitation characteristic from the end of May and throughout June generally result in large flood pulses. The low water period usually sets in by October, followed by a weak increase in discharge. In December, a low water period begins, as the high mountains in the catchment area no longer provide water, due to the freezing conditions. The fluctuation of discharge and associated sediment transport are the governing forces of the evolution of the riverbed. The main flow used to change its course frequently during major flood events, producing a channel network at various elevations, with arbitrary distributions of flows at different stages, in the pristine conditions.

The Slovak-Hungarian section of the Danube can be divided into two main stretches, according to geomorphic patterns, succeeding downstream (Tőry 1952, Pécsi 1959):

- The upper stretch (r.km 1880-1790) is located in the lower Alpine foothills zone. It is an aggrading and anabranching section, formed on a large alluvial cone with extensive floodplains. It was supplied with coarse load mainly by the Upper-Danube. The main arm of the river has a relatively high slope (0.12–0.35%.), and the lateral wandering of anabranches used to be intensive, thus floodplains are parcelled by abandoned channels.
- The lower stretch of the Slovak-Hungarian section (r.km 1790–1708) has a slightly wandering, sinuous channel with irregular islands and narrow floodplains. Its slope is 0.05–0.10%, and the river bed is composed of gravel.

The river and its associated floodplains support a considerable proportion of the fluvial biodiversity in the Hungarian Lowland ecoregion, but they suffer the impacts of a multitude of human activities.

Human impacts

In the 19th century, the acceleration of social, demographic, and economic development generated driving forces for extensive river utilisation and land use. The driving forces (river engineering, navigation, hydropower utilisation, fishery, agriculture, forestry, etc.) provide several benefits for the society and provoke changes in economic production however, these needs put pressure on the riverine environment. The progress of regular boat services, particularly between Budapest and Vienna, necessitated the dredging, tightening and straightening of the river bed, including cutting off meanders. Comprehensive flood protection works were carried out at the end of the 19th century, and the passage of the flood pulses accelerated, therefore the duration of flooding dropped.

In the second half of the 20th century, installations of the high water regulation were maintained or reconstructed, navigability was improved, and hydropower utilisation started to develop. Since the beginning of the 1990s, when the Gabčikovo hydropower dam was put into operation, the Danube has been diverted into a 29 km long bypass canal and only 20% of its discharge (even less during the winter period: 200 m^3s^{-1}, about 10%) has remained in the former river bed. In subsequent years, minor mitigation measures were implemented for water replenishment in the floodplain branches, and several scenarios were proposed for the extensive rehabilitation of the river-floodplain ecosystem, but the bilateral negotiations between Hungary and Slovakia did not resulted in any significant outcomes (Kern & Zinke 2000).

Since the completion of the Rhine-Main-Danube Canal, further improvement of navigability of the Slovak-Hungarian section of the Danube has been encouraged, but the development of the navigation route may have numerous negative impacts on the ecological status of the river. The EU water policy includes strict provisions regarding the options of river engineering, which could lead to confrontations between the inland shipping sector and environmental protection.

The native fish fauna

The fish fauna of the Slovak-Hungarian section of the Danube is characterised by a relatively high number of species (Jancsó & Tóth 1987, Holčik *et al.* 1989, Guti 1997, Holčik 2003, Sallai & Vida 2010). This can be explained by the following reasons:

- the zoogeographical significance of the Danube basin (Bănărescu 1991)
- the transitional zone between the foothill and the lowland zones, i.e. hyporhitron–epipotamon–metapotamon
- the continuously changing river-floodplain ecosystem (Welcomme 1985), characterised by a great variability in geomorphological and hydrological conditions, and a high diversity of aquatic habitats with different degrees of spatio-temporal connectivity

The hydrological variety of the upper braided-anastomising section of the Slovak-Hungarian stretch of the Danube was favourable for fish reproduction. In the spawning period, several fluvial species migrate instinctively against the current, sometimes covering a distance of more than 100 km (Waidbacher & Haidvogl 1998), before they find a suitable habitat for spawning. The high gradient upstream is hard to overcome for most of the migratory species, but fish can spread into floodplain waters during the spring and early summer inundations. The large, slow flowing sidearm systems serve as ideal nursery habitats and provide rich feeding areas for several fish species.

The native fish fauna includes 54 species (Table 1). It contains elements from the montane stretch of the Upper Danube (*Hucho hucho, Salmo trutta*, etc.); and Black Sea migratory species, such as anadromous sturgeons (*Huso huso, Acipenser gueldenstaedti, A. stellatus*). The fish fauna of the eupotamon type riverbed is dominated by rheophilic fish species (*Acipenser ruthenus, Barbus barbus, Chondrostoma nasus, Cottus gobio, Gymnocephalus schraetser, Zingel zingel*, etc.). The connected backwaters represent the parapotamon type habitats, and their fauna includes several rheophilic and eurytopic species (*Rutilus rutilus, Alburnus alburnus, Blicca bjoerkna, Perca fluviatilis*, etc.). The disconnected plesiopotamic or paleopotamic backwaters are populated with eurytopic and limnophilic fish species (*Scardinius erythrophthalmus, Carassius carassius, Tinca tinca, Misgurnus fossilis, Umbra krameri*, etc.) that are bound to the still waters of the floodplain. In general, the diversity of fish species is the greatest in the eupotamon and parapotamon, and it tends to decrease in the plesio- and paleopotamon.

Alien species

The Danube basin is being rapidly colonised by alien species, due to the introduction of exotic species, as well as the overall deterioration of the fluvial ecosystem from the end of the 19th century.

The list of the alien fish fauna of the Slovak-Hungarian river section contains 23 species, 11 of which are exotic in Europe (Table 1). Most of the alien species had been introduced unintentionally into the Danube, therefore a description of potential routes and mechanisms of their introduction, including an assessment of the environmental conditions necessary for their reproduction, is an important issue concerning the long-term changes of the fish fauna.

The development of navigation ways, vessel traffic, and the increasing interconnection of various water bodies promoted by canals significantly contribute to the dispersion of non-native species, such as the spreading of Ponto-Caspian gobies, which began in the final decades of the 20th century. The most abundant species is the round goby (*Neogobius melanostomus*), occurring in rip-rap embankments of the main channel, side arms and irrigation canals. Bighead goby (*Ponticola kessleri*) inhabits the same habitats, while monkey goby (*Neogobius fluviatilis*) prefers the sandy-bottom habitats. Racer goby (*Babka gymnotrachelus*) is more limnophilic, and occurs in more or less disconnected side arms with muddy bottoms.

The severe impacts on native species and the structure and functioning of the ecosystem caused by alien species can be demonstrated on the case of the invasive gobies. European bullhead (*Cottus gobio*) used to be a relatively abundant species along the upper part of the Slovak-Hungarian section of the Danube at the beginning of the 1990s. When the discharge of the Danube was diverted to the bypass canal of the Gabčikovo hydropower station in 1992, the water level in the main arm of the river dropped by 4 m compared to the previous mean water levels, in the section between Rajka and Dunaremete. In this situation, the fish surveys along the rip-rap embankments indicated the massive occurrence of *Cottus gobio*, more the 100 ind./100 m abundance at some sampling sites in the Hungarian side of the main arm. The frequency of the species started to decline in the next years, and it nearly disappeared, parallel to the widespread appearance of *Ponticola kessleri* (Figure 1). Only a few specimens were recorded in Bratislava in 2013. On the other hand, the populations of predators such as burbot (*Lota lota*) seem to be increasing since the gobies started spreading.

The investigation of stickleback specimens collected in the Danube and in Western Hungary demonstrated that specimens of both *Gasterosteus aculeatus* and *Gasterosteus gymnurus* can be found in Hungary. The former presumably spread from the direction of the Black Sea, while the latter, on the contrary, arrived from the Upper-Danube and its tributaries (Harka & Szepesi 2010).

Asian herbivore fish species (*Ctenopharyngodon idella, Hypophthalmichthys molitrix, Hypophthalmichthys nobilis*) were commercially harvested, and their natural reproduction is increasingly successful due to climate change. Their juveniles have been observed along the Hungarian section of the Tisza river (Pintér 1989), and commercial fishermen reported some spawning events in the main arm of the Danube at Dunakiliti in the 1990s.

Siberian sturgeon (*Acipenser baeri*) and other non-native sturgeons that are occasionally recorded in the Danube can mean a threat to native sterlet populations, via competition for resources and possible hybridisation.

It is currently believed that alien species very likely become even more significant in the future, as the importance of the Danube as an international waterway increases. Climate change may be another important factor in the spreading of non-native biological invaders. A rapidly changing climate might favour species which are able to extend their ranges quickly.

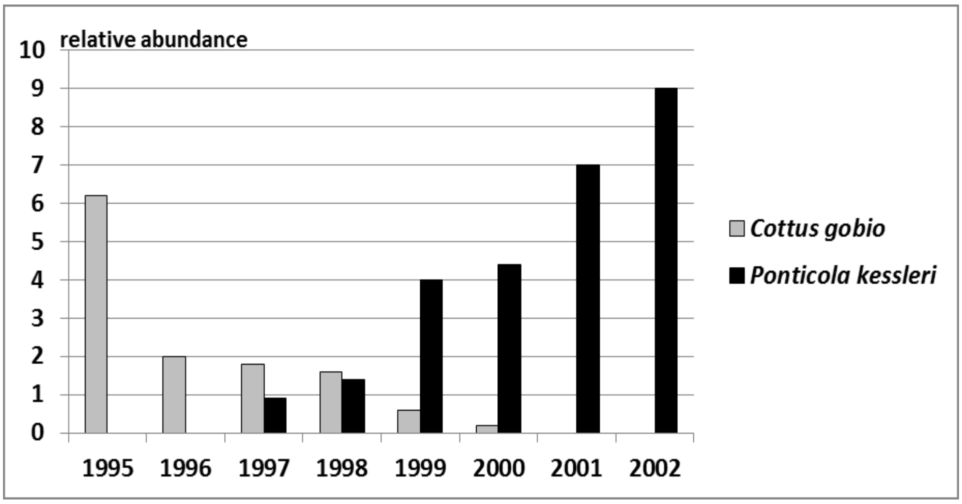

Figure 1. Changes of the relative abundance of *Cottus gobio* and *Ponticola kessleri* at Medve (Medveďov) from 1995 to 2002 (according to Sallai &Vida 2010).

Table 1.: Fish fauna of the Slovak-Hungarian section of the Danube. In the second (native) column, grey cells indicate periodic occurrences. In the third (alien) column, European species are indicated by grey cells and species from other continents are indicated by black cells.

species	native	alien	regionally extinct
Eudontomyzon mariae	■		
Huso huso	▒		■
Acipenser gueldenstaedtii	■		
Acipenser nudiventris	■		
Acipenser stellatus	▒		■
Acipenser ruthenus	■		
Acipenser baeri		■	
Anguilla anguilla	▒		
Rutilus rutilus	■		
Rutilus virgo	■		
Rutilus meidingeri		▒	
Ctenopharyngodon idella		■	
Scardinius erythrophthalmus	■		
Leuciscus leuciscus	■		
Leuciscus idus	■		
Squallius cephalus	■		
Phoxinus phoxinus	▒		
Aspius aspius	■		
Leucaspius delineatus	■		
Alburnus alburnus	■		
Alburnoides bipunctatus	▒		
Blicca bjoerkna	■		
Abramis brama	■		
Ballerus ballerus	■		
Ballerus sapa	■		
Vimba vimba	■		
Pelecus cultratus	■		
Chondrostoma nasus	■		
Tinca tinca	■		
Barbus barbus	■		
Gobio obtusirostris	■		
Romanogobio vladykovi	■		
Romanogobio kessleri	■		
Romanogobio uranoscopus	▒		
Pseudorasbora parva		■	
Rhodeus amarus	■		
Carassius carassius	■		

Carassius gibelio			
Cyprinus carpio			
Hypophthalmichthys molitrix			
Hypophthalmichthys nobilis			
Misgurnus fossilis			
Cobitis elongatoides			
Sabanejewia balcanica			
Sabanejawia bulgarica			
Barbatula barbatula			
Ameiurus nebulosus			
Ameiurus melas			
Silurus glanis			
Esox lucius			
Umbra krameri			
Coregonus lavaretus			
Coregonus albula			
Thymallus thymallus			
Hucho hucho			
Salvelinus fontinalis			
Salmo trutta			
Oncorhynchus mykiss			
Lota lota			
Gasterosteus aculeatus			
Gasterosteus gymnurus			
Cottus gobio			
Lepomis gibbosus			
Micropterus salmoides			
Perca fluviatilis			
Gymnocephalus cernua			
Gymnocephalus baloni			
Gymnocephalus schraetser			
Sander lucioperca			
Sander volgensis			
Zingel zingel			
Zingel streber			
Babka gymnotrachelus			
Neogobius fluviatilis			
Neogobius melanostomus			
Ponticola kessleri			
Proterorhinus semilunaris			
Sum.	54	23	2

Endangered species

Under the pressure of river utilisation and land use, the long-term changes of the pristine fish fauna manifested itself in species extinction, and the increase in the number of endangered and non-native fish species. Habitat loss and modification, due to river engineering, as well as fishery exploitation were the most important factors threatening the fish in the Slovak-Hungarian section of the Danube.

Over-fishing played a primary role in the decay of sturgeon species. Historical archives prove the prevalence and economic importance of sturgeon fishery in the region. For instance, in 1553, 77 specimens of great sturgeon (*Huso huso*) were caught within a day at one fishing site (Unger 1931). Catches began to decline from the 16th century, and in the 19th century, sturgeon were only rarely caught in the region (Kriesch 1876, Károli 1877, Herman 1887, Khin 1957, Hensel & Holčik 1997, Guti 2008, 2014). From the Middle Danube region, anadromous species (*Huso huso*, *Acipenser stellatus, A. gueldenstaedti*) can now be regarded extinct, and ship sturgeon (*A. nudiventris*) and the non-migratory population of Danube sturgeon (*A. gueldenstaedti*) are also at the verge of extinction.

Long-standing river engineering has resulted in the loss of several important fish habitats, alterations in hydraulics, flow regime and sediment transport, as well as the interruption of longitudinal and lateral connectivity of the river-floodplain system. For potamodromous fish species (*Barbus barbus, Chondostoma nasus, Leciscus idus*, etc.), migration (between 30–300 km) means a feeding and reproduction strategy which, by reducing competition, enables the development of abundant fish populations. Interrupting the connectivity between the main arm of the Danube and the floodplain side-arms resulted in a blockage of fish migration into the floodplain spawning habitats, feeding grounds and winter refuges. This poses a serious threat to the reproductive success and recruitment of the medium distance migratory species and can lead to a decline in their populations.

From the end of the 19th century, abandoned oxbows in flood-free areas of the Szigetköz floodplain have lost their direct connections with the Danube, therefore rheophilic species generally disappeared from their fish fauna, and limnophilic elements became characteristic, such as *Carassius carassius*, *Tinca tinca, Misgurnus fossilis, Umbra krameri*. Since the middle of the 1990s, water supply of the branches in the flood-free area of the Szigetköz has been directly provided from the floodplain water replenishment system. This intervention resulted in the shifting of habitat character and the dominance of eurytopic species in their fish fauna.

Closing remarks

High number of endangered as well as alien species along the Slovak-Hungarian section of the Danube indicates the deterioration of ecological integrity of the fluvial hydrosystem. Conservation strategies and management of fish populations (Schiemer & Waidbacher 1992) should be orientated to the improvement of protection of the natural inshore bed structure and the remaining active floodplains with backwaters for the future, as well as to the recreation of the lateral connectivity at selected sites in the flood-free area to allow fish migrations between the main channel and the floodplain waters.

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