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Changes in the fish fauna and fisheries in the Slovak section of the Danube River: a review

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The fish diversity of the Slovak segment of the Danube (representing the transitional zone from the rhithron to the potamon) was under the control of the inland delta which existed in this region until 1992. Seventy-six species were recorded in the studied river section: 61 species were native, 11 were exotic, 5 or 7 were invaders from the lower sections of the Danube, 3 species (and one form) became extinct, and 7 species were not detected during the past 20 years. The increasing pollution until 1985 decreased the fish species richness, but the improvement of water quality thereafter rose their number. However, the construction of the Gabcíkovo River Barrage System put in operation in October 1992 started to change substantially fish species richness and quantity, and fish catch. The formerly functional inland delta controlled by the pulsating discharge disappeared, and was changed to an artificial system of isolated or only marginally connected habitats. The upstream fish migration was stopped by the Gabcíkovo dam and weirs in Cunovo. Therefore, the fish fauna of the side arms lost contact with fish of the main channel and of the bypass canal downstream. The loss of spawning habitats had fatal effects, especially for the wild carp and the pike, which number rapidly decreased. In general, the number of fish species, their density, and fish catch decreased significantly. To improve the situation, it is proposed: 1) to restore the bilateral connection between the main channel and the side arms, 2) to ensure fish migration between the main channel and the side arms, and 3) to simulate the original flooding of the floodplain.

Keywords: Danube River, fish diversity, fisheries, dams, hydraulic engineering impact.

Introduction

The following review describes the fish community and the fisheries of the Slovak part of the Danube River (i.e., the Slovak-Austrian, Slovak, and Slovak-Hungarian stretches), and their changes over more than 100 years. The data were taken from previous works (Marsilius 1726, Grossinger 1794, Heckel & Kner 1858, Kornhuber 1863, Herman 1887, Ortvay 1902), and from thorough ichthyological studies carried out from 1953 to 1989 (Balon 1966, 1967a, b, Holcík et al. 1981, Bastl et al.1990) with addition of recent information (Holcík 1996a, 1998b, c, Holcík et al. 1992, 2001, Stráňai 1997, Stráňai & Andreji 2001, Ahnelt et al. 1998, Kautman 2000, 2001). The data collected after 1992 were only used exceptionally, because of differences in methodologies (Cerný 1995, 1999) and/or controversial statements (Cerný & Kvaszová 1999). Finally, I did not accept at all information concerning the Cunovo reservoir (Kirka 1997, 1998, 1999) because they lack concrete and reliable data. The results of the ichthyological investigations were more complete up to October 1992. Although there was some continuation in ichthyological research afterward, their amount and quality were incomparably low (the worsened economical situation after 1989 strongly limited scientific activity). Before October 1992, the man-made impact on the Danube was relatively minor, and allowed the maintain of more or less natural environmental conditions. In October 1992, the damming of the Danube at Cunovo and the construction of the Gabcíkovo River Barrage system (GRBS) dramatically changed the environmental conditions for fish. Apart from the *species richness* or the *alpha diversity*, i.e., the *number of species*, I shall also touch the problem of the *heterogeneity*, which is the second

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important character of the species diversity problem (Krebs 1985). The scientific nomenclature was mostly used according to Kottelat (1997). To properly understand the situation in this segment of the Danube, the environmental conditions are detailed hereafter.

Characteristics of the Slovak segment of the Danube

The following characteristics of the Slovak segment of the Danube were compiled from the papers by Mucha & Dub (1966), Holcík et al. (1981), Makovinská (1999) and literature herein.

Physiography

The entire Slovak segment of the Danube River amounts to 172 km. It enters the territory of Slovakia at its confluence with the Morava River (river kilometre 1880.2) at an elevation of 133 m a.s.l., and leaves Slovakia at the confluence with the Ipel (Ipoly) River (r.km 1709.2) at an elevation of 101 m a.s.l. (Fig.1). The upper Devín-Wolfsthal section totalling 7.5 km makes up the Slovak-Austrian frontier. Both banks of the Bratislava (Karlova Ves) - Rajka section (which is 23.7 km long) belong to Slovakia and the following 140.8 km section between Rajka and the mouth of Ipel River forms the Slovak-Hungarian frontier. The width of the Danube is 200-300 m at Bratislava and increases to 400-700 m before leaving the territory of Slovakia. This part of the Danube is noteworthy for its gradient conditions. The Danube gradient changes in the vicinity of the village Sap (formerly Palkovicovo; r.km 1810). Upstream from Sap, the Danube gradient is 0.31 ‰, while downstream the gradient decreases to 0.10 ‰. The mean overall gradient of the Slovak Danube is about 0.19 ‰. Differences in the gradient are also reflected by the values of current velocity. Over the gradient break, the maximum current velocity ranged from 2.0 to 3.5 $m.s^{-1}$, and beneath it the current velocity decreased to 0.7-1.8 $m.s^{-1}$. Thus, the section upstream of Bratislava (r.km l870) is an erosional zone; the section downstream of Bratislava is an intermediate zone, whereas the depositional zone starts downstream of the village Sap. The high current velocity is responsible for the Danube's considerable transporting capacity. Within the Bratislava profile, the Danube annually transports about 630 000 m^3 of pebble and gravel, and about 7 million tons of suspended solids.

The Alpine character of the Danube is manifested both in its discharge and temperature regimes. The water level fluctuation depends upon the thawing of the Alpine glaciers. The rhythmical fluctuation of the water level (or the flood-pulse effect, Junk et al. 1989) is characteristic in this segment of the Danube, resulting in the flooding of the floodplain twice a year. According to long-term observations, the first spring flood starts at the beginning of February to culminate by the mid of March, and fades away in April. The second or summer flood starts in May, culminates in July and ends at the beginning of September. The mean discharge amounts to 2050 $m^3.s^{-1}$, water starts to enter the floodplain at 3500 - 4000 $m^3.s^{-1}$, and the complete flooding begins at 4500 $m^3.s^{-1}$. Due to its Alpine character, the Danube in this area has a relatively low temperature. The average annual water temperature of the Danube at Bratislava is 9.6 °C. The average long-term maximum water temperature is 17.4 °C in June and 17.5 °C in August.

From the limnological point of view, the overall Slovak stretch of the river may be characterised as the beginning of the foothill zone (hyporhitron-metapotamon). Owing to the gradient change and the lowering of the transporting capacity of the Danube, a vast floodplain with numerous side arms, swamps and lakes - the inland delta - was created in the past. However, the intensive regulation adjustments which aimed at improving navigation considerably diminished its size. Before 1992, the area of the floodplain delimited by the large river dike at both banks was about 22685 ha. Of this, about 3114 ha consisted in the arm system communicating with the Danube.

Water quality

Long-term observations revealed that the water quality of this segment of the Danube considerably changed during past decades. According to a complex analysis of sanitary, economic and limnological conditions, the River Danube entering the Slovak territory was heavily polluted in the beginning of 1970 as a consequence of both industrialisation (especially construction of chemical and petrochemical industries) and increasing number of inhabitants in vast urban centres on both banks of the Danube. The quality of the water was formerly classified as being of the 3rd degree of purity (*beta-mesosaprobia*), and deteriorated to the 4th degree of purity (*alpha-mesosaprobia*). The self-cleaning capability of the Danube decreased considerably and the toxic effects of industrial wastewaters exceeded the bearable limits for human health and for the life of some organisms. The most dangerous were the wastewaters from petrochemical works that contained a considerable and increasing amount of oil. Although the fish kills were only rarely observed

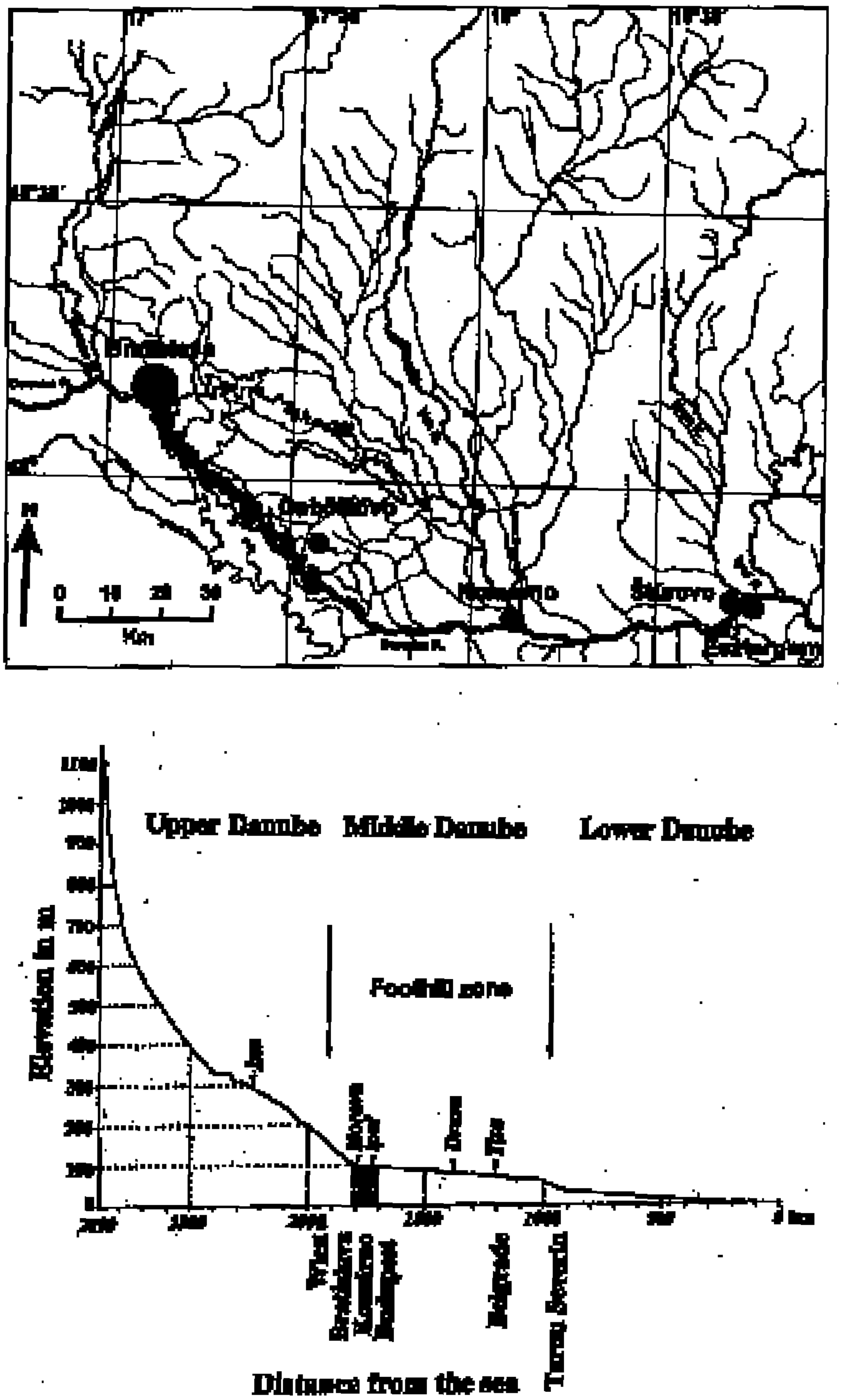

Fig. 1. Slovak segment of the Danube River (top), and profile of the Danube from its source to the Black Sea (bottom). Hatched bar indicates the Slovak segment.

(e.g., in summer 1973), the fish fauna was significantly affected. Some sensitive fish species, such as the brown bullhead *Cottus gobio* Linnaeus, 1758, the minnow *Phoxinus phoxinus* (Linnaeus, 1758), the spirlin *Alburnoides bipunctatus* (Bloch, 1782) and the sterlet *Acipenser ruthenus* Linnaeus, 1758, disappeared from the main channel of the Danube below Bratislava. Other species, like the barbel *Barbus barbus* (Linnaeus, 1758) occurred only rarely. The construction of water purification stations in Vienna, Schwechat and Bratislava at the beginning of the 1980s considerably improved the water quality, and some fish species which disappeared from some river segments below Bratislava re-established their occurrence and populations. There was a considerable increase in eutrophication owing to the increasing amount of nutrients coming from the watershed. The present mean concentrations of nitrogen salts are 3 times higher than 40 years ago. On the other hand, the amount of phosphorus, which increased during past 30 years, started to decrease since the middle of the eighties. The rise of nutrients was accompanied by an increase of pH values. During the past 8 years, the mean pH increased from 7.7-7.8 to 8.1. In sum it may be stated that the increase of the Danube River pollution which characterized the 1955-1985 period has been stopped, and since that time an improvement in water quality has been observed.

Modification of the Danube flow since 1960.

Large changes in the water level have been observed during the last two decades. Since 1960, the water level profile for a discharge of 1000 m^3 has decreased by 1 to 2 m between r.km 1870 and 1840, and between r.km 1805 and 1785. Two factors were responsible for the river bed degradation: 1) the effect of 49 dams built in the German and especially in the Austrian stretches of the Danube lowered the amount of sediments to about 1/4 of the formerly transported volume, and 2) the large scale dredging along the Danube river from both the Slovak and Hungarian sides. The volume of dredged material at some river segments was up to 1.5-2.0 million $m^3.year^{-1}$. The largest amount was dredged out in the city of Bratislava (r.km 1860-1870), where in some years up to 2.5 million $m^3.year^{-1}$ have been excavated. This dredging considerably affected the timing and volume of water entering the side arms and the floodplain. Part of the inland delta between r. k m 1860 and 1840 was flooded and their arms filled with water later than before, and with lower amounts of wa t e r. In some years and seasons, some of these arms completely dried up and this part of the floodplain was not flooded. However, most of the floodplain was still under the rhythmical pulses of the floods, the ecosystem of the inland delta did not show substantial deviations, and the characteristic responses of fish stocks and catches to changes in the hydrological regime remained as expected.

The most serious impact upon the abiotic and biotic conditions of this segment of the Danube was the construction of the Gabcíkovo River Barrage System (GRBS) between 1978 and 1992. After the damming of the Danube at Cunovo (r.km 1852) in October 1992, most of the water from the storage reservoir (with an area of about 4000 hectares) was brought down to the concrete diversion canal. This canal runs along the left-hand side of the river dike, above ground level. The canal is divided by the Gabcíkovo hydroelectric power plant into the upstream (headwater) and downstream (tailwater) sections. The difference in the water level between the headwater and tailwater section varies from 16 to 23 m. The slopes running all along the length of this canal are made from concrete and the bottom is strengthened by compacting the existing clay loam followed by a layer of gravel. The original riverbed of the Danube is now supplied by a limited volume of water amounting to 250-600 $m^3.s^{-1}$. Thus, the water level of the old Danube is 3-5 m below the ground level of the former floodplain and the contact between the side arms and the Danube is completely interrupted. The remaining left hand arms are supplied by the intake structure taking water from the bypass canal at Dobrohost' (r.km 1840) with a discharge capacity of up to 240 $m^3.s^{-1}$. To keep the water in the arms, these were converted to a system of cascades formed by 11 weirs between r.km 1840 and 1820. One fish way was also built between the old riverbed and the lower part of the anabranch system at r.km 1821. However, the flow from the weir openings is over 1 $m.s^{-1}$ and the fish way is not properly constructed, so the upstream fish migration from the Danube is not possible, as shown by the tagging of fish downstream of Gabcíkovo and Cunovo. Natural and pulsating flooding of the inland delta was terminated. Although the artificial flooding of the former floodplain was planned, it was realised only in 1995, 1997 and 2000. However, these floods did not simulate the natural floods as their amount, timing and duration were different. The first artificial flood realised in 1995 began on 25 July, lasted until 25 August and culminated from 1 to 9 August. Because the discharge rose from 35 to only 60-131 $m^3.s^{-1}$, only a small part of the floodplain was flooded. In 1997 the artificial flooding begun on 21 April, culminating between 27-30 April (culmination lasted only 99 hours) and ended on 15 May, with similar values of discharge allowed to enter the floodplain. Relatively little information is available on the flood of 2000: it lasted from 18 June until 6 July, and the water level in the arms increased by 80-100 cm, but the former floodplain was not flooded at all. It may be seen that in 1995 the floods were too late and in 1997 too short, and in both years the area covered by water was too small for the successful spawning of phytophil and phytolithophil fishes. It is also necessary to mention that in the arms fed by the water from the bypass canal, the abundance and biomass of zooplankton decreased substantially and was far below the values found in the predammed conditions (Vr a n o v s ký 1995, 1997, Vr anovský & Illyová 1999). A similar observation was made for the macrozoobenthos biomass (Krno et al. 1999).

After the construction of the GRBS and its operational introduction in October 1992, the formerly functional ecosystem of the inland delta became extinct. It was replaced by an artificial system of more or less isolated habitats. The dramatic alterations of both the hydrological regime and the habitat diversity induced subsequent decrease of the fish food base and the loss of spawning, feeding and wintering grounds for fishes. C o n s e q u e n t l y, the mean annual fish catch, calculated for the period after the damming of the river, dropped by 87 % in comparison with the 1961-1972 period when the construction of the GRBS has been planned (Holcík 1998a, Balon & Holcík 1999).

Fish species richness (alpha diversity)

Although this segment of the Danube is relatively short in comparison with the longest Slovak rivers Váh (403 km), Hron (298 km), Hornád (286 km), and Ipel (232 km), it houses the richest fish fauna. Table 1 shows that 75 fish species were recorded, and another one is anticipated to occur in this stretch of the Danube River. The native species amount to 61 (80.3 %), introduced exotic species to 11 (14.5 %), and recent invaders to 5 (6,6 %) or 6 (7.9 %), if it is supposed that one new invading species is anticipated. Three (3.9 %) species and one form (diadromous form of *Acipenser gueldenstadtii*) became extinct, the presence of other 7 species (9.2 %) was not recorded during past 20 years. The richness of this segment of the Danube can be explained by two reasons: 1) this stretch of the river represents the beginning of the foothill zone (Fig.1), or, more precisely, the *transitional zone* between the *foo - thill* and the *lowland zones* (i.e., *the hyporh i tron-epi - potamon* and *metapotamon*, or *the intermediate zone* according to the classification of Illies & Botosaneanu (1963) and Cummins (1972) respectively), and 2) the gradient change of the Danube, causing the development of a quite complicated braided belt and a vast inland delta with a complex network of numerous side arms. Thus, miscellaneous fish species differing in their environmental requirements may occur together in this relatively short river segment. Various types of environment including the *eupotamon, parapotamon, plesiopotamon* and *paleopotamon* (Roux 1982, Holcík et al. 1989) and the countless number of ecotones have created the diverse combination of environmental conditions suitable for the assembly of different fish species.

Species diversity and equitability

It was found that species diversity and equitability in two types of floodplain side arms were diff e r e n t (Holcík 1998a). Table 2 shows clear differences in several parameters between the main channel (*eupota - mon*) and two types of floodplain side arms (*parapota - mon* and *plesiopotamon*). Table 2 also indicates increasing values of parameters from the *eupotamon* towards the floodplain margin. This suggests that in the main channel of large rivers with inland delta, the indexes of species diversity and equitability are higher than those in the side arms (the actual values for all indexes, especially the species richness in the main channel, are certainly much higher because of a difference in fishing gear used to obtain the data; the values for the main channel represent catches by commercial hauls using a 40x40 mm mesh size net, while those for the *parapotamon* and *pleisopotamon* arose from catches obtained by small mesh size hauls (10x10 mm) combined with trap nets, gill nets and electroshockers). In this respect the Little Danube data are not considered, as this water body is a highly modified flowing arm of the Danube. High species richness and other ecological indexes of the eupotamon are just due to the inland delta existence, which represents one of the ecotone forms (Schiemer et al. 1995). Moreover, the inland delta also supplies the main channel with species reproducing there (e.g., phytophils) which find conditions for their propagation in the main channel. It is necessary to point out that the biological productivity of the inland delta of the floodplain rivers is generally the highest. In this stretch of the Danube, the total fish production is well over 1000 $kg.ha^{-1}$ in average, or over 200 kilograms of the available production per hectare (Holcík, 1996a).

Papers dealing with the problem of heterogeneity of fishes are rather rare (e.g. Talbot et al. 1978, Sale & Williams 1982, Jepsen 1997). As explained elsewhere (Holcík 1998a), this index, and also the species richness and equitability, depend on the water level and

Table 1. List of the fish species occurring in the Slovak segment of the Danube river.1 = status, 2 = reproductive guild, 3 = preferred habitat, 4 = conservation status (IUCN classification, see text). Symbols: • = present, o = not recorded during the past 20 years, x = extinct, ? = occurrence anticipated, (?) = identity not properly known; * = introduced exotic species, ** = recent invader; R = rheophil, L = limnophil, E - eurytopic; A= nonguarders: A.1 = open substratum spawners; A.1.1 = pelagophils, A.1.2 = lithopelagophils, A.1.3 = lithophils, A.1.4 = phytolithophils, A.1.5 = phytophils, A.1.6 = psammophils; A.2 = brood hiders; A.2.3 = lithophils, A.2.5 = ostracophils; B = guarders: B.1 = substratum choosers; B.1.3 = lithophils, B.1.4 = phytophils; B.2 = nest spawners; B.2.2 = polyphils, B.2.4 = ariadnophils, B.2.5 = phytophils, B.2.7 = speleophils.

CLASS - ORDER - Family - Species	1	2	3	4
CEPHALASPIDOMORPHI				
I. PETROMYZONTIFORMES				
I. 1. Petromyzontidae				
1. *Eudontomyzon mariae* (Berg, 1931)	•	A.2.3	R	CR
ACTINOPTERYGII				
II. ACIPENSERIFORMES				
2. Acipenseridae				
2. *Acipenser gueldenstaedtii* Brandt & Ratzeburg, 1833				
2a - migratory form	x	A.1.2	R	Ex
2b – resident form	•	A.1.2	R	CR
3. *Acipenser huso* Linnaeus, 1758	x	A.1.2	R	Ex
4. *Acipenser nudiventris* Lovetsky, 1828	x	A.1.2	R	Ex
5. *Acipenser ruthenus* Linnaeus, 1758	•	A.1.2	R	VU
6. *Acipenser stellatus* Pallas, 1771	x	A.1.2	R	Ex
III. ANGUILLIFORMES				
3. Anguillidae				
7. *Anguilla anguilla* (Linnaeus, 1758)	•	A.1.1	E	-
IV. CYPRINIFORMES				
4. Cyprinidae				
8. *Abramis ballerus* (Linnaeus, 1758)	•	A.1.3	L	VU
9. *Abramis brama* (Linnaeus, 1758)	•	A.1.4	L	-
10. *Abramis sapa* (Pallas, 1814)	•	A.1.3	R	VU
11. *Alburnoides bipunctatus* (Bloch, 1782)	•	A.1.3	R	VU
12. *Alburnus alburnus* (Linnaeus, 1758)	•	A.1.4	E	-

Table 1. (Continued).

CLASS - ORDER - Family - *Species*	1	2	3	4
13. *Aspius aspius* (Linnaeus, 1758)	•	A.1.3	R	-
14. *Barbus barbus* (Linnaeus, 1758)	•	A.1.3	R	-
15. *Barbus peloponnesius* Valenciennes, 1842	•	A.1.3	R	DD
16. *Abramis bjoerkna* (Linnaeus, 1758)	•	A.1.5	E	-
17. *Carassius carassius* (Linnaeus, 1758)	•	A.1.5	L	CR
18. (?) *Carassius gibelio* (Bloch, 1782)	•	A.1.5	E	-
19. *Chondrostoma nasus* (Linnaeus, 1758)	•	A.1.3	R	VU
20. * *Ctenopharyngodon idella* (Valenciennes, 1844)	•	A.1.1	R	-
21. *Cyprinus carpio* Linnaeus, 1758				
21a - wild form (saran)	•	A.1.5	R	CR
21b – domesticated (feral) carp	•	A.1.5	L	-
22. *Gobio gobio* (Linnaeus, 1758)	•	A.1.6	E	–
23. *Gobio kessleri* Dybowski, 1862	•	A.1.6	R	CR
24. *Gobio uranoscopus* (Agassiz, 1828)	•	A.1.6	R	CR
25. * *Hypophthalmichthys molitrix* (Valenciennes, 1844)	•	A.1.1	R	-
26. * *Hypophthalmichthys nobilis* (Richardson, 1845)	•	A.1.1	R	-
27. *Leucaspius delineatus* (Heckel, 1843)	•	B.1.4	L	VU
28. *Leuciscus cephalus* (Linnaeus, 1758)	•	A.1.3	R	-
29. *Leuciscus idus* (Linnaeus, 1758)	•	A.1.4	E	VU
30. *Leuciscus leuciscus* (Linnaeus, 1758)	•	A.1.3	R	VU
31. *Pelecus cultratus* (Linnaeus, 1758)	•	A.1.1	E	CR
32. *Phoxinus phoxinus* (Linnaeus, 1758)	•	A.1.3	R	VU
33. * *Pseudorasbora parva* (Temminck et Schlegel, 1842)	•	B.2.2	E	-
34. *Rhodeus sericeus* (Pallas, 1776)	•	A.2.5	E	DD
35. *Romanogobio albipinnatus* Lukasch, 1933	•	A.1.6	E	-
36. *Rutilus meidingeri* (Heckel, 1851)	•	A.1.4	R	DD
37. *Rutilus pigus* (La Cepède, 1803)	•	A.1.4	R	CR
38. *Rutilus rutilus* (Linnaeus, 1758)	•	A.1.4	E	-
39. *Scardinius erythrophthalmus* (Linnaeus, 1758)	•	A.1.5	L	-
40. *Tinca tinca* (Linnaeus, 1758)	•	A.1.5	L	-
41. *Vimba vimba* (Linnaeus, 1758)	•	A.1.3	R	VU
5. Cobitidae				
42. *Cobitis elongatoides* Bacescu & Mayer, 1969	•	A.1.5	R	VU
43. *Misgurnus fossilis* (Linnaeus, 1758)	•	A.1.5	L	CR
44. *Sabanejewia balcanica* (Karaman, 1922)	•	A.1.5	R	VU

Table 1. (Continued).

CLASS - ORDER - Family - *Species*	1	2	3	4
6. Balitoridae				
45. *Barbatula barbatula* (Linnaeus, 1758)	•	A.1.6	E	-
7. * Ictaluridae				
46. * *Ameiurus melas* (Rafinesque, 1820)	•	B.2.7	L	-
47. * *Ameiurus nebulosus* (Lesueur, 1819)	•	B.2.7	L	-
8. Siluridae				
48. *Silurus glanis* Linnaeus, 1758	•	B.1.4	L	-
V. ESOCIFORMES				
9. Esocidae				
49. *Esox lucius* Linnaeus, 1758	•	A.1.5	E	-
10. Umbridae				
50. *Umbra krameri* Walbaum, 1792	•	B.2.5	L	CR
VI. SALMONIFORMES				
11. Salmonidae				
51. *Hucho hucho* (Linnaeus, 1758)	•	A.2.3	R	CR
52. * *Oncorhynchus mykiss* (Walbaum, 1792)	•	A.2.3	E	-
53. *Salmo labrax* Pallas, 1811	•	A.2.3	R	DD
54. * *Salvelinus fontinalis* (Mitchill, 1814)	•	A.2.3	E	-
12. Thymallidae				
55. *Thymallus thymallus* (Linnaeus, 1758)	•	A.2.3	R	DD
13. Coregonidae				
56. * *Coregonus peled* (Gmelin, 1788)	•	A.1.2	L	-
57. (?) *Coregonus renke* (Schrank, 1783)	•	A.1.2	L	DD
VII. GADIFORMES				
14. Gadidae				
58. *Lota lota* (Linnaeus, 1758)	•	A.1.2	E	VU
VIII. GASTEROSTEIFORMES				
15. Gasterosteidae				
59. ** *Gasterosteus aculeatus* (Linnaeus, 1758)	•	B.2.4	E	-
IX. SCORPAENIFORMES				
16. Cottidae				
60. *Cottus gobio* Linnaeus, 1758	•	B.1.7	R	-
X. PERCIFORMES				
17. *Centrarchidae				
61. * *Lepomis gibbosus* (Linnaeus, 1758)	•	B.2.2	L	-

Table 1. (Continued).

CLASS - ORDER - Family - Species	1	2	3	4
62. * *Micropterus salmoides* (La Cepède, 1802)	•	B.2.5	E	-
18. Percidae				
63. *Gymnocephalus baloni* Holčík & Hensel, 1974	•	A.1.3	R	VU
64. *Gymnocephalus cernuus* (Linnaeus, 1758)	•	A.1.4	E	-
65. *Gymnocephalus schraetser* (Linnaeus, 1758)	•	A.1.3	R	VU
66. *Perca fluviatilis* (Linnaeus, 1758)	•	A.1.4	E	-
67. *Sander lucioperca* (Linnaeus, 1758)	•	B.2.5	E	-
68. *Sander volgensis* (Gmelin, 1789)	•	B.2.5	E	VU
69. *Zingel streber* (Siebold, 1863)	•	A.2.3	R	VU
70. *Zingel zingel* (Linné, 1766)	•	A.2.3	R	CR
19. *Odontobutidae	?			
71. ** *Perccottus glenii* Dybowski, 1877	?	B.2.2	L	-
20. Gobiidae				
72. ** *Neogobius fluviatilis* (Pallas, 1814)	•	B.1.3	R	-
73. ** *Neogobius gymnotrachelus* (Kessler, 1857)	•	B.1.3	E	-
74. ** *Neogobius kessleri* (Günther, 1861)	•	B.1.3	E	-
75. ** *Neogobius melanostomus* (Pallas, 1814)	?	B.1.3	E	-
76. *Proterorhinus marmoratus* (Pallas, 1814)	•	B.2.7	L	-

season and show large fluctuations. Preliminary results revealed that the floodplain river water bodies were highly diversified and unstable systems, in which increasing species richness may, or not, increase the species diversity. However, while an increase in species richness increases ichthyomass, species diversity decreases it.

Comments on the status of some species

Petromyzontidae in this river section as well as in the entire Middle and Lower Danube are represented by the Ukrainian lamprey *Eudontomyzon mariae* (B e rg, 1931) (Holcík & Renaud 1986, Holcík 1995a, b, Holcík & Delic 2000) and not by the Carpathian lamprey *Eudontomyzon danfordi* as reported earlier by Balon (1967a) and Holcík et al. (1981). Recently, it was found in the littoral of Danube between Štúrovo (r.km1820) and the mouth of the Hron River (r.km.1817) and its identification was confirmed (Holcík et al. 2001, Holcík 2003). With regard to the habitat of ammocoetes and metamorphosed specimens, the occurrence of this species is apparently limited to the old riverbed. Further information on the occurrence of the Ukrainian lamprey from this segment of the Danube, especially from the right Austrian-Hungarian shores are needed. Ukrainian lamprey may be considered as critically endangered species.

The great sturgeon or beluga, *Acipenser huso* Linnaeus, 1758, was represented by the winter race. It was caught in great quantities in the Danube between Komárno (r.km 1768) and Sap (r.km 1810), the locations of its main spawning grounds. It regularly migrated up to Bratislava (r.km 1870) and also entered the lower courses of large tributaries such as the Morava, Váh and Hron rivers. The major fishery was concentrated in the Little Danube near the mouth of the V·h River and the village of Kollárovo. A dramatic decline of its catches, as a consequence of overfishing, started as early as the 16th c e n t u r y. The last specimens weighing 140 and 150 kg in this segment of the Danube were caught at Vojka (r.km 1837) and Štúrovo (r. k m 1719) in 1910 and 1925 respectively (Khin 1957, Balon, 1967a, Holcík, 1995b, Hensel & Holcík 1997).

Table 2. Species richness (S), species diversity (H'; calculated with natural logarithms) and equitability (J) of the fish communities in different types of water bodies of the Slovak segment of the Danube river. Data for the main channel are own, those for the arm éofín and Trstená are recalculated (natural logarithms instead the decadic ones) from Holcík (1998 a), for Little Danube and arms between the villages Sap and Medvedov calculated from Miöík (1957) and Bél (1962), respectively.

Habitat	Location (river kilometer)	Year	S	H'	J
Eupotamon	main channel (1730-1851)	1992-1995	29	1.95	0.58
Eupotamon	Little Danube (above Kolárovo)	1954-1955	21	1.84	0.61
Parapotamon	arm Žofin (1836)	1969-1973	28	1.67	0.53
Parapotamon	Sap-Medveďov (1805-1810)	1957	22	1.58	0.51
Plesiopotamon	Trstená (1825)	1981-1989	27	1.36	0.44

The stellate sturgeon, *Acipenser stellatus* Pallas, 1771 has always been rare in this river section and individual specimens caught were therefore recorded. It migrated up to Komárno and also to Bratislava (Grossinger 1794, Fitzinger & Heckel 1835, Kornhuber 1901). It probably also entered the mouth of the Morava River (Mahen 1927). The last specimen taken from the Danube at Komárno on February 20, 1926 measured 1.28 m and weighed 9.8 kg (Holcík 1995c).

The sterlet, Acipenser *ruthenus Linnaeus*, 1758, is the only sturgeon still common in this river section. Its occurrence and distribution declined between 1962 and 1978 but its catches increased until 1992. However, after the GRBS construction was put in operation, catches started to decrease again. It also re-appeared in the Slovak stretch of the Tisza River (Holcík 1995d) and in the lower course of the Morava River (Lusk & Holcík 1998). Only its resident *non-migratory form* now represents the Russian sturgeon *Acipenser gueldenstaedtii* Brandt et Ratzeburg, 1833. It still occurs in this segment of the Danube, but it is extremely rare (Holcík 1995e, Hensel & Holcík 1997).

The ship sturgeon, *Acipenser nudiventris* Lovetzky, 1828, was found in the Danube River only as a resident, and not as diadromous form (Banarescu 1964, Manea 1966). It has always been rare in the entire Danube and completely disappeared from the Slovak segment of the Danube since the end of 19th century if not earlier (Holcík 1995f).

Barbus peloponnesius Valenciennes, 1842 (syn. *Barbus meridionalis* not Risso, 1826, *Barbus petenyi, Barbus meridionalis petenyi, Barbus carpathicus, Barbus balcanicus*) is considered here to be a valid species inhabiting left tributaries of the Danube. *Barbus carpathicus* and *B. balcanicus* recently described by Kotlík et al. (2002) as well as *B. petenyi* are only different populations of *B. peloponnesius* (see Economidis et al. 2003). They differ among themselves only in the combination of their mtDNA alleles. However, mtDNA data are sufficient for the analysis of relationships among populations but of their own accord are not suitable for deep relationships including the estabilisment of new species (Stepien & Kocher 1997). The occurrence of *B. peloponnesius* in the Slovak stretch of the Danube was first recorded by Brtek & Rotschein (1964), then questioned by Balon (1967) and finally confirmed by Zitnan (1972). Nevertheless, its occurrence should be considered as accidental and caused by specimens coming here from the left-hand tributaries, such as the Ipel and Hron rivers, where this species inhabits their foothill segments (Penáz 1995).

The minnow *Phoxinus phoxinus* and the spirlin *Alburnoides bipunctatus* were rare species, found in this river segment only twice (Balon 1964, Žitnán 1972). No recent record of either species is known. However, their presence below and above the Gabcíkovo - Cunovo is presumed.

The Prussian carp, *Carassius gibelio* (Bloch, 1782), was first represented as a unisexual gynogenetic form (Balon 1962, Holcík 1980a, b). The first males appeared in 1992 and since that time, the males form the permanent part of its population. Although this species was already mentioned by Marsilius (1726) as native for the Danube, the population expansion since 1960 is probably caused not only by the decline of predators and the change of the hydrological regime of the river but also by the some introduced unknown strains of this species (Holcík & Zitnan 1978, Holcík 1980b).

The crucian carp, *Carassius carassius* (Linnaeus, 1758) is considered to be the critically endangered species. Its abundance and biomass were already low in the 1960s (Balon 1967a) although before its density used to be high, especially outside the floodplain (Balon 1966). Ten years afterward it shows a sporadic occurrence and very low population density in the Danube River floodplain (Holcík & Bastl 1976), in the Malý Dunaj, and in channels of the Zitný Ostrov region (Nagy & Cerný 1992, Cerný 1999).

The declining commercial catch of *Chondrostoma nasus* (Linnaeus, 1758) as well as ichthyological research revealed a continuous deterioration of its populations. Formerly, the average frequency of this species in catches was around 10 % (Balon 1967a), whereas in our experimental catches from 1992 to 1995 it was only 3.2 %.

The case of the original wild form of the common carp - *Cyprinus carpio* Linnaeus, 1758 or sazan, which is now extremely rare and belongs to the critically endangered species list, will be discussed later.

From four species of the genus *Gobio*, the Danubian gudgeon - *G. uranoscopus* (Agassiz, 1828) - probably disappeared from this river segment, as the last specimens were recorded by Žitnán (1972) downstream of Komárno in the 1970s. *Gobio kesslerii* Dybowski, 1862 is still present, but it is very rare, and since 1991 it was not recorded in any of the monitored localities on the area affected by the GRBS (Cerný 1995, 1999), and therefore it should be considered as a critically endangered species. *Gobio albipinnatus* Lukasch, 1933 is the most abundant species of this genus in all types of water bodies.

Three exotic «herbivorous» carps, i.e. the grass carp *Ctenopharyngodon idella* Valenciennes 1844, the bighead carp *Hypophthalmichthys nobilis* (Richardson, 1845) and the silver carp *Hypophthamichthys molitrix* (Valenciennes, 1844) occurred all along the Slovak segment of the Danube, but mostly in the stretch Moca - Cenkov (r.km 1845 -1835). They were also found in the lower courses of the Váh, Hron and Morava rivers, sometimes over long distances. Their reproduction was not observed and their stock is composed of fishes escaped from fish farms and some inland water bodies situated in Hungary, Slovakia and Czech Republic.

Pelecus cultratus (Linnaeus, 1758) belongs to the group of critically endangered species. It is extremely rare and only occurs in the *eupotamon* and *parapotamon* sections of the Danube.

Pseudorasbora parva (Temminck & Schlegel, 1842) is another exotic species discovered in this stretch of the Danube in 1976, where it penetrated from Hungary. Its occurrence in this segment of the Danube is insular and rather rare.

Rutilus meidingeri (Heckel, 1851) is an accidental invader from the upper course of the Danube and its occurrence is probably associated with floods. At present, however, the GRBS as well as upstream Austrian man-made lakes make its occasional occurrence impossible.

Rutilus pigus (La Cepède, 1803) is strictly confined to constantly flowing water, i.e., in the *eupotamon* and *parapotamon* sections. Its abundance seems to be severely limited by the quality of water.

The spined loach and the golden loach occurring in this segment of Danube belong to *Cobitis elongatoides* Bacescu & Mayer, 1969 and *Sabanejewia balcanica* (Karaman, 1922) and not to *Cobitis taenia* Linnaeus, 1758 and *Sabanejewia aurata* (De Filippi, 1863) respectively, as stated before (Kottelat 1997, Lusk & Penáz 2000).

The European mud-minnow *Umbra krameri* Walbaum, 1792 was relatively abundant in the irrigation canals and some *paleopotamal* water bodies (Mišík 1965), but at the present time it belongs to the critically endangered species list, and can be found in one locality only.

The brown trout from the Danube belongs to the species *Salmo labrax* Pallas, 1814 (Holcík 1969, 2002a, Kottelat 1997). The resident forms the brook trout and the lake trout inhabit the Danube and its tributaries. They were relatively common over the entire Slovak segment of the Danube and the last verified records - indicating 330-491 mm in fork length and a weight of 510-1870 g - were caught below Gabcíkovo (r. k m 1820) in 1993-1995.

Exotic salmonids, the rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) and the brook trout *Salvelinus fontinalis* (Mitchill, 1814), were occasionally found especially in the main channel. Most likely, they penetrate into the Danube from some tributaries where the juveniles are stocked, or from some fish farms.

The huchen, *Hucho hucho* (Linnaeus, 1758), occurs over the entire Slovak Danube, and also in the lower part of the Morava River. Its catches are rare and the species is critically endangered both in the Danube and Slovakia generally (Holcík 1996b, 2002a).

The grayling, *Thymallus thymallus* (Linnaeus, 1758), seldom occurs in the Slovak segment of the river. A recent record of a specimen measuring 340 mm in SL and weighing 660 g was caught at Cenkov (r.km 1730) in June 1993. It was probably washed down from the Váh River or from the Morava and Dyje rivers, where it occurs in their lower courses (Blahák 1980, Lusk 1995).

From two coregonids recorded in this segment of the Danube, *Coregonus peled* (Gmelin, 1788) is an exotic species planted into the Medvedovské arm (r.km 1807) and recorded in 1974 (Holcík et al. 1981). Five other specimens of whitefish discovered in the Slovak segment of Danube in 1970-1995 may be considered as native, although the species is very seldom and occurs accidentally. However, its proper determination is not clear yet. The first specimen, measuring 160 mm in fork length, with 32-gill rakers, was described as *Coregonus lavaretus* (Linnaeus, 1758) by Bastl & Holcík (1971). Four specimens measuring 332 - 432 mm in fork length and weighing 510-1500 grams were caught during the tagging of fishes in this river segment below Cunovo and Gabcíkovo in 1992-1995. The number of their gill rakers varied from 32 to 36 which is in accordance with this count for *Coregonus renke* (Schrank, 1783), native from some Alpine lakes of the Danubian basin, and for which Kottelat (1997) found 30-45 gill rakers. The specimen of whitefish (measuring 164 mm in standard length) caught in the Danube at Vác in Hungary in 1960 also had 29 gill rakers (Berinkey 1960), and belonged to this species. However, Kottelat (*l.c.*) found a similar number of gill rakers for *C. lavaretus, C. albellus* Fatio, 1890 and *C. alpinus* Fatio, 1885, which inhabit lakes belonging to different river basins. Nevertheless, the present population as well as all next possible discoveries of coregonids are associated with man-made lakes of the Upper Danube, where this species was and is continuously planted (Reichenbach-Klinke 1968, Kainz in lett. 16 September 1994).

The three-spined stickleback *Gasterosteus aculeatus* (Linnaeus, 1758) is native from the Danube, but its occurrence is insular. It seems to find suitable environmental conditions in some side channels, and in some localities its populations were exceptionally numerous (Hensel 1984). Contrary to the former opinion that aquarists have introduced this species (Balon 1967b, Bastl 1970, 1976, Holcík et al.1981), I suggest its possible translocation from the lower Danube in the ballast water of ships.

The population density of most percid species is rather low. *Zingel zingel* (Linné, 1766) is a critically endangered species, and *Gymnocephalus baloni* Holcík & Hensel, 1974, *G. schraetser* (linnaeus, 1758), *Sander volgensis* (Gmelin, 1788) and *Zingel streber* (Siebold, 1863) are vulnerable ones. With the exception of *S. volgensis*, all other species are predominantly confined to the *eupotamon* and seldom to the *parapotamon.*

Until 1990, the gobiids were represented only by the tube-nosed goby *Proterorhinus marmoratus* (Pallas, 1814). In 1994, *Neogobius kessleri* (Günther, 1861) was discovered in the Austrian part of the Danube (Zweimüller et al.1996) and in the same year in the Danube at Stúrovo (P. Bitter, pers.comm; Holcík 1998-c). In 1999, *N. gymnotrachelus* (Kessler, 1857) has been discovered in the Danube at Bratislava (Kautman 2000, 2001). In 2001, *N. fluviatilis* (Pallas, 1814) was found along the left bank of Danube below Štúrovo and in the lower course of its tributary, the Hron River (Stráňai & Andreji 2001). Nevertheless, their presence here had to be much earlier and they were probably overlooked. *Neogobius melanostomus* (Pallas, 1814) was not discovered yet, but it certainly occurs also in the Slovak segment of the Danube, because it was already found in the Danube nearby Vienna (Wiesner et al. 2000), some 50 kilometres usptream. A potential species is *N. iljini* Vasil'eva & Vasil'ev, 1996, erroneously reported from the Roumanian segment of the Danube (Ráb, in lett. 18 December 2000) which is very similar to *N. kessleri.* The occurrence of *N. syrman* (Nordmann, 1840), reported from the Austrian segment of the Danube (Zweimüller et al. 2000) which appeared to be *N. melanostomus* (Wiesner et al. 2000) is a marine species, and its occurrence in the middle and upper courses is highly improbable (Holcík 2002b).

Migrations

To assess the effect of damming on fish migrations, an extensive fish tagging was performed from 1992 to 1995. The fishes were tagged and released in the river between Cenkov (r.km 1735) and the Cunovo weir (r.km 1852), i.e., downstream of the dammed river stretch. Altogether, 6274 fish specimens belonging to 29 species were tagged by the FLOY TAG® anchor tags. From the results which will be published elsewhere, until 2002 when the last tagged fish returned, no tagged individual was detected above the Gabcíkovo dam, the Cunovo weir and/or in the anabranches in this region. This is unequivocal evidence that the Gabcíkovo dam and the Cunovo weir, along with weirs built in anabranch system, represent insurmountable obstacles for any species of fish. Our results also revealed that downstream of the GRBS all fish species including the white bream (*Blicca bjoerkna*) performed migrations within the Danube, and also between the Danube and its tributaries.

Reproduction particularities

With regard to appropriate water temperature, which is higher in the flooded floodplain, *plesiopotamon* and *paleopotamon* anabranches, and lower in the main channel and parapotamon side arms, the spawning period for particular fish species was different. During the spring flood two consecutive groups of fish reproduced. The first group included *Esox lucius, Leuciscus leuciscus, Gymnocephalus cernuus, G. baloni, G. schraetser* and *Aspius aspius.* Their spawning occurred at temperatures ranging from 6 to 10 °C. The second group reproduced at water temperature around 10-14 °C, and included *Zingel zingel, Z. streber, Chodrostoma nasus, Abramis ballerus, A. sapa, Rutilus pigus* and *Sander volgensis.*

The fish group which reproduced during the period of the summer flood consisted of (sequentially arranged) *Rutilus rutilus, Perca fluviatilis, Acipenser ruthenus, Sander lucioperca, Leuciscus cephalus, L. idus, Barbus barbus, Vimba vimba, Abramis brama, Pelecus cultratus, Abramis bjoerkna, Carassius gibelio, Cyprinus carpio, Silurus glanis*. The spawning water temperature for this group ranged from 11 to 23 °C.

It has to be stressed that the spawning period of the above-mentioned species overlapped, and the water temperature range at the beginning and end of spawning for species reproducing in spring and in summer varied from 4 to 19 °C and from 5 to 24 °C, respectively.

Fish catch statistics

The mean annual recreational fish catch before the start of the GRBS construction and damming during the period 1961-1979 amounted to 102.7 metric tons (MT). The catch was composed of 47.4 MT (46.1 %) of the economically preferred species: *Cyprinus carpio, Esox lucius, Sander lucioperca* (and *S. volgensis*), *Aspius aspius, Tinca tinca, Silurus glanis, salmonids* (mostly *Salmo labrax,* rarely *Oncorhynchus mykiss, Salvelinus fontinalis* and *Hucho hucho*), *Anguilla anguilla, Ctenopharyngodon idella, Hypophthalmichthys molitrix* and *H. nobilis*. According to reproductive guilds composition, 43.5 MT (42.4 %) consisted of phytophils and 23.5 MT (22.9 %) of lithophils.

During the construction of the GRBS (1980-1992) the total fish catch continuously decreased. The mean annual fish catch in this period was 79.4 MT, i.e. 22.7 % less than the catches recorded before the beginning of the GRBS construction. This decrease which was salient since 1984, is statistically significant ($P<0.01$). The highest fall was recorded for the catch of economically preferred fish, phytophils, and lithophils. Their catch dropped to 23.9, 20.6 and 9.8 MT, i.e., they decreased by 49.5, 52.6 and 58.6 % respectively. Except for *Abramis brama*, the correlation was significant ($P < 0.05$) or highly significant ($P < 0.01$).

During the period 1993-1996, after the GRBS was built and put in operation, the mean annual catch dropped to 26.8 MT, i.e., it was by 73.9 % less than in the period 1961-1979. Catches showed high fluctuations, and regression curves for particular species (which I do not introduce) significantly differed among themselves. Gradual decreases were recorded in the catch of *Esox lucius, Sander lucioperca* and *Abramis brama*, while the total fish catch curve, the catch of economically preferred species, and also the catch of *Chondrostoma nasus* and *Leuciscus cephalus* were convex, showing an increase until 1982-1984, and then a continuous drop.

Endangered fish species and reasons of changes

Considerable changes occurred during the past 100 years, owing to hydraulic engineering projects (riverbank fortification and heightening, cutting off sidearm mouths, damming), overfishing and pollution. Using the IUCN classification and considering the continuously recorded, anticipated and/or still occurring but not recorded species in the past 30 years, the situation is as follows (Table 1).

Three species (*Acipenser huso, Acipenser nudiventris, Acipenser stellatus*) and one form (diadromous race of *Acipenser gueldenstaedtii*), or 6.6 % became extinct, twelve species (19.6 %), including *Eudontomyzon mariae*, the resident form of *Acipenser gueldenstaedtii, Carassius carassius*, wild form (*sazan*) of *Cyprinus carpio, Gobio kesslerii, G.uranoscopus, Pelecus cultratus, Rutilus pigus, Misgurnus fossilis, Umbra krameri, Hucho hucho* and *Zingel zingel* now belong to the the critically endangered species (CR). Seventeen (27.9 %) fish species are considered as vulnerable (VU), and six other ones (9.8 %) are data deficient (DD).

As an example of dramatic changes in the fish fauna composition, the cases of the sazan i.e. the wild form of the carp (*Cyprinus carpio*), and the nase (*Chondrostoma nasus*) may be introduced. The *sazan* was common in the Danube and the lower courses of its larg e tributaries and was also commercially harvested four decades ago. From the data by Mišík (1957) and Bél (1962), one may find that in haul seine catches, both in the Slovak and Hungarian side of this segment of the Danube, *sazan* counted 1.1 % of the total number of fishes caught, or 3.4-10.1 % of the total fish catch weight (Tóth 1960, Balon 1967a). At the present time, however, its distribution is restricted to some parts of the main channel of the Danube and its population is extremely small. Among 6 274 fish taken, tagged, and released in the Danube between Gabcíkovo and Cunovo in 1992-1995, only 18 (0.28 %) were carp, and only one (0.016 %) was a typical *sazan*. The *sazan* is now at the edge of its extinction. The main reason is that after the construction of the GRBS, the inland delta of this stretch of the Danube vanished and the *sazan* lost its spawning grounds. The loss of the reproductive possibilities of this form due to the regulation measures is the main reason of the catastrophic decline of its catches in the whole Danube (Ivanov 1978). Another potential danger is the ignorance of the Slovak Anglers Union Council, responsible for the fishery in all Slovak rivers, which decided to stock the Danube with the Ropshin lineage of carp. This form is a hybrid of *Cyprinus carpio* (Galicia race) and the Amur sazan - *Cyprinus haematopteru s* Temminck & Schlegel, 1842 from the Amur River. It has been bred in Russia since 1930 for the stocking of ponds in the northern regions (Kirpichnikov 1958, Pokorný et al. 1995). Fortunately, the attempts to save the wild carp are now realised in both the Slovak and the Czech Republic (Lusková et al. 2000).

Another example of the consequences of the Danube regulation can be seen on the nase *Chondrostoma na - sus*, a lithophilous species. Although it is reproductively not depending on the floodplain, the floodplain existence is necessary for the survival and rearing of larvae and juveniles. According to several data obtained over several years with the same fishing gear (haul seine 150-300 m in length, 5.2 m in depth, mesh size 35x35 - 40x40 mm), by both fishermen and our investigators, the mean abundance of the nase catch in the 1960s was 10 % (Balon 1967a), but in 1992-1995 it dropped to 3.2 %. As it was found by Keckeis et al. (1996), the nase spawning in the Danube occurrs in some habitats only, i.e., near banks with gentle slopes, over bottoms covered with uniform size gravel, and under relatively strong water current velocities. However, the larvae and juveniles survival and growth depend on the presence of suitable (i.e. flood protected) habitats (Hofer & Kirchhofer 1996). Following numerous observations (e.g. Lelek 1987, Pavlov et al.1994, Kirchhofer 1996, Penczak 1996, Peňáz 1996) hydraulic engineering is the main factor responsible for the decline of the nase both in the Danube and in other European rivers.

Changes in fish catch reflect the changes in fish communities and populations. The Gabcíkovo case confirmed the well known effects of river damming and engineering works upon fish and fisheries (e.g., Goldsmith & Hildyard 1984, 1984a, 1986, 1992, Welcomme 1985, Holcík 1990, 2001, Jankovic 1996, Ribeiro et al. 1995, Petrere 1996). The main effects of river regulation (which first affected the hydrological regime) were the loss of the pulse effect of floods, the modification of the chemical composition and thermal regime of the water, and the blocking of fish migration. Moreover, the loss of floodplain resulted in the catastrophic decline of both habitats and ecotones. It also has to be pointed that: 1) the hydrochemical dynamics controls the nutrient concentration over the entire floodplain, 2) the dependence of fish upon the structural and functional characters of the terrestrial-aquatic ecotones is complex and far-reaching, and 3) the effect of such large amount of different factors is synergistic (Hein et al. 1996, Schiemer et al. 1995 and literature herein).

The importance of floods in the inland delta on fish and fisheries is well documented by the analysis of the correlation between the hydrological regime and both the fish density and the fish catch. In the Slovak segment of the Danube, within the period 1951-1975, the increase of the mean annual water level by one centimetre enlarged the mean annual commercial fish catch by 500 kg in the corresponding year, and by 300 kg in the next one (Holcík & Bastl 1974, 1975, 1977). This was also due to the extremely high ecological fish production, which surpassed the amount of the food produced in the floodplain. In addition, as documented elsewhere (Holcík 1996a), the floodplain fish production is composed of two parts: one is represented by the production created within the floodplain, while the other is represented by fish migrating and/or washed down to the floodplain from the main channel and the upstream segments of the river.

The main negative impact of the Danube damming upon the fish and fisheries is the loss of the functional inland delta. The original floodplain ecosystem was replaced by the artificial system of mutually isolated or only marginally linked habitats. As a result, there was a loss of feeding habitats, and a lower food supply due to the decrease of the abundance and biomass of food o rganisms. Spawning, wintering, and refuge habitats for fish also decreased and/or were lost, not only in the floodplain, but also in adjacent upstream and downstream river sections.

Proposals for the improvement of the inundation environment

Before the projecting and realisation of any measures aiming to mitigate the effect of the Danube damming by the GRBS on the former floodplain, it is necessary to consider two principal factors governing the high species diversity, ecological production and fish catch in any floodplain rivers: 1) the connection of the side-arms system with the main channel enabling the bilateral fish migrations, and 2) the seasonal discharge pulsation and seasonal flooding of the floodplain.

To ensure the bilateral fish migration, it is necessary to build functional fish ways between the side-arms and the main channel, and between particular parts of the arms. The fish way can be constructed as bypass canals (biocorridor), or as rocky-chutes. Both types of fish ways (with which in our country there is no experience of how to construct them) have to allow migration of different species at different size, i.e., they have to be universal. Environmental requirements for the fish ways construction are well known (Holcík & Bastl 1996, Holcík et al. 1992, 2001). Details, including the technical ones were published in Pavlov (1979, 1989), Clay (1995), and Jungwirth et al. (1998).

As mentioned above, there were two floods per year, in spring and in summer. The migration of particular fishes coincided with both floods. The optimal situation should be that both floods cover the entire floodplain up to the big river dike. The start, culmination, and fading away of floods should simulate the situation which existed before the GRBS construction.

It is important to save the course of the filling and then the draining of the flooded area. The filling curve may be steeper, i.e., the flooding can be shorter. However, the draining curve should be more flat - the floodplain draining has to be longer and gradual, in order to secure the hatching of eggs laid, and the emigration of the larvae and juveniles. Particular data dealing with the flood terms should be in accordance with the water thermal regime. During spring flood, the filling should start at the temperature of the filling water (4 °C), and draining should start when water in the floodplain rises to 15 °C. During summer flood, the filling should start at the temperature of the filling water (15 °C), and draining should start when the water temperature in the floodplain ascends to 20 °C.

Summarizing

Seventy-four fish species were found in the Slovak-Austrian, Slovak and Slovak-Hungarian stretch of the Danube River, the occurrence of two species is anticipated. Sixty-one species are native (80.3 %), 11 species were introduced exotic ones (14.5%), and 5 (6.6 %) or 7 (9.2 %), if supposed that two new invading species are anticipated, are recent invaders. Three (3.9 %) species and one form (diadromous form of *Acipenser gueldenstadtii*) became extinct; the presence of other 7 species (9.2 %) was not recorded during past 20 years. After the construction of the Gabcíkovo River Barrage system in October 1992 twelve species, including *Eudontomyzon mariae*, the resident form of *Acipenser gueldenstaedtii*, *Carassius carassius*, wild form (*sazan*) of *Cyprinus carpio, Gobio kesslerii, G. uranoscopus, Pelecus cultratus, Rutilus pigus, Misgurnus fossilis, Umbra krameri, Hucho hucho* and *Zingel zingel* now belong to the critically endangered species (CR). Seventeen fish species are considered as vulnerable (VU) and four other ones are data deficient (DD). The mean annual recreational fish catch from 1993 to 1996 dropped by 73.9 % in comparison with the mean annual recreational fish catch during the 1961-1979 period. The main reason is the loss of the functional inland delta, which was replaced by the artificial system of mutually isolated or only marginally linked habitats. To improve the situation it is proposed to restore the bilateral connection of the main channel with the side-arms, to ensure the fish migration between the main channel and the side arms, and to simulate the original flooding of the floodplain.

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