ECOLOGICAL STATUS AND PROBLEMS OF THE DANUBE RIVER AND ITS FISH FAUNA: A REVIEW

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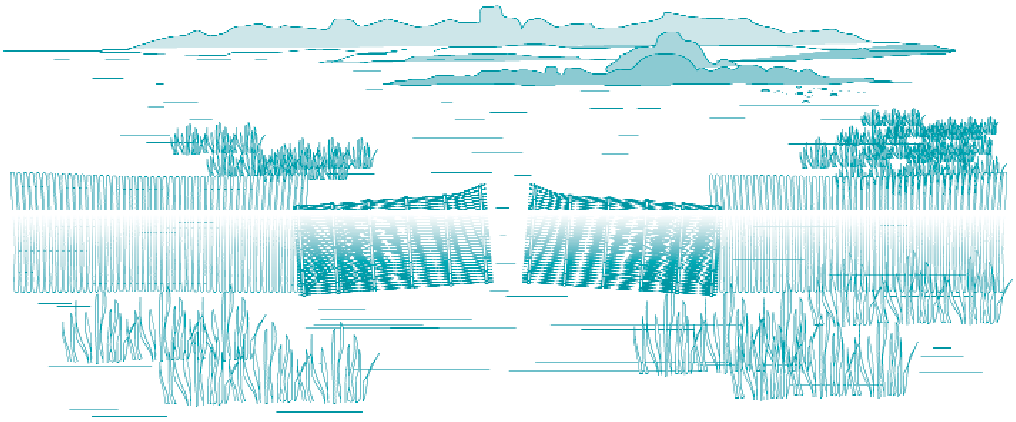


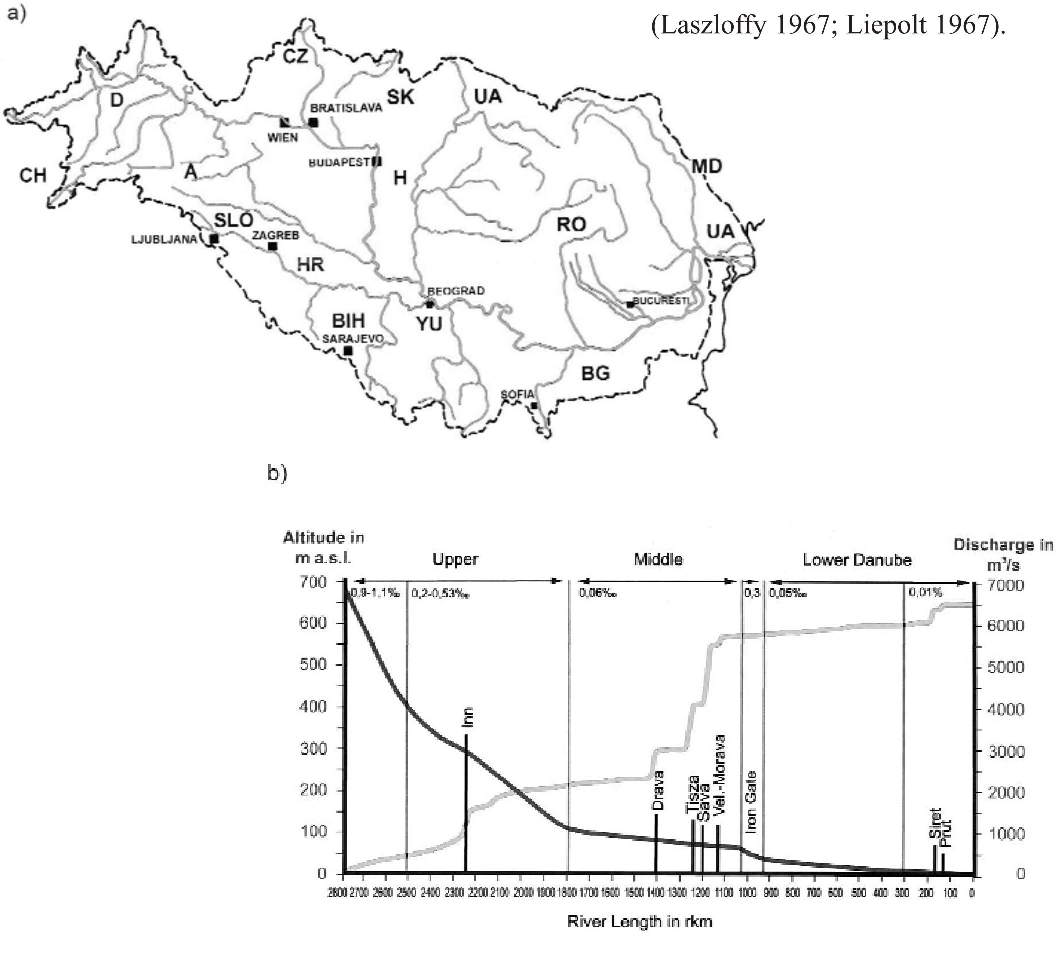
ABSTRACT

The ecological status of the Danube River and its fisheries prior to 1988 has been summarised by Bacalbasa-Dobrovici (1989) for the first International Large River Symposium. Since then the situation has changed in many ways: the trends of river–floodplain disintegration initiated by the major river regulation schemes in the nineteenth and early twentieth centuries accelerated. Moreover, further hydropower dams were built along the course of the river and its major tributaries, further reducing the ecological integrity of the river-floodplain systems in several stretches. On the other hand, a number of mitigation schemes were initiated e.g. in Austria, Hungary and Romania in order to compensate for the continuing losses of riverine landscapes. The measures taken to control water pollution were partially successful and water quality along the river has shown a general improvement. The overall deterioration of riverine habitats due to pollution, river engineering and land use is reflected in the high number of endangered fish taxa. The main cause for the decline of many species is the continuing loss of riverine littoral habitats due to river engineering Therefore the main focus of river management in several of the riparian countries is on the conservation of riverine biota, a stronger incorporation of ecological aspects in river engineering and the development of restoration programmes. Several

international schemes have been proposed to undertake concerted action to improve the overall situation. There is a sound scientific basis for ecologically orientated river management along the Danube: over the past 20 years, environmental conditions, fish ecology and fisheries have been intensively studied at several research institutions by means of large-scale field surveys and experimental studies. These results allow the present ecological status to be redefined. New concepts for commercial and recreational fisheries as well as floodplain restoration were developed. The present contribution synthesises recent developments in fish ecology and fisheries of the Danube and concentrates on key management issues.

THE DANUBE: ITS CATCHMENT, GEOGRAPHY AND HYDROGRAPHY

The Danube flows over nearly 3 000 km from the Black Forest to its delta in the Black Sea, passing through Europe from west to east. It is an international river, flowing through nine countries – Germany, Austria, Slovakia, Hungary, Croatia, Serbia and Montenegro, Bulgaria, Romania and the Ukraine (Figure 1). Thus, the river connects the West, Central and East European countries. The Danube Basin can be divided into three regions. The Upper Danube extends from the Black Forest to the Devin Gate below Vienna, the Middle Danube from the Devin Gate to the Iron Gate where it passes in the Southern Carpatians and the Balkan Mountains and finally the Lower Danube through the Romanian and Bulgarian lowlands. The Danube Delta at the Black Sea is the second largest in Europe with an area of 5 640 km^2. The Upper Danube (Figure 1) is characterized by a steep gradient of 0.2-1.1‰, the Middle and Lower Danube by a low gradient, except for the cataracts of Iron Gate (Laszloffy 1967; Liepolt 1967).



■ ***Figure 1.*** a) The Danube River basin
b) Longitudinal profile of the slope (indicated are the main differences in slope) and the mean discharge (from: Waterway transport on Europe's lifeline, WWF, Vienna, 2002).

With a mean discharge of about 6 500 m^3 s^{-1} at its mouth the Danube is the second largest river in Europe and twenty-first in the world. The hydrological regime of the upper region is characterized by high runoff from the Alps. The main Alpine tributaries are the Lech, Isar and Inn. Maximum discharge rates in this zone are due to the runoff from snowmelt in the Alps between May to August. Increases in discharge to the Middle Danube come mainly from the Save (46.6 percent), Tisza (34 percent) and Drava (29 percent). Below the Tisza and Save there is a characteristic change in the seasonal runoff pattern, with a maximum in April and May and low discharge rates from August to January (Benedek and Laszlo1980; Hock and Kovacs 1987). The Danube exhibits high water level fluctuations in the range of several meters; for example in Mohacs (Hungary) fluctuations exceed 9 m. Large alluvial areas with extensive floodplains exist in unconstrained sections (Tockner, Schiemer and Ward 1998; Tockner *et al*. 2000). The width of the present inundation area downstream of Vienna and in the middle basin varies between 1 and 5 km, in the lower basin between 5 and 10 km.

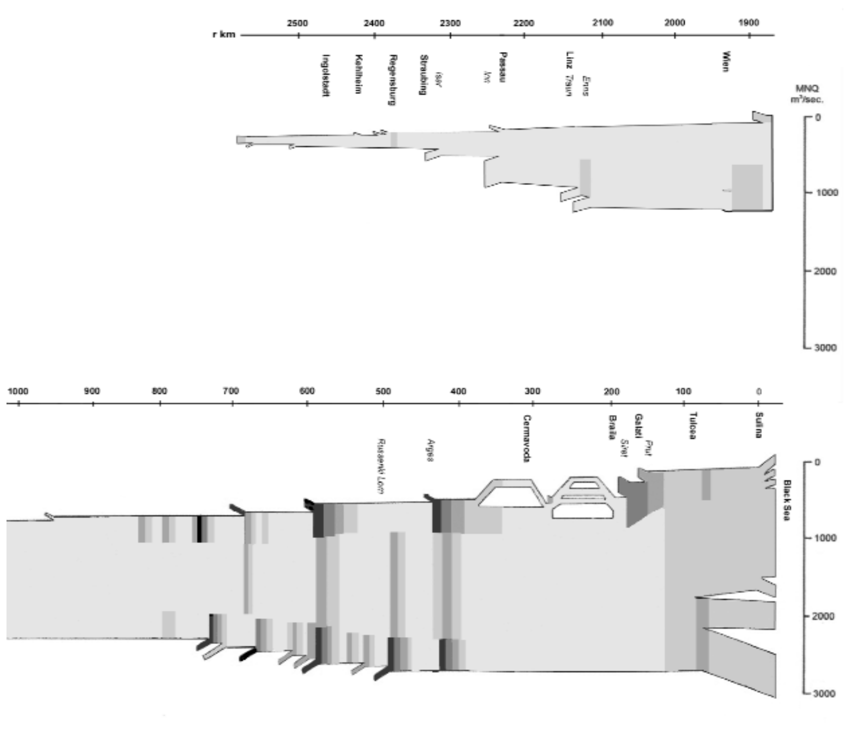
The multi-purpose use of the river is of vital importance for the more than 82 million people inhabiting its 800 000 km^2 basin. The use of the catchment and the river itself has had strong impacts on the environmental conditions of the river-floodplain system (Khaiter *et al*. 2000; Bloesch 1999, 2001).

HUMAN IMPACTS: WATER QUALITY AND RIVER ENGINEERING

WATER QUALITY

Water pollution caused by the high population density and heavy industrialization in the drainage area is a major problem of the Danube. The first and very provisional attempt to map the water quality was made in a monograph on the Danube (Liepolt 1967). More recently Schmid (2000) has given an overview on the Danube and its tributaries.

Between the 1950s to1970s low water quality was found downstream of cities and industrial zones in Germany and Austria. The worst pollution was recognized below industrial centres in Kelheim, Regensburg, Linz and Vienna (quality class III-IV), where pollution temporarily reached class IV (polysaprobity). The self-purification capacity of the Danube during this period had decreased considerably due to toxic effects of industrial wastewaters. Some susceptible fish species in the Upper Danube, such as *Cottus gobio* and *Phoxinus phoxinus*, became rare or disappeared from the main channel of the Danube.



■ ***Figure 2.*** *Water quality along the Danube. Indicated are the river kilometres, major cities and tributaries. The width is given according to the mean flow. The colour code for water saprobity was transferred to a scale of shading: II: opaque, II-III: light gray, III: gray,III-IV: dark gray, IV: black (from Wachs 1997).*

Construction of water purification stations at the beginning of the 1980s considerably improved the water quality almost to the goal of class II (Wachs 1997) and the fish species, which had disappeared from some river segments, re-established themselves (Figure 2).

The water quality situation in the Lower Danube was quite different. Very little information is available for the period 1950 to1975 for the lower section of Middle Danube and for the Lower Danube. Large stretches were considered to have an acceptable water quality of class II due to high dilution. Russev (1979) reviewed the status of water quality and recognized a general and clear trend of water quality deterioration, with low water quality below larger cities. The worst conditions (polysaprobity, IV) were below industrial centres along the whole river course. The pollution remains very serious due to industrial growth and insufficient pollution control measures. The impact of strongly polluted tributaries, e.g. in Romania and Bulgaria the Lom (IV), Ogosta (IV), Olt (IV), Osam (IV), Russenski Lom (IV), can be identified in short stretches of Danube (Figure 2). High flow and self-purification of the Danube improve the situation downstream to saprobity classes II-III.

With regard to heavy metals the situation in the Lower Danube is serious. Concentrations of some of the elements are nearly two orders of magnitude higher compared to the upstream regions. The TNMN (transnational monitoring network) (TNMN-Yearbook of 1998, 2000) assessment in 1998 gave a range of dissolved elements between 0.01-0.1 $\mu g\ l^{-1}$ for cadmium (Cd) in the upper and middle section and 0.9-1.5 $\mu g\ l^{-1}$ below the Iron Gate. The values for lead (Pb) were 0.8-1.2 $\mu g\ l^{-1}$ versus 20-40 $\mu g\ l^{-1}$. Chromium and copper concentrations are also elevated in the Lower Danube. The report of the "Joint Danube Survey" in 2001 shows the spatial distribution of selected elements in suspended solids and sediments along the river course. The report indicates particularly serious pollution in the lower sections of the river, downstream of Novi Sad (Joint Danube Survey-Technical Report of the ICPDR, 2002). Wachs (2000) studied the heavy metal contamination in the water suspended matter, fine sediments and fish in the Upper, Middle and Lower Danube. He concluded that there is a general increase in the lower section, which is reflected most clearly in cadmium and mercury (Hg). Using his evaluation scheme (Wachs 1998) found "very heavy pollution" levels (III-IV) and excessive pollution levels (IV) and higher concentrations of Cd, Cr, Cu, Hg and Zn in the lower reaches.

A harmonized sampling network has been developed recently. The International Commission for the Protection of the Danube River, (ICPDR) established in 1998, is instrumental in successful monitoring of the Danube River System. The International Association coordinated earlier, hydro-biological studies and water quality assessments for Danube Research (IAD), founded in 1956 within the International Association of Theoretical and Applied Limnology (Bloesch 1999).

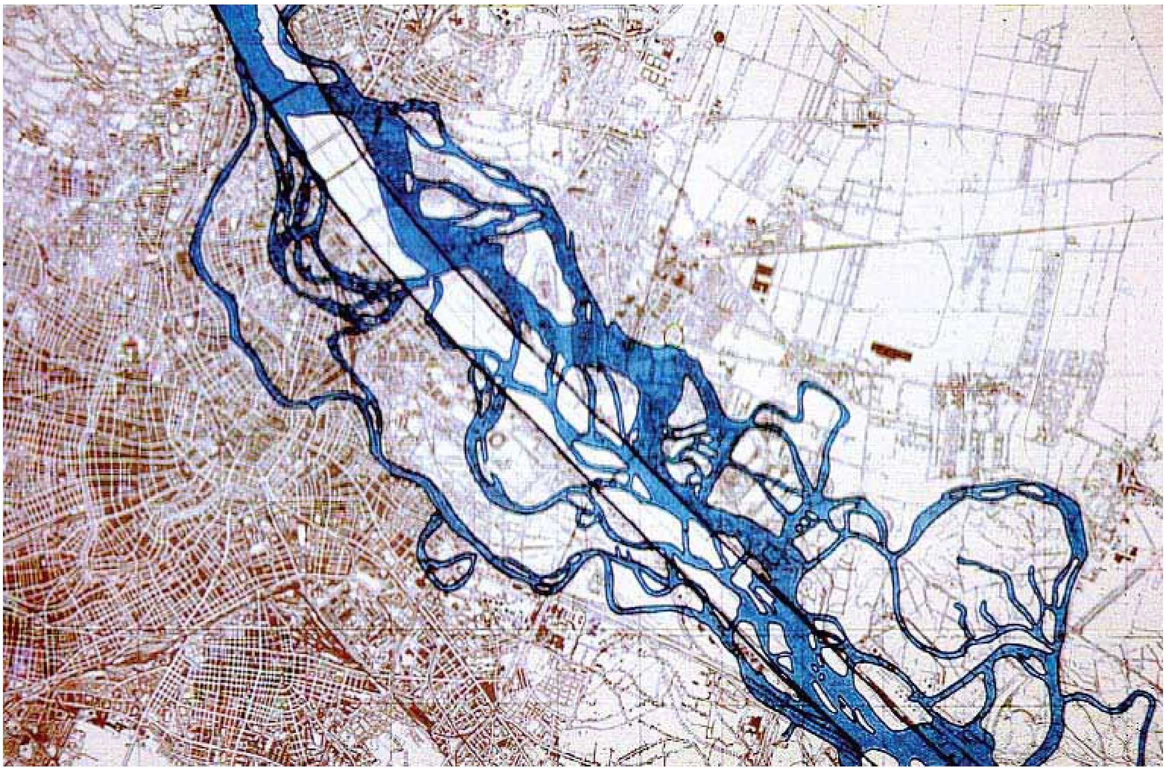
River Regulation and Construction of Hydropower Dams

The key environmental issues of the Danube, as in other large European and North American rivers (Stanford *et al.*1996) result from effects of regulation and engineering. The morphological changes caused by engineering measures, although very serious, have been smaller on the Danube than on the Rhine or the Rhone (Bloesch 2002; Bloesch and Sieber 2003).

In the Upper Danube, including Slovakia and Hungary, the process of intensive engineering began in the nineteenth century with the goal of improving navigation, flood control and drainage of riverine wetlands for agriculture. In Austria, for example, the regulation of the Danube started in 1875. The main engineering approach was to create a single, straightened channel, stabilized by riverside embankments and rip-raps (Figure 3). The former side-arms of the original braided system were cut off. Weirs had to be built on the side arms in order to retain the water level in the wetlands. Levees completely cut off parts of the former floodplains from erosive, scouring flood flow. These measures resulted in major changes in the river profile, slopes, transport of bed sediments and suspended load and runoff characteristics (Schiemer 1999). The immediate effects were:

a) Enormous loss of inshore habitat, large floodplain areas and flood retention capacity
b) Reduced hydrological connectivity between river and floodplains and reduced geomorphic processes
c) Concentration of erosive forces in the main channel and consequently a deepening of the river bed
d) Shortening of the river course (for example in Hungary from an original length of 472 km to 417 km, i.e. by nearly 15 percent)

River regulation initiated trends which are still continuing: a lowering of the water table, combined with sedimentation and conversion of floodplains to dry land leading to permanent changes and a loss of aquatic habitat. Deepening of the Danube riverbed has been observed in the last two decades. In the free-flowing Austrian and the Slovakian part the water level at average discharge rate (MQ) has decreased by 1 to 2 m over the past 50 years as a result of reduced bed load transport (due to upstream dams), higher erosion in the channelized river and large-scale dredging to maintain a waterway for shipping. The deepening of the channel in relation to the floodplain areas and the inflows into side channels has considerably affected the timing and volume of the amount of water entering the side arms and floodplain. In some years and seasons, some of these arms dried up completely and this part of the floodplain was not flooded. However, in spite of the effects of river regulation, the remaining parts of the floodplain were still subjected to the rhythmical pulses of the floods and its fish stocks and catch responded to the hydrological regime (Holcik and Bastl 1976; Holcik 1996).



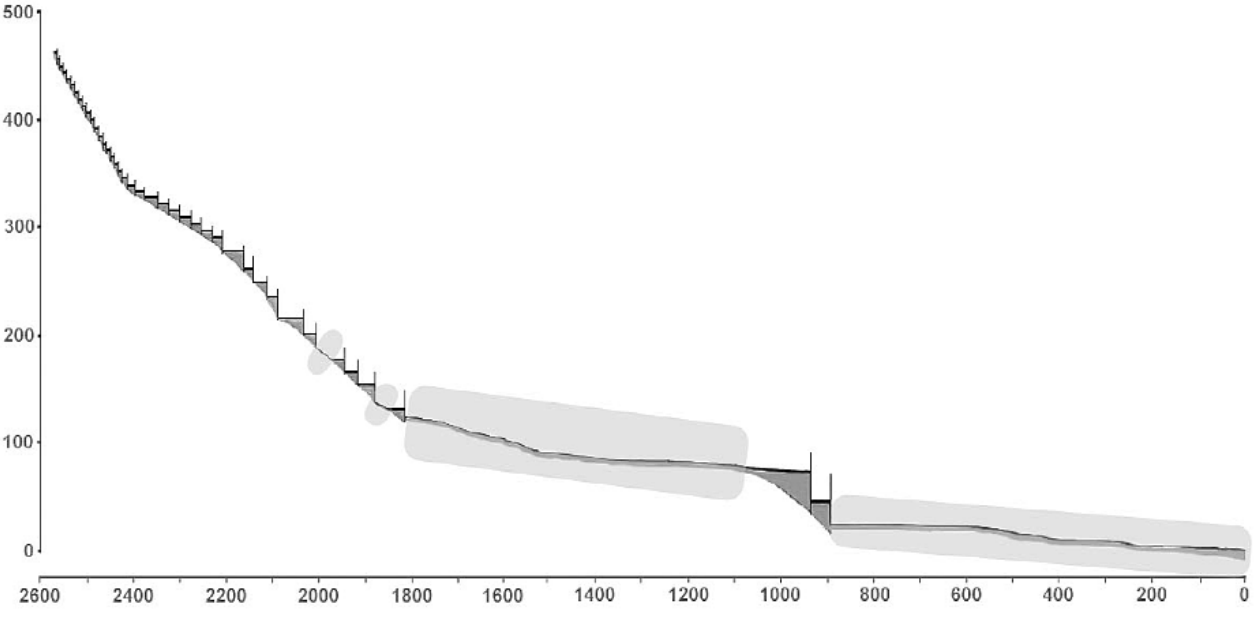
■ **Figure 3.** The Danube regulation at Vienna. The figure shows the braided network of channels and the engineered channel. The river regulation started in 1875.

A major environmental concern is related to the construction of hydropower dams. The Danube has a high potential for hydropower generation that has been largely exploited. Forty-nine base-load hydroelectric power dams are situated in the Upper Danube and three major barrages in the Middle Danube (Gabcikovo, Iron Gate 1 and 2). Figure 4 shows the position of the dams along the whole river course. The construction of impoundments results in severe environmental degradation due to the:

- Loss of ecological diversity
- Destruction of the former shoreline
- Lack of connectivity between the river and the groundwater table
- Almost complete lack of connectivity between the river and its floodplain due to side dams
- Change of the alluvial forests to dry deciduous forests, with a concomitant loss of terrestrial diversity

The impoundments have a short retention time and low water temperature (Schiemer and Waidbacher 1992).

Between 1978 and 1992 a major power plant was constructed below Bratislava in Slovakia (Gabcíkovo River Barrage System, GRBS) with considerable negative environmental impact despite warnings about possible environmental effects (Holcik *et al*. 1981). After the construction of the GRBS and its operational introduction in October 1992 the former ecosystem of the inland delta was replaced by an artificial system of more or less isolated habitats (Lösing 1989; Holcik 1990, 1998; Balon and Holcik 1999). The dam has had a major impact on the floodplains on the Hungarian side (Szigitöz area) (Guti 1993). After the damming of the Danube in 1992, most of the water from the storage reservoir has been diverted through its aboveground level concrete canal along the left-hand side of a river dyke to the Gabcikovo hydroelectric power station. The old riverbed of the Danube is now receiving 250-600 $m^3 s^{-1}$ instead of the former 2 000 $m^3 s^{-1}$. Due to this the water level of the old Danube is 3-5 m below the level of the former floodplain and the contact between the side arms and the Danube is interrupted. The remaining northern (Slovakian) side arm system is supplied with up to 240 $m^3 s^{-1}$. A fish pass built



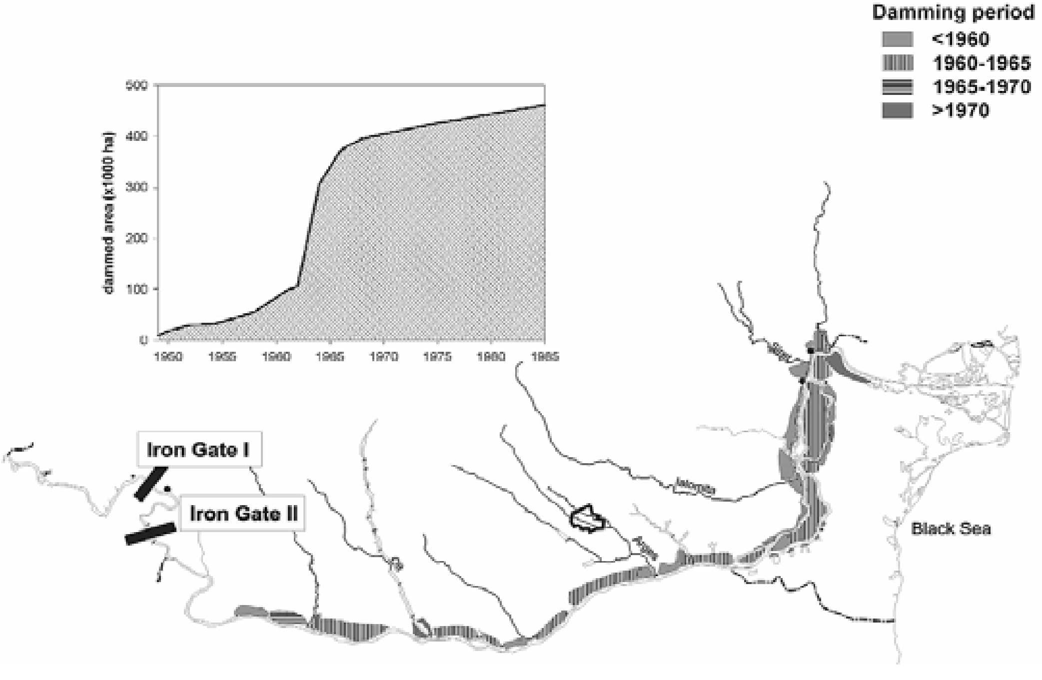
■ **Figure 4.** The position of dams along the river course. The free-flowing sections are shaded.

between the old riverbed and the lower part of the side-arm system does not function well. There is no longer any natural pulse flooding of the inland delta. While the former floodplain has been artificially flooded several times, this did not simulate the natural floods, as the level, timing and duration were different from the natural floods.

On the Lower Danube the construction of barrages Iron Gate I at km 942.5 in 1970 and Iron Gate II at km 863 in 1984 has interrupted longitudinal connectivity of the river and resulted in a physical separation from the Middle Danube. The impoundments have had major consequences with regard to the downstream diurnal flow regime and the transport of suspended sediments and bed load (Bondar 1994). The daily water level variation in the Bulgarian and Romanian can be as high as 1 m day^{-1} and variation in water discharge 1 000 m^3 s^{-1} day^{-1} (Buijs, Uzunov and Tzankov 1992). The sediment transport from the Middle Danube has been reduced, while downstream mean annual erosion in the Romanian and Bulgarian sections has increased. The transport of sediments into the delta was reduced from 67.5 million tonnes $year^{-1}$ in the period 1921 to 1960 to 52 million tonnes $year^{-1}$ in the period 1981-1983 (Bondar 1994).

In this respect the "silicon hypothesis" advocates that the flux of silicon to the Black Sea is considerably reduced due to diatom blooms occurring in the reservoirs. This has led to an overall decrease in silicon concentrations in coastal waters in the Black Sea (Milliman 1997; Ittekkot, Humborg and Schafer 2000). The resulting changes in the ratios of nutrients, e.g. Si:N:P cause a shift in phytoplankton populations.

The separation of the river from its floodplain by side levees in the lower Danube had a major impact on the overall environmental situation and fisheries. This took place upstream of the delta at the end of the 1950s. The former flood pulse was reduced and as a consequence the former inundation areas were also strongly reduced (Figure 5): of the 5 000 km^2 of the former floodplain only 15 percent is still being temporarily flooded. In 1921 the ratio river length (km): floodplain (ha) was 1:612. This was reduced to 1:118 in 1976 (Bacalbasa-Dobrovici 1989). The water retention capacity at floods was reduced from about 15.6 10^9 m^3 to 4.0 10^9 m^3· The water level in the Danube increased by 0.6-0.8 m at maximum discharge of 13 000-15 000 m^3 s^{-1} (Bondar 1977).



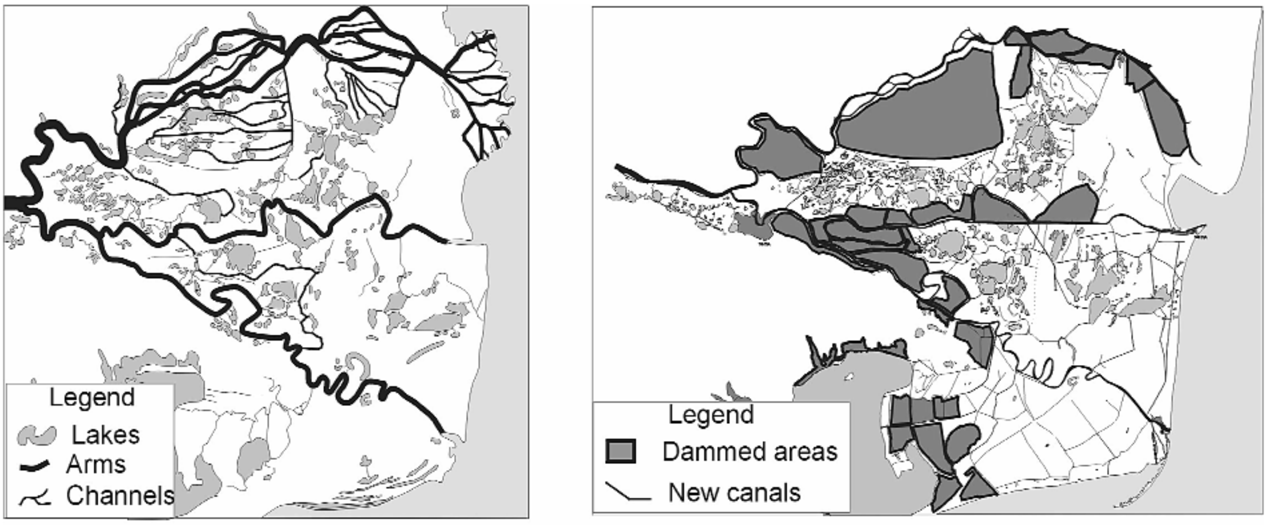
■ **Figure 5.** Disconnection of floodplains in Romania due to the construction of levees. The insert quantifies the increase in dammed area with time.

The Danube Delta including adjacent oxbow lakes and lagoons covers some 5 640 km^3 (about 20 percent in the Ukraine, 80 percent in Romania). Major changes took place between 1960-1989, when 1 000 km^3 were poldered in the Romanian part for agriculture, forestry and fish culture. The fluvial backwaters in the Ukraine have been isolated from the river for aquaculture since the 1960s, whereas the frontal marine lagoons in the Romanian and Ukraine parts were isolated from the sea and used as a reservoir for irrigation purposes after the 1970s (Figure 6). The total length of the channels in the Romanian Delta increased from 1 743 km to 3 496 km (Gastescu, Driga and Anghel 1983). The water discharge from the river to the delta wetlands increased from 167 $m^3 s^{-1}$ before 1900 to 309 $m^3 s^{-1}$ during 1921-1950; 358 $m^3 s^{-1}$ during 1971-1980 and 620 $m^3 s^{-1}$ during 1980-1989 (Bondar 1994). Despite these engineering measures over 3 000 km^2 of the wetlands, including the Razim-Sinoie lagoon and the adjacent Ukrainian secondary delta (250 km^2), remain connected to the river and represent the largest nearly undisturbed wetland in Europe. About 50 percent of the area is permanently aquatic; the rest is seasonally flooded.

BIODIVERSITY OF FISH

Large rivers and their riparian zones are hot spots of biodiversity. Biodiversity levels can be compared across a range of scales e.g. from whole river systems to river segments, lateral and longitudinal gradients within a floodplain, down to the level of single habitat types (Ward, Tockner and Schiemer 1999). Fluvial geomorphic processes provide the habitat diversity and the specific habitat conditions for characteristic species assemblages and result in high levels of habitat diversity, local species richness and differences between habitats and consequently, overall species richness of a river section.

The fish fauna of the Danube is well known from historical studies (Marsilius 1726; Heckel and Kner 1858). The total number of fish species along the whole course is in the order of 100 species. The generally high diversity is due to the zoogeographical significance of the Danube as a major migration route for a diverse Central Asian and Ponto-Caspian fauna (Balon, Crawford and Lelek 1986). From an ecological point of view, this diversity is due to rhithral conditions in most of the Upper Danube and potamal condi-



Pristine status
1887

Man induced changes
(1900-1989)

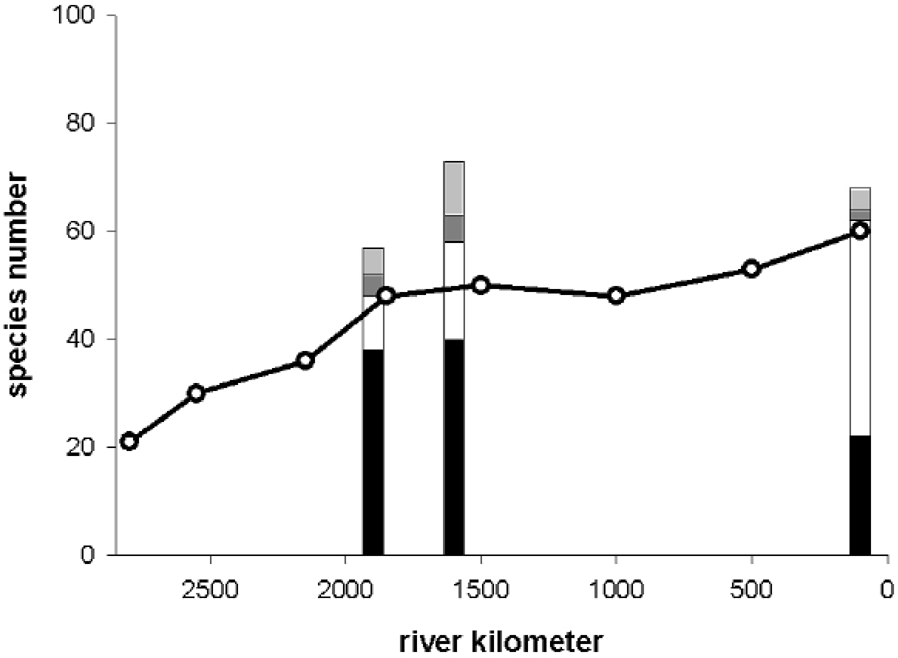
■ **Figure 6.** Loss of floodplain habitat in the Danube Delta during the last century due to polder construction compared to its pristine status.

tions in alluvial zones with extended floodplains and rich habitat downstream from Austria.

Balon (1964) provided an overview of the distribution pattern of individual species along the river course. The longitudinal distribution of species (Figure 7, solid line) is based on his list. Diversity increases in the Upper Danube from the rhithral sections downstream to the extended alluvial plains in Austria. Highest diversity is found in the transition zone between foothills and lowlands, where the gradient change results in an extended braided network of numerous side arms of the Danube. High habitat diversity and the dense ecotonal structure have created the diverse combinations of environmental conditions suitable for the assembly of different fish species (Schiemer 2002; Ward *et al*. 1999). Further downstream in the Middle and Lower Danube species numbers remain fairly constant. In the lowest section in Romania diversity increases again due to invaders from marine and brackish water habitats. The recent status of the fish fauna in Austria, Hungary and Romania is presented as histograms (Figure 7). Table 1 provides species lists from the Danube in these countries with comments on the status of individual species. Information is given on whether a species is a recent immigrant, or an exotic form. The status of endangerment distinguishes if a species is extinct (EX), critically endangered (CE: population strongly declining, habitat deficiencies extremely severe, near extinction), endangered (E) or vulnerable (VU: declining population, fragmented populations). For several species the existing data are deficient (DD). The state of endangerment is discussed below. Comments are made on recent immigrants and exotic species.

IMMIGRANTS

During the last 10 years a number of new fish species have been recorded upstream and downstream of the Devin Gate, apparently immigrants from brackish water. Until 1990 in the Upper and Middle Danube the gobiids were represented only by the tube-nosed goby *Proterorhinus marmoratus*. In 1994 *Neogobius kessleri* was discovered in the Upper Danube. More recently three further species, *N. gymnotrachelus*, *N. melanostomus* and *N. fluviatilis*, were discovered



■ **Figure 7.** Biodiversity of fish of the Danube and the floodplains along the river course. The line gives species numbers according to the review of Balon (1964). the histograms give the present status of the Danubian fish fauna in Austria, Hungary and Romania according to Table 1. Black: endangered; white: not endangered; dark grey: immigrants; light grey: introduced species.

Table 1: Comparison of the present state of the fish fauna of the Danube in Austria, Hungary and Romania. Occ.= Occurrence, Cat.= Category: EX = extinct; exotic; Imm. = Immigrants; CE = critically endangered; E = endangered; VU = vulner-able; DD = data deficient

	Austria		Hungary		Romania	
SPECIES	**Occ**	**CAT**	**Occ**	**CAT**	**Occ**	**CAT**
Eudontomyzon mariae (Berg, 1931)			+	E	+	
Acipenser gueldenstaedtii Brandt & Ratzeburg, 1833		EX		EX^1	+	CE
Acipenser huso Linnaeus, 1758		EX		EX^2	+	CE
Acipenser nudiventris Lovetzky, 1828		EX		EX^3		EX
Acipenser ruthenus Linnaeus, 1758	+	CE	+	VU	+	VU
Acipenser stellatus Pallas, 1771		EX		EX^4	+	CE
Acipenser sturio Linnaeus, 1758						EX
Anguilla anguilla (Linnaeus, 1758)	+		+		+	
Lepomis gibbosus (Linnaeus, 1758)	+	exotic	+	exotic	+	exotic
Micropterus salmoides (La Cepé de, 1802)			+	exotic		
Alosa immaculata Bennett, 1835				EX	+	
Alosa tanaica (Grimm, 1901)			+		+	
Alosa maeotica (Grimm, 1901)					+	VU
Clupeonella cultriventris (Nordmann, 1840)					+	
Atherina boyeri Risso, 1810					+	
Esox lucius Linnaeus, 1758	+	E	+		+	VU
Umbra krameri Walbaum, 1792	+	CE	+	VU	+	VU
Lota lota (Linnaeus, 1758)	+	CE	+	VU	+	VU
Abramis ballerus (Linnaeus, 1758)	+	E	+	VU	+	
Abramis brama (Linnaeus, 1758)	+		+		+	
Abramis sapa (Pallas, 1814)	+	VU	+	VU	+	
Alburnoides bipunctatus (Bloch, 1782)	+	VU	+	VU		
Alburnus alburnus (Linnaeus, 1758)	+		+		+	
Aspius aspius (Linnaeus, 1758)	+	E	+	VU	+	
Barbus barbus (Linnaeus, 1758)	+	VU	+		+	
Barbus peloponnesius Valencienns, 1842			+	VU		
Blicca bjoerkna (Linnaeus, 1758)	+		+		+	
Carassius carassius (Linnaeus, 1758)	+	CE	+	VU	+	
Carassius gibelio (Bloch, 1782)	+		+		+	
Chalcalburnus chalcoides (Gueldenstaedt, 1772)				EX		EX
Chondrostoma nasus (Linnaeus, 1758)	+	E	+	VU	+	
Ctenopharyngodon idella (Valenciennes, 1844)	+	exotic	+	exotic	+	exotic
Cyprinus carpio Linnaeus, 1758 (wild form)	+	CE	+	E	+	CE

SPECIES	Austria		Hungary		Romania	
	Occ	CAT	Occ	CAT	Occ	CAT
Gobio albipinnatus Lukasch, 1933	+	VU	+		+	
Gobio gobio (Linnaeus, 1758)	+	VU	+			
Gobio kesslerii Dybowski, 1862	+	CE	+	VU	+	VU
Gobio uranoscopus (Agassiz, 1828)	+	CE	+	E		
Hypophthalmichthys molitrix (Valenciennes, 1844)	+	exotic	+	exotic	+	exotic
Hypophthalmichthys nobilis (Richardson, 1845)			+	exotic	+	exotic
Leucaspius delineatus (Heckel, 1843)	+	CE	+	VU	+	VU
Leuciscus borysthenicus (Kessler, 1859)					+	
Leuciscus cephalus (Linnaeus, 1758)	+		+		+	
Leuciscus idus (Linnaeus, 1758)	+	CE	+	VU	+	
Leuciscus leuciscus (Linnaeus, 1758)	+	E	+	VU		
Pelecus cultratus (Linnaeus, 1758)	+	E	+	VU	+	
Phoxinus phoxinus (Linnaeus, 1758)	+	VU	+	VU		
Pseudorasbora parva (Temminck et Schlegel, 1842)			+	exotic	+	exotic
Rhodeus sericeus (Pallas, 1776)	+	E	+		+	
Rutilus meidingeri (Heckel, 1851)	+	E	+	Imm		
Rutilus pigus (La Cepé de, 1803)	+	CE	+	VU		
Rutilus rutilus (Linnaeus, 1758)	+		+		+	
Scardinius erythrophthalmus (Linnaeus, 1758)	+		+		+	
Tinca tinca (Linnaeus, 1758)	+	VU	+	VU	+	VU
Vimba vimba (Linnaeus, 1758)	+	VU	+	VU	+	
Cobitis elongatoides Bacescu & Mayer, 1969	+	VU	+	VU	+	
Misgurnus fossilis (Linnaeus, 1758)	+	CE	+	VU	+	VU
Sabanejewia balcanica (Karaman, 1922)			+		+	
Sabanejewia bulgarica Drensky, 1928)			+	VU		
Barbatula barbatula (Linnaeus, 1758)	+		+	VU		
Ameirurus melas (Rafinesque, 1820)			+	exotic		
Ameiurus nebulosus (Lesueur, 1819)			+	exotic		
Ictalurus punctatus (Rafinesque, 1818)			+	exotic		
Silurus glanis Linnaeus, 1758	+	CE	+		+	VU
Gymnocephalus baloni Hol?é k & Hensel, 1974	+	VU	+	VU	+	VU
Gymnocephalus cernuus (Linnaeus, 1758)	+		+		+	
Gymnocephalus schraetser (Linnaeus, 175	+	VU	+	VU	+	VU
Perca fluviatilis Linnaeus, 1758	+		+		+	
Percarina demidoffi (Nordmann, 1840)					+	Imm
Perccottus glenii Dybowski, 1877						
Sander lucioperca (Linnaeus, 1758)	+		+		+	
Sander volgensis (Gmelin, 1788)	+	VU	+	VU		EX
Zingel streber (Siebold, 1863)	+	CE	+	VU	+	VU

	Austria		Hungary		Romania	
SPECIES	**Occ**	**CAT**	**Occ**	**CAT**	**Occ**	**CAT**
Zingel zingel (Linnaeus, 1766)	+	E	+	VU	+	VU
Syngnathus abaster Risso, 1859					+	
Gasterosteus aculeatus (Linnaeus, 1758)	+		+		+	
Pungitius platygaster (Kessler, 1859)					+	VU
Mugil cephalus Linnaeus, 1758					+	
Liza aurata (Risso, 1810)					+	
Liza saliens (Risso, 1810)					+	
Cottus gobio Linnaeus, 1758	+	E	+	VU		
Cottus poecilopus Heckel, 1836						
Hucho hucho (Linnaeus, 1758)	+	CE	+	E		
Oncorhynchus mykiss (Walbaum, 1792)	+	exotic	+	exotic		
Salmo labrax Pallas, 1811	+	VU	+	VU	+	CE
Salvelinus fontinalis (Mitchill, 1814)	+	exotic	+	exotic		
Thymallus thymallus (Linnaeus, 1758)	+	VU				
Coregonus peled (Gmelin, 1788)	+		+	Imm		
Coregonus albula (Linnaeus, 1758)			+	Imm		
Coregonus renke (Schrank, 1783)			+	Imm		
Platichthys flesus (Linnaeus, 1758)					+	
Benthophiloides brauneri Belling & Iljin, 1927					+	CE
Benthophilus stellatus (Sauvage, 1874)					+	
Gobius ophiocephalus (Pallas, 1814)						EX
Knipowitschia cameliae Nalbant & Otel, 1995					+	CE
Knipowitschia caucasica (Berg, 1916)					+	
Neogobius eurycephalus (Kessler, 1874)					+	
Neogobius fluviatilis (Pallas, 1814)			+	VU	+	
Neogobius gymnotrachelus (Kessler, 1857)	+	Imm			+	
Neogobius kessleri (Gunther, 1861)	+	Imm	+		+	
Neogobius melanostomus (Pallas, 1814)	+	Imm	+		+	
Neogobius syrman (Nordmann,1840)			+		+	
Proterorhinus Marmoratus (Pallas, 1814)	+	Imm	+	VU	+	

downstream of Vienna. Recent ichthyological studies demonstrate the role of the Danube as a dispersion corridor (Kautman 2000, 2001; Wiesner, Spolwind, Waidbacher *et al*. 2000; Strásai and Andreji 2001).

Exotic Species

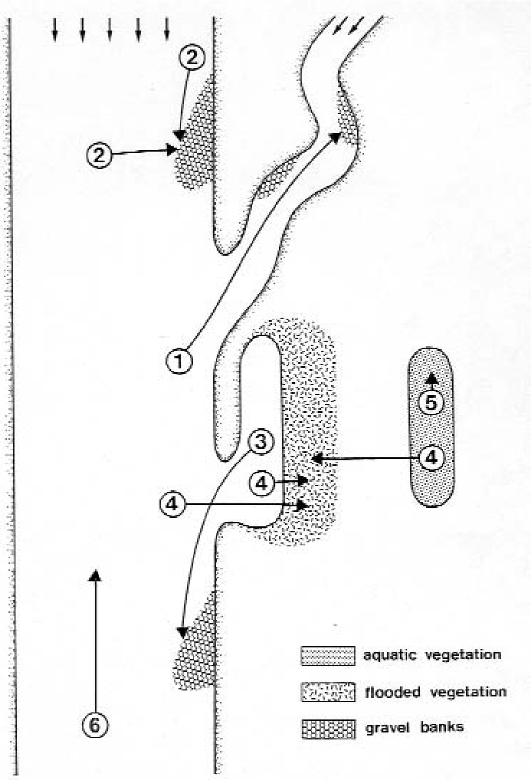
About 15 species have been introduced during the last century: *Carassius gibelio, Pseudorasbora parva, Lepomis gibbosus* are considered naturalised. The Chinese carps *Ctenopharyngodon idella, Hypophthalmichthys molitrix* and *Aristichthys nobilis* have reproductive populations in the Lower Danube (see below).

Carassius gibelio (giebel carp) appeared in the Lower Danube in the first quarter of the last century (Banarescu 1968, 1997) but was very rare until 1970. The expansion thereafter was followed by an invasion in the Middle Danube and Upper Danube. In the Romanian Danube Delta the Giebel carp population became very large: the catch statistics from 1970-2001 show a contribution up to 40-60 percent of the total catch. This invasive potential was explained by its specific reproductive flexibility (gynogenesis). The invasive population was first represented in an unisexual, gynogenetic form (Balon 1962; Holcík 1980). Aggressive feeding behaviour is an advantage in competition with native species. In Slovakia the first males appeared in 1992 and since then males form a permanent part of the population.

Ctenopharyngodon idella (grass carp) was introduced in fish farms in the Danube Delta in 1962, in order to increase productivity and to control aquatic vegetation in the ponds. In 1970 their presence in the wild was recorded, but systematic recording did not start until 1981. Natural reproduction appears to take place in years when suitable conditions occur (Giurca 1980). Because of their rheophilic nature the species is more abundant upstream from the delta. In 1992, a massive occurrence of young silver carp (*Hypophthalmichthys molitrix)* was recorded in the lakes of the upper part of the Danube Delta (Staras, Cernisencu and Constantin 1993). In some years large numbers of larvae are present in the Danube River as a result of successful natural spawning, which depends on two conditions: water temperature above 22°C and increased water velocity after summer rainfalls, from 2 to 5 km h^{-1} (Staras and Otel 1999*)*.

FISH GUILDS AND THEIR ECOLOGICAL REQUIREMENTS

The high biodiversity is explainable by habitat diversity and the existence of several guilds. Guilds can be grouped according to their specific requirements in the course of the life cycle. Appropriate spawning habitats, feeding habitats and refuge from harsh environmental conditions have to be available. Spatial heterogeneity and the connectivity of habitat patches are critical for population dynamics. For large European rivers we have distinguished 5 guilds according to the preferred zones of occurrence of adults and the spawning and nursery grounds (Schiemer and Waidbacher 1992) (Figure 8).



■ **Figure 8.** Schematic presentation of main habitat requirements of six fish guilds. Circles: preferred habitats of adults; arrows: spawning and nursery sites. 1: rhithralic, 2: rheophilic A, 3: rheophilic B, 4: eurytopic 5: stagnophilic, and 6: anadromous species (modified after Schiemer & Waidbacher 1992).

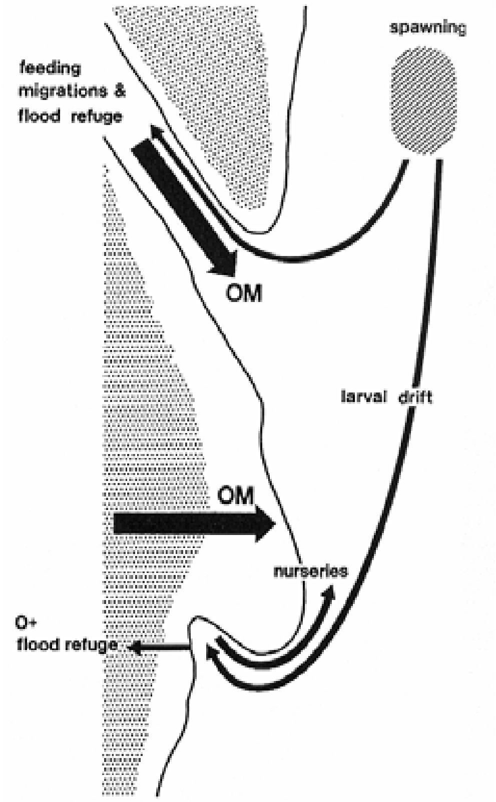
- Riverine species dependent on the connectivity of the river with its tributaries. This group requires rhithral conditions for spawning and during the early life stages (e.g. *Hucho hucho*).
- Riverine species with spawning grounds and nurseries in the inshore zone of the river itself. Group 1 and 2 are now frequently referred to as Rheophilic A.
- Riverine species with a preference for low-current conditions (e.g. connected backwaters) during certain periods in the adult stage (e.g. feeding grounds or winter refuge), but with spawning grounds and nurseries in the river. Such species are referred to as Rheophilic B.
- Eurytopic species (habitat generalists found both in rivers and various types of stagnant water bodies. Some of these species require flooded vegetation as spawning area, e.g. *Esox lucius*).
- Limnophilic species confined to various microhabitats of the floodplain (e.g. disconnected former river branches) with strong development of submerged vegetation.

Considering the whole river system at least one more guild needs to be added, namely anadromous species like sturgeons. They require integrity at a catchment scale in the form of appropriate migration routes from their brackish or marine adult habitats to their upstream reproductive areas.

Six species of sturgeons are or have been native to the Danube. Before the blockage of the migration routes four anadromous species ascended as far as the Upper and Middle Danube to spawn. Smaller scale anadromous migrators spawning in the Delta lakes or the Lower Danube reaches include *Alosa* spp, some of which form the basis of a commercially important fisheries e.g. in the Delta lakes.

Rheophilic species bound to the riverine habitats form the largest group, followed by eurytopic forms that live both under lotic and lenitic conditions. The smallest guild consists of the limnophilic species tied to stagnant water bodies (Schiemer *et al*. 2001a). In a lateral transect from the river to the fringing wetlands, arranged on a gradient of decreasing connectivity to the river the diversity of fish species decreases (Schiemer 1999, 2000). This pattern has been confirmed for the Slovakian and Hungarian sections (e.g. Guti 1993, 2002). In the limnophilic group a specific assemblage of blackwater species such as *Umbra krameri* and *Misgurnus fossilis* occurs in the large floodplains which are found exclusively in strongly fragmented and vegetated pools in the floodplain wetlands (Schiemer 1999; Schiemer *et al*. 2001a) and more commonly in the lakes of the Danube Delta with low connectivity to the river and with dense vegetation along the reed belt (Navodaru, Buijse and Staras 2001). The high diversity in the river itself is due to the co-occurrence of rheophilic and eurytopic forms. In the large European rivers the rheophilic guilds - depending on lotic habitats - contain the highest number of species. Some of them (Rheophilic B) require connectivity between the river and the floodplains to have complementary habitat for feeding and as a winter refuge (e.g. *Abramis ballerus, Aspius aspius*, *Leuciscus idus* in the Danube). These species are excellent indicators of lateral connectivity between lotic and lenitic conditions. The various species exhibit distinct patterns of niche differentiation; e.g. the Danubian percids (*Zingel zingel, Z. streber, Gymnocephalus schraetseri, G. baloni)* or the various species of *Gobio* exhibit clear differences with regard to the preferred current velocity.

Over the past 15 years the requirements of some of these species have been studied in detail with regard to their field occurrence as well as experimentally with regard to their specific eco-physiological requirements and performances and their functional response to major environmental variables (Table 2). We found that during spawning and early life history most riverine species are bound to the inshore zone of the river, where they require a variety of structural properties for successful recruitment (Figure 9):



■ **Figure 9.** Schematic representation of quality criteria of inshore zones with respect to their value as fish nurseries. The scheme indicates the river shoreline with a connected backwater and gravel bar (hatched). Stippled area = terrestrial vegetation; OM = organic material (from Schiemer *et al.* 2001a).

Table 2: Studies on the ecology and eco-physiology of critical stages of Danubian fish

1. Early life history
Schiemer and Spindleer 1989; Schiemer and Zalewski 1992; Wintersberger 1996a, 1996b; Keckeis *et al.* 1996a; Kamler *et al.* 1996; Keckei, Bauer-Nemeschkal and Kampler 1997; Winkler, Keckeis, Reckendorfer *et al.* 1997; Kamler, Keckeis and Bauer-Nemeschkal 1998; Flore and Keckeis 1998; Flore, Reckendorfer and Keskeis 2000; Flore. Keckeis and Schiemer 2001; Keckeis *et al* 2001; Reckendorfer, Keckeis, Tiitu et al. 2001; Schiemer *et al.* 2001a; Keckeis and Schiemer 1992; Schiemer *et al.* 2003

2. Reproductive phase
Keckeis, Franckiewicz and Schiemer 1996b; Kamler and Keckeis 2000; Keckeis 2001

3. Habitat linkage and ecological integrity
Schiemer and Spindler 1989; Schiemer and Waidbacher 1992; Kurmayer, Keckeis, Schrutka *et al.* 1996; Schiemer 1999; Jungwirth *et al.* 1999; Schiemer 2000; Schiemer 2002; Hirzinger, Keckeis, Nemeschkal *et al.* 2003

- Spawning sites must be in close proximity and connected to larval microhabitats. Emerging larvae drift passively to these nursery zones. Population losses are generally higher in channelized rivers with lower flow diversification.
- Diversified inshore structure to cover ontogenetic niche shifts with regard to the velocity of the water current, substrate type and food.
- Connected side arms or inshore retention zones are significant production areas for food for larvae (in the sense of the Inshore Retention Concept (Schiemer, Keckeis, Reckendorfer *et al.* 2001b).
- Shallow sloping embankments and littoral diversification are required to function as buffer zones and refugia for 0+ fish against washout effects in the event of strong water level fluctuations and floods.

Such complex requirements have become the main restriction for the existence of a highly adapted fish fauna in large rivers under regulated conditions (see below).

HUMAN IMPACTS VERSUS ECOLOGICAL REQUIREMENTS OF FISH

Changes in the river environment result in a change in fish species composition and also endanger the aquatic fauna in its totality. Under the impact of human interference the fish fauna has deteriorated in many sections of the Danube. This has been manifested in:

- Extinction of species (Table 1)
- High number of endangered species (Table 1)
- Qualitative and quantitative decline of fisheries
- Change in fish composition from habitat specialists (rheophilic and stagnophilic) to eurytopic forms

The causes are manifold and often cumulative and have to be specifically analysed and addressed in individual situations, be it a river stretch or a particular fish species.

The major negative impacts are:

- Loss of longitudinal connectivity of the river system caused by hydropower dams
- Loss of floodplain habitats and the interaction between rivers and floodplains
- Loss of riverine inshore structure

River regulation and damming have also resulted in a:

- Change in the hydraulics and flow regime
- Change in the thermal pattern due to faster runoff and reduced inshore retention

Additional negative influences are:

- Effects of shipping
- Poor water quality
- Overfishing, illegal fishing, inappropriate fisheries regulations, etc.

The high state of endangerment of former abundant or common fish species in the Upper and Middle Danube and the decline in catch in the Lower Danube are signs of a critical situation where management and mitigation are required.

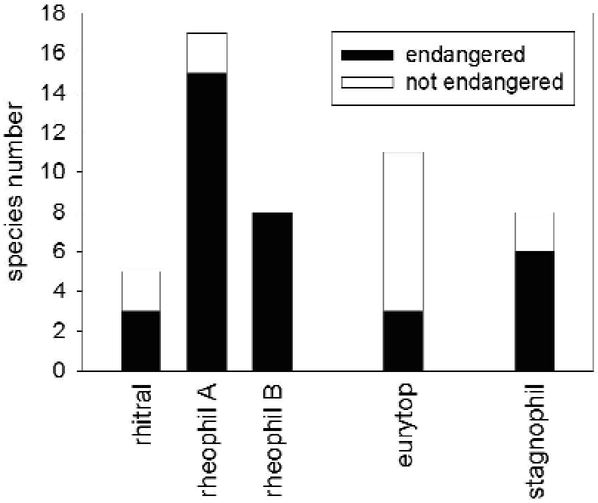
Sturgeons are of main concern from a conservation point of view as well as for fisheries. The anadromous sturgeons became extinct in the Upper and Middle Danube due to the blocked migration route at the Iron Gate. However, already in the nineteenth century the catch statistics in the Middle and Lower Danube had declined due to overfishing. The past and present status of sturgeons has been discussed by Hensel and Holcik (1997); Guti (1998); Bacalbasa-Dobrovici (1998); Navodaru, Staras and Banks (1999); Reinartz (2002) and Reinartz *et al*. (2003).

While a high proportion of the original fauna (nineteenth century status) still exists, a large number of formerly common species shows declining populations. Many taxa have become threatened and are on the Red List. From Table 1 it becomes clear that their number is higher in the upper parts of the Danube than in the Lower Danube and the delta.

The main deficiencies in the Upper Danube plus Slovakia and Hungary result from river engineering and damming which has caused a decline of the ecological integrity of the river-floodplain ecosystem (Karr 1991; Jungwirth, Muhar and Schmutz 2000; Schiemer 2000).

The most destructive effects are caused by the construction of hydropower dams, which result in a reduction of flood pulses and a blockage of fish migration into the floodplain system (which represent spawning and feeding grounds and winter refuges for a number of species). Dams also result in a reduction of appropriate spawning and nursery habitats for rheophilic species within the channel. The composition of the fish fauna in the dammed channel changes from a rheophilic-dominated assemblage to eurytopic forms (Schiemer and Waidbacher 1992). After the Gabcíkovo River Barrage System was put in operation in October 1992, a loss of species and the decline in fish density and productivity has been noted both on the Slovakian and the Hungarian side (e.g. Guti 1993; Balon and Holcik 1999). Phytophilous spawners like wild carp and pike have lost their spawning grounds and declined rapidly. The dramatic alterations of both the hydrological regime and the structural diversity resulted in a decrease of the food resources and a loss of spawning, feeding and wintering grounds for fish. Consequently, the mean annual fish catch, calculated for the period after the damming of the river, declined by 87 percent when compared with the period 1961-1972 (Holcík 1998; Balon and Holcík 1999).

But even in the remaining un-dammed sections the situation is critical. Figure 10 exemplifies the status of the fish fauna in the largest free-flowing stretch (approximately 50 km river length) of the Austrian Danube from Vienna to Bratislava. The area has received IUCN status as a National Park because of the extensive functional floodplains. Since the water quality is good and there is no overfishing it is quite apparent that the critical state is due to a loss of habitat diversity and structural properties. The state of endangeredness is different for the various guilds. It is interesting to note that a limnophilic guild consisting of species which are bound to small, isolated and strongly vegetated waterbodies on the outer floodplain borders, such as *Umbra krameri, Misgurnus fossilis* and *Carassius carassius*, are critically endangered due to the loss of formerly extensive fringing wetlands which covered large areas prior to regulation. The graph clearly shows that the rheophilic guild contains the highest number of species and also the highest percentage of endangered ones.

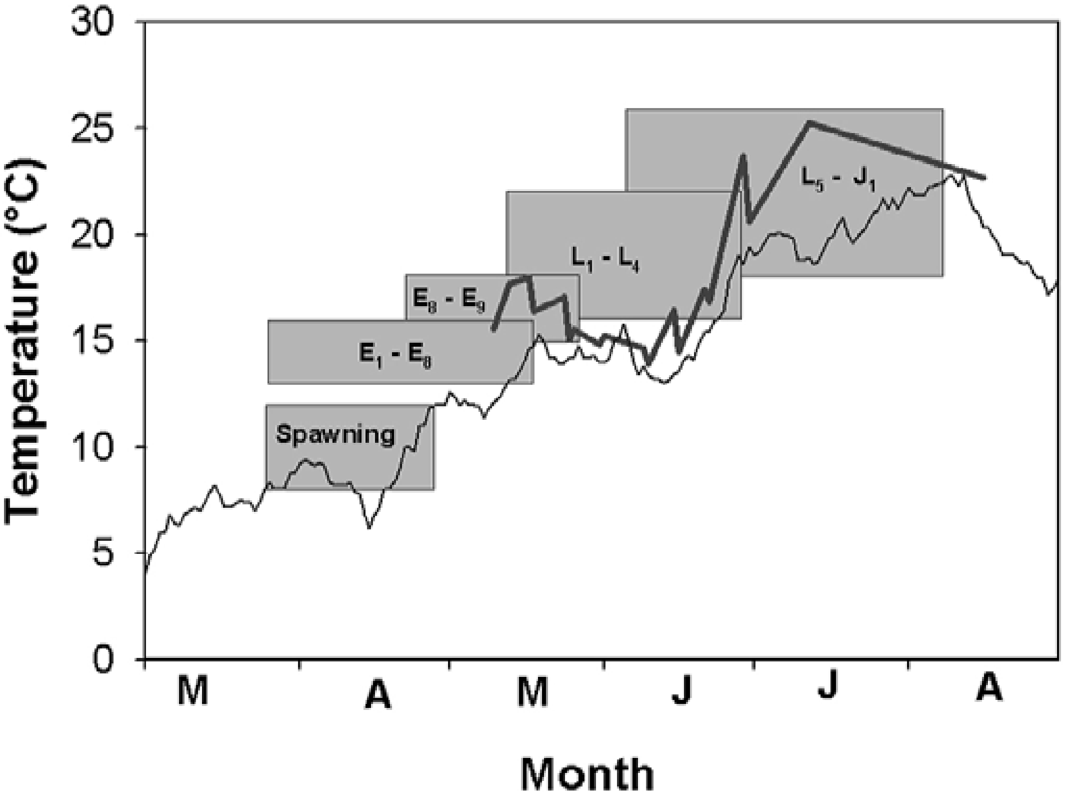


■ **Figure 10.** Guild structure of fish and the number of endangered fish species in the different ecological guilds in the free-flowing Austrian section downstream of Vienna to the Slovakian border.

The early life is critical: the match or mismatch between environmental conditions and requirements during the embryonic and early larval phases is decisive for recruitment (Copp 1989; Schiemer, Spindler, Wintersberger *et al*. 1991; Schiemer *et al*. 2001a). Most of the rheophilic species are bound in the reproductive and the 0+ phase to the inshore areas of high structure and low flow and high productivity (Inshore Retention Concept, Schiemer *et al*., 2001b) (see above). The shoreline structure is thus a decisive characteristic for the existence of a highly specific Danubian fish fauna. Richly structured inshore zones have become a rare commodity in regulated rivers. For example, the approximately 50 km long free-flowing section of the Austrian Danube contains only 18 larger gravel bars of 0.5-2 km length, which form potential fish nurseries. Of these 18 zones only 6 provide high quality conditions for recruitment. This represents approx. 15 percent of the total shore length. Sixty percent are linear embankments made out of ripraps that are virtually devoid of fry. An index of shoreline configuration for such gravel bars correlates strongly with the species number in the 0+ stage and the occurrence and number of rare and endangered species. The quality of inshore zones depends on the interaction between geomorphology and hydrology and on the degree to which two dynamic processes are matched: the ontogenetic change in requirements and the hydrological dynamics of the river, which result in a continuous change of microhabitat locations and conditions. Considering the strong diurnal hydrological fluctuations occurring in large rivers, the inshore zones represent a highly stochastic environment for the early life history stages. Structural heterogeneity of the shoreline is a buffer against population losses (Schiemer *et al*. 2001a). It is likely that this extent of shore structure is inadequate for long-term maintenance of the characteristic fish associations. This is indicated by the decline in formerly common species observed during recent years.

For a detailed understanding of the ecological requirements, experimental studies are required. *Chondrostoma nasus,* which has become a key species for river conservation and for highlighting the environmental conditions of large European rivers (Penáz 1996; Schiemer, Keckeis and Kamler 2003) has been our main experimental animal in recent years. The value of such detailed studies is shown in Figure 11 which exemplifies the mismatch between the temperature requirement during early ontogeny vis-à-vis the field temperatures in the free-flowing Danube downstream of Vienna. The thick line is based on the daily hydrographic readings at 7 a.m. in the main channel. The thin line represents the temperature recording in the inshore zones. It illustrates the high significance of the inshore retention zones: it is apparent that the temperature regime of the inshore storage areas becomes decoupled from main channel conditions to a degree that depends on water retention and exchange. Local temperature conditions are highly significant for temperature-dependent processes of species bound to the littoral. The inserts in Figure 11 show the time of occurrence of different stages of *Chondrostoma nasus* in the field, the width of the blocks indicates their temperature optima, based on experimental data. This shift in temperature optima is in agreement with the environmental temperature increase in rivers after the spawning period of *Chondrostoma nasus*, which usually occurs in March and April. It is apparent that river engineering has reduced the synchronisation between the physiological programme of a characteristic species and the conditions in regulated rivers. Suboptimal temperature results in reduced growth, which leads to a prolonged development through the critical stages with accumulated risks and mortality. We have good evidence that this mismatch also holds good for other environmental conditions like food supply and current velocity pattern. With regard to the latter, wave actions and short-term disturbances in the nursery zones caused by heavy navigation are other critical factors. A detailed analysis showed that the tow and splash pattern, a high variability of water velocities and the translocation of the larval microhabitats, which results from passage of ships, increases larval mortality rates (Hirzinger *et al*. 2002).

The situation in the Lower Danube is similarly critical especially with regard to the fishery, for three reasons: reduction of floodplain areas by side dams and polders, poor water quality and uncontrolled and badly managed fisheries.



■ **Figure 11.** Temperature in the main channel of the Danube at Vienna (thin line) and in the inshore storage zones (average value of the 3 microhabitats) during the spawning and early life history development of *C. nasus* in 1994. The inserted boxes are defined by duration of spawning and of consecutive developmental stages in the field (length of boxes), and by the repective ranges of optimum temperatures (height of boxes). Embryonic (E), larval (L) and juvenile (J) developmental stages determined according to Penaz (1996). Modified from Keckeis *et al.* (2001).

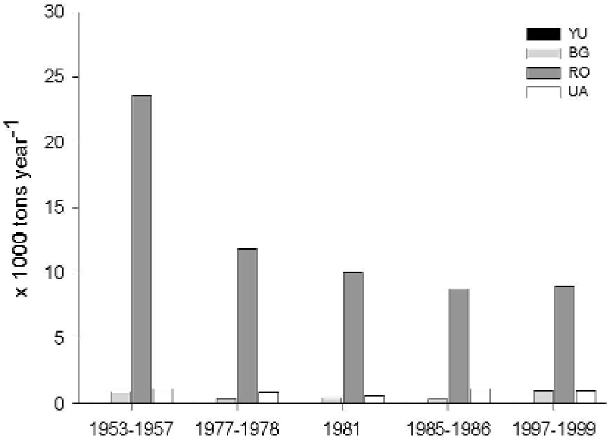
STATUS OF FISHERIES

Bacalbasa-Dobrovici at LARS 1 (1989) presented a survey on "The Danube River and its Fisheries". According to the statistics supplied by the "Joint Commission for the Application of the Fishery Convention in the Danube", the average annual catch of commercial fisheries in tonnes for the period from 1958 to 1983 was approximately 150 in Slovakia, 900 in Hungary, 1 300 in Serbia and Montenegro, 800 in Bulgaria, 20 000 in Romania and 3 000 in the Ukraine. We can use these long-term averages (1958-1983) as a starting point for a discussion on the more recent development and the present-day situation.

In Germany, Austria and Slovakia commercial fisheries are practically zero, however recreational fisheries play a major role. Their quality shows a continuous decline due to the poor connectivity between the river and its floodplain. The value of the multi-species recreational fisheries has been badly hurt by the construction of hydropower dams. In Slovakia, for example, the catch has considerably declined due to the construction of the Gabcikovo dam. The mean annual catch in the period 1961-1979, before the start of the GRBS construction, amounted to 102.7 tonnes and consisted to a large extent (46.1 percent) of economically preferred species such as *Cyprinus carpio, Esox lucius, Stizostedion lucioperca, S. volgensis, Aspius aspius, Tinca tinca* and *Silurus glanis.* In the period 1993-1996, after the GRBS was built and put in operation the mean annual catch dropped to 26.8 tonnes (Holcik, *in litt.*). The fisheries development is described by Guti (1993) in the Szigetköz floodplain in Hungary, strongly affected by the GRBS. The floodplain area is used both for commercial and recreational fisheries. The total catch declined from 207.5 tonnes in 1976 to 77.4 tonnes in 1992, showing a decreasing trend despite higher recreational fishing activity. Popular fish on the market such as pike and carp decreased significantly.

How is the development in the Lower Danube, where commercial fisheries still play a significant role? Antipa (1916) described the situation at the beginning of the last century, when the river was in a near pristine state. Its further development was analysed by Bacalbasa-Dobrovici (1989, 1998). Until 1960 the main controlling factor was the hydrology of the river. The positive relationship between catch statistics and the flood pulses was already recognized by Antipa (1916). After 1960 anthropogenic influences like damming, formation of irrigation reservoirs, eutrophication, pollution, introduction of exotic species and overfishing became the major factors affecting the fish.

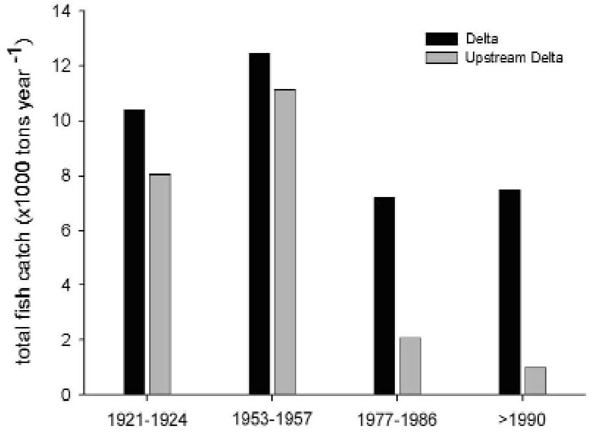
Figure 12 shows the changes in the riparian countries according to official catch statistics. In Romania, which has the most significant fisheries, the catch declined drastically. The strongest decline occurred during the 1960s as an immediate response to the reduction of floodplain areas: until the 1960s the floodplains downstream of Iron Gate II produced nearly 50 percent of the Romanian catch (Figure 13). They were a key habitat for the semi-migratory species like carp, ide, pikeperch and catfish. The drop occurred despite increasing fishing effort due to the unemployment and open access after the collapse of the communist state-controlled system (Bacalbasa-Dobrovici 1998). At the Bulgarian side of the Danube the number of commercial fishers increased from 363 in 1986 to 2000 in 1998. A less drastic but also strong decline in fish catches resulted from the polder construction within the delta.



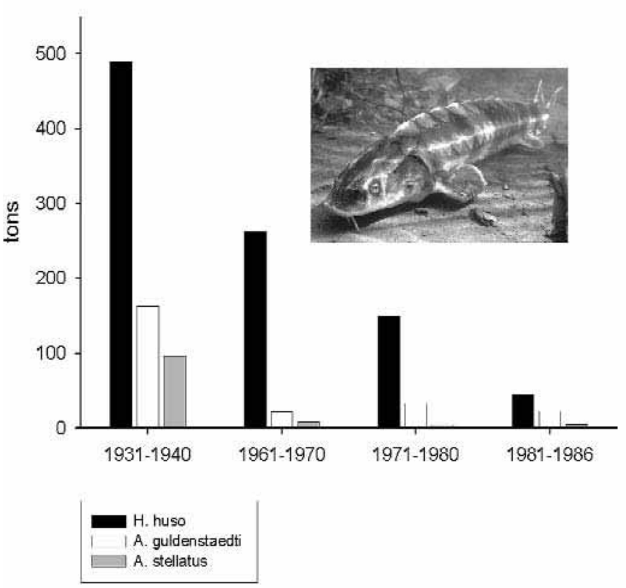
■ **Figure 12.** Development of total catches in the riparian countries over the period 1953-1999 (official fisheries statistics)
1953-1957 : Bacalbasa-Dorovici (1995)
1977-1978 : Report of Joint Commission of the International Agreement of Fishing in the Danube River (JCIAFD), 21st Session, 1979, Budapest
1981 : Bacalbasa-Dobrovici (1989)
1985-1986 : Report of JCIAFD, 28th session, 1987, Bratislava
1997-1999 : National Report on Third FAO/East Fish Technical Consultation, Bulgarian State Fisheries Inspectorate, 1998, Bacalbasa-Dobrovici (1998), Rapid Rural Appraisal Techniques (RO)

ANADROMOUS STURGEON FISHERY

Over the centuries sturgeons have formed the basis of a large and significant commercial fishery, renowned throughout the world (Reinartz *et al*. 2003). In the 1960s and 1970s this fishery yielded between 80 and 300 tons of fish each year mainly in Romania, the Ukraine, Bulgaria and former Yugoslavia. In the last 10 to 20 years the fishery has strongly declined, with official records of 25-30 tons per year (Figure 14). A study carried out in 1997-1998 using Rapid Rural Appraisal technique revealed, however, that official catch records represent no more than 10 percent of the actual catch size (approx. 385 tons; 56 percent in Romania, 30 percent in the Ukraine, 12 percent in Bulgaria, 2 percent in former Yugoslavia) (Navodaru *et al*. 1999).



■ **Figure 13.** Development of total catches in the Romanian Danube vs. the Delta during the period 1921-1986 (official fisheries statistics).
1921-1924 : Fisheries statistics
1953-1957 : Bacalbasa-Dobrovici (1995)
1977-1986 : Report JCIAFD, 21st and 28th Session
>1990 : Bacalbasa-Dobrovici (1992,1998)



■ **Figure 14.** The decline of sturgeon fisheries according to the official catch statistics.

There is a general consensus that the decline in official catches is indicative of a real decline in the Danube Basin sturgeon populations due to a combination of factors such as blockage of migration routes, overfishing, pollution and habitat loss. The damming of the Danube has interrupted the traditional migration of sturgeons. Natural spawning sites have been drastically reduced but still exist downstream of the barrages. The main factor affecting sturgeon stocks is overfishing. Overfishing has caused increased mortality of adult sturgeons, while the size of breeding sturgeon has been decreasing. Breeders are also becoming less and less likely to complete a second migration in the river and the average age of sturgeon has been declining. Overfishing means a decreasing chance that mature specimens will reach spawning areas. The number of fishers has more than trebled since the fully state-controlled system collapsed. The use of more effective gears (monofilament gill nets) has increased as well as stress factors during migration and spawning (e.g. injuries by unbaited hooks).

In order to improve the situation of the fishery of the Lower Danube a transnational framework for common management has to be re-established: The Joint Commission of the International Agreement on Fishing in the Danube River (JCIAFD) established in 1958 has not been active since 1990. The riparian countries have undergone a major transition from a State-controlled to a market system. The legislation and implementing agencies have failed to keep pace with the extent of changes. Legislative structures in all of the countries have to be reviewed in the light of international standards. Main targets have to be:

- Improved and common monitoring system (catch statistics after 1990 are unreliable; the lack of data on fishing effort and catches hampers fish stock management);
- Legal framework and fishery regulations should be harmonized between the countries with regard to closed seasons, fishing methods and gears (e.g. the destructive use of un-baited hooks; this method has been banned in Romania and the Ukraine but is permitted and used intensively upstream in Bulgaria and Serbia for sturgeons) (Bacalbasa-Dobrovici 2002);
- Illegal fisheries require stronger control including international control of the black market (for example, the export of caviar since 1998 in Romania clearly demonstrates that the actual catch of sturgeons is much higher than listed in the official catch statistics).

CONCLUSIONS

1) The current environmental status of the Danube is not satisfactory, for example with respect to the requirements set by the EC Water Framework Directive.

2) The loss of ecological integrity started more than 100 years ago with the large river regulation schemes. The interruption of connectivity between floodplains and the river has intensified as a result of the construction of dams, which has had an accelerating impact on the free-flowing sections due to the disruption of the gravel transport in the river. The lowering of the water level has been caused by bed erosion.

3) The problems have been intensified by pollution, shipping and uncontrolled fisheries.

4) The deterioration of the environment is not only endangering the fish fauna and reducing the potential of the fisheries but is also problematic for other forms of the river use, such as recreation and drinking water supply as well as affecting the self-purification potential of the river floodplain system.

5) For management an efficient monitoring system is required. Fish are the single most important bioindicator group for assessing the status of ecological integrity.

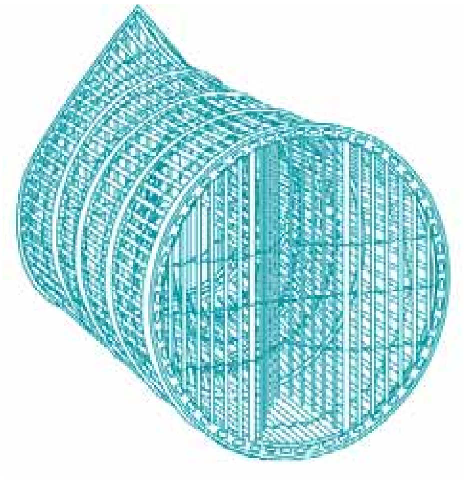
6) Fisheries in the Lower Danube are an important issue because of their economic significance.

7) Conservation and restoration: there have been many efforts to conserve and restore the remaining floodplains. The examples are the establishment of the Alluvial Floodplain National Park in Austria in 1996, Gemenc floodplain area in Hungary – National Park since 1996, the Kopacki Rit Nature Park in Croatia, the Srebarna Lake in Bulgaria, the Danube Delta. Restoration programmes to restore the connectivity between floodplains and the river have been started or are in the planning phase. These programmes are highly significant for improving the ecological functions of the river system (Schiemer *et al*. 1999).

8) The ecology of the Danube requires international attention and harmonized management.

ACKNOWLEDGEMENTS

We acknowledge the help of J. Holcik in providing information on the Slovakian Danube and the constructive criticism by J. Bloesch on an earlier version of the manuscript.



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