Ecological status and problems of the Danube and its fish fauna

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Biodiversity, fish guilds and their ecological requirements

Large rivers and their riparian zones are hot spots of biodiversity (WARD et al. 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 (α-diversity), and between-habitat differences (beta-diversity) and consequently, overall species richness of a river.

The total number of fish 102 species along the whole course of the Danube have been identified. 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 et al. 1986). From an ecological point of view, this diversity results from the intersection of rhithral conditions in most of the Upper Danube and potamal conditions in the alluvial zones with extended floodplains and a rich habitat structure downstream. BALON (1964) provided an overview of the longitudinal distribution pattern of individual species along the river course (Figure 1, solid line). Diversity increases in the Upper Danube from the rhithral sections to the extended alluvial plains. 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 ecotonal structure have created conditions suitable for the assembly of different fish guilds (SCHIEMER, 2002; WARD et al. 1999). Further downstream in the Middle and Lower Danube species numbers remain fairly constant. In the Danube Delta diversity increases again due to invaders from marine and brackish waters. The recent status of the fish fauna in Austria, Hungary and Romania is presented as histograms (Figure1). During the last 10 years a number of new species, neobiota, were recorded upstream and downstream of the Devin gate, as immigrants from the Lower Danube. About 15 exotic species have been introduced in the last century.

Fish species can be grouped into guilds to their specific requirements in the course of their life cycle (EROS et al. 2005). For large European rivers 6 guilds have been distinguished characterised by their preferred zones of occurrence of adults and the spawning and nursery grounds (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.
- Riverine species with spawning grounds and nurseries in the inshore zone of the river itself. They are 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. They are excellent indicators of lateral connectivity between lotic and lenitic habitat types.
- Eurytopic species.

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- Limnophilic species confined to disconnected former river branches with strong development of submerged vegetation.
- Anadromous species like sturgeons, which require integrity at a catchment scale.

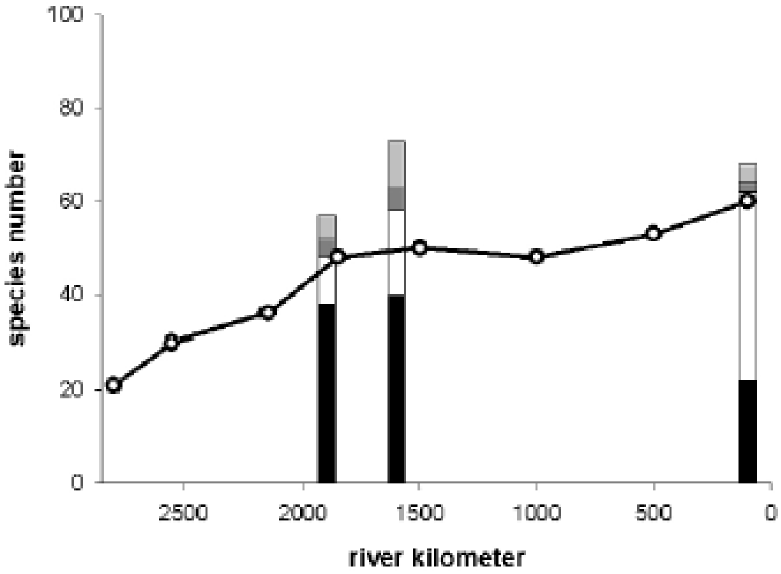

Figure 1. Biodiversity of fish of the Danube and the floodplains along the river course. The line gives species numbers according to the review of BALON (1964). The histograms give the present status of the Danubian fish fauna in Austria, Hungary and Romania 1. Black: endangered; white: not endangered;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

Over the past 15 years some of these species have been studied in detail with regard to their specific eco-physiological requirement and performances and their functional response to major environmental variables.

We found that most riverine species during the spawning and early life history period are bound to the inshore zone of the river, where they require a combination of structural properties for successful recruitment:

1) 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 channelised rivers with lower flow diversification.
2) A rich inshore structure is required to cover ontogenetic niche shifts with regard to the velocity of the water current, substrate type and food.
3) Connected side-arms or inshore retention zones are significant as production zone of food for the larvae (in the sense of the „Inshore retention Concept“, SCHIEMER et al. 2001b).
4) Shallow sloping embankments and littoral diversification is required to function as buffer zones and refugia for 0+ fish against wash-out 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.

Human impacts: water quality, river regulation and the construction of hydropower dams

The first and very provisional attempt to map the water quality was made in a monograph on the Danube (LIEPOLT, 1967): Between the 1950 and 1970s low water quality was found downstream of cities and industrial zones, especially in Germany and Austria, where pollution temporarily reached class IV (polysaprobity). The self-purification capability of the Danube at this period had decreased considerably due to toxic effects of industrial waste waters. Construction of waste water treatment plants at the beginning of the 1980s considerably improved the water quality to class II (WACHS, 1997).

Water quality development in the Lower Danube during 1950-1975 was quite different. Large stretches were considered to have an acceptable water quality of class II due to high dilution (RUSSEV, 1979). Later on, conditions deteriorated due to industrial growth, poor pollution control and inflow of strongly polluted tributaries. Their polluting effect can be recognized over relatively short stretches in the Danube. High flow and self purification processes improve the situation downstream. For the fish fauna, however, these heavily polluted tributaries are detrimental with regard to spawning migrations.

The key environmental impacts result from regulation and engineering. In the Upper Danube the process of intensive engineering began in the 19th century. The main engineering approach was to create a single, straightened channel, stabilized by riverside embankments and rip-raps. 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

River regulation initiated trends which are still continuing: a lowering of the water table and a deepening of the riverbed combined with sedimentation processes in sidearms is leading to permanent changes and a loss of aquatic habitat. 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.

A major ecological concern is related to the construction of hydropower dams. The Danube represents a high potential for hydropower generation which has been largely exploited. 52 base-load power dams exist in the Upper Danube and 3 major barrages in the Middle Danube (Gabcikovo, Iron Gate 1 and 2).

In the Lower Danube, the separation of the river from its floodplain by side levees had a major impact on the overall environmental situation and fisheries. The extent of flood pulses was reduced: of the 5,000 km^2 of the former floodplain only 15 percent is still being temporarily flooded.

The Danube Delta including adjacent oxbow lakes and lagoons covers some 5,640 km^3. 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.

Human impacts vs. ecological requirements of fish

Changes in the river environment result in a change in fish species composition and threaten the total aquatic biota. This has been manifested in:

- Extinction of species
- High number of endangered species
- Qualitative and quantitative decline of fisheries
- Change in fish composition from habitat specialists (rheophilic and limnophilic) 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 (dredging, channelization, etc)
- Poor water quality
- Overfishing, illegal fishing, inappropriate fisheries regulations, etc.

The highly endangered formerly abundant or common fish species in the Upper and Middle Danube and the decline in catch in the Lower Danube reflect 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 (see the Sturgeon Action Plan; BLOESCH et al. 2006).

A high proportion of the original fauna (19^{th} century status) is still existing. However, a large number of formerly common species exhibit declining populations. Many taxa became threatened and are on the Red List, as for example *Zingel* spp., *Chondrostoma nasus* or *Leuciscus idus*.

The most destructive effects had the construction of hydropower dams. The composition of the fishfauna in the dammed channel changes from a rheophilic dominated assemblage to an assemblage dominated by eurytopic forms (SCHIEMER & WAIDBACHER, 1992).

Among the whole fish community the rheophilic guild contains the highest number of species and also the highest percentage of endangered ones.

The early life history period is the critical stage: the match or mismatch between environmental conditions and requirements during the embryonic and early larval phases is decisive for recruitment (SCHIEMER et al. 2001a). Most of the rheophilic species are bound in the reproductive and the 0+ stage 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.

An index of shoreline configuration for gravel bars correlate 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, on the degree to which two dynamic processes are matched a) the ontogenetic change in requirements and b) the hydrological dynamics of the river which result in the 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 of the critical condions, experimental studies are required. *Chondrostoma nasus*, which has become a flagship species for river conservation and for highlighting the environmental conditions of large European rivers has been our main experimental animal over the recent years.

From the experimental results (e.g. SCHIEMER et al. 2003) it is apparent that river engineering has reduced the synchronisation between the physiological programme of a characteristic species and the conditions in regulated rivers. We have good evidence that this mismatch also holds 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 navigation is another critical factor.

Conclusions

1) The current environmental status of the Danube is not satisfactory, e.g. 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.
3) The problems have been intensified by pollution, hydropower, 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 ecological services, e.g. affecting the self-purification potential of the river floodplain system.
5) For management an efficient monitoring system is required (see SCHABUSS et al., 2006). Fish are the single most important bioindicator group for assessing “ecological integrity”.
6) Conservation and restoration: efforts have to be intensified to restore the connectivity between the floodplains and the river.
7) The ecology of the Danube requires international attention and harmonized management. This is basically performed by ICPDR.

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