Opusc. Zool. Budapest, XXXIII, 2001

Water bodies in the Gemenc floodplain of the Danube, Hungary
(A theoretical basis for their typology)

By
G. GUTI*

Abstract. The 30 km long section of the Danube in the Gemenc region has a large inundated floodplain. A drying-out process was observed in this moderately regulated stretch in the 20th century due to the deepening of the riverbed. Technical interventions are necessary for the restoration of the fluvial hydrosystem and the classification of the aquatic biotopes would be an important guideline for the development of the management strategy. This paper reviews the most significant human impacts on the Gemenc floodplain and outlines a typological analysis of the hydrosystem. The study of the fish fauna is one of the useful tools for the ecological description of the different water body types.

The Gemenc floodplain is one of the last remaining extensive inundated floodplain of the Danube. In the 19th century river regulation works resulted in the isolation of floodplains from the main stream, cutting through meanders and straightening of the riverbed. Reduction in river length accelerated the passage of floods, while low water stages became more common, with lower levels. Thus, river regimes became more extreme. Another consequence of the river regulations is the deepening of the riverbed, causing the continuous fall in water levels over large areas, and the drying-out process of floodplain water bodies during the 20th century. Drastic aquatic habitat changes were the main cause of the fish decline, which indicates a decrease in biodiversity.

The remaining fragments and elements of the original Danubian floodplains have geological, botanical, zoological and scenic values at the beginning of the 21st century, but technical interventions must be taken now in order to save and restore them. The ecological management of the river ecosystem must consider the different biotopes occurring within the floodplain and their ecological functions. (Individual units of well defined communities occur almost always among similar environmental circumstances, thus we reserve the term „biotope" for the habitat of biotic communities [Udvardy, 1959] in this study.) The typology of floodplain

**Dr. Gábor Guti,* MTA ÖBKI Magyar Dunakutató Állomás (Institute of Ecology and Botany of the Hungarian Academy of Sciences), 2131 Göd, Jávorka Sándor u. 14, Hungary.

water bodies would be essential in the development of an effective conservation strategy. The present paper proposes a theoretical basis for the typology of water bodies in the Gemenc floodplain with the integration of geomorphological, hydrological and ecological aspects.

The hydrosystem of the Gemenc floodplain

The natural system

The Gemenc region of the Danube (r.km 1497-1467) is covering an area of 178 km^2, so it is one of the largest inundated floodplains in Europe. It is situated in the south-western margin of the Great Hungarian Plain, along an irregularly meandering lowland section of the Danube. The main riverbed is characterized with low flow velocity and slow lateral movement. Its sediments consists of sand or silt. Cut-offs often occur, and the channel stability allows the complete formation of oxbow lakes, even as whole development of ecological successions in the extensive floodplain.

In the range of the Gemenc floodplain, the gradient of the Danube is 5 cm km^{-1}, the mean discharge is 2260 $m^3 s^{-1}$, and its extreme values were 470 $m^3 s^{-1}$ and 8700 $m^3 s^{-1}$ (Bulla, 1962). The difference between the lowest and the highest water level is usually 5-7 m, but the maximum difference reaches 9-10 m. Due to the melting of the snow-cover and ice-flows of the Alps, the flood regime has a glacial character. The low-water winter periods are generally followed by smaller floods ("icy-flood") in March and April. Larger floods ("green-flood") usually occur in May and June. Low waters are typical in October.

The Gemenc region includes aquatic, semi-aquatic and terrestrial biotopes within the floodplain in lateral dimension that are interconnected with the lotic environment of the river. This fluvial hydrosystem has three main components (Welcomme, 1979, 1983, 1985):

1) The *lotic component* is represented by the permanently flowing main riverbed.

2) The *floodplain,* which is seasonally inundated. It can be divided into lower and higher regions. The lower one is 4-5 m and the higher one is 7-10 m above the 0 point of the water-gauge at Baja. The lower region is flooded annually (Pécsi, 1959).

3) The *lentic components* are represented by a variety of standing waters (permanent or semi-permanent standing waters are in residual former channels, backwaters, oxbows, etc.), which remain in the floodplain during the dry season. These water bodies expand and contract according to the annual flood cycle. During the highest floods they tend to merge into a continuous water cover over the whole floodplain. The permanent standing waters of the floodplain are generally shallow, rarely exceeding 4 m in depth and may be in connection with the river. Aquatic habitats on the floodplain

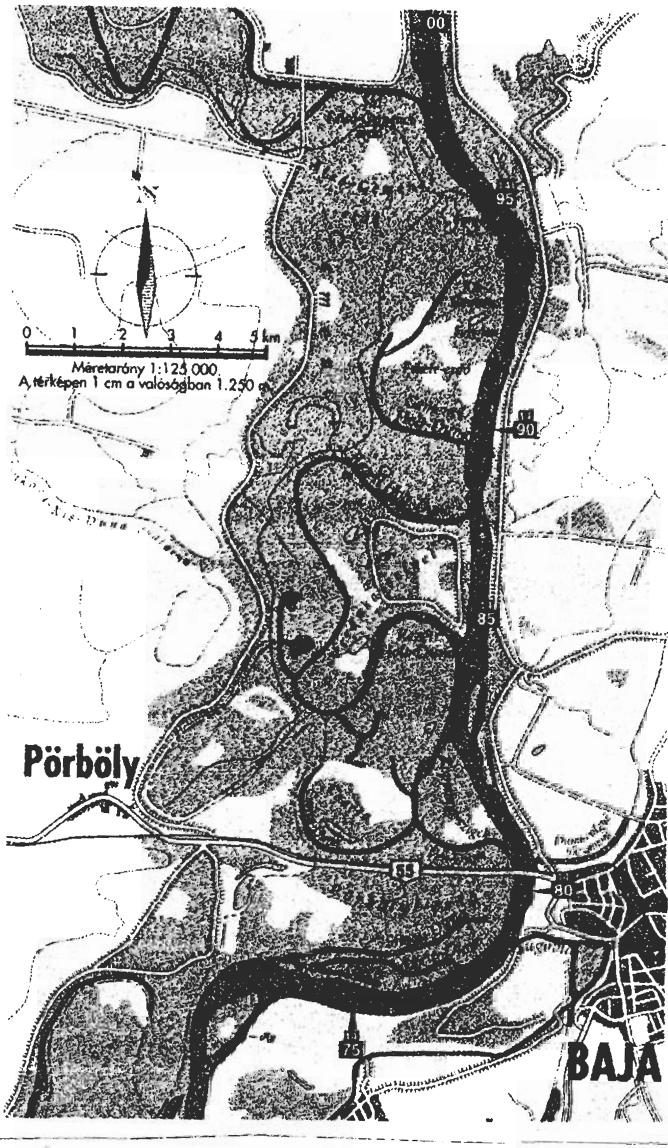


Fig. 1. Map of the Gemenc floodplain in our age

loose water by evaporation and infiltration throughout the dry season. This results in the shrinking and eventual drying out of many water bodies.

Human impacts

The management history of the Danubian floodplains started several centuries ago. During the 3rd century Romans built boat-towing roads along the right bank of the Middle Danube (Balon, 1967; Rakonczay, 1987). In the Middle Ages the Danube valley was an outstanding economical axis of Hungary. Systematic agricultural activity started in the 9th century on the floodplains. The most important human impacts, which changed the hydrological condition of the Gemenc floodplain, were the creation of drainage canals (fok-system) and later the river regulations for flood control and navigation.

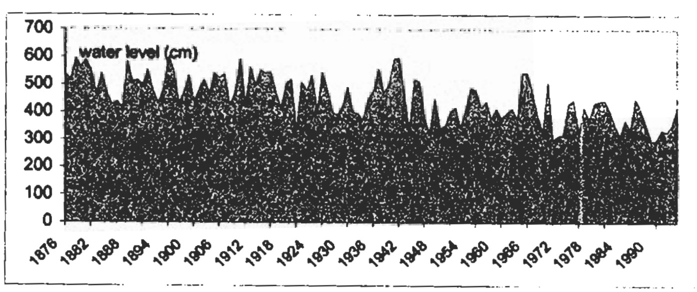


Fig. 2. Decreasing trend of the annual water level of the Danube at Baja between 1876 and 1995

The inhabitants of the Danube valley developed a high-level floodplain farming in the Middle Ages. The ancient "fok"-system consisted of small drainage canals and the artificial inlet, "fok" in Hungarian, opening the way for the water into the floodplain through natural levees. The fok-systems of the Gemenc floodplain connected the oxbow lakes to the Danube and to each other. Through the canals, the oxbow lakes and their connected areas were frequently supplied with water from the river for the benefit of fishery and extensive agriculture. In the 16th and 17th century the fok-system nodded to its fall and the advance of the floodplain framing broke off because the small settlements on the Danubian floodplain became depopulated during the 150 years of Turkish conquest (Andrásfalvy, 1973).

The economic development has demanded the regulation of the Danube stretch between Dunaföldvár and Mohács (r.km 1560-1447) since the 18th century. In the Gemenc region the regulation of the Sió-Sárvíz hydrosystem (a right side tributary of the Danube) was the most considerable attempt of water management in the 18th century. Inhabitants, who had interest in the traditional floodplain farming, revolted against these works. Overall river regulations started in the 19th century. Their main aims were flood control and improved navigation. River regulation involved construction of dikes along the river thereby inundated floodplains were reduced to less than 10% of heir original area. The middle and low water regulations resulted in the straightening and shortening of watercourses, cutting through meanders and isolating them from the riverbed. The most important steps of these operations were the following in chronological order (Károlyi, 1973):

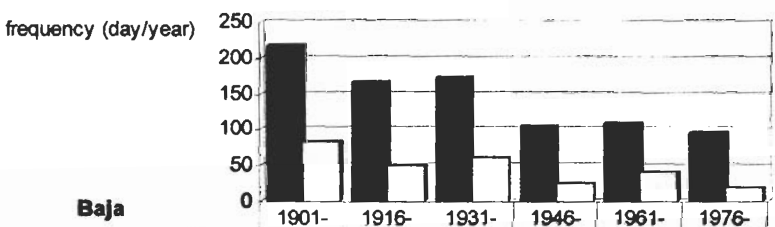
- the cutting through of four meanders between Fadd (r.km 1507) and Mohács (r.km 1447), which shortened the Danube bed by 33.4 km in 1820 and 1821;
- a regular steamboat service started between Budapest and Baja in 1833;
- the cutting through a 30 km long meander at Tolna (r.km 1504) with a 7 km long cut-off between 1843 and 1852;
- the excavation of a 4 km long channel from the Sió-Sárvíz river to the Danube in 1854 and 1855, while the original tributary at Báta (r.km 1465) was closed up by a sluice and a new tributary was created at Tolna (r.km 1497), thereby the 50 km long lower section of the Sió-Sárvíz was by-passed;
- flood control dikes were built along the Danube between Szekszárd and Báta from 1870 to 1872, however an extensive inundated area is left in the Gemenc floodplain;
- the cutting through of three meanders in the Gemenc area between 1893 and 1898 (the Grébeci-Danube at Sükösd, the Rezéti-Danube at Érsekcsanád and the Vén-Danube at Koppány), which shortened the Danube bed by 18 km;
- the excavation of a drainage ditch network in the flood free area of the right side floodplain from 1896 to 1930 making the 50 km long by-passed bed of the Sió-Sárvíz river the main channel of the new 145 km long ditch network;
- the low water regulation of the Danube stretch between Bogyiszló (r.km 1502) and the outlet of the Vajas-fok (r.km 1486) from 1905 to 1914;
- the closing up the Kádár side arm in 1946;
- the low water regulation works for better navigability since the end of the 1960s.

The river regulation works have had a number of indirect effects on the hydrology and channel morphology:

- There are 23 cut-off meanders along the Dunaföldvár–Mohács Danube stretch (r.km 1560-1447). The shortening of the riverbed was 77 km that is

41% and the gradient increased from 5 cm km^{-1} to 8 cm km^{-1} after channelization (Károlyi, 1973; IUCN, 1995).

- River length reduction accelerated the passage of flood peaks, while low water stages with lower levels became more common, than before the river regulation works. The river regime became more extreme. Flow velocity increased and floods became higher.
- River channelization increased channel erosion, which led to a deepening of the main riverbed as shown by a 1.5 m dropping of low water levels. Riverbed degradation restricted the connectivity of the floodplain water bodies to the main river channel, which led to a decreasing water supply and an increasing silt deposition in the lentic components of the hydrosystem. Two important examples are the following:



	1901-	1916-	1931-	1946-	1961-	1976-
■ inflow (450 cm)	217	165	171	105	109	95
□ inundation (600 cm)	83	49	61	26	41	19

Fig. 3. Frequency of the 450 cm and 600 cm water levels of the Danube at Baja during the 20th century

a) The minimal water level that provides an inflow to the side arms of the Gemenc floodplain is 450 cm at Baja (r.km 1479). At the beginning of the 20th century, the frequency of the water level above 450 cm was 217 days in a year. At the end of the century this frequency decreased by 56%, that is 95 days in a year (Fig. 3), even if the discharge of the Danube does not have trend line in the 20th century.

b) The dropping of the water level affected floodplain inundation, too. The Gemenc floodplain is inundated at a water level higher than 600 cm at Baja. At the beginning of the 20th century, the frequency of the 600 cm water level was 83 days in a year. By the end of the century this time decreased by 77%, that is 19 flooded days in a year (Guti and Keresztessy, 1997).

After the overall river regulation the economic development has changed several basic characteristics of the Gemenc region. The forestry practices have unfavourable effects on the natural floodplain ecosystems. The replacement of the natural forest with hybrid poplars and other fast-growing exotic trees causes a biodiversity decrease. A related problem is the age distribution of the trees which is becoming more uniform, 20 years old stock is dominating while trees of 80 to 90 years have became rare. Recreational activities have led to uncontrolled and illegal building of weekend cottages since the 1970s. From an ecological point of view the related problems are mostly local (rubbish dumping, wastewater discharge, visual hindrance). The Gemenc floodplain was qualified as a region of national importance and its protection was declared in 1977. It has been incorporated into the Danube-Drava National Park since its foundation in 1996.

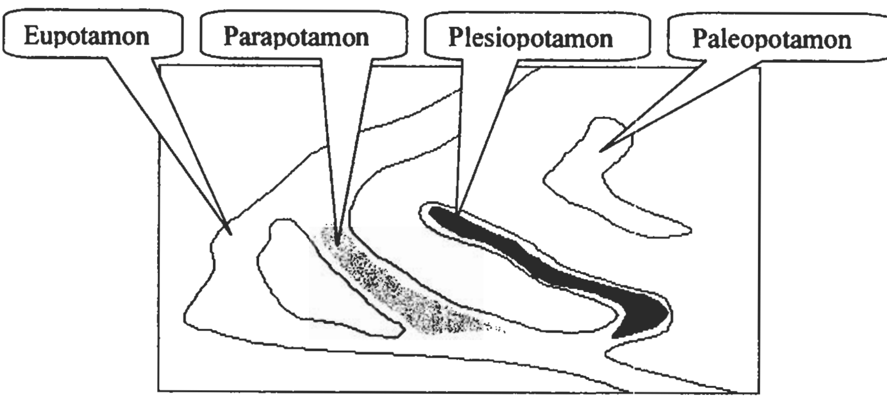


Fig. 4. Schematic representation of different functional sets of floodplain rivers

Typology of the floodplain waters

One of the most extensive classification systems of the water bodies of the floodplain rivers was provided by Roux et al. (1982), which was based on geomorphological, hydrological, and ecological analysis. Their system subdivides the water bodies into four main types or "functional sets" (Holčik et al., 1989; Amoros, 1991):

1) Eupotamon: The main channel of the river and its sidearms have a permanent flow. These lotic channels are not considered as floodplain water bodies. Their bottom is composed of stones, gravel and coarse sand. Macrophytes are absent or very scarce.

2) Parapotamon: Sidearms permanently connected to the main channel at their downstream end. Semi-stagnant floodplain waters that cut off and silted up at their upstream ends. Their flow is fed by surface and ground water. The bottom is composed of gravel mixed with sand and silt. Macrophytes are scarce.

3) Plesiopotamon: Permanent or temporary standing water bodies in the floodplain that were formerly channels or sidearms with no permanent and direct connection to the main channel of the river. They are connected during high water levels and highly influenced by the discharge of the river. The bottom consists of silt and clay. Macrophytes grow densely.

4) Paleopotamon: Permanent standing water bodies in the floodplain that were former anatomised channels or meanders (oxbow lakes), with no direct connection to the river. These water bodies are larger and deeper than the plesiopotamon, and mildly influenced by river discharge. The bottom consists of silt and clay. Macrophytes grow very densely.

In reality, a temporal continuum exists since ecological succession develop from eupotamon towards parapotamon and then to plesiopotamon. Some transitional cases between plesiopotamon and paleopotamon can also occur in relation to their geographical location and their hydrological function (Amoros et al., 1987).

The geomorphological stability of the meandering Gemenc area of the Danube allowed the complete formation of oxbow lakes (Pécsi, 1959), therefore the whole development of ecological succession (several development stages of ecosystems from juvenile to mature) occurred here before the river regulations. The transition of a cut-off meander to terrestrial biotopes requires 2-3 centuries. However, such biotope modifications are combined with ecological successions. Their progress differ according to the predominance of allogenic processes (general lowering of the water-table, deposition of mineral sediments, etc.) or autogenic process (colonization, vegetation dynamics, eutrophication, etc.). Human interventions may accelerate or reduce the rate of ecological succession by the modification of the fluvial dynamics (Amoros et al., 1987).

There has been no attempt to identify the functional sets and classify the aquatic biotopes within the floodplain in the Gemenc region. The typology of the floodplain water bodies must incorporate geomorphological, hydrological, hydrobiological and historical informations, as well as expedient examinations need to amplify the incomplete store of our knowledge.

Typological analysis uses functional describers as research tools. A functional describer is a component of either the biotope, or the biocenosis that provides information about the type of development stages of the ecosystem. Two elements of the ecosystem are particularly useful as functional describers: sedimentological and biotic characteristics. The granulometric pattern describes not only the sedimentology of the fluvial deposit but also the function of a biotope type. Living organisms and their population structure provides information about present and previous ecological conditions. Indicator taxa or ecological guilds can be used as functional describers (Amoros et al., 1987).

Fish fauna as a functional describer of the floodplain hydrosystem

The history of the fish fauna surveys of the Danube in the Gemenc floodplain goes back to the end of 1950s. There are 30 fish species in the collection of the Hungarian Natural History Museum that were gathered in the Gemenc region between 1957 and 1960 (Berinkey, 1972). Observations of amateur ichthyologists resulted in a list of 47 fish species in the area from 1970 to 1995 (Kalocsa and Schmidt, 1996), while the surveys of the Hungarian Danube Research Station have recorded 44 species since 1994. According to the historical and recent data, occurrence of 56 fish species were recorded in this Danube section. Most of the original fauna is still present, only large migratory sturgeons (*Huso huso, Acipenser gueldenstaedti, A. stellatus, A. nudiventris*) have disappeared due to overfishing and the blocking of their migratory route. The presence of *Umbra krameri* was not confirmed during the recent investigations. However, a specimen collected in 1957 (Berinkey, 1972) documents its previous occurrence (Table 1).

Fish species distribution is not accidental within a river system. The composition, density and biomass of fish assemblages depend on the nature of the functional sets or their particular biotopes. The fish fauna, or the structure of fish assemblages represents an important aspect in the evaluation of ecological functions of different water bodies in floodplain rivers (Holčik et al., 1981; Schiemer and Spindler, 1989; Schiemer et al., 1991; Schiemer and Waidbacher, 1992; Peňáz et al., 1991; Guti, 1993).

For instance, the fauna composition of the eupotamic main riverbed is dominated by rheophilic fish species (*Acipenser ruthenus, Barbus barbus, Chondrostoma nasus, Gymnocephalus cernuus, Zingel zingel, Cottus gobio,* etc.) that bound to the lotic component of the river. The connected backwaters represent the parapotamic functional set and their fauna includes several rheophilic and eurytopic fish species. Species grouped in the eurytopic guild (*Rutilus rutilus, Alburnus alburnus, Blicca bjoerkna, Perca fluviatilis, Proterorhinus marmoratus,* etc.) occur in all types of lotic and lentic components of the river. The disconnected plesiopotamic or paleopotamic backwaters are populated with eurytopic and limnophilic fish species (*Scardinius erythrophthalmus, Carassius carassius, Tinca tinca, Misgurnus fossilis, Umbra krameri,* etc.) that bound to the standing waters of the floodplain. In general, the diversity of fish species is the greatest in the eupotamon and parapotamon and it tends to decrease in the plesio- and paleopotamon, while the fish biomass shows an opposite trend (Holčik et al., 1989).

Table 1. List of fish species found in the different type of water bodies (1 = main riverbed, 2 = connected backwaters, 3 = disconnected standing waters) in the Gemenc region of the Danube. ■ *common,* ░ *rare,* x *historical data*

Fish species	1	2	3
Eudontomyzon mariae			
Acipenser ruthenus	■		
Acipenser gueldenstaedti	X		
Acipenser nudiventris	X		
Acipenser stellatus	X		
Huso huso	X		
Oncorhynchus mykiss			
Umbra krameri			X
Esox lucius	■	■	■
Rutilus rutilus	■	■	■
Rutilus pigus virgo			
Ctenopharyngodon idella			
Scardinius erythrophthalmus		■	■
Leuciscus leuciscus	■	■	■
Leuciscus cephalus	■	■	■
Leuciscus idus	■	■	■
Aspius aspius	■	■	■
Alburnus alburnus	■	■	■
Blicca bjoerkna	■	■	■
Abramis brama	■	■	■
Abramis ballerus	■	■	
Abramis sapa	■		
Vimba vimba	■		
Pelecus cultratus	■		
Tinca tinca			■
Chondrostoma nasus	■		
Barbus barbus	■		
Gobio gobio	■		
Gobio albipinnatus	■		
Pseudorasbora parva		■	■
Rhodeus sericeus amarus		■	■
Carassius carassius			■
Carassius auratus	■	■	■
Cyprinus carpio	■	■	■
Hypophthalmichthys molitrix	■		
Aristichthys nobilis			
Misgurnus fossilis			■
Cobitis taenia			■
Silurus glanis	■		
Ameiurus nebulosus			
Ameiurus melas		■	
Anguilla anguilla	■		
Lota lota	■		
Lepomis gibbosus	■	■	■
Micropterus salmoides			
Perca fluviatilis	■	■	░
Gymnocephalus cernuus	■	■	░
Gymnocephalus baloni	■		
Gymnocephalus schraetzer	■		
Stizostedion lucioperca	■	■	
Stizostedion volgense			
Zingel zingel	■		
Proterorhinus marmoratus	■	■	■
Neogobius fluviatilis	■		
Neogobius kessleri	■		
Neogobius syrman			

Using fish in the typological analysis of the fluvial hydrosystem has several advantages:

- fish sampling and identification is relatively fast and easy,
- the environmental requirements of fish are more widely known than those of invertebrates or other taxonomic groups,
- fish are on the top of the aquatic food chain and therefore integrate the response of the food chain to environmental change,
- fish are relatively long-living organisms therefore their population structure indicates the fluctuation of environmental variables over a long period.

Acknowledgements. The present study was supported by the János Bolyai Research Fellowship and the Danubius Project of the Hungarian Academy of Sciences.

REFERENCES

1. AMOROS, C. (1991): Changes in sidearm connectivity and implications for river system management. - Rivers, 2: 105–112.
2. AMOROS, C., ROUX, A. L., REYGROBELLET, J. L., BRAVARD, J. P. & PAUTOU, G. (1987): A method for applied ecological studies of fluvial hydrosystems. - Regulated Rivers, 1: 17–36.
3. ANDRÁSFALVY, B. (1973): A Sárköz és a környező Duna-menti területek ősi ártéri gazdálkodása és vízhasználatai a szabályozás előtt. - Vízügyi Történeti Füzetek, 6: 1–75.
4. BALON, E. K. (1967): Vyvoj ichthyofauny Dunaja, jej sucasny stav a pokus o prognozu dalsích zmien po vystavbe vodnych diel. - Biologicke prace, 13: 1-121.
5. BERINKEY, L. (1972): Magyarország és a r. Hung., 13: 3–24.
6. BULLA, B. (1962): Magyarország természetföldrajza. - Tankönyvkiadó, Budapest: 1–424.
7. GUTI, G. (1993): Fisheries ecology of the Danube in the Szigetköz floodplain. - Opusc. Zool., Budapest, 26: 67–75.
8. GUTI, G. & KERESZTESSY, K. (1997): Effects of long-term hydrological changes on fish communities in the Middle-Danube. - 32. Konferenz der IAD, Wien, 2: 161–176.
9. HOLČIK, J., BASTL, I., ERTL, M. & VRANOVSKY, M. (1981): Hydrobiology and ichthyology of the Czechoslovak Danube in relation to predicted changes after the construction of the Gabcikovo-Nagymaros River Barrage System. - Práce Lab. Ryb r. Hydrobiol., 3: 19–158.
10. HOLČIK, J., BĂNĂRESCU, P. & EVANS, D. (1989): General introduction to fishes. - In: J. Holčik (ed.) The freshwater fishes of Europe. 1/II. - AULA-Verlag, Wiesbaden: 18–147.
11. IUCN (1995): River corridors in Hungary: A strategy for the conservation of the Danube and its tributaries (1993-1994). - IUCN, Gland Switzerland and Budapest, Hungary: 1–124.
12. KALOCSA, B. & SCHMIDT, A. (1996): Halfajok a Dunában és mellékágaiban Baja környékén. - Bajai Honpolgár, 1996/3: 7.

13. KÁROLYI, Z. (1973): A Duna-völgy vizeinek szabályozása. - In: Ihrig D. (ed.): A magyar vízszabályozás története. - Országos Vízügyi Hivatal, Budapest: 155–248.

14. PÉCSI, M. (1959): A magyarországi Duna-völgy kialakulása és felszínalaktana. - Akadémiai Kiadó, Budapest: 1–346.

15. PEŇÁZ, M., COPPG. H., OLIVIER, J. M. & ROUX, A. L. (1991): Fish reproductive potential of regulated fluvial ecosystems: An application of juvenile fishes as functional describers. - In: M. Peňáz (ed.): Biological monitoring of large rivers, Brno: 93–98.

16. RAKONCZAY, Z. (1987): Kiskunságtól a Sárrétig. A Dél-Alföld természeti értékei. - Mezőgazdasági Kiadó, Budapest, 1–320.

17. ROUX, A.L., *et al.* (1982): Cartographie polythématique appliquée a la gestion écologique des eaux. - CNRS, Lyon: 1-113.

18. SCHIEMER, F. & SPINDLER. T. (1989): Endangered fish species of the Danube River in Austria. - Regulated Rivers, 4: 397–407.

19. SCHIEMER, F., SPINDLER, T., WINTERSBERGER, H., SCHNEIDER, A. & CHOVANEC, A. (1991): Fish fry associations: Important indicators for the ecological status of large rivers. - Verh. Internat. Verein. Limnol. 24: 2497–2500.

20. SCHIEMER, F. & H. WAIDBACHER (1992): Strategies for conservation of a Danubian fish fauna. - In: P. J. Boon, P. Calow, G. Petts (eds.): River conservation and management. - John Wiley & Sons Ltd.: 363–382.

21. UDVARDY, M. (1959): Notes on the ecological concepts of the habitat, biotope and niche. - Ecology, 40: 725-728.

22. WELCOMME, R. L. (1979): Fisheries ecology of floodplain rivers. - Longman Group Ltd., London, 1-297.

23. WELCOMME, R. L. (1983): River basins. - FAO Fisheries Technical Paper, 202: 1–60.

24. WELCOMME, R. L. (1985): River fisheries. - FAO Fisheries Technical Paper, 262: 1–330.