Development of zoobenthos in the Slovak Danube inundation area after the Gabčíkovo Hydropower Structures began operating

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CONCLUSIONS River regulation works and pollution, which the Danube had undergone in the far past, affected the benthos fauna very negatively. Cutting off the side arms, in order to improve conditions for shipping, created conditions for changing the parapotamon side arms to plesiopotamon type with the development of macrophytes and eutrophication. The tendency leading towards habitats similar to drying periodical wetlands is then inevitable. Environmental changes resulted in the fragmentation of the biotopes in the inundation area, and in a retreat of rheophilous, potamophilous and stenotopic forms of macrozoobenthos, these being replaced by rather eurytopic and stagnicolous forms and affecting the environment very negatively.

After putting the hydropower structures into operation in 1992, two changes occurred in the hydrological regime in the Danube: 1) discharge in the old main channel declined, and 2) water levels in the adjacent side arms (supplied again continuously with water) started fluctuating. In the Danube, just above the confluence with the tail water canal (upstream Sap), sedimentation has increased. Furthermore, eutrophication in this part of the Danube has been increasing, and the saprobity has been getting worse. Microzoobenthos and meiozoobenthos, and later also macrozoobenthos, have increased both in quantity and quality. The main increase has appeared in terrestrial microzoobenthos originating from the eroded soils and alluvial sediments during the flood in winter 1992/1993 and partially from the newly created Čunovo Reservoir. A significant decline of water level in the Danube resulted in the formation of communities typical for rotting processes associated with a massive development of bacteria. This development lead to an increase in abundance, as well as diversity, of ciliophores and flagellates. On the littoral parts, a massive dying of benthos was observed. The changes in the hydrological regime caused the original riverbed to differentiate. In the upper part (at Dunajské kriviny), the formerly mobile bottom has partially stabilised. Modified abiotic factors allowed excessive development of algae on the gravel bottom. Proportional composition of trophic guilds has shifted from filtrators towards scrapers (algophagous species). Thus, periphyton has also increased in quantity, and the metabolism of the river has shifted from heterotrophy to autotrophy. The increased amount of food selection has resulted in a significant increase of abundance and biomass of these organisms. In the lower section of the Danube, upstream the confluence with the tail water canal, the changes in the structure of coenoses of benthos were the most significant. After the character of substrate and hydrological regime had changed, the original community of benthos underwent a major destruction. Soon after the damming, the bottom contained almost no benthic animals, atthough the abundance of these has gradually increased. A decline in depth and an increase in transparency allowed scrapers to increase in proportion. The abundance of permanent fauna and chironomids has also increased.

After 1995, short-term fluctuation of water levels occurred in the upper section of the Danube, due to supplying the Hungarian side arm system with water. This caused a large area of the ripal to emerge. An underwater weir was built up in the Danube at Dunakiliti, and as fine sediments started to cover the bottom, theabundance of zoobenthos has declined. However, in the deeper parts of the ripal, benthic fauna remains rich in for both quantity and quality. Since the discharge into the Danube increased in 1995, rheophilous fauna has been developing, and filtrators have started to reappear in greater proportions.

In communities of microzoobenthos and meiozoobenthos, a stabilisation tendency prevailed. In permanently flowing side arms, larvae of rheophilous insects (Ephemeroptera, Trichoptera) appeared. Currently, the patterns of fluctuation in water levels in the side arms with continuously flowing water differ from those before 1993, and this change impacted benthos in the littoral zone. Concerning permanent fauna, the abundance and biomass of most oligochaetes and amphipods has decreased. In contrast, species with short life cycles, e.g. Naididae (oligochaetes) have attained higher abundance. Isolated side arms have also undergone changes, having been shifted from plesiopotamon to paleopotamon type. This change becomes apparent as a strong development of submersed macrophytes in formerly open water and/or gravel bottom. Increasing amounts of organic matter results in an increasing number of shredders. Another reason why species diversity in such types of side arms is so high can be considered the leaking cold ground water. However, these side arms are expected to disappear, as they will dry up and get overgrown by terrestrial vegetation. Such a process can be observed at Istragov, where the former gravel sediments have been covered with silt and sandy sediments. As a result of this kind of development, detritophagous species have increased in abundance, especially from the Tubificidae family (Oligochaeta), whereas the diversity of benthos as a whole has decreased.

Introduction

Zoobenthos plays an irreplacable role in biological processes in the Danube river system. The structure, dynamics and production of zoobenthos reflect the status of a river system, water quality, economical potential and characteristics including fisheries management, water management, agriculture and industry. Zoobenthos also tell us a lot about possible use of the water for recreation.

The community of zoobenthos represents an important part of the environment, which characterises both, the main channel, and the side-arm system. It is a significant functional indicator that allows making conclusions about changes that have occurred, are occuring, and may occur under various conditions in the future.

The groups of zoobenthos also represent the base for trophic relationships in the river ecosystem. Production of zoobenthos strongly affects higher levels in the food webs. As a source of food for numerous vertebrates, zoobenthos also affects the composition of adjacent land ecosystems. Lower systematic groups take an important part in the mineralisation of dissolved organic matters, and thus have a direct impact on the production of vegetation.

Material and methods

Microzoobenthos and meiozoobenthos were collected directly from the littoral zone. Most species were identified *in vivo*, though, for some species, standard fixing and staining methods were used. The material was always examined within 24 hours after the sampling.

The samples taken from the littoral zone were collected from the substrates typical for each locality and put in 200-ml bottles. Apart from that, benthic sampling bottles (200 ml bottles dug in the substrate for one month) were also applied. However, due to the fluctuation of water level, it was possible to use them only once.

The following groups of microzoobenthos and meiozoobenthos were studied: Mastigophora, Amoebina, Ciliophora, Rotifera, Nematoda, Tardigrada and Oligochaeta.

For quantitative evaluation, ten drops of water from each sample were taken using a micro-pipette (10-?l volume). Subsequently, all the Protozoa and microscopic Metazoa present in this volume were counted and the number per 1 ml of sediment was re-calculated.

Macrozoobenthos was collected in intervals of two or three months. Quantitative samples from ripal and littoral gravel were taken using a benthometer (the sampling area was 0,2 to 0,4 m^2), and/or Zabolocký grab (sampling area 0,01 cm^2). Permanent fauna was also collected from the surface of weir stones. In certain groups (Porifera, Bryozoa), the surface area covered was estimated. Semiquantitative samples were taken by a kick-net with the mesh size 0,3 mm, each sampling lasted about 10 minutes. Quantitative sampling of pre-imago stages of mosquitoes followed standard methods with the use of a wooden frame 25 x 25 cm. Imagoes were collected by an entomological net, after tapping on vegetation. Material was preserved in solution of 4 %formaldehyde, and processed subsequently at magnification 10 x. Organisms were identified to species level, when possible, and their abundance was calculated. For semiquantitative samples, a six-degree scale (1-6) was used. To identify oligochaetes and chironomid larvae, the material was mounted on slides.

Characteristics of changes in certain ecological parameters after the Gabčíkovo Hydropower Structures began operating

During the construction of the Gabčíkovo hydropower structures, several changes with an impact on the hydrofauna of the River Danube occurred.

The discharge regime in the old main channel of the Danube underwent two changes (in 1992 and 1995, respectively). In the Gabčíkovo-Medveďov section the discharge rate varied following the discharge rate at Bratislava, and partially depended also on the operation of turbines (water level fluctuation ca 0,5 m). In the section situated above the confluence with the tail water bypass canal, backwater impoundment occurred (slightly increased since 1995, after "Agreement"), though, in general, the water level slightly declined. Consequently, sedimentation of silt increased in this area, just above the confluence. After 1995, short-term fluctuation of water level (0.5 to 0.75 m) occurred in the upper section of the Danube (Dunajské kriviny - Bodíky). This fluctuation repeated in 5 to 10 days' intervals, following the regulated inlet of water to Hungarian side-arm system.

After October 1992, the water level declined considerably in the Slovak side-arm system. This decline was, however, eliminated in May 1993, when water from the bypass canal started to feed the side-arm system through the intake structure at Dobrohošť. Since then, the fluctuation in water level became relatively low, with the exception of controlled flooding.

The temperature regime of the Danube (the Dobrohošť-Bodíky section) has also changed. Winter temperatures of water do not drop under 3.5 °C, which is due to discharge reduction and water seepage from the reservoir into the aquifer and further into the river bed. On the other hand, the increase of summer maximum water temperatures by 2 °C in the Danube between Bratislava and Medveďov, which was found before the damming, persists.

As a consequence of increased assimilation activities of phytoplankton, higher pH values in the vegetation zone have been recorded.

Since 1997, the concentration of insoluble matters in the left-sided system of arms has been decreasing compared to that in the Danube, currently attaining 5 to 10 $mg.l^{-1}$. The total amount of phosphorus in the old main channel of the Danube has been decreasing since 1992, approximately from 0,15 to 0,1 $mg.l^{-1}$. This confirms a general reduction of phosphorus in the Danube and reducted production of phytoplankton.

The concentration of chlorophyll in the Bratislava-Medveďov section has been continuously increasing. However, after the damming, the increase rate was slightly reduced. In 1995-1997, the saprobity index (macrozoobenthos) in the Danube above Bratislava attained values from 1,8 to 2,5 (mean 2,35), being slightly lower in the side-arm system (mean 2,15; 1,9 to 2,5). In the old main channel of the Danube it varies from 1,9 to 2,7. On the other hand, in the stretch at Medveďov, the saprobity index has improved and has stabilised within the interval 1,8 to 2,2.

Hydrological conditions, such as discharge in the side-arm system, have also changed. In those main arms, that became permanently flowing in 1993, the velocity of current increased, the relationship between the drift, sedimentation and erosion changed, the water level rose and the width of the arms increased. The banks became longer and less straight, new pools with stagnant water appeared in depressions, the old main channel of the Danube started meandering within the original river banks, and the weirs provided more variability in water currents.

In contrast, no changes in the oxygen regime of the Danube and the side arms with flowing water have been recorded. Changes have been recorded in river branches with previously stagnant or periodically flowing water.

Results and discussion

Communities of zoobenthos in the inundation area in pre-dam conditions

Microzoobenthos and meiozoobenthos

The evaluation of microzoobenthos communities is based mostly on the communities of ciliates (Ciliophora), which represent the major group of microzoobenthos with a high diversity of species. Other groups of both microzoobenthos and meiozoobenthos were not examined in detail, since investigation of these groups requires special methods of sampling and processing.

In general, the major impact of damming appeared as a significant increase of species diversity after 1993 (**Fig. 1**).

Macrozoobenthos

In the presented analysis, only autochthonous species of macrozoobenthos are considered; allochthone (which drift from tributaries) species have been excluded. The Danube and its inundation area has been suffering from strong human pressure for more than a century, which has already resulted in the extinction of 90 percent of the Danubian stoneflies (**Fig. 2**), more than 50 percent of the mayflies, and more than 30 percent of the caddisflies [1, 2, 22, 52, 53, 40, 29, 4, 43, 39, 27, 38, 25, 23, 10, 5, 6, 18, 19, 47, 37, 46, 48].

Technical measures taken to reduce the risk of floods and to improve shipping conditions were first concentrated on deepening the river bottom, bank regulations, elimination of riparian woodland and cutting off the side-arms [11]. This resulted in important increase in current velocity in the main channel, an intensive erosion of the river bottom, and reduction of current velocity in flowing arms, originally of the parapotamon type. Thus, the original heterogeneity of mesohabitats in the main channel of the Danube declined dramatically. Consequently, the conditions for the migration of larvae deteriorated, as well as for the reproduction of aquatic insects and other aquatic organisms [26].

Cutting off the connections between the side-arms and the main channel, together with the decline of water levels in the main channel, prepared conditions for: 1) an extension of plesiopotamon type side-arms, which can be characterised by a development of macrophytes; 2) eutrophication; and 3) a continuous modification of aquatic habitats towards periodically drying wetlands. Following that, rheophilous, potamophilous and highly specialised forms of macrozoobenthos retreated, being replaced by more eurytopic species. The gradually proceeding disconnection of the side-arm network in the inundation area also acted negatively. The benthos communities were negatively affected by the pollution of the Danube, which was increasing after World War II and reached its maximum in the seventies.

Communities of zoobenthos in the main channel of the Danube in pre-dam conditions

Micro-meiozoobenthos

There have been several papers published on micro-meiozoobenthos of the Danube [13, 14]. The highest number of micro-meiozoobenthos organisms could be found in periphyton, which contained mainly Amoebina, crawling ciliophores and sessile rotifers.

Before the damming a poor species composition and a low abundance of ciliophores were found in all the localities. Eurytopic (bacterivorous) species, such as *Cyclidium glaucoma, Aspidisca cicada, A. lynceus, Glaucoma scintilans*, etc., predominated. Plankton species were relatively rare; the other groups of microzoobenthos and meiozoobenthos were found just sporadically. The main factors for this were: 1) a lack of suitable substrates, 2) the high current velocity, 3) sedimentation of mud, 4) the turbulent drifts, and 5) the fluctuation of water levels. After flooding, inactivated specimens were found repeatedly, which was probably caused by the presence of toxic matters.

In this period, relatively rare species, such as *Ophryoglena flava, Tintinnopsis cilindrata, Stegochilum fusiforme, Frontonia anbigua, Strombidium turbo,* also appeared in individual localities.

Macrozoobenthos

The permanent fauna of macrozoobenthos was qualitatively uniform throughout the entire studied stretch of the Danube. The most abundant species - *Eunapius fragilis* (Porifera), *Dendrocoellum lacteum* (Turbellaria), *Dina punctata* (Hirudinea), *Ancylus fluviatilis, Lymnaea ovata, Bithynia tentaculata* (all Gastropods), *Dreissena polymorpha, Sphaerium corneum* (both Bivalvia) - were found at all three sampling points. Oligochaeta were represented by Naididae species and *Stylodrilus heringianus* (Lumbriculidae), though tubificid species were rare. Several other species, such as *Hypania invalida* (Polychaeta) and *Dikerogammarus haemobaphes* and *Corophium curvispinum* (Amphipoda) were also important. Absolutely most abundant at all profiles were the following species: *Ancylus fluviatilis* (2000 to 3000 specimens per m^{-2}), *Lymnaea ovata*, *Dreissena polymorpha* (400 to 600 specimens per m^{-2}) and *Dikerogammarus villosus* (300 to 400 specimens per m^{-2}). Certain differences were found at the profile of Kľúčovec, which is situated downstream of the change of the slope of the Danube. This was the only stretch where *Lithoglyphus naticoides* (Gastropoda) was found, with the most upstream locality of its occurrence being Sap (Palkovičovo). Before damming, no extinction nor appearance of a new species were recorded.

In the taxocoenoses of temporal fauna of the Danube (**Fig. 3**), *Baetis fuscatus, Heptagenia sulphurea, Caenis pseudorivulorum* (Ephemeroptera), *Hydropsyche contubernalis, H. bulgaroromanum*, *Psychomyia pusilla, Brachycentrus subnubilus, Ceracklea dissimilis* (Trichoptera; **Fig. 4**), predominated before 1992. Compared to the situation in the eighties [25,26], several species of mayflies (*Heptagenia coerulans*, the genus *Ecdyonurus*) were missing, other species, such as *Baetis vardarensis, Heptagenia flava*, *Ephemerella ignita* and *Potamanthus luteus,* were found to be very rare. Concerning quantity, the richest fauna was found below the mouth of the side-arms at Gabčíkovo (**Fig. 5**), especially on rocky substrate, where the fauna was 3 to 5 times more abundant than that on gravel terraces. At the rocky substrate, *H. bulgaroromanum* predominated, and at the gravel substrate *H. contubernalis*. In general, filtrators (Hydropsychidae, *Brachycentrus*) prevailed.

Impact of damming in 1993-1995

Microzoobenthos and meiozoobenthos

The damming of the Danube lead to dramatic changes in the communities of macrozoobenthos and microzoobenthos. First of all, the number of terrestrial species (the genus *Colpoda*) increased, as a result of drift from formerly terrestrial habitats. A decline in the discharge after damming, a major drop in the water level, and the filling process of the Čunovo Reservoir, all resulted in the formation of communities associated with rotting processes. Therefore, bacteria developed rapidly, and subsequently both the abundance and diversity of ciliophores and flagellates increased significantly. Consequently, the character of biotopes also changed. Formerly fast flowing currents slowed down, and, in some localities, turned to isolated stagnant waters with typical lenitic communities. The processes, which the entire studied section of the Danube underwent, lead to the formation of communities typical for side arms of parapotamal type. Both the species diversity and the abundance of flagellates and ciliophores increased. These processes were most apparent in the section at Dunajské kriviny (**Fig. 6**).

On the other hand, the section above the dam (locality of Kopáč) has not changed so much, and the diversity and abundance of microzoobenthos and meiozoobenthos have maintained the levels typical for the previous main channel of the Danube. During the study period, several rare species were found, some of them having been recorded in the territory of Slovakia for the first time (*Stentor multiformis*, *Balantidioides bivacuolata*). In the main channel, species diversity and abundance of Mastigophora have increased slightly, due to a decline in current velocity and increased sedimentation. The number of terrestrial species (*Colpoda cucullus*, *C. inflata*, *Leptopharynx costatus*, *Colpoda steinii*) has apparently increased, which indicates that the currents drift a lot of sediments and that settling of sediments on the bottom occurs.

Macrozoobenthos

After the discharge and water level in the main channel of the Danube declined, after damming the Danube, a massive dying of macrozoobenthos fauna was observed. In 1993, an increased abundance of gastropods (**Fig. 7**) was recorded in the Dunajské kriviny - Gabčíkovo section. In those species that had already predominated before (*Ancylus fluviatilis* , *Lymnaea ovata* and *Bithynia tentaculata*), the increase in abundance was the highest. The following species were recorded as new species for Slovak fauna: *Nais christinae* (Naididae), *Limnodrilus hoffmeisteri*, *Potamothrix vejdovkyi* (Tubificidae), *Gammarus roeseli* and *Chaetogammarus tenellus* (Amphipoda). On the other hand, the abundance of *Dendrocoelum lacteum* (Turbellaria) and *Dikerogammarus haemobaphes* (Crustacea) decreased. Once the Gabčíkovo Power Structures started to operate, species composition of benthic fauna in the Danube at Istragov changed dramatically: species diversity has declined (**Fig. 8**), the originally predominant amphipods have disappeared, and new species of oligochaetes have appeared. The later are associated with muddy substrates, (e.g. *Limnodrilus* species), and their abundance has been increasing gradually. Analyses of biological and oxygen parameters (O_2, BOD_5, COD) revealed that water quality in this stretch was worse than that at Dunajské kriviny. New stagnophilous species, such as *Asellus aquaticus* and *Limnomysis benedeni* (Crustacea) appeared in this section.

In 1994, the changes in fauna became more intensive, with the tendency to increase the number of species. At Gabčíkovo, *Lithoglyphus naticoides* appeared; *Physella acuta* (a new species of Gastropoda) spread along the entire shoreline of the River Danube from Dunajské kriviny to Gabčíkovo. Apart from that, a formerly very rare species *Potamopyrgus antipodarum* (Gastropoda) increased in number. After the damming, important changes occurred in the former main channel of the Danube. Changes in the hydrological regime resulted in differentiation of the former continuous riverbed into two different stretches. In the upper stretch, which includes Dunajské kriviny, the originally movable bed stabilised, as current velocity decreased. As a result of such abiotic changes, a rich cover of algae (*Cladophora* sp.) formed on the firm gravel bottom. The highest increase in abundance of gastropods was found at Dunajské kriviny (**Fig. 7**). In 1994 it attained more than 25000 specimens per m^2 , the abundance of *Lymnaea ovata* exceeding 20000 specimens per m^2 . *Ancylus fluviatilis* and *Bythinia tentaculata* also increased in abundance. As in temporary fauna, the composition of trophic guilds shifted from filtrators to scrapers (algophagous), which reflected the large increase of periphyton in the river and the modification in the river metabolism from heterotrophy to autotrophy. Both the abundance and biomass of Pontocaspian crustaceans (*Jaera sarsi*, *Corophium curvispinum* and *Dikerogammarus villosus*) also increased significantly. Concerning oligochaetes, tubificid species increased in numbers (**Fig. 8 and 9**). Therefore, scrapers such as *Dikerogammarus haemobaphes, Dikerogammarus villosus, Corophium curvispinnum* (Amphipoda), as well as eaters of filamentous algae, as *Jaera sarsi* (Isopoda), and species of Naididae family that live on algae, became predominate. Fine sediments deposited created suitable habitats for tubificids (*Limnodrilus* spp., *Potamothrix* sp.), which prefer muddy substrates. As a result of increased amounts of available food, both the biomass and abundance of these species increased considerably. At Istragov, formerly predominant amphipods disappeared, whereas new or formerly rare species of oligochaetes (such as *Limnodrilus* spp.) preferring muddy substrates, appeared. Moreover, the abundance of these new species was gradually increasing from 350 specimens per m^2 to 40000 specimens per m^2 (**Fig. 10**). Major changes in the structure of benthic biocoenoses occurred in the lower stretch (at Istragov), which was affected by backwater impoundment. Complete changes in substrate characteristics and hydrological regime (an extreme decline in discharge and current velocity) resulted in the destruction of the original benthos community. Therefore, early after the damming, almost no benthos were present at the bottom. Newly created benthos communities were gradually increasing in abundance only later, though they still consisted mainly of oligochaetes, which were not authochtonous for this type of habitat (*Limnodrilus claparedanus, L. hoffmeisteri*).

However, at Kľúčovec (below the mouth of the bypass canal), no such increase in abundance occurred, and the structure of permanent fauna did not exceed its variability known from previous years.

After 1993, significant qualitative and quantitative decreases in the abundance of mayflies occurred in the old main channel of the Danube (**Fig. 11 and 5**, respectively). Since then, only two eurytopic species - *Baetis fuscatus* and *Caenis luctuosa* - have been found there regularly. Another such species - *C. macrura* - has been found only rarely. The former two species replaced *Caenis pseudorivulorum* in the entire stretch from the deviation of the Danube at Dobrohošť to the mouth of the bypass canal at Sap. Like the mayflies, the fauna of the caddisflies was also represented only two genera - *Hydropsyche* and *Psychomyia* - the same as in large regulated European rivers (e.g. Rhône and Rhine, [3]). The number of algae eating species (*Psychomyia*) increased substantially (**Fig. 12**), whereas the number of filtrators (*Hydropsyche*) declined. *Hydropsyche contubernalis* and *H. bulgaroromanum* were replaced by *H. pellucidula* and *H. modesta* (**Fig. 4**). Later, *Rhyacophila dorsalis* appeared, too. The latter species are typical for smaller rivers, which reflects the massive reduction of the former main channel of the Danube below Dobrohošť. In chironomids, the number of filtrators (Tanytarsinae) decreased, whereas the number of scrapers (*Cricotopus*) increased (**Tab. 1**). Apart from that, the predatory genus *Tanypus* disappeared. This indicates that the river continuum has shifted upstream. Shallower and more transparent water allowed scrapers to attain higher abundance.

Stabilisation of the bottom, together with better trophic conditions, allowed this significant quantitative increase in the abundance of mayflies and caddisflies (especially that of the latter) in 1994 and in the first half of 1995 (**Fig. 4**).

Under the influence of damming, the number of chironomid species recorded at Dunajské Kriviny increased considerably (**Tab. 1**). Six species were recorded in 1990-1992, whereas during 1993-1995, the number of chironomid species increased to 18. This change was associated with changes in the hydrological regime. A decrease in discharge and current velocity led to a stabilisation of the bottom, allowing arrivals of new species that had formerly been limited by extreme lotic conditions. The abundance of the originally predominating species *Chironomus* gr. *fluviatilis* decreased slightly, whereas the abundance of several, originally somewhat rare species (*Microtendipes* gr. *chloris, Chironomus* gr. *reductus* and *Chironomus* sp.) increased considerably. Among the species that have kept their stability in distribution and abundance are *Cryptochironomus* gr. *defectus* and *Dicrotendipes nervosus.*

The considerable decline of current velocity in the Danube above the confluence with the tail-water canal resulted in formation of a more than 0,5 m thick layer of sandy-and muddy sediments. Apart from some chironomids, such as *Chironomus* gr. *fluviatilis*, *Chironomus* gr. *reductus, Cryptochironomus* gr. *reductus, Cryptochironomus* gr. *defectus, Endochironomus* sp., *Polypedilum* gr. *nubeculosum*), and the stagnicolous psammophilous *Ephemera vulgata* (Ephemeroptera), no other aquatic insects were found on this substrate.

Impact of changes in the hydrological regime after 1995

Microzoobenthos and meiozoobenthos

After the damming, communities with a high diversity and abundance have stabilised. The composition of these communities has tended to approach that of side arms of the parapotamon type. However, species diversity declines gradually from Dobrohošť to Istragov (**Fig. 6**), due to changes in the bottom substrate. Higher diversity was also found at Kľúčovec (see also changes in abundance at Dunajské Kriviny, **Fig. 13**). Before the damming, the abundance of ciliophores was low throughout the year (200 specimens per 1 ml), and the impact of damming became apparent only after 1993, when the abundance increased to 1400 specimens per 1 ml. This tendency continued in subsequent years, due to more stabilised river bottom.

Macrozoobenthos

In the second half of 1995, a considerable decline in the abundance of permanent macrozoobenthos fauna was recorded in the Danube (from Dunajské Kriviny to Gabčíkovo). These changes were connected with the construction of the underwater weir at Dunakiliti (upstream of the intake structure at Dobrohošť), which caused strong turbidity. Subsequently, fine silt covered the bottom. In 1996, fluctuations of water level caused the ripal to be flooded and drained repeatedly, following the water supply of the Hungarian side-arm system. Since the flooding always took a short period of time, the littoral benthic fauna was relatively poor. In the upper stretch, which includes Dunajské Kriviny, a rich algae (*Cladophora* sp.) cover developed on the gravel bottom. In August 1995, only five species were recorded in this stretch, *Lymnaea ovata* attaining an abundance of only 1102 specimens per 1 m^2 . In autumn the permanent fauna appeared to have recovered: ten species were recorded. *Ancylus fluviatilis* predominated, though it attained an abundance of only 1900 specimens per m^2 , compared to more than 3000 specimens per 1 m^2 in 1994. In 1996, such species as *Plumatella repens* (Porifera), *Fredericella sultana* (Bryozoa), *Hypania invalida* (Polychaeta), *Potamopyrgus antipodarum, Physella acuta* (Gastropoda), *Sphaerium corneum* (Bivalvia) and *Dikerogammarus haemobaphes* (Amphipoda) were absent in the upper part of the Danube (at Dunajské Kriviny). Later, a significant increase in abundance of *Ancylus fluviatilis* and *Lymnaea ovata* (to 6000 specimens per 1 m^2 and 3000 specimens per 1 m^2 , respectively) was recorded. In contrast, the abundance of *Bythinia tentaculata* declined significantly (below 100 specimens per 1 m^2). However, in deeper parts of ripal, which were not affected by water fluctuation (never emerging), the benthic fauna remained rich, both qualitatively and quantitatively. Thus, in deeper parts of ripal, scrapers as *Dikerogammarus* spp., *Corophium curvispinum* (Amphipoda), eaters of filamentous algae *Jaera sarsi* (Isopoda), and Naididae, living in dense algae, belonged among the predominant species. In general, however, the bottom in this upper stretch of the Danube has been inhabited by rheophilous fauna. At Gabčíkovo, no significant reduction in the number of species occurred, though a decline in abundance has been recorded.

In 1997, most of the species of permanent fauna, which had disappeared from the upper stretch, came back, and their abundance increased. In the Danube at Gabčíkovo, the endangered gastropod *Esperiana esperi* was restituted successfully. The lower stretch, which has been affected by backwater impoundment, suffers water level fluctuation depending on the operation of turbines. Both the amounts and granulometry of sediments varies according to the current velocity. They either drift away (at higher current velocities), or settle down (at lower current velocities). In spring and summer, when the discharge in the Danube is higher, erosion prevails. During autumn and winter, however, the discharge decreases, and sedimentation prevails. In this stretch, detritophagous oligochaetes (Tubificidae) predominate. In summer, a high abundance of *Hypania invalida* (Polychaeta) has been recorded. In the Danube at Sporná sihoť, the abundance of permanent fauna remains quantitatively very poor (being much lower than in the upper stretches), due to fluctuations of water level below the Power Station.

In the second half of 1995, after the discharge had increased significantly, the abundance of mayflies and caddisflies declined considerably. This decline was accompanied by a gradual return of filtrators (both quantitative and qualitative; **Fig. 4 and 12**). However, in the upper stretch of the Danube, no changes were recorded in mayflies (**Fig. 3**). In contrast, the more tolerant forms of mayflies, such as *Heptagenia sulphurea, Potamanthus luteus,* as well as the stonefly *Leuctra fusca*, reappeared in the Danube at Medveďov.

Changes in species composition, which occurred after the spring 1995, were associated with changes in the hydrological regime (increase of discharge according the "Agreement"). These changes allowed several new species, formerly limited by original lotic conditions, to settle down. In 1995, 12 species of chironomids (**Tab. 1**) were found in the upper stretch of the Danube (at Dunajské kriviny), which represented an increase by more than two-times. The proportion of rheophilous taxa (*Chironomus* gr. *fluviatilis*), filtrators of subfamily Tanytarsinae, and the genus *Glyptotendipes* (eater of aquatic and riparian macrophytes) increased. On the other hand, the proportion of more stagnicolous representatives of the genus *Chironomus* and *Microtendipes*, decreased. In 1997, eight species of midges were found at this locality, compared to 17 species in 1996. The reason for such a significant decrease was the fluctuation of water levels. The sampling sites were dry in winter.

In the impounded section of the Danube at Istragov, *Microtendipes chloris* and *Dicrotendipes nervosus* were the most abundant species during this period. Larvae of the genus *Dicrotendipes* inhabit mainly littoral sediments in stagnant waters; larvae of *Microtendipes* live in the littoral and sublittoral zone of larger water bodies with stagnant water. After the discharge increased in 1995, filtrators from the subfamily Tanytarsinae also started to appear in increased numbers.

Using Buffaggni's analysis it was found that the benthos communities deteriorated significantly after 1993. Although since 1995 the situation appears to have been improving, however, it is not comparable with the situation at places which have not been affected by the Gabčíkovo structures, e.g. localities at Chľaba (downstream from Štúrovo - Estergom) [12].

Stössel and Fruget [44, 16, 17] demonstrated the impact of regulations on the structure of macrozoobenthos in large European rivers (Rhine, Rhône). The main impact was found in the homogenisation of communities and violation of longitudinal zoning. Such communities consisted mostly of permanent fauna (Oligochaeta, Mollusca, Crustacea) and chironomids, which suppressed the other groups of temporary fauna. In this respect, an analogy between these rivers and the Danube after 1992 can be observed. For example, in temporal fauna of the lower Rhine , such species as *Baetis fuscatus, Caenis luctuosa* (Ephemeroptera), *Psychomyia pusilla, Hydropsyche modesta* and *Ceraclea dissimilis* (Trichoptera) predominated [16]. However, even after the water quality in the Rhine improved, no fundamental changes in the structure of macrozoobenthos occurred [51]. The reason for this phenomenon is similar to that from the Danube: a decline in the geomorphologic diversity of the river, including its connections with the side-arm system, has resulted in a significant decrease in the heterogeneity of hydrosystems [17], as well as violating the functional integrity of the connection between the river and its side-arm system. For example, despite having no significant deterioration of chemical quality recorded in the water above the Gabčíkovo structures (downstream the Slovnaft oil refinery), hydrozoocoenoses deteriorated both in quantity and quality [12]. This can be illustrated using the example of mayflies: the number of species in this taxocoenosis decreased to three, which is equal to that found in our study.

Perhaps the most important macrozoobenthos development pattern in the sections examined here is that, although the quantitative parameters have been improving, the qualitative ones have not. Also, shifts in both, permanent and temporary fauna can be observed. If the temporary fauna of the Danube formed about 30 percent of macrozoobenthos (annual average) before the damming, by 1998 this value had dropped down below 10 percent, which is similar to the natural situation in the side-arm system.

Communities of zoobenthos in the side-arm system and temporal waters before the damming

Parapotamon

Microzoobenthos and meiozoobenthos

In Slovakia, microzoobenthos and meiozoobenthos were studied mainly in the side arms, e.g. at Čičovské mŕtve rameno [33, 50,], or Karloveské rameno [45].

However, concerning the structure of the taxonomic groups studied, it is not possible to assess the side arms as a whole. Separate communities of each group developed differently, at times, in accord with their character and changing environmental conditions.

Before the damming, the common pattern for all the examined side arms was a long-term decline in water levels, which resulted in the modification of formerly permanent parapotamon to temporary parapotamon type side arms (water in these side-arms was flowing only during higher water levels in the Danube). Water level was also low at the locality Kráľovská lúka, which was rich in communities typical for stagnant waters. These communities were separated from the main channel of the Danube, having thus a different character.

Typical side arms with stagnant water, though flooded irregularly, were characterised by a wide range of species and a high abundance of all groups of macrozoobenthos (Ciliophora, Mastigophora, Heliozoea, Amoebina, etc.).

Macrozoobenthos

Species composition of parapotamal type permanent fauna in the littoral zone was originally equal to that in the main channel of the Danube (e.g. *Corophium curvispinnum, Dikerogammarus haemobaphes, Hypania invalida,* Naididae, *Stylodrilus heringianus*). Tubificid worms of the genera *Psammoryctides* and *Potamothrix* also occurred there. *Dugesia tigrina* (Turbellaria) and *Dreissena polymorpha* (Bivalvia) were also highly abundant, covering 50 to 95 percent of the surface of stones. *Erpobdella octoculata* (Hirudinea), as well as *Viviparus acerosus, Bithynia tentaculata* and *Lymnaea peregra* (Gastropoda) were found less often (**Tab. 2**).

Temporary fauna in the side arms of parapotamal type was very poor (**Fig. 4**), being represented only by *Cloeon dipterum*, *Caenis horarria, C. luctuosa* (Ephemeroptera) and the genera *Ecnomus, Cyrnus, Anabolia, Athripsodes* (Trichoptera). Concerning dragonflies, *Calopteryx splendens* and *Lestes viridis* predominated [31]. The former is a rheophilous species, whereas the latter occurs in both stagnant and slowly flowing waters with dense shore vegetation. The community of midges was characterised by species preferring flowing waters (*Cricotopus bicintus, Tanypus kraatzi*) as well as by those preferring slower or stagnant waters (*Dicrotentipes* spp., *Polypedilum* spp.).

Plesiopotamal

Microzoobenthos and meiozoobenthos

Long-term stable communities were typical mainly for the localities Kráľovská lúka and Sporná sihoť, which could be considered relicts of the old side-arm system of the Danube. However, during the hot summer, water at Kráľovská lúka periodically overheated (due to shallow water and a decline of water level), which resulted in changes of structure of the communities. This especially concerned ciliophores, some species of which proliferated in mass numbers (e.g. *Coleps nolandi*).

Macrozoobenthos

In the littoral zone of plesiopotamon type side arms, the bottom was either gravel-sandy (Kráľovská lúka) or muddy. Species composition of permanent fauna was more diverse on the gravel-sandy bottom, which contained not only tubificid worms but also naidid worms feeding on algae. On the other hand, in muddy substrate, tubificid species and/or amphibiotic species of Enchytraeidae family and *Eiseniella tetraedra* predominated. Even the other groups of macrozoobenthos were not rich for species, though gastropods predominated (14 species). The abundance of most of the species was low, only *Asellus aquatics* (Crustacea) was abundant in 1992. Temporary fauna was represented mainly with stagnophilous dragonflies *Sympetrum flaveolum, Lestes barbatus*, *Cordulia aenea*, though a semi-rheophilous *Platycnemis pennipes* was also found (Majzlan 1992). The community of chironomids was poor in species composition. Pelophilous *Cryptochironomus defectus* and *Polypedilum nubeculosum* predominated.

Impact of the damming in 1993-1995

Parapotamon type side arms supplied with water

This group, of the localities monitored, includes two side arms: Bodícka brána and Žofín. The former is one of the main side arms, and as such it has become of the parapotamon type. In this kind of side arm, fluctuation of discharge is simulated by discharge variability in the old main channel of the Danube. Permanent flow in the medial part of these side arms allows the existence of rheophilous fauna. The littoral zone emerges frequently, which results in changes of its fauna.

Microzoobenthos and meiozoobenthos

Once the side-arm system was supplied with water, species diversity at Bodícka brána has declined. Soon after these environmental changes, the communities were characterised by unstable species composition. For a short period, several rare species, such as *Glaucoma myriophylli, Plagiocampa metabolica, Askenasia volvox*, and *Monodinium balbiani,* appeared.

Macrozoobenthos

Before the damming, the permanent fauna of gravel-sandy littoral zone was rich in both quality and quantity. However, in 1992-1993, when this side arm dried up completely, tubificid worms (Oligochaeta), and *Hypania invalida* (Polychaeta) disappeared. Oligochaetes were represented only by Naididae family living in periphyton and able to re-colonise rapidly, or by several amphibiotic species. Re-colonisation of other groups of permanent fauna was supported by drift. At the beginning, the abundance and biomass of each group were low, however, the last sampling revealed that both of these parameters increased. Re-colonisation was relatively fast; during two months biodiversity increased by almost two times. In 1994, fluctuations of water levels in this side-arm affected the benthic fauna in the littoral zone (**Fig. 15**). The abundance of Amphipoda and Mysidacea decreased considerably. In the spring sample, oligochaetes of the Naididae family predominated, as in the main channel of the Danube. In 1995, amphibiotic, mobile species (Amphipoda) and Naididae, with a short life cycle, predominated. In the autumn, diversity increased, compared to spring.

The permanent fauna of big littoral stones (used for water flow regulation purposes) was developing in the following way: at the beginning, *Dugesia tigrina,* three leech species and *Viviparus acerosus* (Gastropoda) disappeared, the abundance of *Dugesia polychroa, Erpobdella octoculata*, *Dreissena polymorpha* and *Bithynia tentaculata* decreased. On the other hand, an increase in abundance was recorded in *Lymnaea stagnalis, Physella acuta* and, especially, in *Gyraulus albus*, probably due to drift from upper parts of the side-arm system, which had been originally of the plesiopotamon type. In 1994, lotic conditions resulted in absence of *Erpobdella octoculata*. The abundance of several, mostly stagnicolous gastropods (which had been highly abundant in 1993), such as *Lymanea stagnalis, L. peregra, L. auricularia, Physella acuta,* and *Gyraulus albus* decreased. In contrast, the abundance of Turbellaria, as well as *Bithynia tentaculata* (Gastropoda) increased, and the populations of sedentary bivalve *Dreissena polymorpha* recovered. In 1995, gastropods *Anisus vortex* and *Bithynia leachi,* bryozoans *Fredericella sultana* and *Plumatella emarginata* appeared. Interestingly, the former two species are stagnicolous, whereas the latter two rather rheophilous. An unexpected increase in the quantity of both turbellarian species, *Dreissena polymorpha* (very significant) and *Cristadella mucedo* (Bryozoa) was also recorded.

In temporary fauna, several rheophilous species appeared (**Fig. 11**). In 1993, "pioneer" species of dragonflies - *Anax imperator* and *Libellula quadrimaculata* - were recorded. In 1994-1995, the locality contained both rheophilous (*Calopteryx splendens, Platycnemis pennipes*) and stagnicolous species (*Enallagma cyathigerum*, *Coenagrion puella*). However, after 1995, no stagnicolous species were recorded, whereas the number of rheophilous species increased. Colonisation of the locality with new species continued (especially with species of the genus *Sympetrum*, which appeared at all the localities examined). During 1993-1997, the proportion of stagnophilous species was decreasing continuously, whereas that of rheophilous species was increasing. Species composition in chironomids also changed, compared to that of 1992. The following new species appeared: *Potthastia longimana, Paracladius conversus, Endochironomus* gr. *signaticornis, Endochironomus* sp., *Glyptotendipes* sp., *Polypedilum convictum* and *Microspectra junci.* On the other hand, formerly present *Macrolepia nebulosa, Chironomus* gr. *fluviatilis, C.* gr. *salinarius, Dicrotendipes* sp., *Paratendipes intermedius*, *Stictochironomus* sp.*, Paratanytarsus* gr. *lauterborni* and *Tanytarsus* sp., were not recorded. In 1994, a massive arrival of the phytophilous species of the genus *Glyptotendipes,* as well as of *Polypedilum exectum,* continued. These species found good conditions in dense algae growing on the gravel substrate, and have become the most abundant. In 1995, the hydrological regime changed repeatedly. In spring, when more water entered the side-arm system, rheophilous *Cricotopus bicintus* appeared, whereas in autumn (less water in the side-arm system), species as *Microtendipes chloris, Glyptotendipes gripekoveni* and *Chironomus* gr. *thumi* indicated that the hydrological regime approached conditions in stagnant waters.

Another type of side arm is that at the locality of Žofín. In this type, hydrological conditions improved. This formerly disappearing remnant of a side arm became slightly flowing, due to constructions. Monitoring of this locality began in summer, 1995. The species composition of permanent fauna was poor in summer. However, in autumn it improved (**Fig. 17**). This was probably caused by fluctuation of water level, which also resulted in high abundance of amphibiotic species of the family Enchytraeidae. In temporary fauna of macrozoobenthos, the diversity of caddisflies increased. Under new lotic conditions of another locality at Žofín (original side arm of plesiopotamon type), typically stagnicolous *Caenis horaria* was gradually replaced by *C. luctuosa.* A more regular occurrence of such species as *Baetis fuscatus, Caenis luctuosa* (Ephemeroptera), *Athripsodes cinereus, A. albifrons, Oecetis furva* and the genus *Anabolia* (Trichoptera) indicates that the side arms, formerly of plesiopotamon type, have been permanently saturated with both superficial and ground water. In contrast, typically stagnicolous taxa, as *Caenis simile* (Ephemeroptera), genera *Cyrnus* and *Oligotrichia*, as well as *Mystacides azurea* (Trichoptera), have been disappearing. The community of chironomids was found to be relatively rich int the area with slowly flowing water. In the area monitored, species preferring slowly flowing to stagnant waters *(Endochironomus albipennis, Microtendipes chloris, Polypedilum convictum*) occurred (**Fig. 16**).

Parapotamon type side arms not supplied with water

In the area around Istragov, in which the water management has not been resolved yet, significant changes (similar to those in the old main channel of the Danube) in the structure of aquatic fauna occurred. In the side arm at Istragov, which had formerly been flowing and had not contained macrophytes, submerged macro-vegetation started to appear sporadically. This kind of development has been caused by the fact that water enters this side arm only from the lower end and not from the upper one. Therefore, lotic conditions, which kept the side arm without vegetation, turned to lenitic conditions. Muddy-to-sandy sediments and silt with organic remnants covered the original gravel bottom.

Microbenthos and meiobenthos

The community of microbenthos and meiobenthos is characterised by typical representatives of sapropel and muddy substrate, which prevails all over the locality. Less common species, as *Strombidium turbo*, *Oxytricha chlorelligera* and *Histriculus histrio,* also sporadically appeared.

Macrozoobenthos

Representatives of permanent fauna, such as tubificid oligochaetes (*Limnodrilus* spp.) predominated in this side arm, attaining both a high abundance and biomass (**Fig. 15**).

Temporary fauna was represented mainly by chironomid larvae. In 1994 and 1995, 11 and 10 species were found, respectively. Species of the genus *Glyptotendipes, Chironomus* gr. *fluviatilis, Procladius* sp., *Cladotatytaurus* gr. *mancus* were the most abundant. However, in 1995, the abundance of these species declined dramatically from several hundreds of individuals per m^2 to a few individuals per m^2 . Species of the genus *Glyptotendipes* disappeared completely, and the genus *Chironomus* became very rare. *Cricotopus* sp., *Procladius* sp. and *Cladotanytarsus mancus* occurred in spring, *Cryptochironomus defectus* and *Chironomus* gr. *semireductus* were also present. Larvae of dragonflies also decreased in a number of species.

Isolated stagnant side arms in the area saturated with water

The side arms, formerly having been situated in the inundation area, and flooded during floods, but currently disconnected from the side arm system (e.g. the side arm at Kráľovská lúka), have been undergoing significant changes. Because of their isolation, their side arms have been turned to the paleopotamon type, which was formerly known only in the area outside of inundation. The Kráľovská lúka side arm is saturated with water leaking from adjacent parapotamon side arms. The macrophytes have been developing very rapidly, and even the deepest, formerly open parts get overgrown with vegetation. In 1993, from the beginning of the year to September, the water level was very low (0,3 m on the water level gauge), and did not rise before October. During this period, water temperature increased as high as 33 ^{o} C (9 June 1993). Typical representatives of permanent fauna were *Asellus aquaticus* (Isopoda) and *Limnomysis benedeni* (Mysidacea). New species, such as *Psammoryctides albicola* and *Gammarus roeseli*, also appeared. In 1995, *Rhynchelmis limosella* and *Dero digitata*, as well as *Nais* spp. (Oligochaeta), typically occurred. The abundance of bryozoans *Plumatella fungosa* and *P. repens* increased significantly, so that these animals covered 50 percent of the surface on solid substrata. In 1994, species formerly known to occur (by 1992), e.g. *Erpobdella octoculata* (leech), *Planorbis planorbis* and/or *Bithynia tentaculata* (bivalves), reappeared. New species, such as the gastropods *Physella acuta* and *Hippeutis*, also showed up. Several other gastropods, e.g. *Lymnaea auricularia*, *L. stagnalis* and *Gyraulus albus*, increased in quantity. In 1995, the water level increased by almost 1 m, attaining this higher values than before. In spring, submersed *Batrachium* sp., and in summer *Ceratophylum* sp. and *Myriophyllum* sp. prevailed at the surface in open water. As a new species for this locality, *Anisus vortex* (Gastropoda) was recorded. The most significant increase in abundance was found to be in *Dugesia tigrina* (Turbellaria). On the other hand, the abundance of *Limnomysis benedeni* (Crustacea) declined so much that only few specimens were found, and only in spring.

In temporary fauna, changes in the species composition of mayflies have occurred. In these side arms, *Caenis robusta* replaced *C. horaria* and *C. luctuosa*. In dragonflies, stagnophilous species (*Ischnura elegans*, *Coenagrion puella*, *C. pulchellum*, *Enallagma cyathigerum*, *Eryhtomma* spp.)

predominated at these localities. Increasing eutrophication and higher water temperatures have resulted in the appearance of thermophilous species *Crocothemis erythraea* and *Sympetrum meridionale*. In general, the proportion of stagnophilous species increased, so that these started to prevail outnumber eurytopic species. Chironomids represented a community typical for stagnant side arms with well-developed macrophytes and/or rich algae cover on gravel-to-sandy substrate: *Procladius* sp., *Paracladius conversus*, *Endochironomus* gr. *nymphoides*, *Glyptotendipes* sp. and *Polypedilum convictum*. The abundance of *Microtendipes chloris* and *Polypedillum pedestre* decreased. At this locality, the number of species changed compared to the previous year. In 1993, 11 species were recorded, whereas 17 and 16 species were found in 1994 and 1995, respectively. In contrast with 1993, *Ablabesmyia monilis*, *Polypedilum* gr. *nubeculosum*, *Cladotanytarsus* gr. *mancus*, *Tanytarsus* gr. *lobatifrons*, *Tanytarsus* gr. *macrosandalum*, *Paratanytarsus* gr. *lauterborni*, and *Endochironomus* gr. *tendens* were recorded. The abundance of *Glyptotendipes* spp. increased significantly, and the same tendency continued in subsequent years.

Stagnant waters in the area not supplied with water

This group of localities includes the side arm at Dunajské kriviny, for which no technical solution of water supply has yet been attained. Therefore, since the damming, this side arm lacks water. At present, its bottom is overgrown with dense vegetation. If solution is found for water supply in the upper part of the inundation area, the side arm at Dunajské kriviny will dry up completely and disappear.

Side arms in the area outside of impact of the Gabčíkovo Structures

Side arms of the plesiopotamon type

This type of side arm is currently represented by the side arm at Sporná sihoť. It is a shallow side arm attaining approximately the same depth as before the damming (20 to 40 cm). Its bottom is muddy; some places are covered with scarce submersed macrophytes. The side arms situated below the confluence of the tail water canal with the old main channel of the Danube have undergone almost no changes.

Microbenthos and meiobenthos

Communities of microbenthos and meiobenthos prefer water rich in organic matters and with a high number of Mastigophora (30000 specimens per 1 ml). The community of ciliophores was strongly affected by water levels. A sudden decline in the water level resulted in an increased abundance of Mastigophora and Ciliophora, including sapropel species *Spirostomum minus*, *Paramecium caudatum*, *P. putirnum*, *Loxodes striatus*, and others. Several rare species, such as *Furgasonia trichocystis*, *Holophrya nigricans*, and *Histriculus erethisticus* were also present.

Macrozoobenthos

Permanent fauna was exclusively composed of a few species of Oligochaeta. The genus *Limnodrilus* was typical for this locality, especially *L. hoffmeisteri* and *L. claparedanus*. *Ilyodrillus templetoni* was less common. Before 1993, only oligochaetes occurred here; in 1994 Isopoda, represented by *Asellus aquaticus,* appeared. In 1994, a very low oxygen concentration (1,6 $mg.l^{-1}$) and very high BOD_5 (25,7 $mg.l^{-1}$) were recorded. This indicated that intensive decomposing of organic matter occurred at the bottom.

Temporary fauna was represented by chironomid larvae, which preferred muddy substrate and vegetation. Only little changes occurred, compared to 1992: three species (*Cricotopus* sp., *Chironomus* gr. *thumi* and *Cryptochironomus* gr. *defectus*) disappeared, being replaced by two new species (*Endochironomus* gr. *nymphoides* and *Paratanytarsus* gr. *lauterborni*). The abundance increased in *Chironomus* gr. *plumosus*, *Polypedilum* gr. *pedestre*, and especially in *Tanypus kraatzi* (a predatory species). In subsequent years, the community of chironomids remained stable. The accessory species *Eukieferella devonica*, *Brillia modesta* and *Rheotanytarsus exiguus* were also present. Dragonflies were represented by only a few species, including the semi-rheophilous species *Platycnemis pennipes*, which attained the same proportional occurrence as the eurytopic species.

Side arms in the area affected by the Gabčíkovo Structures after 1995

Parapotamon type side arms supplied with water

This group of side arms includes the monitored side arms at Bodícka brána and Žofín. During the vegetation season, the side arm at Bodíky became permanently flowing. Water management control has prevented extreme hydrological conditions - both extremely high and, especially extremely low, water levels. Currents have also covered the littoral zone, which prevents sedimentation of fine silt over the gravel substrate.

Microbenthos and meiobenthos

Compared to the previous period (1993-1995), no changes were observed.

Macrozoobenthos

At this locality, benthos fauna is similar to that from the upper part of the main channel of the Danube (at Dunajské kriviny), though not so rich for a number of species. At the sampling sites, the littoral zone was covered by a gravel-to-sandy substrate with a well-developed periphyton. Concerning permanent fauna, amphipods predominated on the gravel substrate. In 1997, species diversity increased, though the amphipods still kept their high abundance, especially in summer and autumn. In autumn samples, *Jaera istri* (Isopoda) was found to be very abundant, though it had not been recorded before. A new species for the fauna of Slovakia, *Chaetogaster setosus*, was also found. In permanent fauna inhabiting bank stones (used for regulation purposes), modification of species composition continued. Two new bryozoans (*Hyalinella punctata*), plus the gastropods *Valvata cristata*, *Hippeutis complanatus* and *Anisus spirobris* were recorded. After five years of absence, *Glossifonia complanata* (leech), appeared. On the other hand, *Dugesia tigrina*, which had been common in 1995, disappeared. Certain species, such as *Anisus vortex*, *Bithynia leachi* and *Viviparus acerosus* (all Gastropoda), were recorded irregularly (they were probably not so abundant and not distributed uniformly). Concerning molluscs, the most abundant was found to be *Dreissena polymorpha*, which attained a density of 2359 specimens per m^2 in 1996, and 1763 specimens per m^2 in 1997. This represented 70 to 80 percent cover of the surface area of stones, which was close to that of 1991 and 1992. Abundance of all the other species was much lower, and only in *Bithynia tentaculata* (snail) did exceed 100 (129) specimens per 1 m^2 .

In the side arms with flowing water, several rheophilous species of temporary fauna appeared (**Fig. 11**), and in 1997, typical Danubian rheophilous species such as *Heptagenia sulphurea*, *Serratella ignita* and *Psychomyia pusilla* (typical rather for side arms of eupotamon type) were recorded. In all the side arms saturated with water, the abundance of *Ecnomus tenellus* (Trichoptera) declined significantly. The tendency leading towards an increased number of rheophilous species, which replaced the stagnophilous species, also continued in dragonflies. In spring, rheophilous species also predominated in the community of chironomids (*Orthocladius thienemenni*, *Cricotopus bicintus*, *Rheotanytarsus* sp., and *Pottastia gaedii*). In the second half of both 1996 and 1997, species preferring stagnant water (*Microtendipes chloris*, *Glyptotendipes pallens* and *G. gripekoveni*) predominated.

The second type of side arm at Žofín had never been one of the main side arms in the original side arm system. Originally it belonged among the side arms of a plesiopotamon type. However, now connected to a side arm situated upstream, it had become slightly flowing.

As a consequence of the frequent fluctuation of water levels, littoral permanent fauna consisted mainly of amphibiotic species of oligochaetes, such as Enchytraeidae, and/or *Eisenella tetraedra* (Lumbricidae). In 1996, a new species *Ophidonais serpentina* was recorded in this locality, as well as in the old main channel of the Danube at Dunajské kriviny. The species composition remained rather poor in 1997. In the littoral zone, tubificid worms predominated. However, an interesting species of Polychaeta (*Hypania invalida*), not recorded before, was found.

In 1996, the community of chironomids representing temporary fauna consisted of 18 species. In spring, *Cricotopus* sp. and *Polypedilum nubeculosum*, and in summer, *Polypedilum pedestre* and *Procladius* (*Holantypus*) were the most abundant. In 1997, 17 species of chironomids were found at this locality. In spring, *Tanytarsus* gr. *macrosandalum* and *Tanytarsus medius* were the most abundant (approximately 1500 specimens per 1 m^2). However, in summer the abundance of the latter declined by approximately 33 percent, whereas *Cladotanytarsus mancus* became the most abundant (2600 specimens per m^2). The third most abundant summer species was found to be *Cryptochironomus defectus* (100 specimen per 1 m^2). In autumn samples, *Tanytarsus mendax* and *Polypedilum pedestre* were the most numerous. In general, the abundance of chironomids was the highest at this locality.

Parapotamon side arms not supplied with water

In the side arms situated between the mouth of Baka side arm system and the confluence of the tail water canal with the old main channel of the Danube, water supply management has not yet been resolved. Therefore, water enters these side arms through their lower mouths, due to impoundment in the old main channel of the Danube. As a result of this, submersed macrophytes (*Potamogeton pectinatus*) occur in the bed of these side arms. The original gravel bottom has been covered with muddy-to-sandy sediments and silt, which is in fact the same kind of substrate as that in the old main channel of the Danube. Concerning permanent fauna, Oligochaetes represented by tubificid species (*Limnodrilus hoffmeisteri*, *L. claparedeanus*) predominated. In 1997, after a high discharge in the old main channel of the Danube, amphipods (*Dikerogammarus bispinosus* and *Corophium curvispinnum*) appeared in our summer samples. However, these species were not present in autumn samples, which indicated that current hydrological conditions in this side arm did not meet their ecological requirements.

Temporary fauna was represented by larvae of dragonflies and midges. In 1997, stagnicolous species of dragonflies disappeared, and only eurytopic species were present at this locality. In 1998, dragonflies disappeared completely. From among chironomids, *Chironomus* gr. *semireductus*, *Polypedilum convictum*, *Cryptochironomus defectus* and *Chironomus* gr. *thumi*, as well as the predatory *Procladius* (*Holantypus*) were the most numerous.

Isolated side arms with stagnant water

The side arm at Kráľovská lúka, though situated in the inundation area of the Danube, has no surface water connection with the neighbouring side arms. It has been saturated with the seepage water from the adjacent side arm system. Since the seepage of water is sufficient, the oxygen regime in this side arm appears favourable. Water level follows fluctuations of that in the adjacent side arm system. The development of macrophytes has been continuing, and both the surface and the bottom have been getting overgrown with submersed vegetation. This results in a fast reduction of depth and a gradual change towards terrestrial biotope. In fact, this side arm has been shifting from a plesiopotamon type to a paleopotamon type.

Microbenthos and meiobenthos

The tendency of stabilisation in microfauna and meiofauna has been continuing, which results in increasing species diversity. From among rare species, *Histiobalantinum natans*, *Tintinnopsis cylindirca*, *Ophrydium crassicaule*, *Frontonia ambigua*, *Holosticha grisea*, *Strombidium turbo*, *S. velox*, and others were found.

Macrozoobenthos

In the littoral zone of the side arm with a gravel-to-sandy substrate, the permanent fauna contained shredders and detrivorous animals, such as *Asellus aquaticus*, and oligochaetes. Periphytic species from the Naididae family (*Dero* spp. and *Stylaria lacustris*) predominated at this locality, and formed a diverse community. In 1997, further new species (*Chaetogaster langi* and *Pristina longiset*, both of them new for fauna of Slovakia) appeared. The diversity in this side arm was relatively high (compared to other side arms), due to the high species diversity of the Naididae family. Species composition continued changing. After an absence of several years, *Hemiclepsis marginata* (Hirudinea) and *Planorbis corneus* (Gastropoda) reappeared in 1996, whereas *Viviparus contectus* and *Lymnaea peregra* (both Gastropoda) reappeared in 1997. New species were also recorded for this locality: *Dugesia lugubris* (Turbellaria), Glossifonia *complanata* (Hirudinea) and *Armiger crista* (Gastropoda) in 1996, as well as *Glossifonia concolor*, *Theromyzon tessulatum* and *Erpobdella testacea* (all Hirudinea) in 1997. On the other hand, the permanent presence of certain species, e.g. *Limnomysis benedeni* (a crustacean lastly found in 1995) and *Anisus vortex* (a gastropod lastly found in 1996) could not be confirmed. During this two year period, the abundance of species also changed. For example, the abundance of *Lymnaea auricularia*, *L. stagnalis*, *Gyraulus albus*, *Bithynia tentaculata*, *Physa acuta* (all Gastropoda), *Erpobdella octoculata* (Hirudinea), and *Asellus aquaticus* (Crustacea) increased greatly, especially in 1997. In temporary fauna, only stagnophilous dragonflies (as in previous years), e.g. *Ischnura elegans*, *Coenagrion puella*, *C. pulchellum*, *Enallagma cyathigerum*, genus *Erythromma*), predominated at this locality. Increasing eutrophication and higher water temperatures resulted in the presence of thermophilous species *Crocothemis erythraea* and *Sympetrum meridionale*. The proportion of stagnophilous species was increasing gradually, so that they prevailed over eurytopic species. Changes in the coenosis of dragonflies showed up in 1998, when both larvae and imagoes of semi-rheophilous *Platycnemus pennipes* were recorded. The community of chironomids was affected by a continuing growth of macrophytes, which led to a significant increase in the abundance of phytophilous and pelophilous species *Glyptotendipes gripekoveni*, *Einfeldia* gr. *pectoralis*, *Einfeldia* gr. *pagana*, *Tanytarsus* gr. *macrosandalum* and *Dicrotendipes nervosus*.

Side arms outside of the area affected by the Gabčíkovo Structures

Side arms of plesiopotamon type

This category of side arms is represented by the side arm at Sporná sihoť. Since it is a very shallow side arm, its bottom is almost completely overgrown with submersed macrophytes during the vegetation season. In 1998, the surface area covered by water changed significantly, due to water level fluctuation. However, the composition of benthos barely changed throughout the monitoring period. The number of species, abundance and biomass remained very low.

Microbenthos and meiobenthos

Compared to the previous period, no changes were observed.

Macrozoobenthos

Permanent fauna contained Isopoda, represented by *Asellus aquaticus*, and Oligochaeta, with dominant species of the genus *Limnodrilus*. Both the quantity and diversity of the taxonomic groups monitored were low. The community of midges - temporary fauna - did not undergo any significant changes. Its species composition was affected by the fluctuation of water levels and intensive growth of macrophytes. Therefore, pelophilous (*Endochironomus tendens*, *Chironomus* gr. *thumi*, *Polypedilum pedestre*, *P. convictum*, *Cryptochironomus defectus*) as well as phytophilous species (*Glyptotendipes gripekoveni*, *G. pallens*) predominated. In autumn 1996 and 1997, abundance of the predatory species *Procladius* (*Holantypus*) increased significantly.

Assessment of parasitic dipterous insects (Diptera, Culicidae) in stagnant waters and periodical pools in the area of the Gabčíkovo Structures

The area of the Large Danube Island has been always known as a region with both quantitatively and qualitatively rich communities of mosquitoes, as well as with regular calamities associated with floods. Trpiš [53] reported 28 species of mosquitoes from this area in 1962. Since then, this region has undergone major changes, connected with intensive impacts of various human activities. Probably the most important change has been associated with the construction of the Gabčíkovo structures. Operation of the Gabčíkovo structures caused significant changes in the hydrological regime, especially in the former inundation area of the Danube. These changes subsequently led to changes in flora and fauna, including the communities of mosquitoes, which have undergone significant changes in both the quality and quantity of species. With regard to the fast reaction of culicids to changes in the hydrological regime, mosquitoes appear to be good functional indicators for the monitoring of environmental changes.

Side arms with stagnant water

At Dunajské kriviny (monitoring site 6), two biotopes were selected for monitoring: a remnant of a side arm in a riparian woodland (1), and a side arm with its mouth situated at an open area with meadows. The latter was extended by the excavation of gravel, and partly overgrown with reeds. In pre-dam conditions, both of these biotopes had sufficient amounts of ground water. The composition of mosquito communities reflected this situation. Regular triple-peaked curves of floods, so common in the past, changed to single-peaked curves. In pre-dam conditions, the area was characterised by very high abundance of mosquitoes in spring (several thousands of pre-imago specimens per 25 x 25 cm). The highest abundance of calamity mosquito species, such as *Aedes vexans* and *A. sticticus*, was found to be in the meadow. In the woodland side arm, the quantity was significantly lower. Since 1993, the area monitored has dried up, and the vegetation has been shifting from wetland to a habitat of xerophilous type. During controlled floods in 1995-1997, when the level of groundwater rose up, no pre-imago stages of mosquitoes were found. This is associated with the fact that since 1993, females of calamity mosquito species have been found only in minimum numbers.

At Bodícka brána (monitoring site 9), a side arm with stagnant water, supplied from the Čunovo Reservoir and situated about 100 m from the main channel of the Danube, was selected in 1994 as the biotope for monitoring. In 1994-1995, *Anopheles maculipennis* was found in May and June samples only in minimum numbers. In 1996-1998, no pre-imago stages of mosquitoes were found, which was probably associated with 1) intensive growth of vegetation in this side arm, 2) fluctuation of water levels, and 3) abundant fauna of fishes and amphibians.

At Kráľovská lúka (monitoring site 10), the west side of a side arm with dense stands of *Fragmites australis* was selected as the biotope for monitoring. Before 1992, this biotope was supplied with leaking water from the Danube during higher water levels, and especially the part situated close to the woodland used to be a typical hatching site for calamity mosquitoes. In May and June, the quantity of larvae and pupae attained almost 10000 individuals per area of 25 x 25 cm. Once the Gabčíkovo Structures started operating (1993), a significant decline in water level occurred, and mosquitoes stopped proliferating in calamity numbers. Since 1996, this side arm has been supplied with water, and current hydrological conditions appear suitable, which has resulted not only in the quantity, but also in the quality of mosquito coenoses. In 1995-1996, the following species were recorded: *Anopheles maculipennis* s.l., *Culiseta annulata*, *Aedes vexans*, *A. sticticus*, *A. cinereus*, *A. dorsalis*, *A. cantans*, *A. leucomelas*, *A. communis*, *A. flavescens*, *Culex pipiens*, *C. territans*, and *C. modestus*. The presence of *Anopheles maculipennis* s.l. and *C. territans* suggests long-term good hydrological conditions at this locality. With regard to the water supply, it can be supposed that the hydrobiological parameters of this side arm will be improving.

At Istragov (monitoring site 14), a narrow side arm situated about 200 m from the dam was selected for monitoring. In 1991-1992, the quantity of pre-imago stages attained several thousands of specimens per area of 25 x 25 cm. Once the Gabčíkovo Structures started to operate, this locality began drying rapidly, and sufficient water level was found only during significantly higher water levels in the old main channel of the Danube, e.g. in 1996. At that time, *Aedes vexans*, *A. sticticus*, and *A. cantans* were found. Since 1997, intensive devastation of this biotope has occurred, due to tree cutting and the subsequent filling of the side arm with ground.

The locality Sporná sihoť (monitoring site 18) has not been affected by the Gabčíkovo Structures directly, being situated outside of the area of these Structures. A marginal part of a side arm strongly affected by fluctuation of water levels in the main channel of the Danube was monitored. This biotope does not appear to be suitable for pre-imago stages of mosquitoes. Therefore, only a few specimens of *Aedes vexans* and *A. sticticus* were found during most of the monitoring period. In September 1998, when the water lever decreased significantly and the side arm got overgrown with dense aquatic vegetation, *Anopheles maculipennis* s.l. was found in massive numbers. Apart from that, *Culex hortensis* and *Culex pipiens* were recorded, though in lower numbers. This suggests stability of the locality examined.

Pools and pits in the inundation area

Pools represent the most important biotopes for pre-imago stages of mosquitoes (especially for calamity species) in the inundation area of the Danube. These can be characterised as natural and/or man-made depressions, supplied by leaking water during higher water levels in the main channel of the Danube.

At Bodícka brána (monitoring site 9), two inundation pools were selected for monitoring, one in a shady floodplain woodland, and one in a stand of shrubs, the latter with a gravel bottom and a water level of approximately 1 m in 1990-1992. Both of these localities were situated only a few meters from the main the Danube. In 1991, mosquitoes of the genus *Aedes* (*A. vexans*, *A. sticticus*, and *A. cinereus*) predominated. In

1992, *Culex pipiens*, *C. territans* and *Anopheles maculipennis* s.l. were also found. However, in the subsequent years, this biotope started to dry up. Nevertheless, in 1995, controlled flooding provided good conditions for the development of mosquitoes. As a result, very interesting and very rare species, such as *Culex territans*, *C. hortensis* and *Culiseta ochroptera*, were recorded. In 1996, water leaking occurred in autumn, due to a significantly increased water level in the main channel of the Danube. In 1995-1997, both controlled flooding and good hydrological conditions in the old main channel of the Danube provided water enough for the two biotopes monitored. During this period, pre-imago stages of spring species, e.g. *Aedes cantans*, *A. communis* and *A. leucomelas*, appeared. Unfortunately, the positive influence of good hydrological condition was subsequently suppressed by a cutting of the woods, which lead to complete destruction of the two localities studied.

At Istragov (monitoring site 14), two inundation pools situated a few meters from the dam, were selected for monitoring. The first biotope, situated closer to the port of Gabčíkovo, was very suitable for development of calamity mosquitoes in 1991-1992 (their abundance attained 500 specimens per 25 x 25 cm). However, since 1993, intensive degradation of this biotope has started, due to the significant decline of ground water level after the Gabčíkovo structures had begun operating. It contained water only during increased water levels in the main channel of the Danube, as in 1996-1997, though without pre-imago stages. At present, this biotope is overgrown by dense shrubby vegetation, and covered partly with ground and leftovers from the timber. The second biotope (inundation pool at western margin of the area examined), pre-imago stages of certain species, e.g. *Anopheles maculipennis* s.l., *Aedes vexans*, *A. sticticus*, *A. dorsalis*, and *Culex territans*, were found every year. In 1996, *Aedes vexans*, *A. dorsalis* and *A. cantans* also occurred. Unfortunately, this biotope, which appeared suitable for monitoring of mosquitoes (especially because of the favourable depth and the dependence of water levels on ground water), was also devastated by timber exploitation in 1997.

The inundation pool at the Sporná sihoť monitored area (monitoring site 18) is a typical hatching site for calamity mosquitoes. During increased levels of ground water, mass proliferation of mosquitoes occurs, especially *Aedes vexans* and *A. sticticus*. In 1990-1994, such a mass development occurred during May and June, when the quantity attained 1000 specimens per area 25 x 25 cm. Apart from the species above, *A. cataphyla*, *A. cinereus*, *A. cantans* and *C. pipiens*, were also recorded. This biotope has been affected mainly by the irregular fluctuation of water levels in the main channel of the Danube, and therefore, pre-imago stages of mosquitoes can occur in various seasons.

Gravel pits

This type of biotope, for example the gravel pit at the village of Vojka, is not suitable for mosquito development.

Periodical and rain pools

At Dunajské kriviny (monitoring site 6), a rain pool on a field road contained a lot of larvae of *Anopheles maculipennis* s.l. This species occurs in such biotopes relatively rarely, and in the subsequent period it was not recorded in any rain pools. In 1991, a periodic pool, one dependent on rains, contained both larvae and pupae of *Aedes vexans*. However, in subsequent years all the periodic pools dried quickly, due to a decline in ground water levels, and, therefore, did not provide a suitable environment for the development of mosquitoes.

Conclusions

Regulations and pollution, which the Danube had undergone in the far past, affected the fauna of benthos very negatively. Cutting off the side arms, in order to improve conditions for shipping, prepared conditions for the flowing side arms (parapotamon) to become side arms of a plesiopotamon type. Such side arms can be characterised by the development of macrophytes and eutrophication. The tendency leading towards habitats similar to drying, periodical wetlands, is then inevitable. All these environmental changes resulted in a fragmentation of the biotopes in the inundation area, and in a retreat of the rheophilous, potamophilous and stenotopic forms of macrozoobenthos, these being replaced by rather eurytopic and stagnicolous forms. The gradual and continuous disconnection of the side arm system also affected the environment very negatively.

After the damming in 1992, two changes occurred in the hydrological regime in the Danube: 1) the discharge in the old main channel declined, and 2) the water levels in the adjacent side arms started fluctuating. In the Danube above the confluence with the tail water canal, sedimentation increased. Furthermore, eutrophication has been increasing, and the saprobity has been getting worse. Microzoobenthos and meiozoobenthos, and later also macrozoobenthos, have increased both in quantity and quality. The main increase has appeared in terrestrial microzoobenthos originating from the Čunovo Reservoir. A significant water level decline in the Danube resulted in the formation of communities typical for rotting processes associated with a massive development of bacteria. This development led to an increase in abundance, as well as diversity, of ciliophores and flagellates. On the emerged littoral parts, a massive dying of benthos was observed. The changes in the hydrological regime caused the original riverbed to differentiate into two different sections. In the upper part (at Dunajské kriviny), the formerly mobile bottom has stabilised, due to a decreased current velocity. Modified abiotic factors allowed the excessive development of algae on the gravel bottom. Subsequently, proportional composition of trophic guilds has shifted significantly from filtrators towards scrapers (algophagous species). Thus, periphyton has also increased in quantity, and the metabolism of the river has shifted from heterotrophy to autotrophy. Increased amounts and offer of food has resulted in the significant increase of abundance and biomass of these organisms. In the lower section of the Danube, above the confluence with the tail water canal, changes in the structure of coenoses of benthos were the most significant. After the character of substrate and hydrological regime (significant decline in current velocity) had changed, the original community of benthos underwent major destruction. Therefore, soon after the damming, the bottom contained almost no benthic animals, though the abundance of these has gradually increased. All these processes indicate that the river continuum has shifted upstream. The reduced depth and increased transparency allow scrapers to increase in proportion. The abundance of permanent fauna and chironomids has also increased.

After 1995, short-term fluctuations of water levels occurred in the upper section of the Danube, due to a saturation of the Hungarian side arm system with water. This caused a large area of the ripal to emerge. A weir was built up in the Danube at Dunakiliti, and as the fine sediments started to cover the bottom, theabundance of zoobenthos declined. However, in the deeper parts of ripal, benthic fauna remains rich in both quantity and quality. Since the discharge in the Danube increased in 1995, rheophilous fauna has been developing, and filtrators have started to reappear in greater proportion.

In communities of microzoobenthos and meiozoobenthos, a tendency towards stabilisation prevailed. However, macrozoobenthos, which is more dependent on the hydrological regime, reacted variously. In permanently flowing side arms, larvae of rheophilous insects (Ephemeroptera, Trichoptera) appeared. Currently, the patterns of fluctuation in water levels in the side arms with flowing water differ from those before 1993 (short-term fluctuations prevail instead of long-term fluctuations), and this change impacted benthos in the littoral zone negatively. Concerning permanent fauna, the abundance and biomass of most oligochaetes and amphipods has decreased. In contrast, species with short life cycles, e.g. Naididae (oligochaetes), have attained higher abundance. Isolated side arms have also undergone significant changes, having been shifted from plesiopotamon to paleopotamon type. This change becomes apparent as a strong development of submersed macrophytes in formerly open water and/or gravel bottom. The destruction of plant matter contributes to increasing amounts of organic matter, which results in increasing number of shredders (zoobenthos feeding on dead organic matter). Another reason that species diversity in such types of side arms is so high can be considered the peeping of cold ground water. However, these side arms are expected to disappear, as they will dry up and get overgrown by terrestrial vegetation. Such process can be observed at Istragov, where the former gravel sediments have been covered with silt and sandy sediments. As a result of this kind of development, detritophagous species have increased in abundance, especially from the Tubificidae family (Oligochaeta), whereas the diversity of benthos as a whole has decreased.

Proposals

Measures aimed at improving conditions for the survival of hydrobionts should not be focused only on improvements in the quantity and quality of water, but also on the **diversification of both aquatic and terrestrial habitats** with the opportunity the keep these in a complex system.

It is very important to enhance the ecological integrity in the ecosystem of inundation area, which can be achieved only by keeping a direct **contact between the side arms and the Danube**, and by **increasing water levels in the Danube**, especially at the places of such connections.

The question of water saturation for the Istragov side arm system should be definitively resolved. This **water control management should follow discharge changes in the Danube above the Gabčíkovo structures**, and **emphasise the aspects of a vegetation season and natural floods**.

Long-term monitoring revealed that, although the **impoundment of water level** in the old main channel of the Danube, achieved with the use of weirs, helped to solve the problems with the saturation of the side arm system with water (e.g. at Istragov), the hydrological regime in such waters differs from that typical for a river. Therefore, such **weirs should be as shallow as possible**.

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Tables (457 kB)

Figures

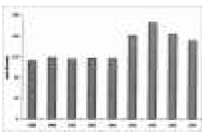

Figure 1. Beta-diversity of ciliophores in the inland delta of the River Danube.

Figure 2. Beta-diversity of temporary macrozoobenthos fauna (Ephemeroptera, Plecoptera, and Trichoptera) in the inland delta of the River Danube.

Figure 3. The development in the taxocoenosis of mayflies (Ephemeroptera) in the River Danube (Dunajské kriviny).

Figure 4. The development in the taxocoenosis of caddisflies (Trichoptera) in the River Danube (Dunajské kriviny).

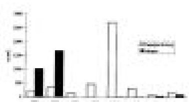

Figure 5. Abundance of mayflies and caddisflies in the River Danube.

Figure 6. Beta-diversity of ciliophores in the River Danube.

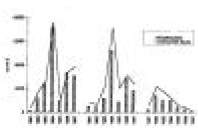

Figure 7. Abundance of permanent fauna of macrozoobenthos on rocky substrate of the River Danube.

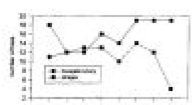

Figure 8. Alfa-diversity of permanent fauna of macrozoobenthos in the River Danube.

Figure 9. Abundance of permanent fauna of macrozoobenthos in the River Danube (Dunajské kriviny).

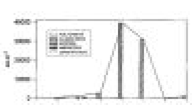

Figure 10. Abundance of permanent fauna of macrozoobenthos in the River Danube (Istragov).

Figure 11. Alfa-diversity of temporary fauna of macrozoobenthos (Ephemeroptera, Trichoptera) in the inland delta of the River Danube.

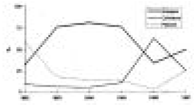

Figure 12. Trophic guilds of temporary fauna of macrozoobenthos (Ephemeroptera, Plecoptera) in the River Danube (Dunajské kriviny).

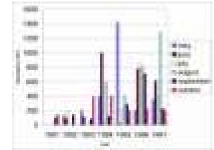

Figure 13. Abundance of ciliophores in the River Danube (Dunajské kriviny).

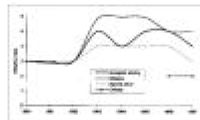

Figure 14. Assessment of the original status of the River Danube, according to the method of Buffagni (1997); 1 = original, .6 = absolutely unoriginal status of a biotope.

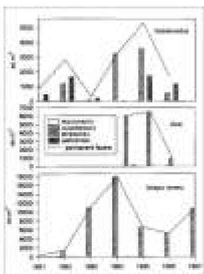

Figure 15. Abundance of permanent fauna of macrozoobenthos in side arms with flowing water.

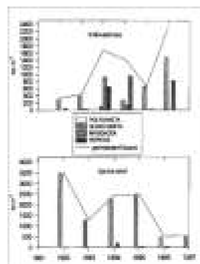

Figure 16. Abundance of permanent fauna of macrozoobenthos in stagnant waters.

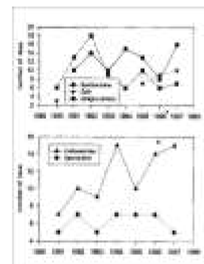

Figure 17. Alfa-diversity of permanent fauna of macrozoobenthos in flowing and stagnant waters.

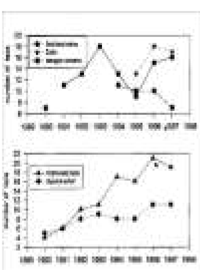

Figure 18. Alfa-diversity of midges (Chironomidae) in flowing and stagnant waters.