# 4 ECOLOGICAL STATUS CHARACTERISATION

## 4.1 Introduction

The aquatic community in rivers responds to both the effects of pollution and changes in hydro-morphology. The appearance and distribution of aquatic organisms in rivers is significantly influenced by the following criteria in particular:

- flow conditions
- habitat/substrate conditions and variation
- chemical conditions of the aquatic medium (e.g. organic pollution/pollution of easily biodegradable matter, nutrient content, oxygen content, toxic substances)
- temperature
- transparency – since the availability of light is essential to primary producers (alge/macrophytes) as an energy source for photosynthesis

Therefore, species composition and the frequency of benthic and planktic communities are used as the basis for the characterisation and assessment of the ecological status of rivers as laid down in the EU-Water Framework Directive.

The qualitative and quantitative composition of the benthic aquatic communities in particular is determined on the one hand by longer-term, stable conditions and on the other hand by biologically critical modifications of the environment being repeated on a short-term basis. That is why the results of biological-ecological monitoring in a river stretch may differ from the chemical water analysis since the latter's informative values are mostly episodic and only valid for the sampling date.

The Joint Danube Survey (JDS), organised by the International Commission for the Protection of the Danube River, was launched to obtain comparable, reliable data concerning chemical and ecological water status for the whole longitudinal stretch of the Danube River. JDS provided a unique, first-time opportunity for scientists to get an overview of the planktic and benthic aquatic communities and assess the quality of habitat along the entire Danube stretch between Neu Ulm (river km 2581) and the last three sampling points in the Danube Delta arms (river km 12). All biological elements referred to in the Water Framework Directive as parameters for the assessement of the ecological status (benthic invertebrates, phytobenthos, macrophytes and phytoplankton) were investigated during JDS except for fish because this group of organisms would have required another sampling method. Zooplankton was analysed for additional information about the biological situation of the Danube and its tributaries.

Special emphasis was placed on the evaluation of organic pollution (saprobity) and eutrophication.

JDS also included an analysis of microbiological parameters (total coliforms, faecal coliforms, feacal streptococci, hetrotrophic plate count/colony count 22°C) in the water as indicators of feacal and organic pollution caused by raw sewage, municipal waste water treatment plants and diffuse sources from farmland.

All samples were taken by the core team and all analyses were done by applying the same method. This was the only way to guarantee comparability of results between the sampling sites.

Since geo-morphological landscape features strongly impact the chemical and biological condition of rivers, the nine geo-morphological Reaches defined for the entire stretch of the Danube covered by JDS (see Chapter 3) were in many cases resorted to in interpreting and getting a clearer understanding of the biological results.

The sampling and analysis methods and the results they yielded are described for each of the investigated biological element in the subchapters that follow. Conclusions are drawn and recommendations made.

## 4.2 MACROZOOBENTHOS

### 4.2.1 Introduction

Macroscopically recognizable invertebrates, the so-called macrozoobenthos, are an important part of the biological aquatic community. In accordance with the specific autecological demands for life in water, individual organisms react in different ways to variations in its physical and chemical state. Aquatic populations are not influenced only by variations in natural parameters such as radiation balance, temperature, flow velocity, oxygen offer and the structure of the river bed, but also by pollution from point and non-point sources.

Macrozoobenthos taxa are interrelated as space and/or food competitors with different feeding habits and are capable of self-regulating their population size. However, as part of the aquatic ecosystem, they are also dependent on other biological compartments, in particular on micro-organisms, whose metabolic activity during decomposition of great amounts of organic substances (saprobity) can lead to negative effects on the oxygen budget of the water body and its fauna. On the other hand, phytoplankton and higher aquatic plants are as primary producers also involved in nutrient conversion processes (trophy) and may influence both nutrient and oxygen conditions.

The procedure for calculating saprobity indices is based exclusively on the food resources available at the sampling place for the different types of nutrition specialists among the organisms and their demand for oxygen. It consequently calculates the saprobic valences of all indicator species collected, i.e. the range of tolerance of the water's load with easily biodegradable organic substances within the species can exist (Sladecek, 1973).

However, the assessment of the biological quality of the Danube water by means of a faunistic analysis of macrozoobenthos community and the saprobity calculation based on it, must be considered in connection with the special hydraulic and sedimentary conditions in the different sections of the Danube.

The interpretation of saprobity assessment may cause problems in cases where the damming of large stretches of the river have resulted in drastic changes of flow velocities, sedimentation and modifications of the bank structures. In the dammed river sections with reduced flow velocities, the following main effects occur, especially under low water conditions: the intensity of primary production increases, phytoplankton and suspended solids reduce light irradiation onto the riverbed, muddy sediment composition changes and fine-grained deposits accumulate. With increasing depth of the reservoir, stratification can develop in the water body followed by seasonal oxygen depletion in the lower layers and sediments. In these cases many aerobic and current adapted benthic macrozoa are no longer able to settle – independently of water pollution with biodegradable substances. They are replaced by saprobic species prefering finer sediments which indicate a water quality worse than it actually is.

The above mentioned effects should be taken into account when interpreting changes in the qualitative composition of the species community along the Danube.

Results of the biological assessment of benthic invertebrate fauna can only be seen as an overview. During JDS, which took place in August and September, a large number of aquatic insects had already emerged.  These species were missing in the samples or only indeterminable stages of eggs and juvenile larvae could be found. Furthermore, because of the limited sampling sites and collection time as well as seasonal difficulties, it was impossible to detect all taxa of the biocoenosis that really exists in the Danube and its tributaries.

### 4.2.2 Methods

Benthic invertebrates were taken from the river bottom with a polyp grab in order to gain sufficient samples of animals from larger depths of water. This method was used because it had yielded good results during former investigations in the Rhine and Main rivers, while the use of dredges and core samplers is very time-consuming and sensitive.The manual sampling method at the riverbank is only possible at times of a low water level and it is limited at very low temperatures. The grab method also takes the quantitative aspect into acount, if the necessary experience is present.

However, the big polyp grab on board the ARGUS could only be employed in the main stream of the Danube. Collecting in small or flat tributaries was not possible because of the insufficient draught of the ship. Therefore, no benthos samples were taken from the Hron, the Ipoly, the Timok, the Olt and the Russenski Lom tributaries.

In addition to the benthos samples, water insects were caught by light during the night to allow taxonomic comparisons with the larvae taxa found in the different river sections.

The collection of mussels for residue analyses of pollutants was carried out in a selective manner by "kick sampling" and diving in bank proximity during the search for sediment areas at the river bottom, the actual habitat of this group of animals. Such biological samples often contain more mussels than those samples taken with the grab. The evaluation of the samples in the laboratory was carried out in four steps: juvenile and adult stages of macroinvertebrates were selected from the raw samples and pre-sorted according to higher taxa (i.e. classes, orders, families).  Each taxa group was identified at least to the genera and the most important taxa to the species level. Because of the shortage of time available for sample processing, determination of some taxonomically difficult groups had to be left aside. Relevant taxa for saprobiological calculations, e.g. sponges, leeches, fresh-water polychaetes, molluscs, amphipods, isopods, bryozoans and aquatic insects (except some Diptera) were identified. For useful determination keys see literature. The analysed specimens were preserved in ethyl alcohol (70 %) and labelled. The label indicated the name of the taxon, JDS-station number, stream-km and position (right/left-hand side of the bank), day and year of collection.

Quantitative sampling of macrozoobenthos in large rivers in order to determine its population density on the surface of a specific substrate is practically impossible. According to every semi-quantitative sampling method in use, it is not reasonable to count the whole number of specimens of each taxon. Therefore, the frequency of all taxa ascertained for a specific sampling station was estimated according to the following seven categories of relative abundance:

1 = single; 2 = rare; 3= rare to common; 4= common;
5= common to abundant; 6= abundant; 7= very abundant.

To define a realistic frequency number, the investigator has to consider the mutual relation of the estimated individuals of taxa.

A list of the species or taxa, including their frequency, was compiled for every sampling site.

Since a general unified saprobity scheme for benthic invertebrates doesn't yet exist in the Danube Basin, MLIM Expert Group agreed that saprobity should be computed by using the list of the Austrian Fauna Aquatica ed. by MOOG (1995).

For the mathematical calculation of saprobity indices, formulae indicated in the DIN 38410 [1] were applied:

Saprobic index **S** = $\frac{\sum_{i=1}^{n} s_i \cdot A_i \cdot G_i}{\sum_{i=1}^{n} A_i \cdot G_i}$  Standard deviation $\mathbf{S_M}$ = $\sqrt{\frac{\sum_{i=1}^{n} (s_i - S)^2 \cdot A_i \cdot G_i}{(n-1) \cdot \sum_{i=1}^{n} A_i \cdot G_i}}$

where i = number of the taxon; $s_i$ = saprobic value of the $i^{th}$ taxon; $A_i$ = relative abundance value of the $i^{th}$ taxon ; $G_i$ = indicative weight of the $i^{th}$ taxon ; n = number of taxa.

The following conditions have to be fulfilled: $\mathbf{S_M} < 0{,}2$ and $\sum_{i=1}^{n} A_i > 15$.

| SAPROBITY | INTERVAL OF SAPROBIC INDICES | SAPROBIOLOGICAL WATER QUALITY CLASS | |
|---|---|---|---|
| OLIGOSAPROBIC | < 1,25 | I | (UNPOLLUTED) |
| OLIGOSAPROBIC TO β-MESOSAPROBIC | 1,25 TO 1,75 | I-II | (LOW POLLUTED) |
| β-MESOSAPROBIC | 1,76 TO 2,25 | II | (MODERATELY POLLUTED) |
| β-MESOSAPROBIC TO α-MESOSAPROBIC | 2,26 TO 2,75 | II-III | (CRITICALLY POLLUTED) |
| α-MESOSAPROBIC | 2,76 TO 3,25 | III | (STRONGLY POLLUTED) |
| α-MESOSAPROBIC TO POLYSAPROBIC | 3,26 TO 3,75 | III-IV | (VERY HIGH POLLUTED) |
| POLYSAPROBIC | > 3,75 | IV | (EXCESSIVELY POLLUTED) |

**TABLE MZB-1:** Saprobiological classification according to the Austrian standard ÖNORM M 6232

Transformation of the saprobic indices to biological water quality classes was established following the Austrian standards ÖNORM M 6232 (see table above).

In order to determine the degree of conformitiy of the spectrum of species on the two bank sides of a collecting station, Sørensen's quotient of similarity (QS) was computed. The mathematical calculation is made according to the formula:

$$QS\ (\%) = \frac{2 \cdot T}{n_R + n_L} \cdot 100$$

where T = number of the species occurring together at both bank sides ; $n_R$, $n_L$ = number of invertebrate species on the right and/or left bank side of a JDS station.

### 4.2.3 Results and Interpretation

#### 4.2.3.1 Comparison of the Number of Taxa Found in the Danube, Its Main Side Arms and Tributaries

THE DANUBE

The total number of aquatic invertebrate taxa found in the benthos was 268 (see species list, Table MZB-2). The caddisfly species, which were additionally collected in light traps, have not been subsumed under this figure, although they definitely exist in the Danube. Oligochaeta and aquatic Diptera have been determined to a small degree only.

| Taxa | Danube | | | Tributaries and Arms | Bioindicator |
|---|---|---|---|---|---|
| | Upper Section | Middle Section | Lower Section | | |
| **Porifea** | | | | | |
| Ephydatia fluviatilis | | x | | | |
| Ephydatia muelleri | | x | x | x | |
| Eunapius fragilis | x | x | x | x | |
| Porifera indet. | | | x | x | |
| Trochospongilla horrida | | | x | x | |
| **Hydrozoa** | | | | | |
| Cordylophora caspia | | x | x | x | |
| Craspedacusta sowerbyi | | | | x | |
| Hydra sp. | x | x | x | x | |
| **Turbellaria** | | | | | |
| Dendrocoelum lacteum | x | x | | | |
| Dendrocoelum romanodanubiale | x | x | x | x | |
| Dugesia lugubris | x | x | | x | |
| Dugesia tigrina | | x | x | x | |
| Polycelis nigra | x | | | | |
| Turbellaria indet. | | x | | | |
| **Nematoda** | | | | | |
| Gordius sp. | x | | | | |
| **Gastropoda** | | | | | |
| Acroloxus lacustris | x | | | x | x |
| Ancylus fluviatilis | x | x | | x | x |
| Bithynia tentaculata | x | x | x | x | x |
| Bithynia tentaculata f. producta | | x | x | | x |
| Chondrula albolimbata | | | | x | |
| Esperiana acicularis | | x | x | x | x |
| Esperiana esperi | | x | x | x | x |
| Ferrissia wautieri | | x | x | x | x |
| Gastropoda indet. | | x | | | |
| Gyraulus albus | x | x | | x | x |
| Gyraulus laevis | | | x | | x |
| Gyraulus sp. | | | | x | |
| Holandriana holandrii | | x | x | | x |
| Holandriana holandrii holandri | | | x | | |
| Lithoglyphus naticoides | x | x | x | x | x |
| Lymnaea stagnalis | | | | x | |
| Physa fontinalis | | | | x | x |
| Physella acuta | x | x | x | x | x |
| Planorbidae | x | x | x | x | |
| Planorbis planorbis | x | x | x | x | x |
| Potamopyrgus antipodarum | x | x | | x | x |
| Potamopyrgus antipodarum f. carinata | x | | | | x |
| Radix ovata | x | x | x | x | x |
| Radix peregra | | x | | x | x |
| Theodoxus danubialis | x | x | x | x | x |
| Theodoxus fluviatilis | | x | x | x | |
| Theodoxus prevostianus | | x | | | x |
| Theodoxus transversalis | x | x | x | | x |
| Valvata piscinalis | x | x | x | x | x |
| Valvata pulchella | | x | x | x | |
| Valvata naticina | | x | x | x | |
| Vertigo antivertigo f. sexdentata | | | x | | |
| Viviparus acerosus | x | x | x | x | x |
| **Bivalvia** | | | | | |
| Anodonta anatina | x | x | x | x | x |
| Anodonta cygnea | | x | x | x | x |
| Cerastoderma exiguum | | | x | | |
| Chamelea gallina | | | x | | |
| Corbicula fluminea | x | x | x | x | |
| Dreissena polymorpha | x | x | x | x | x |
| Musculium lacustre | | x | | | x |
| Pisidium amnicum | x | x | x | x | x |
| Pisidium henslowanum | x | x | | | x |
| Pisidium moitessierianum | x | | | | x |
| **Bivalvia** | | | | | |
| Pisidium sp. | x | x | | x | |
| Pisidium subtruncatum | x | x | x | x | x |
| Pisidium supinum | x | x | x | x | x |
| Pseudoanodonta complanata | x | x | x | x | x |
| Sinanodonta woodiana | | x | x | x | x |
| Sphaerium corneum | x | x | | x | x |
| Sphaerium rivicola | x | x | x | x | x |
| Unio crassus | | | x | x | x |
| Unio pictorum | x | x | x | x | x |
| Unio tumidus | | x | x | x | x |
| **Polychaeta** | | | | | |
| Hypania invalida | x | x | x | x | x |
| **Oligochaeta** | | | | | |
| Branchiura sowerbyi | | x | x | x | x |
| Chaetogaster limnaei | | x | | | |
| Criodrilus lacuum | | x | x | x | x |
| Dero sp. | | | x | | |
| Eiseniella tetraeda | x | x | x | x | x |
| Limnodrilus hoffmeisteri | | | | x | x |
| Limnodrilus sp. | x | x | x | x | x |
| Limnodrilus udekemianus | | | x | | x |
| Lumbriculidae | x | x | x | x | |
| Lumbriculus variegatus | x | x | x | x | x |
| Naididae | x | x | x | x | |
| Oligochaeta div.gen.div.sp. | x | x | x | x | |
| Stylaria lacustris | | x | x | x | x |
| Stylodrilus heringianus | x | x | | x | |
| Tubifex sp. | x | x | x | x | x |
| Tubifex tubifex | x | x | x | x | x |
| Tubificidae | | x | x | x | |
| **Hirudinea** | | | | | |
| Alboglossiphonia heteroclita | | x | x | x | x |
| Alboglossiphonia sp. | | x | | | |
| Branchiobdella parasita | | | x | x | x |
| Caspiobdella fadejewi | x | x | x | x | x |
| Dina lineata | x | x | x | | x |
| Dina punctata | | x | x | x | x |
| Erpobdella nigricollis | x | | | | x |
| Erpobdella octoculata | x | x | x | x | x |
| Erpobdellidae | | x | | x | |
| Glossiphonia complanata | x | x | | x | x |
| Glossiphonia concolor | | | | x | |
| Glossiphonia palludosa | | x | | | x |
| Haemopis sanguisuga | | x | | | |
| Helobdella stagnalis | x | x | x | x | x |
| Piscicola geometra | x | x | | | x |
| Theromyzon tessulatum | | | | x | x |
| **Arachnida** | | | | | |
| Hydracarina | x | x | x | x | |
| **Branchiura** | | | | | |
| Argulus sp. | | | | x | |
| **Decapoda** | | | | | |
| Astacus leptodactylus | | x | x | x | x |
| Orconectes limosus | | | | x | x |
| **Mysidacea** | | | | | |
| Hemimysis anomala | x | | | | |
| Limnomysis benedeni | x | x | x | x | x |
| **Cumacea** | | | | | |
| Schizorhynchus scabriusculus f. danubialis | | | x | | |
| **Isopoda** | | | | | |
| Armadillidium pictum | | | x | | |
| Asellus aquaticus | x | x | x | x | x |
| Jaera sarsi | x | x | x | x | x |

| Taxa | Danube | | | | |
| --- | --- | --- | --- | --- | --- |
| | Upper Section | Middle Section | Lower Section | Tributaries and Arms | Bioindicator |
| **Amphipoda** | | | | | |
| Corophium curvispinum | x | x | x | x | x |
| Dikerogammarus haemobaphes | x | x | x | x | x |
| Dikerogammarus villosus | x | x | x | x | x |
| Dikerogammarus villosus bispinosus | x | x | | x | x |
| Echinogammarus ischnus | x | x | x | x | x |
| Gammarus fossarum | x | | | | x |
| Gammarus pulex | x | | | x | x |
| Gammarus roeseli | x | x | | x | x |
| Obesogammarus obesus | x | x | x | x | |
| Orchestia cavimana | x | | | | |
| Pontogammarus sp. | | | x | | |
| **Ephemeroptera** | | | | | |
| Baetis atrebatinus | | | x | | |
| Baetis buceratus | x | | | | x |
| Baetis fuscatus | x | x | | x | x |
| Baetis lutheri | x | | | | x |
| Baetis rhodani | x | | | | x |
| Baetis sp. | x | | | x | |
| Baetis vernus | x | | | | x |
| Caenis beskidensis | x | | | x | x |
| Caenis horaria | x | x | x | x | x |
| Caenis luctuosa | x | | | x | x |
| Caenis rivulorum | x | | | | x |
| Caenis robusta | | x | x | x | |
| Cloeon dipterum | x | x | x | x | x |
| Ecdyonurus aurantiacus | x | | | | x |
| Ecdyonurus torrentis | x | | | | |
| Electrogena quadrilineata | x | | | | |
| Epeorus sylvicola | x | | | | x |
| Ephemera danica | x | | | | x |
| Ephemerella major | x | | | | x |
| Ephoron virgo | x | | | | x |
| Heptagenia coelurans | x | x | | | x |
| Heptagenia flava | | x | x | x | x |
| Heptagenia sp. | | | x | x | |
| Heptagenia sulphurea | x | x | | x | x |
| Palingenia longicauda | | | | x | |
| Potamanthus luteus | x | | | | x |
| Raptobaetopus tenellus | | x | | x | |
| Serratella ignita | x | | | | x |
| Siphlonurus sp. | | | | x | |
| **Plecoptera** | | | | | |
| Dinocras cephalotes | x | | | | |
| Leuctra fusca | x | | | x | |
| Leuctra sp. | x | | | | |
| Protonemura sp. | | | | x | |
| **Odonata** | | | | | |
| Anax imperator | | | | x | x |
| Calopteryx splendens | | | | x | x |
| Coenagrion pulchellum | | | | x | x |
| Coenagrionidae | | x | | | |
| Gomphus flavipes | | x | x | x | x |
| Gomphus vulgatissimus | | x | x | x | x |
| Ischnura elegans | | x | x | x | x |
| Orthetrum cancellatum | | | x | | |
| Platycnemis pennipes | | | x | x | x |
| **Heteroptera** | | | | | |
| Aphelocheirus aestivalis | x | | | | x |
| Corixidae | x | x | | | |
| Ilyocoris cimicoides | | | x | | |
| Plea leachi | | | x | | |

| Taxa | Danube | | | | |
| --- | --- | --- | --- | --- | --- |
| | Upper Section | Middle Section | Lower Section | Tributaries and Arms | Bioindicator |
| **Coloptera** | | | | | |
| Agabus sp. | x | | | | |
| Berosus spinosus | | | x | | |
| Brychius elevatus | x | | | | x |
| Dryopidae | x | | | | |
| Elmis aenea | x | | | | |
| Elmis latreillei | x | | | | x |
| Elmis maugetii | x | | | | x |
| Elmis ritscheli | x | | | | |
| Esolus sp. | x | | | | |
| Haliplus laminatus | | | x | x | x |
| Haliplus sp. | | | x | x | |
| Hydrochara caraboides | | | x | | x |
| Ilybius sp. | | | | x | |
| Laccobius minutus | | | | x | |
| Laccophilus hyalinus | | | x | | |
| Laccophilus sp. | | | | x | |
| Limnius sp. | | x | x | x | |
| Limnius volckmari | x | | | | x |
| Macronychus quadrituberculatus | x | | | | |
| Ochthebius sp. | | | x | | |
| Orectochilus villosus | x | | x | x | x |
| Oulimnius tuberculatus | | | | x | x |
| Platambus maculatus | | | x | | x |
| Potamonectes depressus | x | | | | |
| Riolus subviolaceus | x | | | | x |
| Staphylinidae | | | x | | |
| **Megaloptera** | | | | | |
| Sialis lutaria | x | | | x | |
| **Planipennia** | | | | | |
| Sisyra fuscata | x | | | x | x |
| **Trichoptera** | | | | | |
| Agapetus laniger | | | | x | x |
| Allogamus auricollis | x | | | | x |
| Anabolia furcata | x | | | | x |
| Anabolia nervosa | x | | | x | x |
| Brachycentrus maculatus | x | x | | | |
| Brachycentrus subnubilus | x | x | | x | x |
| Ceraclea alboguttata | x | | | x | x |
| Ceraclea annulicornis | x | x | | | x |
| Ceraclea dissimilis | x | x | x | x | x |
| Ceraclea nigronervosa | x | | | | x |
| Cheumatopsyche lepida | x | | | | x |
| Cyrnus trimaculatus | x | | | | x |
| Ecnomus tenellus | x | x | x | x | x |
| Hydropsyche angustipennis | x | | | | |
| Hydropsyche bulgaromanorum | x | x | x | x | x |
| Hydropsyche contubernalis | x | x | x | x | x |
| Hydropsyche exocellata | x | x | x | x | |
| Hydropsyche guttata | | | | x | |
| Hydropsyche incognita | x | | | | x |
| Hydropsyche pellucidula | x | x | | x | x |
| Hydroptila sparsa | x | x | x | x | x |
| Hydroptila tigurina | | | x | | |
| Lepidostoma hirtum | x | x | | x | x |
| Lithax niger | | | | x | |
| Lype reducta | x | | | x | |
| Micropterna lateralis | x | | | | |
| Mystacides azurea | x | | | x | x |
| Mystacides longicornis | | | x | | x |
| Neureclipsis bimaculata | x | x | x | x | x |
| Odontocerum albicorne | x | | | | x |
| Oecetis lacustris | x | | | | x |
| Oecetis notata | x | | | | |

| Taxa | Danube | | | Tributaries and Arms | Bioindicator |
|---|---|---|---|---|---|
| | Upper Section | Middle Section | Lower Section | | |
| **Trichoptera** | | | | | |
| Oecetis ochracea | x | x | x | x | x |
| Orthotrichia costalis | | x | x | x | x |
| Plectrocnemia conspersa | x | | | | x |
| Polycentropus flavomaculatus | x | | | | x |
| Potamophylax latipennis | x | | | | x |
| Psychomyia pusilla | x | x | | x | x |
| Rhyacophila (Rhyacophila) sp. | | | | x | |
| Rhyacophila dorsalis | x | | | | x |
| Sericostoma flavicorne | x | | | | |
| Sericostoma sp. | x | | | | |
| Silo nigricornis | x | | | | x |
| Tinodes maculicornis | x | | | | |
| Tinodes pallidulus | x | | | | |
| Tinodes waeneri | x | | | | x |
| **Lepidoptera** | | | | | |
| Acentropus niveus | | x | | | |
| Parapoynx stagnata | | x | x | | |
| **Diptera** | | | | | |
| Antocha sp. | x | | | | |
| Atherix ibis | x | | | | |
| Ceratopogonidae | | | x | x | |
| Chironomidae | x | x | x | x | |
| Chironomus plumosus Gruppe | x | x | x | x | x |
| Chironomus thummi Gruppe | | x | x | x | |

| Taxa | Danube | | | Tributaries and Arms | Bioindicator |
|---|---|---|---|---|---|
| | Upper Section | Middle Section | Lower Section | | |
| **Diptera** | | | | | |
| Empididae | x | | x | x | |
| Limoniidae | x | | x | x | |
| Psychodidae | x | | | | |
| Simuliidae | x | | | x | |
| Simulium austeni | x | | | | |
| Simulium ornatum | x | | | | x |
| Simulium reptans | x | | | | |
| Simulium reptans var. galeratum | x | | | | |
| Simulium sp. | x | | | x | |
| Stratiomyidae | x | | | | |
| Tabanidae | x | | | x | |
| Tipulidae | x | | | | |
| **Bryozoa** | | | | | |
| Cristatella mucedo | x | | | x | |
| Fredericella sultana | x | x | x | | x |
| Paludicella articulata | x | x | x | x | x |
| Plumatella emarginata | x | x | x | x | x |
| Plumatella pulchata | | | | x | |
| Plumatella repens | | x | | | x |
| **Kamptozoa** | | | | | |
| Urnatella gracilis | | | | x | |

**TABLE MZB-2:** List of macrozoobenthos species found during the JDS

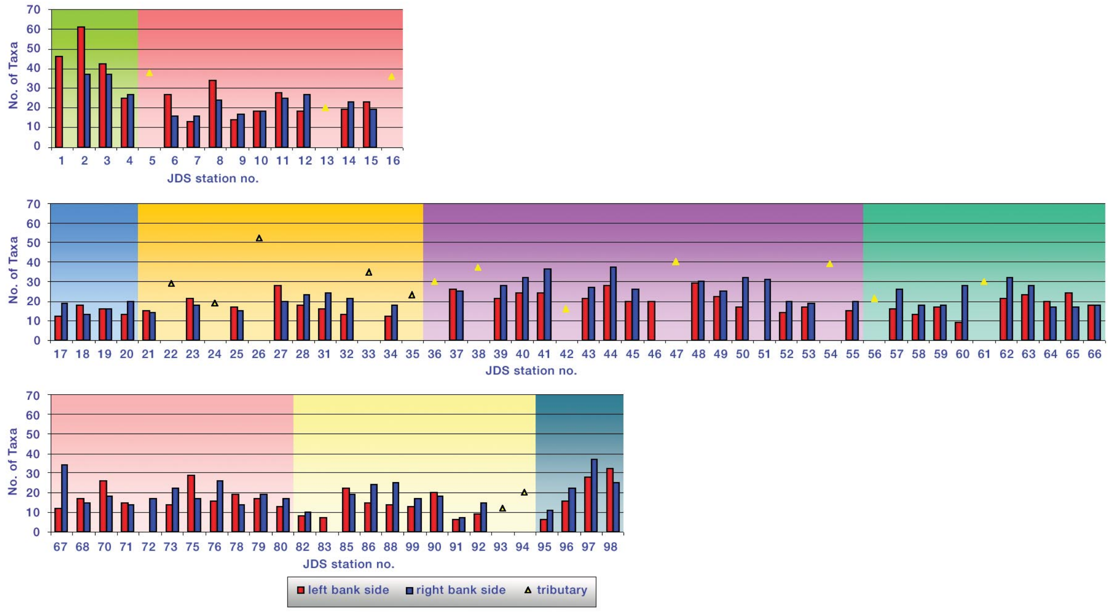



**FIGURE MZB-1.** Number of macrozoobenthos taxa for every bank side at the different JDS stations within the 9 geo-morphological Reaches of the Danube. Triangle symbols indicate taxa numbers for tributaries (no. 5, 13, 16, 26, 42, 47, 54, 56, 61, 81, 93, 94) or side-arms (No. 22, 24, 33, 35, 36, 38). Right bank side: blue bars; left bank side: red bars.

The number of species found during JDS is low compared to the Danubian fauna by DUDICH (1967). This is due to the examination of the benthos being made only once and at an unfavourable time. Another crucial factor might be the limited number of samples in regard to the total length of the Danube as well as the position of the sampling sites. In order to make the sampling of sediments possible, many sites had been placed in the dammed parts of the River. Accordingly, only a macrozoan-fauna typical for sedimentary biotopes and containing few species were found at those sites. Furthermore, anthropogenic impact during the past 30 years has influenced the composition of the benthic biocoenosises.

In the evaluation of macrozoobenthos data, results are presented for the nine geo-morphological Reaches (see Chapter 3) or by summarizing the three sections of the Danube as follows:

- upper section includes Reaches 1 and 2
- middle section includes Reaches 3 ,4, 5 and 6
- lower section Reaches 7 ,8 and 9

This is different from the definitions used in discussing chemical results in Chapter 5, where the upper section also includes Reach 3 and the middle section only consists of Reaches 4,5 and 6.

This different approach for evaluating biological results was adopted because it had been proved by prevoius investigations that downstream of the confluence of the Danube and the Morava the aquatic community totally changed its alpine character at the so-called "Porta Hungarica".

As expected, the number of taxa per sampling site is the highest in the upper part of the Danube up to the mouth of the Inn (fig. MZB-1); the left bank of station JDS2 was inspected intensively. The decline of the taxa-count starting at JDS4 (Kachlet) up to and including JDS10 (Ybbs-Persenbeug) is a result of the sampling sites being situated upstream of the dams.

Along the middle Reaches, the impact of Gabcikovo Dam soon becomes noticeable.

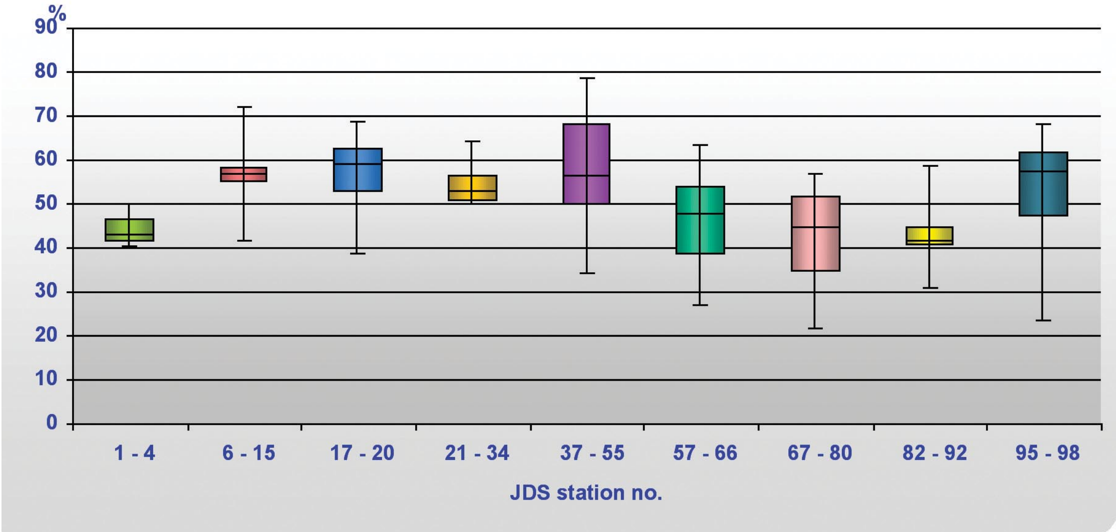



**FIGURE MZB 2.** Conformity of taxa from the two bank sides (right and left) of a JDS station. The columns indicate species correspondence in half of the samples, in percentages; the horizontal line represents the median value. Vertical lines show the variation between the highest and lowest value of species identity (SÖRENSEN's-quotient). The higher the percentage the higher the similarity within the composition of species.

With the exception of the Delta, a decline in the taxa-count from the middle to the lower Reaches was observed, especially for specific classes and orders. The species found in the Delta are not representative for the entire Delta since only the waterways were spot-checked. Among the last four sampling sites, only the last two provide a limited account of the situation in the Danube Delta, while the species composition at the stations JDS95 and JDS96 can be traced back to stronger urban influence.

Species identity quotient according to SØRENSEN shows the degree of agreement between the spectra of the species on both banks at a sampling site. Looking at the results of complete sections of the Danube, the medians do not vary significantly (fig. MZB-2). At more than half of the sampling sites it is usually the dominant species that account for an agreement of at least 42 to 60 % between the animal population on both banks. The crucial factors influencing the degree of agreement (mind the variation) are comparable or varying conditions of the current and the substratum. Variations occur as a result of the samples being collected at the outer or inner banks of the river bends, as well as at the end of transverse groynes, which form the boundaries of shallow bays but cannot be dredged by ship. Such a situation occurred repeatedly on the right bank in section 5 and is illustrated in fig. MZB-1. Additionally, both municipal or industrial discharges as well as the varying load of tributaries are of importance.

In the lower Danube, where fine-grained substrata predominate, the number of taxa increased because additional, frequently hard-to-find substrata (deadwood, aquatic plants) were collected. Not only were fewer taxa per sampling point found beyond the Iron Gate, but the correspondence between the species spectra on both banks was also the lowest.

Where there are no distinctions between both banks either in terms of geo-morphologic or hydrologic conditions, or in saprobity or trophy, an uneven distribution of many recedents or companion species at the bottom of running waters is the reason for their presence in only one of the two samples.

If the list of taxa were established by summarising the number of taxa from both banks of JDS sampling points, as it has been done for the arms and tributaries of the Danube, the number of taxa for the Danube would also be higher.

As a result of altered flow velocity, substratum and sedimentation conditions in the intact arms or free-flowing stretches of the "old Danube", a larger number of variously structured habitats could develop. Their structure and the associated species variety are primarily the result of the frequently intensive usage of such waters.

## SIDE ARMS

In the arms of the Danube, the number of taxa from only one bank side does not vary greatly from those at sampling sites in Reaches 4 and 5 of the middle section of the Danube (fig. MZB-1).

If one analyses longer bank stretches, the number of snails and mussels in particular increases. Therefore, the number of species in the old arms of the Danube can be desribed as ranging from 22 (Moson - JDS 24) to 48 (Old Danube - JDS 22).

## TRIBUTARIES

With the polyp grab of the ARGUS, samples could be taken from the mouths of twelve tributaries. Both the Schwechat and the Olt were too shallow for the ship to enter, so that - like at the mouths of the Iskar and the Arges - biological samples were taken with a net from a small motorboat. No macroinvertebrates were found in the stony-shingly sediment of the Iskar. Higher taxa groups were also missing on both banks of the Olt and the Arges rivers. The sample of the Arges, however, showed large colonies of microzoa species of the genus Epistylis and Carchesium, a strong indicator of pollution by insufficiently treated sewage.

The large tributaries, the Inn (JDS 5), the Morava (JDS 16), the Drava (JDS 47), the Tisza (JDS 54), the Sava (JDS 56), the Siret (JDS 93) and the Prut (JDS 94) showed no greater variations compared to the stretches of the Danube downstream of their mouths either in terms of the number of taxa (fig. MZB-1) and species composition of the benthos, or in terms of the frequency of individuals of the dominant species. An exception is mayfly Palingenia longicauda, which was found only in the Prut. Additional differences concern species that are often not recognized because of their small size and that showed only a limited distribution throughout JDS.

*Urnatella gracilis* (Kamptozoa) was found in larger numbers only in the samples taken from the Morava and occasionally in those from the Vah. The species is known to have entered the Danube from the Black Sea and conquered the tributaries, especially the Tisza. However, this species was not found in the samples from the Tisza, but *Cordylophora caspia* was. This species of Ponto-Caspian origin, belonging to Hydrozoa, was confirmed several times in the samples from Reach 5 (JDS35 to JDS55).

Repeatedly *Branchiura sowerbyi* (Oligochaeta) was confirmed to exist in the Sio, the Tisza, the Sava, the Velika Morava, and the Jantra tributaries. After occuring a few times upstream of Belgrade, this thermophilic worm, presumably native to Southeast Asia, appeared more frequently in the samples from the last Reach of the middle section and from the lower section of the Danube.

The number of taxa (species diversity) should not be used as the only measurement in assessing the ecological quality of water, especially when all taxa are part of only very few orders or families. It has often been proved that some - but not excessive - organic pollution or input of nutrient might lead to an increase in species diversity. When assessing the composition of the biocoenosises to classify the ecological status, the existing composition has to be compared to the type-specific, near-natural reference conditions (ökologisches Leitbild) as stated in the EU-Water Framework Directive.

### 4.2.3.2 Dominant Benthic Taxa Groups

When macroinvertebrate species found in the nine geo-morphological reaches of the Danube are classified according to higher taxonomic units (Fig. MZB-3), there are noticeable variations both in the number of species of individual classes or orders as well as with regard to an increase or decrease of the taxa numbers of one group within the different reaches. An especially striking decrease in the number of species was observed in Reach 3 within the Grabcikovo reservoir. With a total of 42 species, caddisflies (Trichoptera) are the most common order, followed by snails (Gastropoda) with 30, mayflies (Ephemeroptera) with 27, beetles (Coleoptera) with 22, mussels (Bivalvia) with 20 and crustaceans with 18 taxa. With the exception of dragonflies (Odonata), all other aquatic insects showed a decline in the number of species as one approached the Delta.

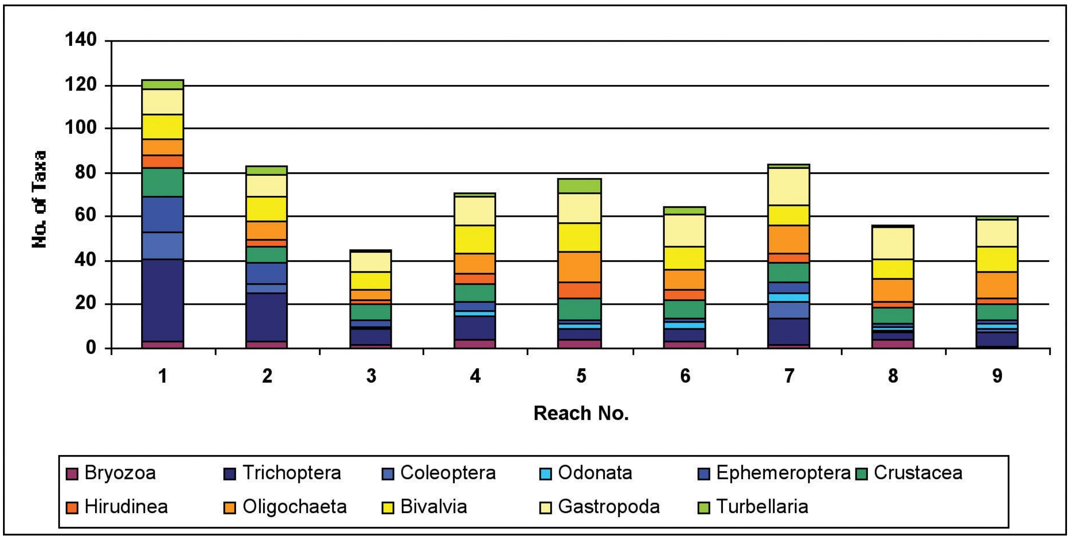



**FIGURE MZB-3.** Number of benthic invertebrate taxa per order and their distribution within the nine geo-morphological reaches.

A clearer picture of the distribution of taxa in the Danube appears if one considers only the relationships of the higher taxa groups between the upper, middle and lower reaches of the River (fig. MZB- 4). In the middle, but especially in the lower Danube with its flat banks and sandy/muddy sediments, Gastropoda, Bivalvia, and Oligochaeta gain importance not only on species level, but also with regard to the frequency of individuals. With relatively few species, compound animals like sponges (Porifera) and bryozoans form huge local populations, which cover all solid substrata, including shells of molluscs.

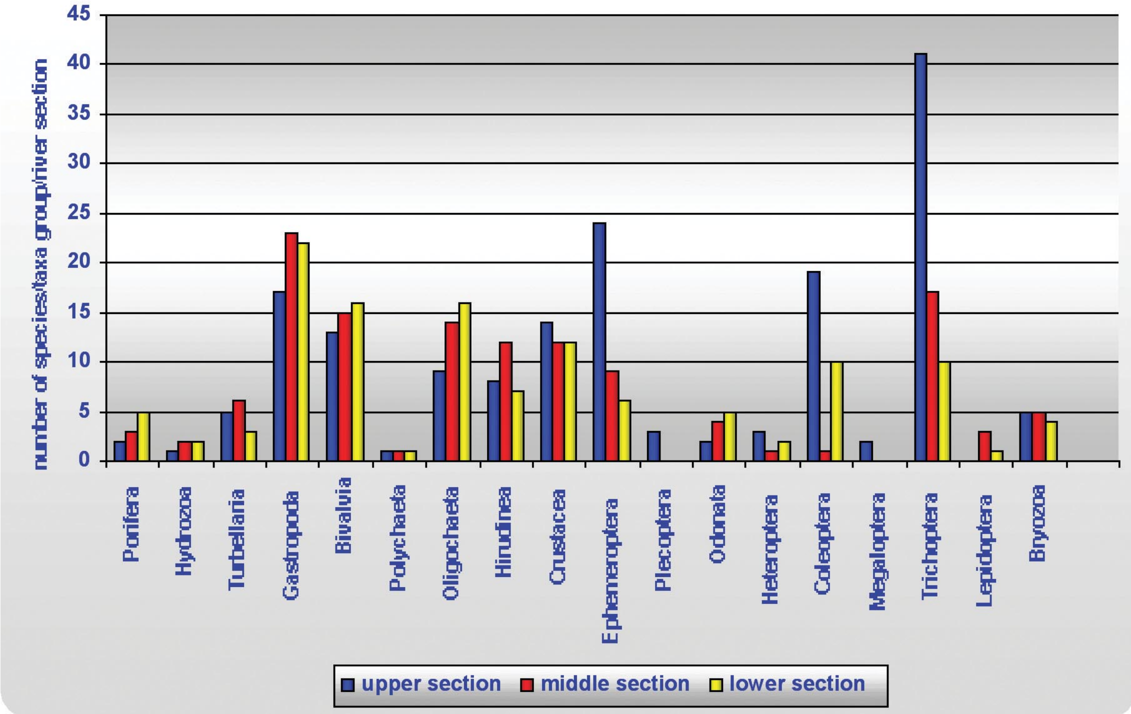



FIGURE MZB-4. Total number of species of the higher taxa groups (classes, orders) of macrozoobenthos in the three sections of the Danube (upper - Reaches1,2; middle - Reaches 3,4,5,6; lower - Reaches 7,8,9).

As expected, aquatic insects proved to represent the most frequent animals along the entire course of the Danube River (see fig. MZB-5). The dominance of this community would be even higher if chironomids were included. In the case of the three species-rich taxa groups - ephemerids, beetles and caddis flies - a general decrease in the number of taxa could be observed downstream. Stone flies (Plecoptera) are very sensitive and quick to respond to to oxygen deficits, small flow velocities or muddy sediments and inhabit only some favourable areas of the River's headwater.

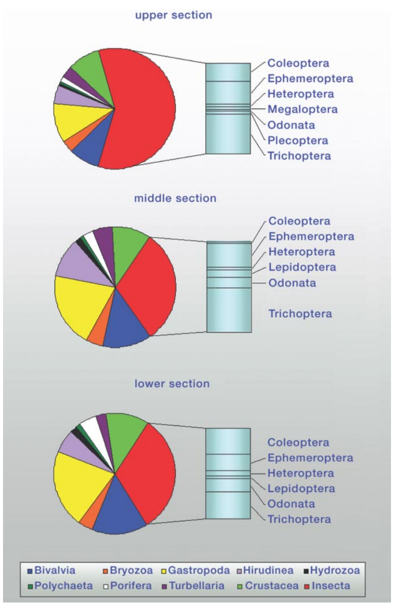



FIG. MZB-5. Percental distribution of different taxonomic groups of macrozoobenthos within the three sections of the River, with separation of aquatic insects according to orders. It has to be considered that the absolute number of taxa decreases downstream.

**Snails (Gastropoda)**

This order is highly represented in all samples, with the species spectrum slightly changing along the course of the Danube.

The river limpet, *Ancylus fluviatilis*, belonging to the lithophilous species living as grazers, dominates the upper reaches and the first reach of the middle sections (fig. MZB-6). The fact that *Potamopyrgus antipodarum* was not found in the samples downstream of Dunaföldvar (km 1560) is due to a change of substrata condititions.

Species belonging to the genus of *Theodoxus* were found even in the second reach upstream of both the Greifenstein lock and the mouth of the Morava. However, their large populations in the middle and lower sections of the Danube (fig. MZB-7) make them a typical part of the benthos biocoenosises in that part of the River.

These species favor a solid substratum (boulders, stones, plant parts), but they can also be found on sandy or muddy river bottom. Since they are predominantly found on stony substratum, that is where the highest frequency of individuals was always found. The highly heterogeneous occurrence on both banks of a sampling site, especially in the lower Reaches, mirrors the local substrata.

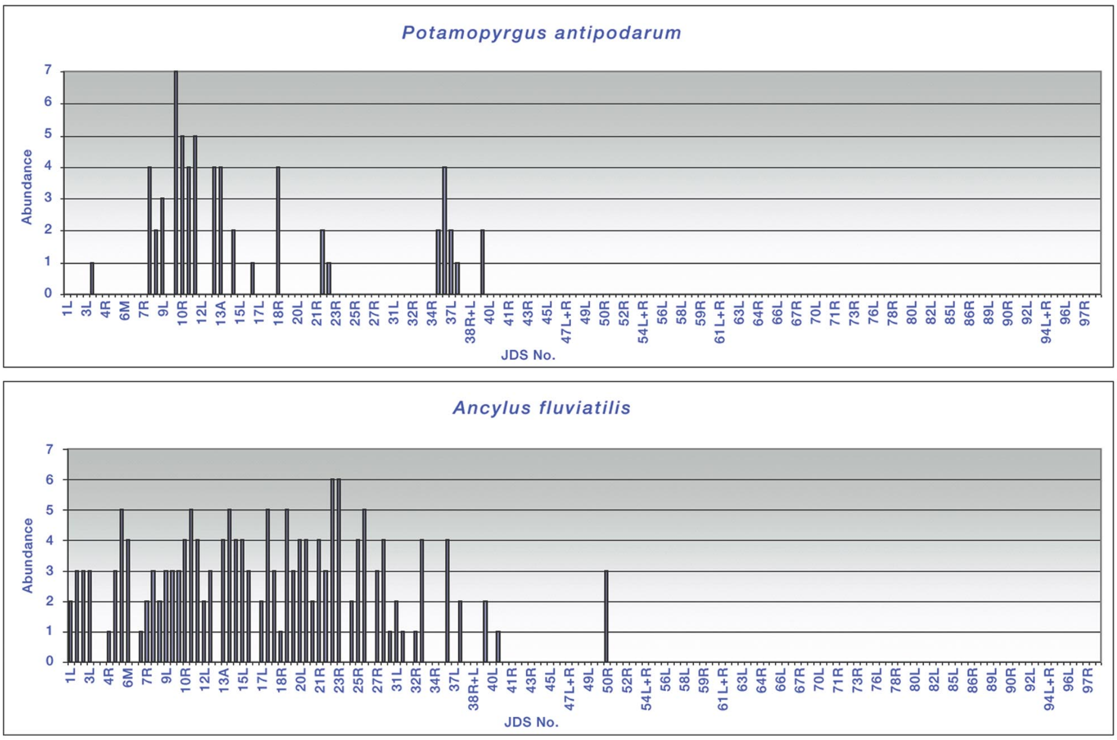



**FIGURE MZB-6.** Relative frequency of Potamopyrgus antipodarum and Ancylus fluviatilis at JDS sites.

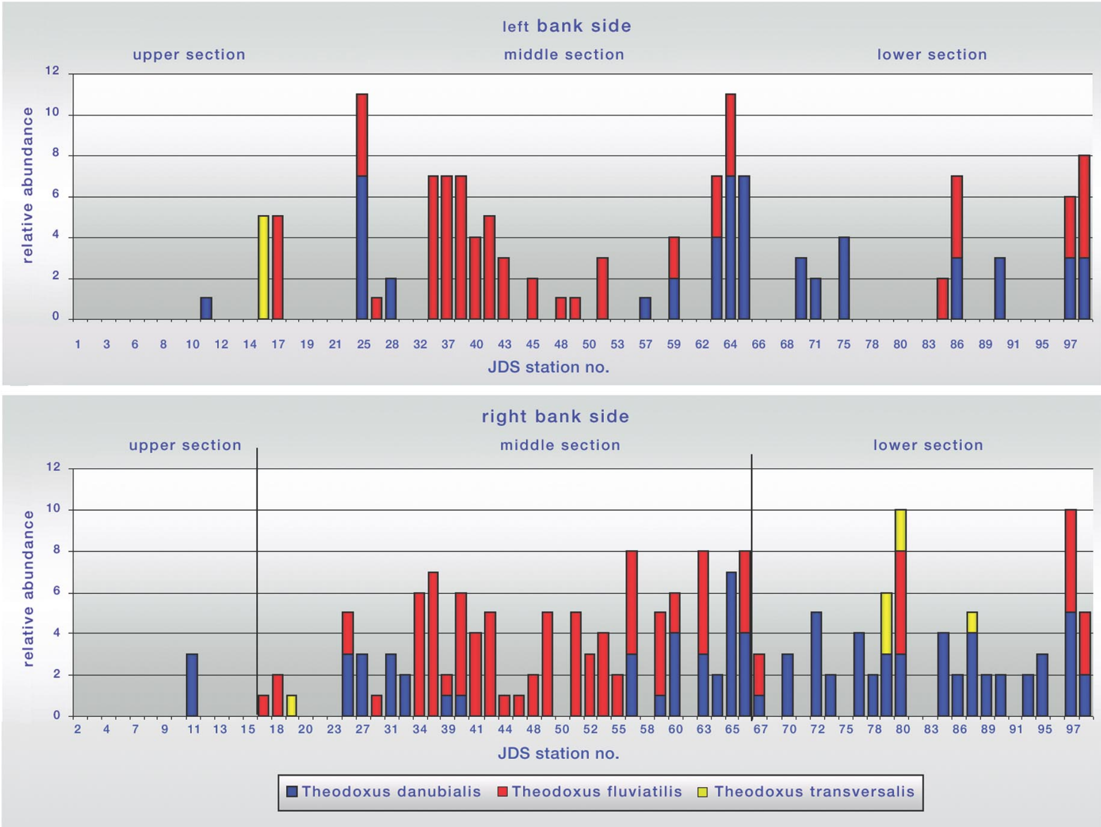



**FIGURE MZB- 7.** Relative frequency of species of the genus Theodoxus at the collecting stations, differentiated according to their occurrence on the left and right bank side of the Danube.

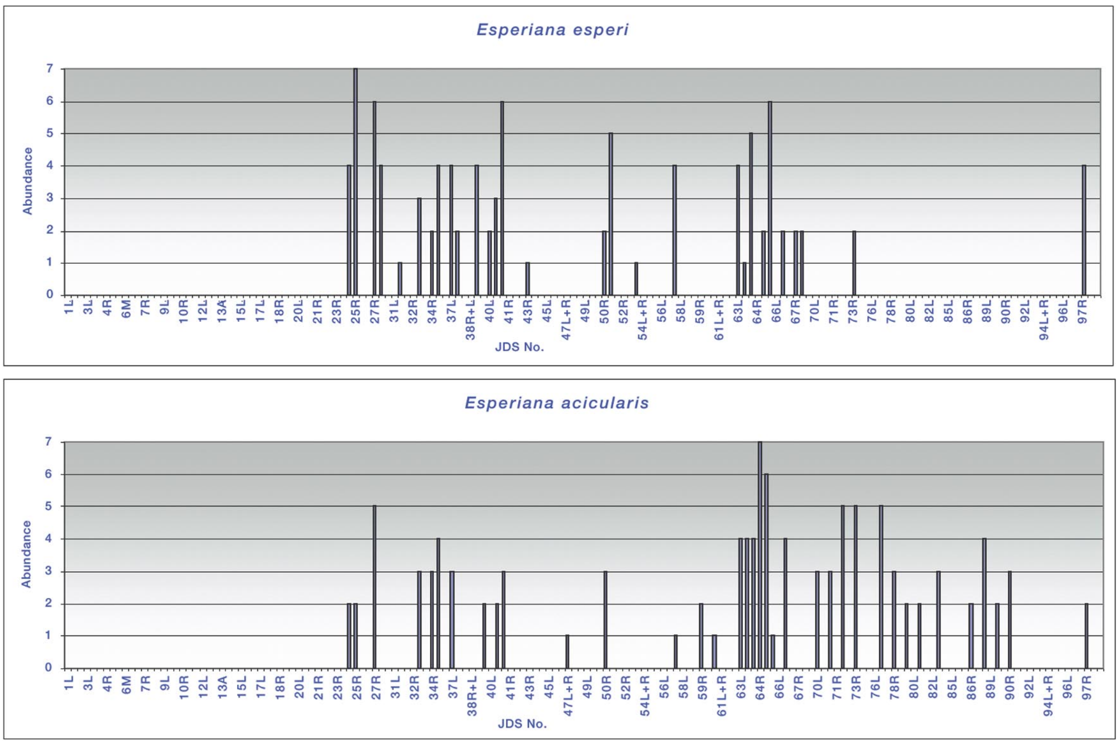



**FIGURE MZB-8**. Relative frequency of species of the genus Esperiana at JDS sites

Both Esperiana species (fig. MZB-8) are part of the benthic coenosises starting at the middle reaches only. They frequently coincide, but *E. esperi* forms larger populations in the middle reaches, while *E. acicularis* does so at some points in the lower reaches. Since these meta- and hypopotamalous species are not true grazers, but also detritus feeders, the question arises whether the same saprobic value (s = 2,0) is justified.

A species well adapted to living on soft sediments is *Lithoglyphus naticoides*. This mainly detritivorous snail was usually dominant at sampling sites with fine-grained sediment both in the middle (Csanyi, 2002) and lower reaches (fig. MZB-9). In terms of distribution, Holandriana holandri is limited to the lower Danube (fig. MZB-9)

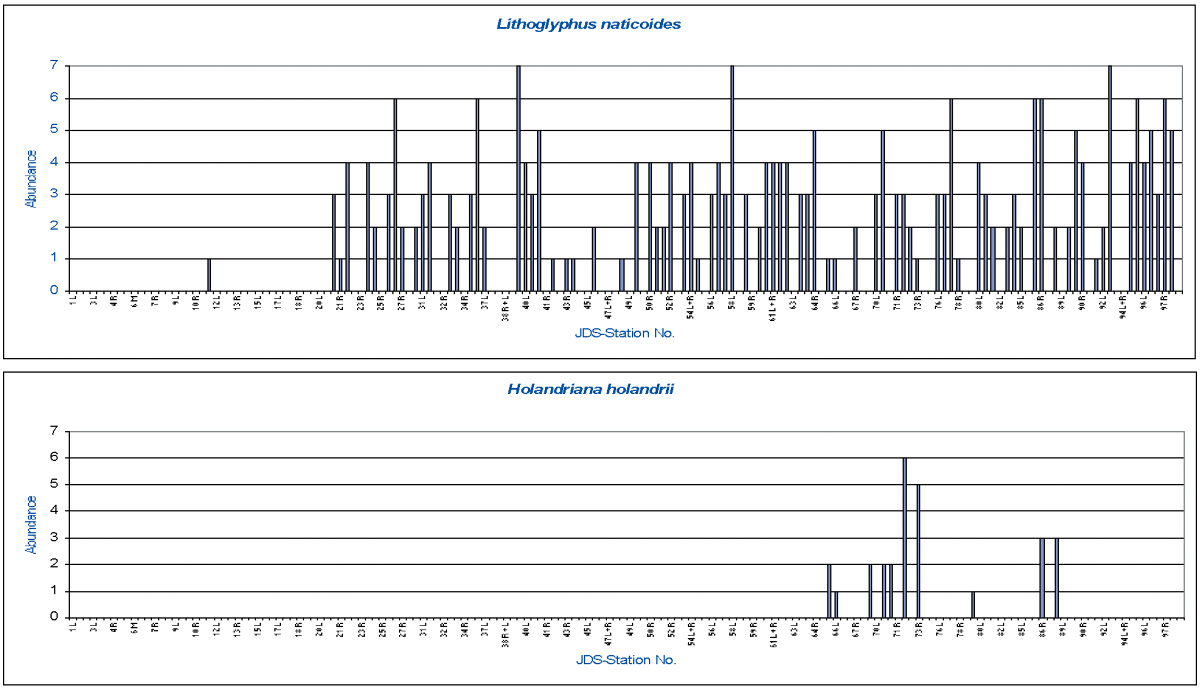



**FIGURE MZB-9.** Relative frequency of species of the genus Lithoglyphus and Holandriana at JDS sites.

## Mussels (Bivalvia)

Similarly to gastropods, the percentage of mussel species as a whole increases compared to other groups as one approaches the Delta (fig. MZB-5).

The most common is the Zebra mussel, *Dreissena polymorpha*, which settles on all solid substrata, predominantly in the middle section (fig. MZB-10). In the upper reaches, population density is lower; in the lower reaches mostly empty shells were found.

While Unionidae were hardly ever found at the official JDS sampling sites in the upper reaches and the upper parts of the middle reaches, they frequently formed large population densities in backwaters and bank areas with fine-grained sediment. *Unio tumidus* is the most common species, but *Unio pictorum* and *Anodonta anatina* was found almost everywhere. *Unio crassus* appears to be living solely in the Tisza River and the Delta. The Chinese mussel, *Sinanodonta woodiana*, was found primarily in the lower Hungarian section of the Danube (Csanyi, 2002).

*Corbicula* (fig. MZB-10) which has recently immigrated into the middle reaches of the Danube via the Main-Danube Canal (Csanyi, 1998-99) can by now be proven to exist all the way down to the Delta. In the immediate environs of the banks, the mussel was found primarily on sandy or pebble-covered ground. Very big specimens were found in the lower reaches.

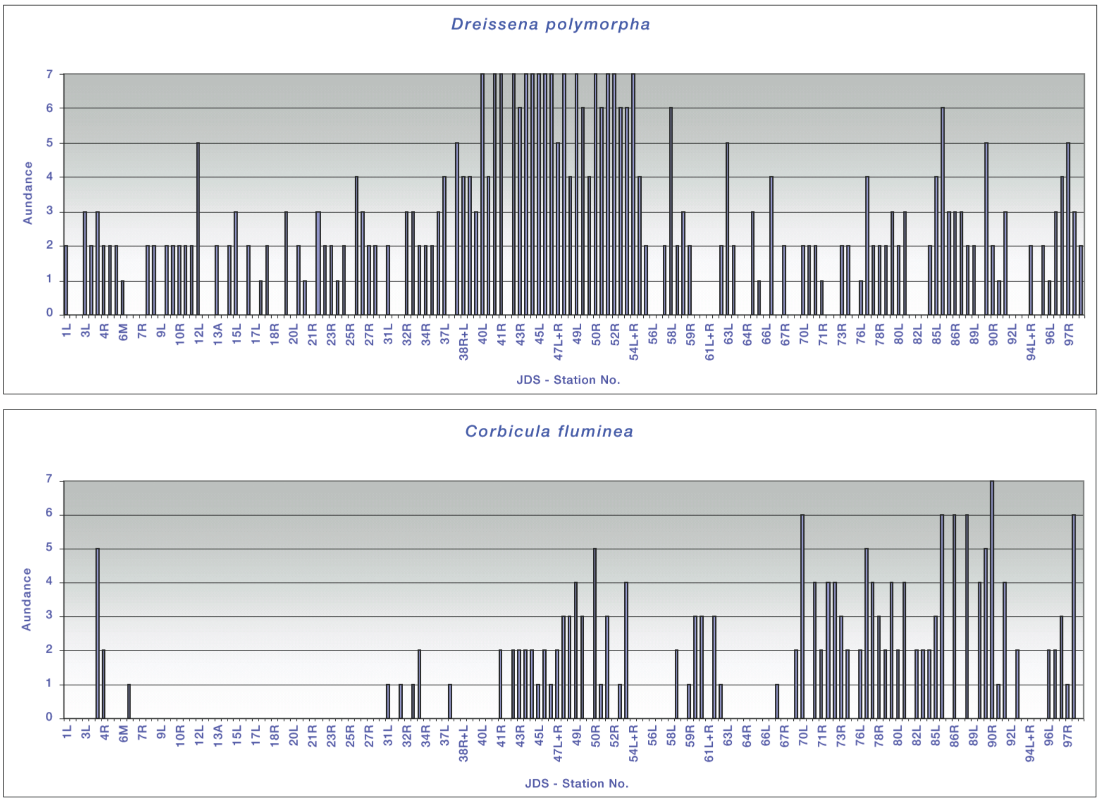



**FIGURE MZB-10.** Relative frequency of the mussels Dreissena polymorpha and Corbicula fluminea at JDS sites.

## Crustacea

Crustacea stand out not so much for the number of species living in the Danube as for the frequency and high abundance with which some representatives of this group colonize the River. Among the species with a high constancy of occurrence, frequently more than 80 % are *Jaera sarsi, Corophium curvispinum*, and *Dikerogammarus villosus*. They also keep occurring in all sections of the River with the highest frequency of individuals (Fig. MZB-11a, b).

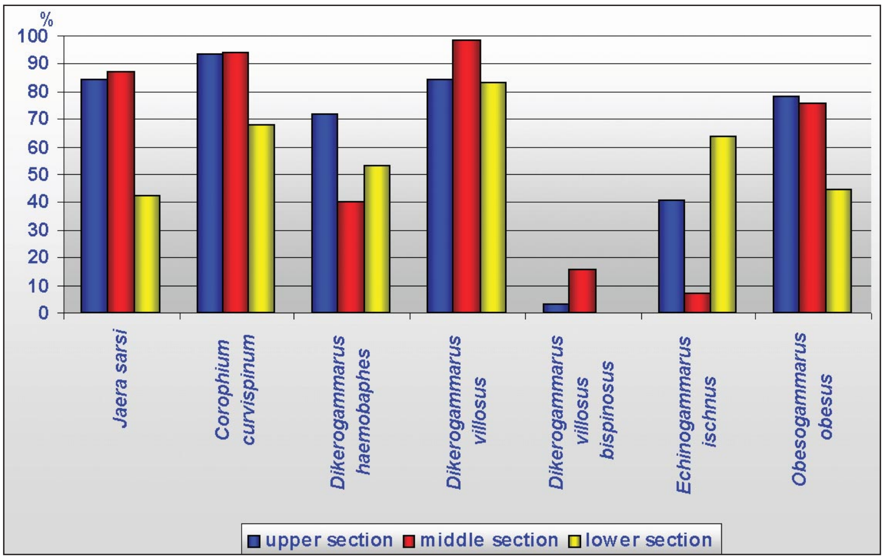



**FIGURE MZB-11A:** Steadiness of occurence (in %) of crustacea species across the Danube sections

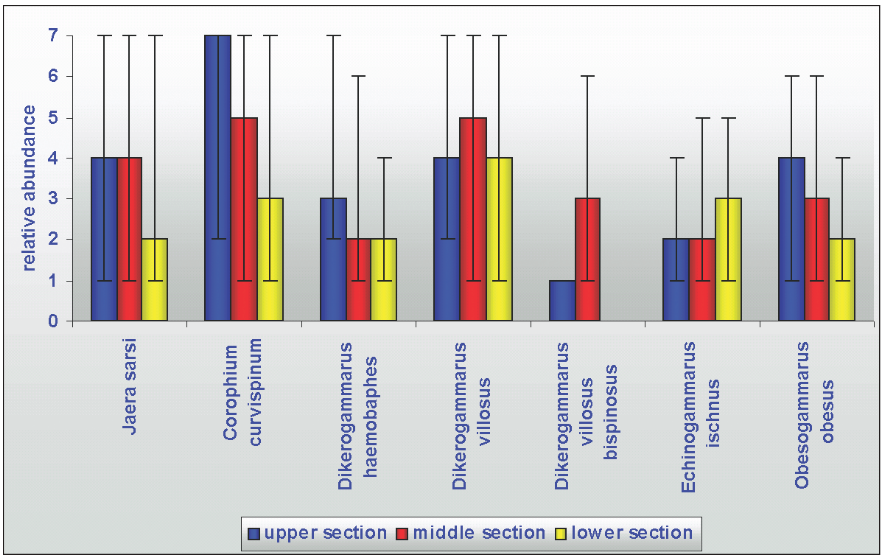



**FIGURE MZB-11-B.** Mean relative frequency (median) and its extreme values of crustacea species within the respective sections of the Danube.

**Caddis flies (Trichoptera)**

With the exception of aquatic Diptera, caddisflies represent a frequent and widespread group of insects in freshwater. This means that they are of great importance for the water-ecosystem, since they contribute considerably to the transfer of energy and nutrients through the trophic chain of the system. Their larvae have developed a huge diversity of morphological, physiological and behavioural mechanisms of adaptation to the different aquatic habitats. Therefore, they colonize almost all stagnant and running waters of the continents.

For a long time now, caddisworms have been used as indicators in biological water quality assessment. However, in their early stages they avoid waters that are strongly contaminated with biodegradable organic substances and do not, therefore, occur under polysaprobic conditions.

In the Danube, too, caddisflies belong to the most frequent insect taxa - with the exception of Diptera - verified by most JDS stations. In the upper and middle section their share of the remaining groups of insects amounts to almost 50 %, referring to stoneflies, ephemerons, beetles, bugs, sludge flies and dragonflies (fig. MZB-3, MZB-4, MZB-5). In the light traps and benthos collections 60 Trichoptera species were found in total, spread over 33 genera and 15 families. This number consists of 16 species which were determined exclusively on the basis of larvae material in the benthos samples, 20 species that occurred only in light traps and 24 species that were found in both the benthos and the light traps (see Annex - Macrozoobenthos).

The highest number of species (56) was found in the upper Danube section between Neu-Ulm and upstream of the Morava tributary, which represents 82 % of all species registered for the Bavarian stretch of the Danube in the last few years (Mauch, 1999).

In the middle part of the River downstream towards the Iron Gate, the frequency decreases to 25 species. This enormous decline may be partly explained by the decreasing diversity of the benthos choriotopes and changes in the hydraulic conditions in the impoundments as well as by possibly negative influences due to wastewater loads. Previously, 92 species were registered in the Hungarian part of the Danube (Uherkovic, 2001) for many years.

In interpreting the results of the Joint Danube Survey, one has to take into account the timing of the Survey, i.e. the fact that it was conducted in late summer, as well as the small number of samples. The fact that only 14 more species were found in the lower section all the way to the Danube Delta can be attributed to the same causes.

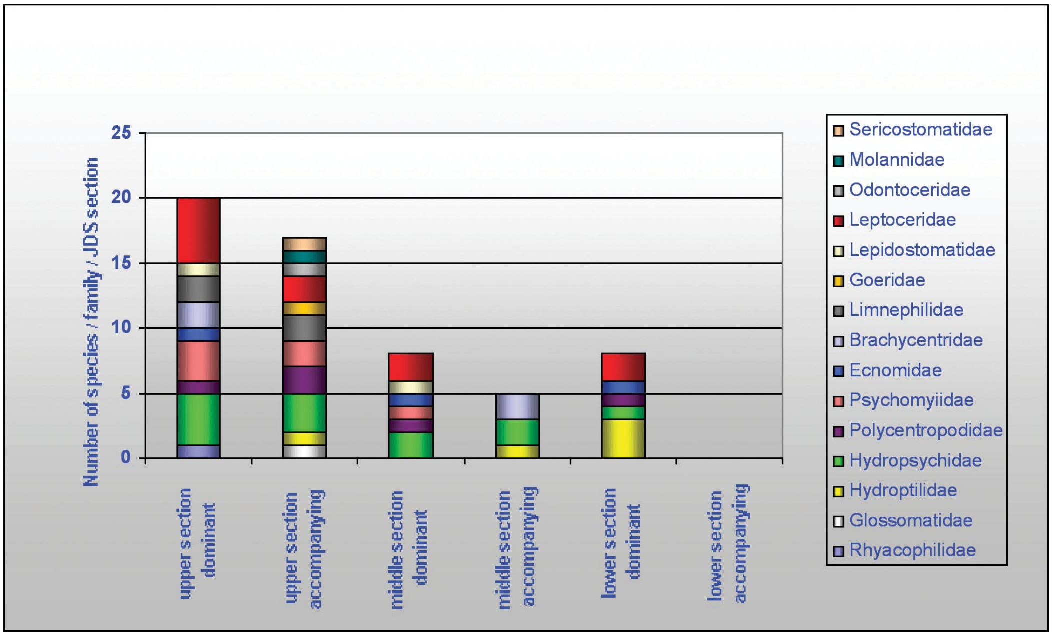



**FIGURE MZB-12.** The share of dominant and accompanying species, with reference to families and river sections. A species is described as dominant if its share of the total number of all species registered in a section amounts to more than 3.2 %. The share of the accompanying species represents less than 3.2 % (Engelmann, 1978).

Considering the total number of species and their frequency in every one of the three river sections, a distinction can be made between the dominant and the so-called accompanying species (Engelmann, 1978). The most dominant, constant species can be found in the Hydropsychidae and Leptoceridae families. In the upper and middle Danube sections, the species of Hydroptilidae are still underrepresented. However, they become the dominant group in the lower section. The number of accompanying species drops to zero as one moves downstream (fig. MZB-12).

The following nine taxa were scattered over all three sections of the River: the caseless caddisflies *Hydropsyche bulgaromanorum*, *Hydropsyche contubernalis* (Hydropsychidae), *Neureclipsis bimaculata* (Polycentropodidae), *Tinodes maculicornis* (Psychomyiidae), *Ecnomus tenellus* (Ecnomidae) and the case- bearing species *Hydroptila sparsa*, *Orthotrichia costalis*, *Orthotrichia tragetti* (Hydroptilidae) as well as *Oecetis ochracea* (Leptoceridae). Most of them belong to the functional feeding groups of filterers or they are scrapers, predators and detritivores. Therefore, they can exploit the primary production of planktonic and sessile microalgae as well as zooplankton as a food resource in the impoundment sections and in the lower course of the Danube with higher trophy level. In addition, they tolerate a higher degree of saprobity of water, especially the three species *Ecnomus tenellus, Hydropsyche contubernalis* and *Hydropsyche bulgaromanorum*.

## 4.2.3.3 Population Movements and Neozoa

Species transported by ship over long distances, predominantly those of Ponto-Caspian origin, have found their place in ecological niches of all European waterways. The building of canals between the big river systems has facilitated the transport of species far beyond their original ranges. The building of the Main-Danube Canal and its opening in 1992 removed a natural barrier that had existed for millennia between the Rhine and the Danube. A bi-directional transfer of hitherto geographically isolated faunal elements and genetic potential followed. The competition between local species and neozoa (alien species) for food and habitat has resulted in changes in the diversity of potamal biocoenosis.

Among the aquatic macrozoa collected during the Joint Danube Survey there are many, often frequent species, which today already inhabit the Rhine River system as neozoa or have migrated from there to the Danube as "newcomers".

Changes in the number of species and population densities within the coenosises of macro-invertebrates in the Danube, the Main-Danube Canal, and in the Main and Rhine rivers have been documented extensively in recent years, e.g. in the magazine "Lauterbornia". Special consideration has been given to the occurrence and migration of crustaceans. Among the taxa originally native to the Ponto-Caspian area are the predominately halophilous Amphipoda *Dikerogammarus haemopbaphes*, *D. villosus*, *Obesogammarus obesus*, *Echinogammarus trichiatus*, *E. ischnus*, *Corophium curvispinum*, the Mysidacea *Limnomysis benedeni*, *Hemimysis anomala*, and the Isopoda-species *Jaera sarsi syn. istri* (WEGMANN, A. et al., 2002).

Further Ponto-Caspian species are *Dendrocoelum romanodanubiale* (Turbellaria) and *Hypania invalida* (Polychaeta), which have spread since 1993, just like Jaera, from the Danube via the Main-Danube Canal into the Main and the Rhine rivers. This also applies to *D. haemobaphes*, which was proven to live in the Main-Danube-Canal just one year after its opening. *D. villosus* had already reached the Dutch reach of the Rhine River by 1994/95 and arrived, via North-German canals, in the Elbe in 1998. Occasionally *Echinogammarus ischnus* and *G. trichiatus*, which by now live in the Main and Rhine rivers, have appeared in the upper Danube for the first time since 1994/96. By 1974, *Obesogammarus obesus* was still limited to the middle and lower section of the Danube, but it was found for the first time in the German reach in 1995 and will thus presumably soon advance into the Rhine River system. *Limnomysis benedeni* is a euryoecious species which was found in the Austrian Danube in 1973 and which presumably advanced up to Passau by 1982 and into the Rhine River up to Koblenz in 1998.

The freshwater shrimp, *Atyaephyra desmaresti*, native to the Mediterranean, migrated in the opposite direction and was found in the Danube for the first time in 1998 at Engelhartszell. Another remarkable case is the dispersal of the mussel *Corbicula*. It was transported by ship from Europe and Egypt (Nile) as far as North America and then returned to Europe around 1980. It migrated into the Danube in 1997 starting in the Rhine River, reached the Hungarian region by 1998/99 (Csanyi, 1998-99) and was found in the Delta during the Joint Danube Survey in 2001.

A reverse trend could also be proven in the case of *Dendrocoelum romanodanubiale* (Tricladida, Turbellaria). Its population density increases significantly going upstream (fig. MZB-13).

These rapidly occurring population movements of various benthic invertebrates throughout the course of the River are largely due to anthropogenic causes. They are primarily due to the shipping traffic that serves as a means of transportation for the animals. Compared with earlier faunistical data, results of the current Joint Danube Survey clearly show that in the Danube, too – as in other waterways – a regional shift of colonization centers of autochthonous and newly immigrated benthic species can no longer be stopped.

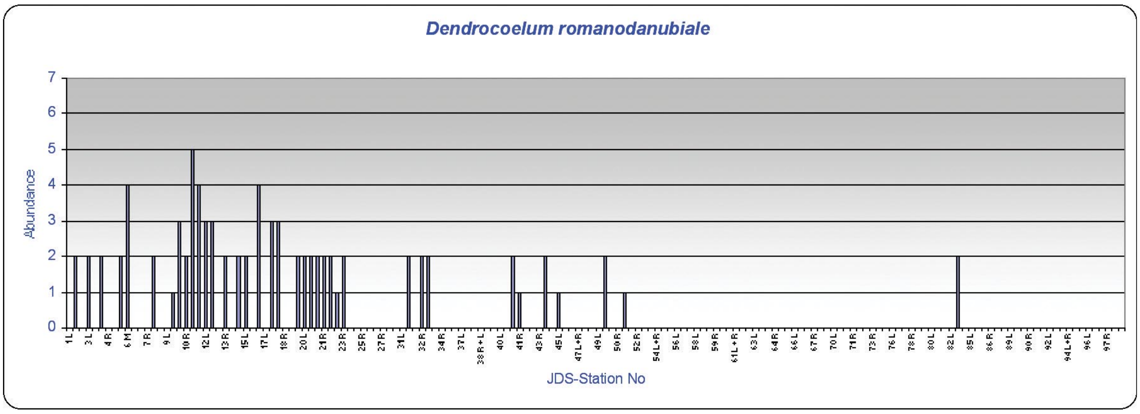



**FIGURE MZB-13:** Relative frequency of Dendrocoelum romanodanubiale at JDS sites.

### 4.2.3.4 Functional Feeding Groups

In order to get a picture of the distribution of trophic types of macroinvertebrates in the longitudinal course of the Danube, the percentage of each group was established for every sampling site, accounting for the abundance of the taxa determined, and was then integrated into an analysis of each of the three sections of the Danube respectively (Fig. MZB-14).

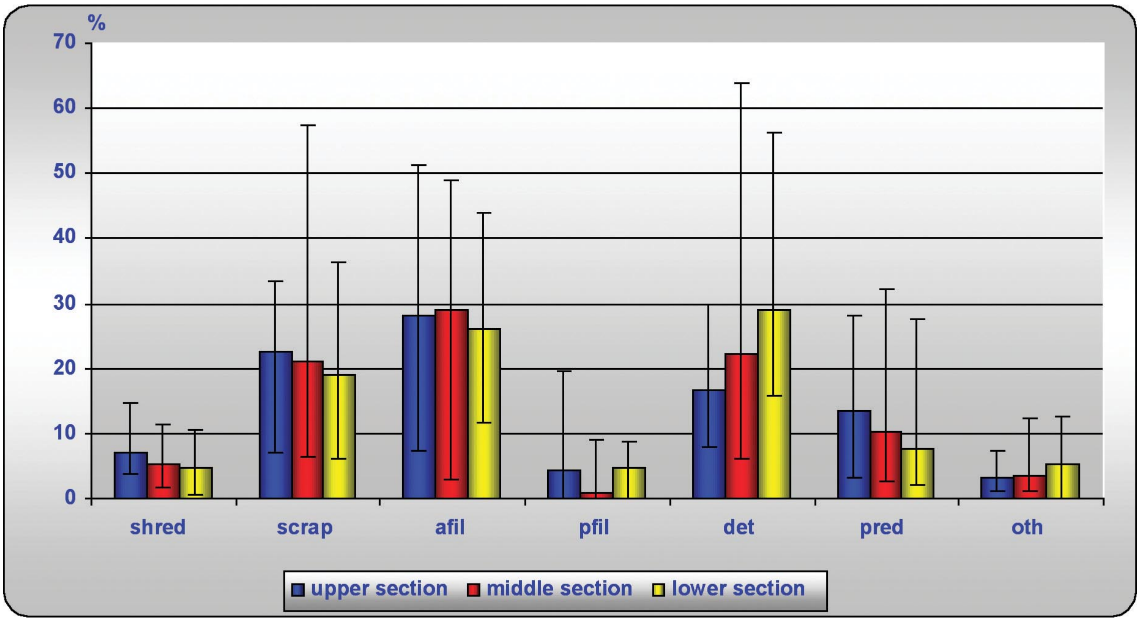



**FIGURE MZB-14.** The percentage of different nutritional types of aquatic macroinvertebrates and their distribution in the three sections of the Danube. The coloured columns represent the median value; the vertical lines show the variation between the highest and lowest percentage. Abbreviations: shred = shredder; scrap = scraper/grazer; afil = active filter feeder; pfil = passive filter feeder; det = detritus feeder (detritivor); pred = predator; oth = other type of feeding.

Following the River-Continuum Concept, the percentage of shredders decreases from the upper reaches to the mouth, while the percentage of detritivores increases. The relatively high proportion of detritivores already in the upper section is connected to the usual procedure of taking samples only upstream of dams, a typical sedimentation area for fine-grained particles. The proportion of organic carbon-compounds is relatively high in places like these compared to the free-flowing river reaches. The percentages of detritivores found in the middle and lower sections are considerably above the median and indicative (Fig. MZB-14) of mud deposits, partly as a result of sewage discharges. The high organic proportion in the sediment of the middle section is also the result of secondary pollution with dead phytoplankton, which reaches its highest abundance in this area.

With declining transparency downstream, the percentage of scrapers specializing on benthic algae decreases, while the group of active filter feeders increases in and out of dammed areas. In the middle section, colonization of boulders from the bank area was registered frequently. Resulting from this, biocoenosis in the free-flowing, organically moderately loaded river stretches consists mostly of scrapers (see also the percentage spread given in Fig. MZB-14). Active filter feeders like Bivalvia, Porifera, Bryozoa and *Corophium curvispinum* as well as passive filterers (Simuliidae, some Trichoptera) are well represented in all suspended-solid-rich sections of the Danube. Suspended solids can consist to a large degree of planktonic algae, which is the case in the middle section of the Danube.

The percentage of predators simply mirrors the amount of available food.

Scrapers and active filter feeders dominate at sampling sites in the arms of the Danube that are moderately polluted following their saprobity-indices (Old Danube, Szentendre arm ). In the Moson arm, detritivores account for more than 60 % of the biocoenosis because of the fine-grained sediments. In the dammed arms, the water bottom and the banks are predominantly colonized by filter feeders and detritivores, while the percentage of predators and scrapers ranges from 9 % to 20 %.

### 4.2.3.5 Evaluation of Saprobity - Biological Water Quality Class

Aquatic organisms - and macroinvertrebrates (macrozoobenthos) in particular - have for many years been widely used in Europe in assessing the organic pollution of rivers. In the Danubian area, this assessment is mainly based on the saprobic system that leads to a classification of water quality into seven biological water quality classes (four main classes and three in-between classes - see Chapter 4.2.2). Water quality class II (moderately pollutes) indicates the general water quality objective.

The saprobic system takes into account the varying sensitivity of the macrozoobenthos species to oxygen depletion in particular.

Not all invertebrate species found during JDS could be included in the evaluation, because for some species the saprobic values have not been established yet. Due to this, even species that were found relatively often in many samples, e.g. *Corbicula fluminea, Dendrocoelum romanodanubiale* and *Obesogammarus obesus*, had to be left out of the evaluation.

Based on the species determined and their relative abundance, saprobity indices were calculated for all JDS sampling sites. For the arms of the Danube, results were calculated by integrating the samples from both banks into a single saprobity index (see Annex - Macrozoobenthos). The results of the saprobic evaluation - expressed as water quality classes - can be seen in Fig. MZB-15.

As already mentioned in the introduction, there are some difficulties in the interpretation of the saprobic results of impounded rivers. Very often the saprobic indices calculated for impounded sections are a little bit lower compared to free- flowing sections although no additional discharge of pollution takes place. This is due to the fact that the decrease in flow velocity in reservoirs resulted in a change of sediment grain size to smaller fractions, up to a fine, muddy substrate in particular. Therefore, those oxygen-sensitive species that usually prefer stony substrates and high flow velocities and are used as an indicator of good water quality would disappear in impounded sections only because of the absence of their preferred substrate and not because of higher pollution. This proved to be the case during JDS assessment of the impounded, regulated upper section of the Danube. All JDS samples were taken in the headwaters of the dams, though in varying distances to the dams themselves. The saprobic index at those sampling sites very often bordered on water quality class II – III. In order get a more realistic picture and to be able to differentiate between organic pollution effects and effects due to habitat changes, additional samples were also taken in some free-flowing stretches in the run-off water of the following dams: Kachlet, Aschach, Abwinden-Asten, and Ybbs-Persenbeug. The saprobity indices of these additional samples proved that water quality in the dammed parts of the upper section of the Danube could be classified as good (water quality class II) with only a moderate level of saprobity.

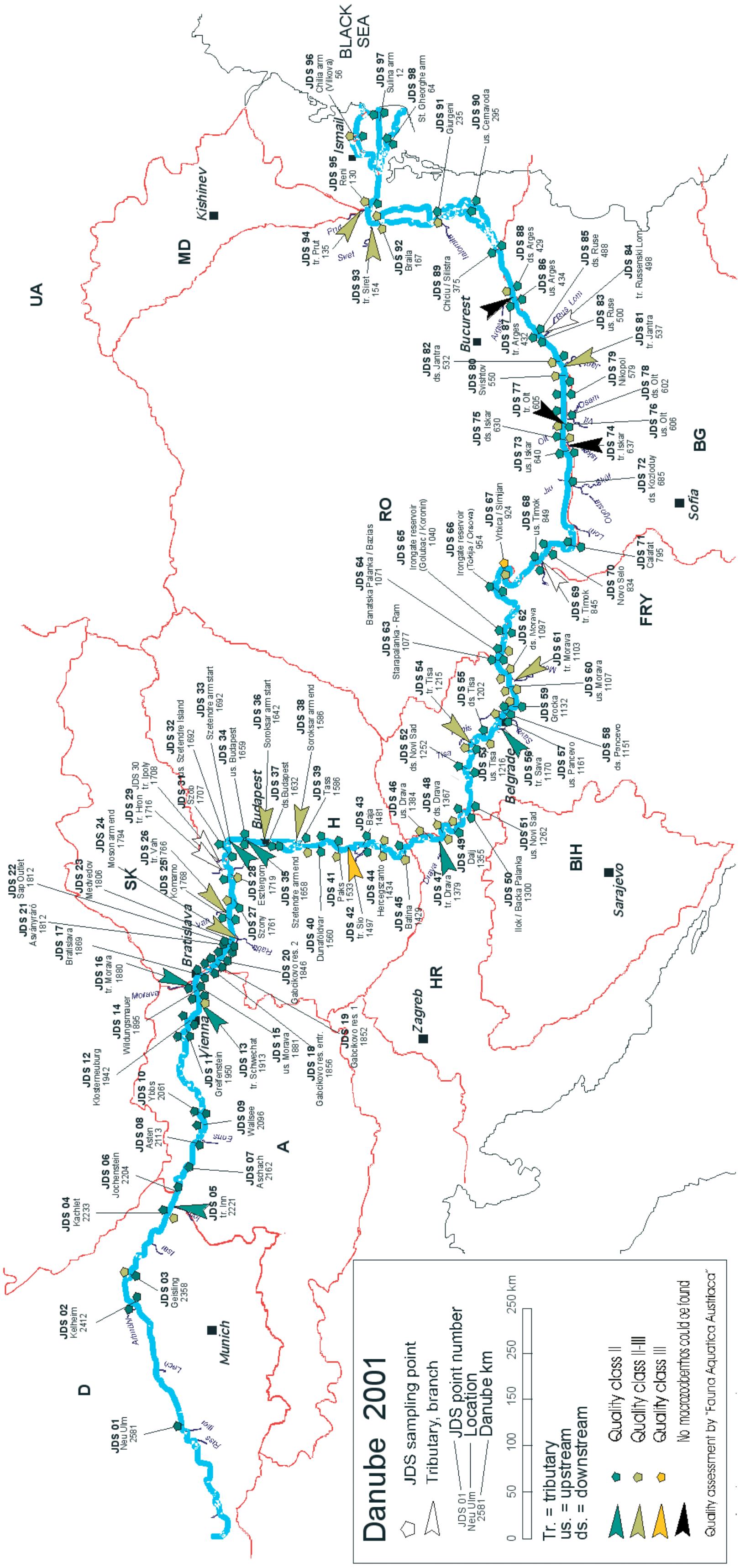
Saprobity indices of samples upstream of the Gabcikovo Dam indicated moderately polluted water (quality class II) in geo-morphological Reach 3.

Compared to the dammed Reach 3, the higher flow-velocity of geo-morphological Reach 4 from downstream of the Gabcikovo Dam to upstream of Budapest, contributes to a downstream movement of pollution. Flow velocity and substratum conditions influence the composition of benthic biocoenosises, which predominantly show water quality class II.

Downstream of Budapest, in Reach 5, where the Danube passes through the Hungarian Lowlands, water quality was often lower. At many sampling sites, water quality class II-III could be observed, indicating a critical level of organic pollution. Taking also into account the high chlorophyll-a values (see Chapter 4.5) as well as the extreme supersaturation with oxygen in this Reach, secondary pollution with autotrophic organisms is clearly recognizable which usually leads to increased saprobity after the end of the vegetation period.

In Reach 6, water quality varied between II and II-III. A trend began to appear, which continued in the lower section of the Danube: both banks of a sampling point began to differ concerning their saprobity, which seemed to be due to the effects of discharging tributaries that are heavily polluted. Only the impounded reach upstream of the Iron Gate showed saprobity values far below the limit for water quality class II (ß-mesosaprobic).

**FIGURE MZB-15.** Saprobic situation of the Danube



Interpretation of results for the lower Danube is far more difficult. The mainly flat banks with their sandy to clayey sediments might themselves be the reason for a reduced number of animal groups. However, especially downstream of big cities, discharges seemed to result in a turnover mainly on the level of destruents, bacteria and detritus feeders. Even toxic effects might be possible. On the left bank of the Danube, for example at Vrbica/Smiijan (JDS 67), no invertebrates were present on rocks and pebbles, and the very fine-grained, reduced sediment was predominantly inhabited by a few oligochaetes and chironomids.

The communities of microorganisms, plants and animals of a river section are exposed to environemental conditions changing periodically and aperiodically. Unlike the physical-chemical snapshots of water analyses, the saprobic index gives a significant information for a longer period of time. In this case the most unfavourable and not the average conditions are of decisive importance.

Looking at the sums of abundance of all species at a sampling point throughout the JDS-course of the Danube (Annex – Macrozoobenthos), in can clearly be seen that there is a significant decrease in the lower section of the Danube with an even more significant decrease on the left bank in Reaches 7 and 8 in particular. Because of the very low number of saprobic bioindicators at some sampling sites resulting from unfavorable substrata conditions or from toxic effects, some saprobity indices of certain sampling sites could not be validated statistically (Annex – Macrozoobenthos).

Taking into account the results of the chemical analyses, the high pollution of the tributaries of the lower Danube and the relatively low species variety in the Danube River on the way to its Delta, an even higher saprobic load as indicated by a large part of the saprobic results might be expected. On the one hand, high oxygen concentration speaks against a strong pollution with biologically easily degradable substances. In spite of high nutrient concentrations, however, measurable supersaturations do not occur – contrary to what happens in the middle section. Growth of algae is reduced, compared to the middle section (see Chapter 4.5). Looking at the chlorophyll-a values and oxygen saturation for the upper, middle, and lower sections of the Danube respectively, it is only for the lower section that the values do not correlate. It can be presumed that - as it happened in certain impoundments of the Main River many years ago - chemical pollution has a retarding effect not only on phytoplankton but also on macrozoobenthos. For example, the toxic effect of nitrite on some aquatic animals is well known.

Concerning the side arms of the Danube, the Moson arm (JDS 24) and the dammed Rackeve-Soroksar arm (JDS 36 and 38) are critically polluted (water quality class II-III), while saprobity indices of the Old Danube (JDS 22) and the Sszentendre arm (JDS 33 and 35) show moderate pollution (water quality class II). When comparing the number of taxa for each tributary with the saprobity indices, a higher load is indicated by species-poor biocoenosises with relatively few saprobiological indicators.

The Schwechat, the Drava and the Tisza can be classified as bordering between classes II and II-III.

The mouths of the Vah, the Velika Morava, the Jantra, the Siret and the Prut tributaries are critically polluted (water quality class II-III). The Sio even reached water quality class III. As a result of missing macro-invertebrates, the Iskar, the Olt and the Arges tributaries had to be rated as the worst (water quality class III).

However, a direct influence of the tributaries on the biological quality of the Danube, could be proved only in some cases, for example downstream of the Iskar and the Arges. This might be due to the position of the sampling sites, which were too far downstream. Already a distance of 1000 meters can act as an efficient, natural self-purification stretch, as shown downstream of the small Ipoly tributary, for example. JDS sampling sites on the Danube were often located at a distance of between 5 to 15 km downstream of the confluence with the tributary.

### 4.2.4 Comparison of Results with JDS National Reports

The German, Austrian, Romanian and Slovakian experts established close cooperation onboard the laboratory ship ARGUS with particular regard to sample taking. Methodological questions were discussed on site and so were the collected species. All samples from the German and Austrian reach of the Danube were given to the Senckenberg Institut for determination. The Romanian team conserved and took with them only a few records of the often very sparse material from the lower section of the Danube for documentation purposes after intensive and cooperative identification with the optic means available on board.

Samples taken with the polyp grab were shared with the Slovakian team. This team performed a large part of the identification process of living material aboard the ship.

The Hungarian team analyzed biological samples from bank areas, which had been taken submerged with a custom-made sweep net; additionally, organisms had been collected at a longer bank section as well, which did not directly correspond to the official JDS sampling points.

All species listed by the Slovakian team for each sampling point - with the exception of some chironomids - were also found by the JDS team. The number of taxa per sampling point given by the national team was expressed as "relative frequencies" and was generally slightly lower than that found in the samples taken by the Core Team (see Annex - Macrozoobenthos) because very small species or juvenile stages were not included.

As a result of the special method of collection, the qualiative species spectrum of the Hungarian report in some cases comprises a larger number of snail and mussel species, especially in samples taken from the arms of the Danube. Additionally, Mysidacea, which swim close to the bottom, were found more often in samples taken with the sweep net than in those taken with the polyp grab. Only kick sampling brought a substantial sample at the steep bank of the first JDS sampling point on the non-navigable Danube.

Porifera, Turbellaria, and Bryozoa were not listed by the Hungarian national team and nor were Jaera and caddisworms, of which often only young stages were missing.

The saprobity indices established by the Slovakian team by using their nationmal method varied only slightly from those calculated for this report.

### 4.2.5 Recommendations for Future Investigations of the Benthic Invertebrate Fauna of the Danube

Many years of practical experience gained through the examination of macrozoobenthos in large, deep streams like the Rhine and the Main rivers have shown that the collecting of samples with a heavy, hydraulically operated polyp-grab on board a ship like the ARGUS is a very suitable method. A stainless steel catching tub and the sieve device of the ARGUS also proved to be very useful.

Manual collecting from close at the bank is only possible at low water levels and ice-free conditions. By no means, the taking of samples should happen at a rising water level due to the fact that the previously dry bank strip has not yet been colonized by all macrozoa again. Solid substrates should always be brushed off under water as far as possible in order for the quantity of all sessile and attached organisms to be identified. It is not advisable to collect only with a pair of tweezers since this makes very small species (e.g. Turbellaria, Jaera) and juvenile larvae-stages easy to overlook and an assessment of the specific abundance becomes difficult.

If possible, sampling should take place in spring and early summer at sinking water levels, which is the most favourable time for examinations of fluvial macroinvertebrates. At this time many species of water insects are still in the aquatic phase of ontogenetic development as adult larvae, whereas later on they will already be emerged and it will no longer be possible to prove them to be contributing to macrozoobenthos. The taxonomic identification of eggs or 1.-2. instar larvae would not be not possible or could only be done by specialists.

When planning a new JDS, enough time should be allowed for a thorough sampling and for the taxonomically important live observation on board the ship.

In order to also get a more precise picture of the potentially possible benthic organisms and for a better comparability of the composition of species from sampling locations with differently structured river bottom, it is advisable to bring out artificial substrates for the colonization with macrozoa. This method should above all be applied in the lower course of the Danube.

Biological investigastions of dammed sections should be supplemented by additional samples in the run-off of the dams.

Special focus should be laid on the taxa list, which should be as complete as possible to allow any ecological evaluations.

Additionally, it is recommendable to thoroughly register the variety of animal population in the Danube Delta as a genetic pool for re-colonization of the lower course of the River.

### 4.2.6 Summary and Conclusions

An analysis of the fluviatile fauna of benthic invertebrates was a basic element in the investigation programme of the broadly diversified Joint Danube Survey.

Many years of experience in the Rhine and the Main area have proved the polyp grab to be a very suitable tool for sampling in large and deep streams. In the Danube, too, collecting benthos samples with the heavy grab of the ARGUS proved to be a very practical method.

In the stretch of the River between Neu-Ulm (Germany) and the Delta, 268 taxa have been ascertained. Including all the species from accessory light trap catches and from manual collections with a sweep net, this number would increase to slightly less than 300 taxa. It might also increase considerably in case of multiple collections at JDS stations and differentiated determination of taxonomically difficult groups like oligochaetes and chironomids.

The highest number of taxa could be found in the upper section, with an average of 40 species. In the middle and lower section the taxa number ranged from 30 to 10. The different substrate grain size and different flow velocities in the Danube have a considerable impact on the number of taxa. The taxa number for both banks matches only up to 60 %. Therefore, the total number of taxa per sampling point is higher than indicated. Concerning the number of taxa found, the main stream of the Danube differs only slightly from its tributaries.

The dominant groups of invertebrates show a varying distribution along the course of the Danube. While in the case of crustaceans the same species colonizes all of the Danube, insects show the greatest decrease in the number of taxa downstream. Molluscs and detritivores dominate the middle and lower sections.

With the construction and opening of the Main-Danube Canal, the biogeographical barrier between the Rhine and the Danube systems was removed and a mutual fauna transfer started. Shipping supports the fast dispersal of neozoans, for example in the case of the mussel Corbicula, which has already reached the Delta.

The saprobic indexes are also influenced by the diversity and habitat/substrate conditions. Due to this, saprobiological assessment of the impounded sections of the upper part of the Danube should always be supplemented by additional assessments of free-flowing stretches.

The saprobity of the Danube varied between water quality class II (moderately polluted) and II-III (critically polluted).

A high nutrient load in the middle section results in increased algae production, which leads, as an organic secondary pollution, to increased saprobity.

Many side arms arms and tributaries of the Danube are more strongly polluted than the mainstream and even reach water quality class III (strongly polluted) or higher. Due to the high discharge of the Danube, the pollution load from the tributaries mostly has only local influence on the invertebrates coenosis and the saprobity of the main stream.

The saprobity of the lower Danube could not be statistically validated because the number of bioindicators found was too small. So far, it hasn't been possible to clarify whether certain chemical components of the water do have a retarding or toxic effect on the development of aquatic organisms in the Danube.

No macrozoobenthos at all was found in the Iskar, the Arges and the Olt, which seemed to be due to toxic effects.

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