UNDP/GEF DANUBE REGIONAL PROJECT

"STRENGTHENING THE IMPLEMENTATION CAPACITIES FOR NUTRIENT REDUCTION AND TRANSBOUNDARY COOPERATION IN THE DANUBE RIVER BASIN"

ACTIVITY 1.1.7 "IMPLEMENTING ECOLOGICAL STATUS ASSESSMENT IN LINE WITH REQUIREMENTS OF EU WATER FRAMEWORK DIRECTIVE USING SPECIFIC BIO-INDICATORS"

FINAL REPORT

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Introduction

The report at hand presents the final outputs of the Activity 1.1.7 of the UNDP/GEF Danube Regional Project (DRP) "Strengthening the Implementation Capacities for Nutrient Reduction and Transboundary Cooperation in the Danube River Basin". The overall objective of the DRP is to complement the activities of the International Commission for the Protection of the Danube River (ICPDR) required to strengthen a regional approach for solving transboundary problems. This includes the development of national policies and legislation, the definition of priority actions for pollution control, especially nutrient reduction, and to establish sustainable transboundary ecological conditions within the Danube River Basin (DRB) and the Black Sea Basin area.

The presented results are part of the Output 1.1 "Development and implementation of policy guidelines for river basin and water resource management" supporting the Danube River Basin countries in the development of common tools and in implementation of common approaches, methodologies and guidelines for sub-basin management plans. The project assists in the implementation of the EU Water Framework Directive in Danube River Basin in order to apply a basin wide concept of river basin management.

With the reports of the activities 1.1.2, 1.1.6 and 1.1.7 the high priority tasks pressure and impact analysis, typology of surface waters, ecological status assessment have been executed. As products of this project we present a newly developed, validated stream section typology for the Danube River, which completely fulfils the requirements of the Water Framework Directive and is already agreed among the Danube River countries. The section types are described by means of short tables ("passports"), which may serve as hydromorphological reference conditions. For the definition of biological reference conditions an example is presented using historical data of the fish fauna of the Danube.

Beside this, tools for the analysis of pressures and impacts along the Danube are provided. For ecological assessment proposals for suitable methods have been developed after checking a variety of possible metrics. In this context saprobic reference conditions of the Danube are recommended based on macroinvertebrate data of the Joint Danube Survey. Furthermore, results of a detailed overview on biological and hydromorphological assessment methods used in the Danube River Basin are presented along with descriptions of individual methods available at http://starwp3.eu-star.at (Waterview Database).

The individual activities comprised the following steps:

Activity 1.1.2 "Adapt and implement common approaches and methodologies for stress and impact analysis with particular attention to hydromorphological conditions"

1. Development of the methodological approach (overview on driving forces and according pressures, development of criteria for significant impacts of a pressure):
    - Developing/completing a list of drivers that may cause important pressures that change the hydromorphological conditions in the Danube River stretch of the according country.
    - Developing/completing a list of pressures induced by each of the drivers that may provide important impacts on the biotic conditions in the Danube River stretch of the according country.
    - Developing/discussing a system to assess if a pressure has a significant impact and the water body is at risk to fail the good ecological status.
2. Outlook on necessary activities to achieve an overview of stress and impacts caused by changes of hydromorphological conditions in the Danube River.

Activity 1.1.6 "Develop the typology of surface waters and define the relevant reference conditions"

1. Division of the entire Danube River into section types featuring homogeneous abiotic characteristics.
2. Bottom-up validation of the proposed river-section types by means of Joint Danube Survey data and similarity analyses.
3. Agreement on the proposed typology of the Danube River between the Danube River countries and adaptation as part of the national typology systems for rivers.
4. Description of hydromorphological reference conditions for each of the section types by means of type-specific „passports".
5. Description of biological reference conditions (Austrian reference fish fauna as example).

Activity 1.1.7 "Implement ecological status assessment in line with requirements of EU Water Framework Directive using specific bio-indicators"

1. Conducting an overview study on existing ecological status assessment and classification systems in the Danube River Basin, which serve as a basis for harmonisation in line with the requirements of the Water Framework Directive.
2. Test of potentially suited assessment metrics based on the benthic invertebrate data of the Joint Danube Survey.
3. Establishing of type specific saprobic reference conditions for the Danube River itself.

Overview of Biological and Hydromorphological Assessment Methods in the Danube River Basin

SEBASTIAN BIRK

1. INTRODUCTION

One priority objective of the UNDP/GEF Danube Regional Project is to assist the Danube River Basin countries in the implementation of the EU Water Framework Directive (EU WFD) in order to establish river basin and water resource management. This includes support in developing systems to monitor the ecological status of surface waters. The EU WFD demands the application of methods that consider water body type-specific variations of the biotic communities, and their (near-)natural composition as benchmark of appraisal (the so-called reference state).

The implementation of these specific requirements currently initiates scientific and administrative activities throughout Europe: Existing monitoring programs and assessment systems are redesigned and new methods for the evaluation of surface water quality are in preparation (e.g. SCHMUTZ & HAIDVOGL 2002, HERING et al. 2003). Except for the Transnational Monitoring Network (TNMN) the present situation in the Danube River Basin is characterised by monitoring systems on regional and national levels. This fact leads to a large variety of methods at the cost of basin-wide comparability of results. Yet the EU WFD demands standardisation of assessment procedures and intercalibration of the outputs in order to reach harmonised water quality evaluation. This can only be put into practice on the basis of profound knowledge of each single, even regionally applied method. Such information has to be acquired and made available to the scientific community, the water management and the general public.

This study reviews methods used to monitor and assess the biological and hydromorphological quality of watercourses in the Danube catchment and outlines a policy towards harmonisation of quality classification.

2. METHODS

To collect data on assessment methods for watercourses in the Danube River Basin, two different questionnaires have been circulated to national consultants associated with the UNDP/GEF Danube Regional Project - one for methods using the biological quality elements: benthic invertebrates, macrophytes, phytobenthos, phytoplankton or fish; another for methods assessing general habitat quality (hydromorphological quality elements). Since the EU WFD places emphasis on biological parameters to assess the ecological state of surface waters, data on chemical assessment schemes have not been inquired. The questionnaires have been designed as blank forms with answers to be ticked or filled in. Recipients have been asked to complete the digital forms at the computer after receiving them via electronic mail.

Both questionnaires consisted of six chapters. The first chapter asked for general description of the method including scope of application, detected type of anthropogenic pressure and relevant literature references. In the second chapter questions covered sampling devices used and procedures applied, taxonomical data (e.g. level of identification) or recorded hydromorphological features, and costs of sampling. Chapter three dealt with calculation and assessment techniques such as score formula, conversion into quality classes, whether the evaluation is related to reference conditions, and the region where the method is applied. The fourth chapter queried data on presentation, monitoring programs and databases. Two final chapters allowed to describe how outputs are combined in order to obtain an integrated appraisal of ecological status, and to add comments.

To enable a comprehensive presentation additional sources such as methodological references, literature reviews, overview reports, internet resources and personal communication were used.

The acquired information has been entered into the Waterview Database, an Internet-based review of European assessment methods for rivers and streams (http://starwp3.eu-star.at).

3. RESULTS

The overview of biological and hydromorphological assessment methods for watercourses in the Danube River Basin comprises 47 schemes in 13 countries. Table 1 provides all biological methods currently applied or under development. In table 2 the differences of saprobic systems used by the countries of the Danube catchment are specified.

In the following section the national practices concerning biological and hydromorphological monitoring and assessment are summed up. Detailed descriptions of each method comprising the complete set of acquired data are available at http://starwp3.eu-star.at (Waterview Database).

Biological Assessment Schemes

Austria

Biological assessment of watercourses in Austria is based on the investigation of various quality elements. By means of benthic invertebrate and phytobenthos sampling the degree of organic pollution is monitored in a national network of 244 sites. Within this program the benthic flora is additionally used to indicate the trophic state. At the large rivers Danube, March and Thaya chlorophyll-a measurements are continuously carried out. Additionally, most of the federal states conduct regional networks, which evaluate benthic invertebrate samples and sometimes phytobenthos. In the federal state Upper Austria e.g. eutrophication of smaller watercourses is detected using diatoms.

From the early sixties to the mid eighties the Austrian water management put a focus on the documentation of organic pollution effects on rivers. Since 1985 water management shifted from a technocratic to a more integrative view by introducing the ecological integrity („ökologische Funktionsfähigkeit") of a water body as a political goal (CHOVANEC et al. 1994). The methods to describe the ecological integrity of rivers is described by MOOG (1994), CHOVANEC et al. (2001) and the Austrian standard ÖNORM M6232 (1997) that outlines a general framework for the ecological assessment of running waters. Within the context of implementing the WFD two multimetric schemes for assessing the ecological status of rivers are in preparation: The „Multi-level Concept for Fish-based, River Type-specific Assessment" (SCHMUTZ et al. 2000) shall enable a large-scale, nation-wide assessment of ecological integrity. A macroinvertebrate-based stressor-specific multimetric index for monitoring running waters in Austria has been tested and will be developed until end of 2004 (AQEM CONSORTIUM 2002; OFENBÖCK et al. 2002, 2003).

In this context it is planned to extend the national monitoring network to a maximum of 900 sites at which all biological quality elements will be sampled (benthic invertebrates, macrophytes, phytobenthos, fish) according to their relevance.

Within the „Multifunctional Integrated Study Danube Corridor and Catchment" (JANAUER et al. 2003) the aquatic vegetation of the Danube River Basin is surveyed covering Germany, Austria, Slovakia, Hungary, Slovenia, Croatia, Serbia-Montenegro, Bulgaria and Romania.

Bosnia-Herzegovina

In Bosnia-Herzegovina watercourses have been monitored using the saprobic system combined with „Species Deficit" (KOTHÉ 1962) until 1991 (cancelled due to war in April 1992). By using benthic invertebrate and phytobenthos samples the Saprobic Index is calculated according to PANTLE & BUCK (1955) formula and presented in seven quality classes. The „Species Deficit" method is based on the ecological principle that increasing watercourse deterioration is accompanied by decreasing species diversity. With reference to undisturbed conditions the percentage of remaining species is calculated. Results are used to complement findings of the saprobic system.

Bulgaria

The official method to monitor the biological quality of running waters in Bulgaria is a Biotic Index based on the Irish „Quality Rating System" (CLABBY et al. 1982). The index relates the relative abundance of five key groups of benthic invertebrates (sensitive forms to most tolerant forms) to water quality. Since most taxa are identified to family level application of this scheme requires less expertise and is cost-effective.

The Danube and its tributaries are investigated on the basis of macroinvertebrate data for more than twenty years. Analyses of species diversity, dominance and evenness are carried out and Saprobic Indices according to PANTLE & BUCK (1955) and ROTHSCHEIN (1962) are calculated (PEEV & GERASSIMOV 1999).

Croatia

Based on the investigation of different quality elements the Saprobic Index (PANTLE & BUCK 1955) is calculated. Benthic invertebrates and phytobenthos are sampled in the Sava basin. In the Danube basin planktonic communities are assessed. In addition, density of phytoplankton and chlorophyll-a concentration is used to determine the trophic state of large rivers.

Preliminary studies on the implementation of the WFD are carried out and assessment methods are harmonised according to the demands of the EU WFD. This includes revision of indicator lists with respect to stream typology, redefinition of the classification scheme, developing a quality control system, education of future experts and organising workshops and seminars to prepare future standardisation.

Czech Republic

Saprobiological monitoring is used for standardised assessment of organic pollution in Czech rivers. It is applied in a large monitoring network (approx. 1450 sites) and evaluates the degree of pollution according to the technical norm ČSN 75 7716 (1998). Within a separate method the investigation of phytobenthos is specified to detect organic pollution and acidification of watercourses.

Since 2002 small watercourses are monitored by using the PERLA prediction system (KOKES et al. 2001). The method compares the sampled fauna with a stream type-specific reference fauna to detect general degradation. A multimetric approach is followed in the Czech AQEM system. Organic pollution, morphological and general degradation are assessed comprising three small and mid-sized stream types. Combined approach including fish, phytobenthos and chemical assessment is under development.

Germany

In Germany both the federal structure and implementation of the WFD account for a broad spectrum of methods currently applied or under development.

The Danube River Basin covers parts of Baden-Wuerttemberg and Bavaria. In these states the degree of organic pollution is monitored using benthic invertebrates and heterotrophic periphyton (mostly ciliates). The German standard DIN 38 410 (1990, 2003) which is presently revised including an enhanced list of indicator species provides the methodological framework. In regions sensitive to acidification two similar schemes are applied derived from the „Indication of the Class of Actual

Acidity“ (BRAUCKMANN 1992). This Biotic Index differentiates four macroinvertebrate groups of gradual sensitivity to acidification. Organisms belonging to the same indicator group are summed up to determine the acidity-class by exceeding a specific frequency-threshold. The trophic state of rivers in both federal states is investigated by chlorophyll-a analysis. Additionally, plant communities indicate trophy at Bavarian streams dominated by macrophytes.

The „Potamon-Type-Index“ (SCHÖLL & HAYBACH 2001) is specifically designed for the assessment of large watercourses. Species traits are considered for indication of general degradation.

Expansion of the multimetric approach conducted in the AQEM project to all German stream types comprising modules for the detection of organic pollution, acidification and general perturbation will be finalised in 2005. A nationwide stream type-specific assessment scheme based on reference conditions using macrophytes and phytobenthos is almost finished (SCHAUMBURG et al. in prep.).

Hungary

Monitoring of Hungarian watercourses is chiefly done by saprobiological analysis of the bioseston of rivers (Hungarian Norm MSZ 12 756 1998). Chlorophyll-a concentration of planktonic organisms acts as an indicator for eutrophication. In 2001 a small program has started to regularly sample benthic invertebrates at 100 sites throughout Hungary. Since taxonomical skills have to be expanded an adapted BMWP score (BIOLOGICAL MONITORING WORKING PARTY 1978) has been developed requiring family-level identification (CSÁNYI in NÉMETH 1998).

Within the Hungarian Biodiversity Monitoring Program various quality elements (benthic invertebrates, macrophytes, fish) are sampled at all major habitats including watercourses. The program aims at assessing the general state of the biota and communities, and studying the direct and indirect effects of human-induced changes.

Moldova

In Moldova regular monitoring of saprobiological water quality is carried out at the Prut River since 1976. Samples are jointly taken by Romanian and Moldavian water authorities and further data are exchanged.

By end of 2004 a new saprobiological assessment scheme will be finalised that includes investigation of benthic and planktonic organisms. Besides determination of the Saprobic Index the percent ratio of oligochaete-individuals to benthic invertebrates in total, and the abundance of saprophytic bacteria make up multimetric assessment. The overall water quality (six classes) is obtained by averaging the individual classifications.

Romania

Monitoring of aquatic biota throughout Romania is seasonally conducted in the National Water Monitoring System started in 1978. Formerly supported by the „Index of Relative Quality“ (KNÖPP 1955) pollution bioassessment of watercourses is now exclusively based on determination of the Saprobic Index according to PANTLE & BUCK (1955). As of 2004 resulting index scores will be classified in a five-fold scheme following the recommendations of KNOBEN et al. (1999). Additionally, chlorophyll-a concentration of phytoplankton is analysed to evaluate the trophic state of rivers.

To meet the demands of the EU WFD a national stream typology system will be finished by mid of 2004. In 2003 a multimetric method assessing the biological water quality has been completed regarding biodegradable substances, toxic substances and hydromorphological alterations. It is planned to combine the results of this method with the outputs of other methods in order to reach integrated appraisal of the aquatic environment by end of 2004. Additional monitoring of fish and macrophytes starts in June 2004.

Serbia-Montenegro

Based on the PANTLE & BUCK (1955) index water quality in Serbia is assessed since 1967. Monitoring comprises sampling of benthic invertebrates, phytoplankton and zooplankton. Eutrophication is indicated by classification of chlorophyll-a concentrations.

To meet its requirements Serbia-Montenegro aim at stepwise implementation of the WFD (TRIPKOVIC 2003): In the first phase effectual biological monitoring is made operational until 2004. In parallel, scientific and administrative foundations are elaborated including testing of appropriate metrics, establishment of a stream typology and definition of reference conditions. In the second phase national monitoring is integrated in the European network until 2007 providing data on assessment of ecological water status. For immediate incorporation into biological monitoring benthic invertebrates, macrophytes, phyto- and zooplankton and fish are suggested. In addition, phytobenthos and microzoobenthos are included in a second step.

Slovakia

In Slovakia watercourse monitoring is performed since 1963. It comprises investigations of the benthic and planktonic communities. Classification of biological quality is standardised (STN 83 0532 1978/79) and includes determination of the Saprobic Index according to ZELINKA & MARVAN (1961). The index values for macroinvertebrates, phytobenthos and bioseston are separately classified. Five classes of chlorophyll-a concentration complete the overall assessment.

To evaluate the ecological status of small watercourses a modified version of the AQEM system is prepared using benthic invertebrates and phytobenthos. In this context reference sites are investigated since 2003. An adapted method for large rivers like Váh, Hron, Ipel and Danube is also under development.

Slovenia

The classification of water quality in Slovenia is based on physical, chemical and biological analysis. Determination of the Saprobic Index is part of the biological watercourse monitoring program (GRBOVIĆ 1999). Periphyton and benthic invertebrates are investigated according to DIN 38 410 (1990).

Switzerland

Although the Swiss part of the Danube River Basin is rather small the headwater of the River Inn, an important tributary to the Danube, is located in the canton of Grisons. The cantonal water authorities use the „Swiss Diatom Index“ for biological water assessment (HÜRLIMANN & NIEDERHAUSER 2002). Based on the weighted average equation of ZELINKA & MARVAN (1961) the diatom index is calculated using 220 different taxa. To each taxon an indicator value is assigned which correlates with six chemical parameters.

The scheme is part of the „Methods for Investigation and Assessment of Running Waters in Switzerland“ which contain survey procedures at three intensity levels for the areas hydrodynamics and morphology, biology, and chemical and toxic effects. In future the multidisciplinary approach will lead to an integral assessment of running waters (LIECHTI et al. 1998).

Table 1: Biological assessment methods for watercourses in the Danube River Basin

Name of method	Country	Biological Quality Elements[1]								Stressors detected[2]					Status	Monitoring Program	Category
		BI	MA	PB	PP	ZP	FI	HP	PlB	OP	MD	AC	EU	GD			
AQEM Austria (Stressor-specific multimetric approach)	Austria	■								■	■				under developm.	under developm.	Multimetric Index
Assessment of Saprobiological quality of rivers	Austria	■		■				■		■					currently used	yes	Saprobic Index
Plankton Monitoring of large watercourses	Austria				■								■		currently used	yes	Biomass Analysis
Diatom-based Trophic State Indication	Austria			■									■		currently used	yes	Biotic Index
Multifunctional Integrated Study Danube Corridor and Catchment (MIDCC)	Austria		■								■		■	■	currently used	yes	*no assessment*
Multi-Level concept for Fish-based, river-type-specific Assessment (MuLFA)	Austria						■							■	under developm.	under developm.	Multimetric Index
Trophic state indication and geochemical evaluation of running waters	Austria			■									■		currently used	yes	Biotic Index
Revised Saprobic Index combined with Species Deficit	Bosnia-Herzegovina	■		■						■				■	currently used	cancelled	Saprobic Index
Biotic Index based on „Quality Rating Scheme“	Bulgaria	■								■				■	currently used	yes	Biotic Index
Saprobic Index according to ROTHSCHEIN (1962)	Bulgaria	■								■					currently used	no	Saprobic Index
Saprobic Index	Croatia	■	■	■	■	■				■			++		currently used	yes	Saprobic Index/Biomass Analysis
AQEM Czech	Czech Republic	■								■	■			■	under developm.	no	Multimetric Index
Assessment of Saprobity based on species composition of Microphytobenthos	Czech Republic			■						■		■	++		currently used	no	Saprobic Index/Biomass Analysis
Perla	Czech Republic	■												■	currently used	yes	Community Assessment
Saprobiological Monitoring	Czech Republic	■								■					currently used	yes	Saprobic Index
AQEM Germany	Germany	■								■	■				currently used	no	Multimetric Index
Assessment of Watercourses - Saprobity	Germany	■						■		■					currently used	yes	Saprobic Index

[1] BI – Benthic Invertebrates; MA – Macrophytes; PB – Phytobenthos; PP – Phytoplankton; ZP – Zooplankton; FI – Fish; HP – Heterotrophic Periphyton; PlB – Planktonic Bacteria
[2] OP – Organic Pollution; MD – Morphological Degradation; AC – Acidification; EU – Eutrophication; GD – General Degradation
++ additional detection of eutrophication by classification of chlorophyll-a concentration
§§ Macrophyte investigation in the context of the 'Multifunctional Integrated Study Danube Corridor and Catchment'

Table 1 (continued): Biological assessment methods for watercourses in the Danube River Basin

Name of method	Country	Biological Quality Elements								Stressors detected					Status	Monitoring Program	Category
		BI	MA	PB	PP	ZP	FI	HP	PIB	OP	MD	AC	EU	GD			
Bio-Ecological Investigation of Watercourses	Germany	■						■		■					currently used	Yes	Saprobic Index
Bioindication of Acid Condition	Germany	■										■			currently used	yes	Biotic Index
Ecological classification system for rivers and lakes using Macrophytes and Phytobenthos	Germany		■	■								■	■	■	under developm.	no	Multimetric Index
Indication of Actual Acidity	Germany	■										■			currently used	yes	Biotic Index
Mapping of Trophy	Germany		■	■	■								■		currently used	yes	Biomass Analysis/Community Assessment
Unified watercourse assessment scheme using Benthic Invertebrates	Germany	■								■		■		■	under developm.	no	Multimetric Index
Potamon-Type-Index	Germany	■												■	currently used	yes	Process Assessment
BMWP - HY (adapted to Hungarian conditions)	Hungary	■								■					currently used	yes	Biotic Index
Macrozoobenthos Sampling Project of the Hungarian National Biodiversity Program	Hungary	■												■	currently used	under developm.	*no assessment*
Sampling Fish by Electric Fishing	Hungary						■							■	under developm.	under developm.	*no assessment*
Saprobiological Investigation of Hungarian watercourses	Hungary				■	■			■	■			++		currently used	yes	Saprobic Index/Biomass Analysis
Vegetation sampling as part of the Hungarian Biodiversity Monitoring System	Hungary		■											■	currently used	yes	*no assessment*
Saprobiological assessment based on various metrics	Moldova	■			■	■		■	■	■					under developm.	yes	Saprobic Index
Determination of Saprobic Index according to PANTLE & BUCK (1955)	Romania	■		■	■	■				■			++		currently used	yes	Saprobic Index/Biomass Analysis
National Water Monitoring Strategy	Serbia-Montenegro	■	§§	■	■	■	■	■		■			■	■	under developm.	no	Multimetric Index
Saprobiological Investigations using PANTLE & BUCK (1955) Index	Serbia-Montenegro	■			■	■				■			++		currently used	yes	Saprobic Index/Biomass Analysis
National Surface Water Quality Monitoring System	Slovakia	■	§§	■	■	■				■	■		■	■	currently used	yes	Saprobic Index
Saprobiological Analysis	Slovenia	■		■						■					currently used	yes	Saprobic Index
Swiss Diatom Index	Switzerland			■						■			■		currently used	yes	Biotic Index

Table 2: Saprobic systems used in the Danube River Basin

Country	Elements[3] used to calculate SI	No. of Quality Classes	Upper Quality Class boundaries							Calculation	Lists of indicator species[4]	No. of abundance classes
Austria[5]	BI, PB, HP	7	< 1.25/ < 1.3	1.75/ 1.7	2.25/ 2.1	2.75/ 2.5	3.25/ 3.0	3.75/ 3.4	> 3.75/ > 3.5	ZELINKA & MARVAN (1961)	MOOG (1995, 2002); ROTT et al. (1997)	*no. of ind.* or 5 classes
Bosnia-Herzegovina	BI, PB	7	< 1.5	< 1.8	< 2.3	< 2.7	< 3.2	< 3.5	≥ 3.5	PANTLE & BUCK (1955)	SLÁDEČEK (1973); UZUNOV, KOSEL & SLÁDEČEK (1988); WEGL (1983)	3
Bulgaria	BI	5	> 80	80	60	40	20			ROTHSCHEIN (1962)	SLÁDEČEK (1973); UZUNOV, KOSEL & SLÁDEČEK (1988)	*no. of ind.*
Croatia	BI, MA, PB, PP, ZP	5	1.8	2.3	2.7	3.2	> 3.2			PANTLE & BUCK (1955)	WEGL (1983)	3
Czech Republic	BI, PB	5	< 1.5	< 2.2	< 3.0	< 3.5	≥ 3.5			ZELINKA & MARVAN (1961)	ČSN 75 7221 (1998)	*no. of ind.*
Germany (nationwide)[6]	BI	5	*stream type-specific* (see ROLAUFFS et al. 2003)							ZELINKA & MARVAN (1961)	DIN 38 410 (2003)	7
Germany (Baden-Wuerttemberg and Bavaria)	BI, HP	7	< 1.5	< 1.8	< 2.3	< 2.7	< 3.2	< 3.5	≥ 3.5	PANTLE & BUCK (1955)	BLfW (2003)	7
Hungary	PP, ZP, PlB	5	< 1.8	2.3	2.8	3.3	> 3.3			PANTLE & BUCK (1955)	GULYÁS (1998)	6
Moldova[7]	PP, ZP, HP, PlB	6	< 1.1	1.5	2.5	3.5	4.0	> 4.0		PANTLE & BUCK (1955)	SLÁDEČEK (1973)	*no. of ind. or cells*
Romania[8]	BI, PB, PP, ZP	5	1.8	2.3	2.7	3.2	> 3.2			PANTLE & BUCK (1955)	MARVAN, ROTHSCHEIN & ZELINKA (1980); SLÁDEČEK (1977); SLÁDEČEK (1981)	*no. of ind. or cells*
Serbia-Montenegro	BI, PP, ZP	4	< 1.5	< 2.5	< 3.5	≥ 3.5				PANTLE & BUCK (1955)	SEV (1973); SLÁDEČEK (1973); UZUNOV, KOSEL & SLÁDEČEK (1988); Uzunov (1979); WEGL (1983)	BI: 5 PP, ZP: 6
Slovakia[9]	BI, PB, PP, ZP	5	< 1.8/ < 1.5	2.3/ 2.0/	2.7/ 2.5	3.2/ 3.0	> 3.2/ > 3.0			ZELINKA & MARVAN (1961)	STN 83 0532 (1978/79)	BI, PP, ZP: *no. of ind. or cells* PB: 7
Slovenia	BI, PB	7	1.5	1.8	2.3	2.7	3.2	3.5	> 3.5	ZELINKA & MARVAN (1961)	SLÁDEČEK (1973)	3

[3] BI – Benthic Invertebrates; MA – Macrophytes; PB – Phytobenthos; PP – Phytoplankton; ZP – Zooplankton; FI – Fish; HP – Heterotrophic Periphyton; PlB – Planktonic Bacteria
[4] Some lists are partly modified and adapted to national requirements.
[5] different Quality Class boundaries (BI / PB)
[6] SI is one metric among others (Multimetric Index).
[7] SI is one metric among others (Multimetric Index).
[8] Here, only Class boundaries for Benthic Invertebrates are stated.
[9] different Quality Class boundaries (BI, PP, ZP / PB)

Method Categories

Assessment of environmental quality is based on the analysis of measurable components of the biotic and abiotic environment. According to type and scope of measured parameters („metrics“) different categories of assessment methods can be distinguished:

- A simple assessment of the trophic state of running waters is the **Biomass Analysis** by means of classification of chlorophyll-a concentration. In several countries spectrometric determination according to ISO 10 260 (1992) is applied to phytoplankton samples. The different national quality classifications are listed in table 3.

- **Biotic Indices** integrate taxa richness and pollution tolerance metrics. Basic principle of this approach is the assumption that taxa showing different sensitivity to disturbance disappear in a certain order as the pressure increases. In addition, the number of taxonomic groups is reduced. Both the Hungarian BMWP score and the Bulgarian „Quality Rating System“ belong to this category.

  Extended by abundance information **Saprobic Indices** represent specific modes of biotic scores. Especially in the Danube River Basin their application is widespread to detect organic pollution. Based on the work of KOLKWITZ & MARSSON (1902; 1908; 1909) saprobic systems have been revised with regard to quality classification and presentation (LIEBMANN 1951), calculation (PANTLE & BUCK 1955), indication (ZELINKA & MARVAN 1961) and general scientific framework (SLÁDEČEK 1973). Due to these modifications different specifications of the system exist. In the Danube catchment twelve countries apply Saprobic Indices using different quality elements, class boundaries, indicator lists and calculation formulas (table 2).

  Apart from detection of organic pollution Biotic Indices are used to assess eutrophication of watercourses. By means of weighted average equation (ZELINKA & MARVAN 1961) indicator values of phytobenthos species are taken into account.

- Within **Community Assessment** complete species assemblages are considered. A basic implementation of this approach is represented by the „Mapping of Trophy“ (BLFW 1998) applied in Bavaria. Different macrophyte assemblages are described and allocated to diverse levels of trophic condition.

  The Czech PERLA system is a Community Assessment scheme based on multivariate analysis techniques. To implement the scheme biological data of different reference sites have been classified according to their species assemblage. These classes have been related to a series of environmental watercourse attributes. Based on these variables the undisturbed species community can be predicted at any site and compared to the community observed at this site. Results are presented as Ecological Quality Ratios.

- **Process Assessment** focuses on evaluation of taxon characteristics such as functional groups and species traits.

  The definition of distinct reference communities as basis of assessment for large watercourses is difficult due to substantial anthropogenic influence and the occurrence of newcomer species occupying ecological niches. Here, the concept of Process Assessment is suitable as it appraises the performance of ecological functions rather than the presence of individual species. The „Potamon-Type-Index“ thus operates on the basis of an „open“ taxon list in which all species showing preference to potamal habitats are indicators of high quality. By definition newcomers have low ecological values.

- A fundamental concept of **Multimetric Assessment** is to analyse community health composed of community structure, community balance and functional feeding groups (BARBOUR et al. 1992). In this context it represents an integrative approach to water quality assessment combining various metrics like Biotic and Saprobic Indices, and Process Assessment measures.

All Multimetric Assessment schemes in the Danube River Basin are under development or have been implemented in recent times. As novel methodologies they feature stream type-specific assessment based on reference conditions.

Table 3: National quality classifications of chlorophyll-a concentration

<table>
<tr><th>Country</th><th>No. of Classes</th><th colspan="70">Upper Quality Class boundaries [µg/l]</th></tr>
<tr><td>Austria</td><td>10</td><td colspan="7">< 1</td><td colspan="7">3</td><td colspan="7">5</td><td colspan="7">8</td><td colspan="7">16</td><td colspan="7">30</td><td colspan="7">50</td><td colspan="7">100</td><td colspan="7">> 100</td><td colspan="7">-</td></tr>
<tr><td>Croatia</td><td>5</td><td colspan="14">< 2.5</td><td colspan="14">10</td><td colspan="14">30</td><td colspan="14">> 30</td><td colspan="14">-</td></tr>
<tr><td>Czech Republic</td><td>5</td><td colspan="14">< 10</td><td colspan="14">< 25</td><td colspan="14">< 50</td><td colspan="14">< 100</td><td colspan="14">> 100</td></tr>
<tr><td>Germany</td><td>7</td><td colspan="10">4</td><td colspan="10">8</td><td colspan="10">30</td><td colspan="10">50</td><td colspan="10">100</td><td colspan="10">> 100</td><td colspan="10">-</td></tr>
<tr><td>Hungary</td><td>10</td><td colspan="7">0</td><td colspan="7">< 1</td><td colspan="7">3</td><td colspan="7">10</td><td colspan="7">20</td><td colspan="7">50</td><td colspan="7">100</td><td colspan="7">200</td><td colspan="7">800</td><td colspan="7">> 800</td></tr>
<tr><td>Romania</td><td>5</td><td colspan="14">25</td><td colspan="14">50</td><td colspan="14">100</td><td colspan="14">250</td><td colspan="14">> 250</td></tr>
</table>

Hydromorphological Assessment Schemes

In most countries of the Danube River Basin hydrological and hydromorphological features of running waters are surveyed. However, systems for quality assessment based on abiotic parameters exist in only a few countries.

In the various federal states of Austria different methods to evaluate the structural quality of streams are applied (Upper Austria and Styria: Eco-morphological classification of channels according to WERTH 1987; Vorarlberg: Riverstructures Recording-Assessing-Representing – BUHMANN & HUTTER 1996; Tyrol: Inventory of Hydromorphology and Land-Use – AMT DER TIROLER LANDESREGIERUNG 1996a+b; Lower Austria: NÖMORPH – FREILAND UMWELTCONSULTING 2001a+b). Except for the Tyrolese method all these schemes represent more or less regional adaptations of WERTH (1987). Several hydromorphological attributes are summarised to assess five main-parameters (channel route, channel bed, water-land-interfaces, bank structure, riparian vegetation).

In Tyrol the modified Swiss „Rapid Ecomorphological Assessment“ (BUWAL 1998) is used. In Switzerland this scheme is part of the „Methods for Investigation and Assessment of Running Waters“ and aims at both assessing streams and providing a guide to the degree of naturalness of running waters in a particular region.

Data for the above mentioned methods are acquired in the field by recording structural features of the stream. In Germany, Baden-Wuerttemberg and Bavaria apply a low-cost screening method (Stream Habitat Survey–“Übersichtsverfahren“ - LAWA 1999) for the compilation of spacious survey maps. It is based on map-derived data and surveys a small number of parameters at section lengths of 1 km. An official German scheme for large watercourses using field-derived data is still under development. In a recent study the „Ecomorphological Survey of Large Rivers“ has been described by FLEISCHHACKER et al. (2002) to fill this gap. It has been applied to sections of the rivers Elbe, Main, Moselle, Rhine and Odra in Germany as well as in the Czech Republic.

Structural quality of Slovene watercourses is assessed by the „River Habitat Survey“ scheme (RHS - RAVEN et al. 1997). The method has been developed to support river management and habitat conservation in the United Kingdom. Within the European STAR project (http://www.eu-star.at) RHS is applied to provide hydromorphological data about the sampled sites. Participating countries in the Danube River Basin are Austria, Czech Republic, Germany and Slovakia.

In Romania an assessment scheme called „IMPAHID“ is under development. It is based on structural criteria subject to the type of hydraulic works which physically modifies the watercourse morphology.

Table 4: Hydromorphological assessment methods in the Danube River Basin

Name of Method	Country	Region	Status	Monitoring Program
Eco-morphological classification of channels according to WERTH	Austria	Upper Austria and Styria	currently used	yes
Riverstructures Recording-Assessing-Representing	Austria	Vorarlberg	currently used	yes
Inventory of Hydromorphology and Land-Use	Austria	Tyrol	currently used	no
NÖMORPH	Austria	Lower Austria	currently used	yes
Stream Habitat Survey – „Übersichtsverfahren“	Germany	Baden-Wuerttemberg and Bavaria	currently used	yes
Ecomorphological Survey of Large Rivers	Germany and Czech Republic	rivers Elbe, Main, Moselle, Rhine and Odra	currently used	no
IMPAHID	Romania	all large river basins	under developm.	no
River Habitat Survey	Slovenia; Austria, Czech Republic, Germany, Slovakia (STAR project)	STAR project: small number of sampling sites	currently used	no
Rapid Ecomorphological Assessment	Switzerland	throughout the country	currently used	yes

Danube River Basin assessment in a pan-European context

In figure 1 results of the present survey are compared to findings of an overview study covering 139 assessment methods in 33 European countries (BIRK 2003). Both overview studies result in the fact that mainly schemes using benthic invertebrates are applied. Water quality appraisal by means of benthic or planktonic algae represents another main focus in the Danube region, whereas only four percent of methods investigate fish communities to detect anthropogenic disturbance. Hydromorphological assessment methods and schemes sampling macrophytes make up equal percentages in both the Danube River Basin and entire Europe.

In the Danube basin the detection of organic pollution ranks first. One third of systems indicates this stressor. Throughout Europe water pollution and general degradation are the main pressures identified by biological quality elements. Eutrophication and morphological degradation are of higher relevance when assessing running waters in eastern Europe. However, schemes to detect toxic substances are not applied in the Danube region.

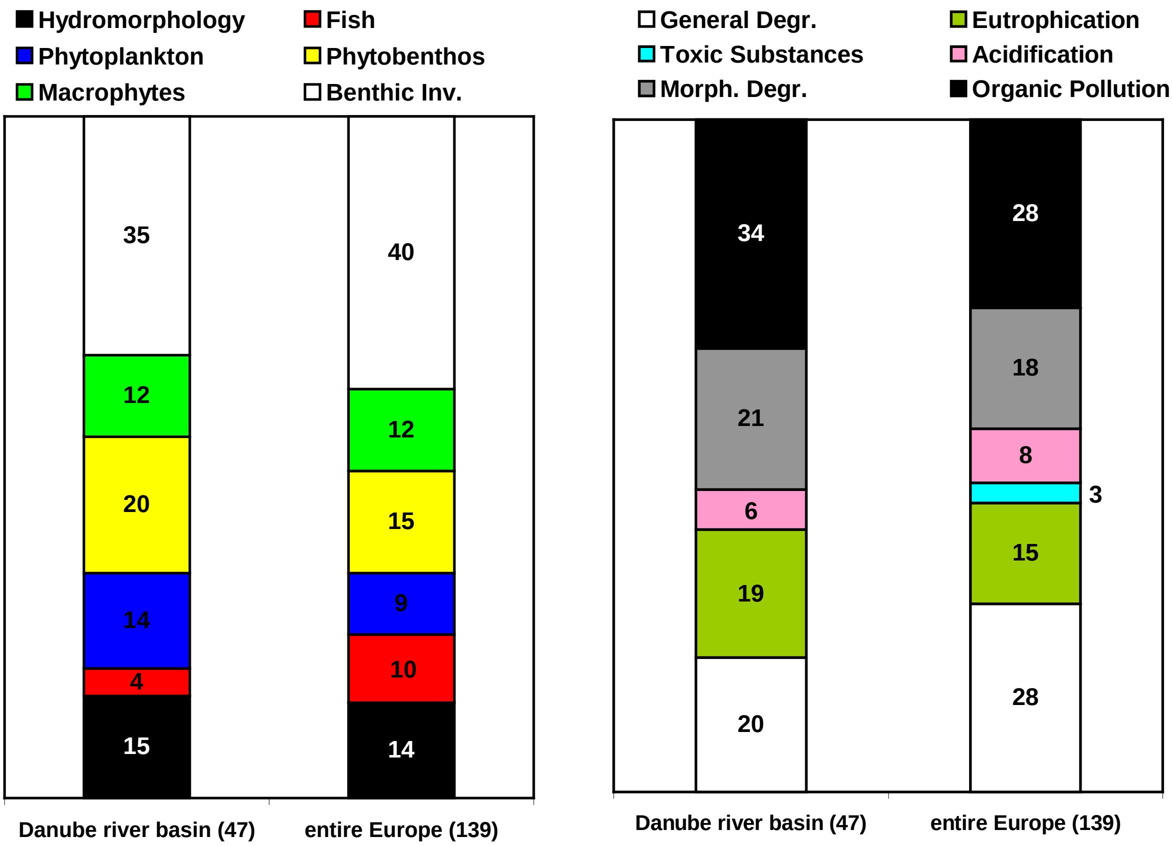

Figure 1: Percentages of quality elements used (left) and stressors detected (right) in watercourse assessment in the Danube River Basin and entire Europe (digits in brackets indicate total number of methods)

4. DISCUSSION

The large number of methods compiled in this overview reveals the importance of biological and hydromorphological assessment in environmental quality control in the Danube River Basin. Almost every country monitors the biological condition of running waters by means of specific programs. Although organic pollution traditionally represents the focus of bioassessment (e.g. SLÁDEČEK 1973) the broad spectrum of stressors which can be detected, and the various biotic groups used to identify the nature of impairment point out that multiple challenges of watercourse deterioration are addressed.

The current task set by the EU WFD is obtaining comparable assessment and classification of ecological quality of watercourses across Europe. This study illustrates two major shortcomings which are likely to impede realisation of these objectives in the Danube River Basin.

Harmonisation of quality assessment

The large variety of methods regionally developed and applied complicate to compare outputs of assessment. The alternative of specifying standardised methods and unified classification with which all countries must comply is difficult to achieve politically and technically in the short to medium term. On the one hand this would lead to loss of spatial and temporal consistency in present national monitoring. On the other hand, scientific requirements to implement a system for the entire Danube catchment have not yet been substantiated. This issue is currently addressed by the International Commission for the Protection of the Danube River which aims at reconciling national methodologies and practices.

The Standard Operational Procedure (KNOBEN et al. 1999) represents a first approach towards harmonisation of biomonitoring in the Danube River Basin. It provides a framework for sampling macroinvertebrates in the Danube and its tributaries and is intended for TNMN sites. Numerical evaluation of taxon lists is done by Saprobic Index calculation (ZELINKA & MARVAN 1961) including counted number of individuals per sample. The procedure recommends the use of saprobic indicator values based on the list of the Bavarian Water Management Agency (revised version: BLFW 2003). Quality is presented in a five-fold scheme and class boundaries are proposed according to ÖNORM M6232. A preliminary list of indicator species for the Danube River Basin has been compiled by MAKOVINSKA (2000) comprising benthic invertebrates, macrophytes, periphyton, phyto- and zooplankton. Nevertheless, STUBAUER & MOOG (2003) point out that complete harmonisation of saprobic lists for the Danube biota is still in demand.

With regard to national implementations of the saprobic system numerous country-specific modifications are applied (table 2). They comprise differences in investigated taxonomical groups, lists of indicator species, numerical evaluation schemes and quality classifications. Since these individual systems presently form the basis of watercourse evaluation in the Danubian countries the first step towards harmonisation has to include a compilation of data about the specific methodologies. The Waterview Database represents a means to facilitate transparency of national activities and exchange of knowledge by providing a comprehensive description of European assessment schemes (BIRK 2003). Its Internet-posted contents are publicly available and offer opportunity to obtain selected information suited to specific needs of the user by means of query. At present, the database contains more than 130 descriptions of methods applied in Europe and is continuously updated.

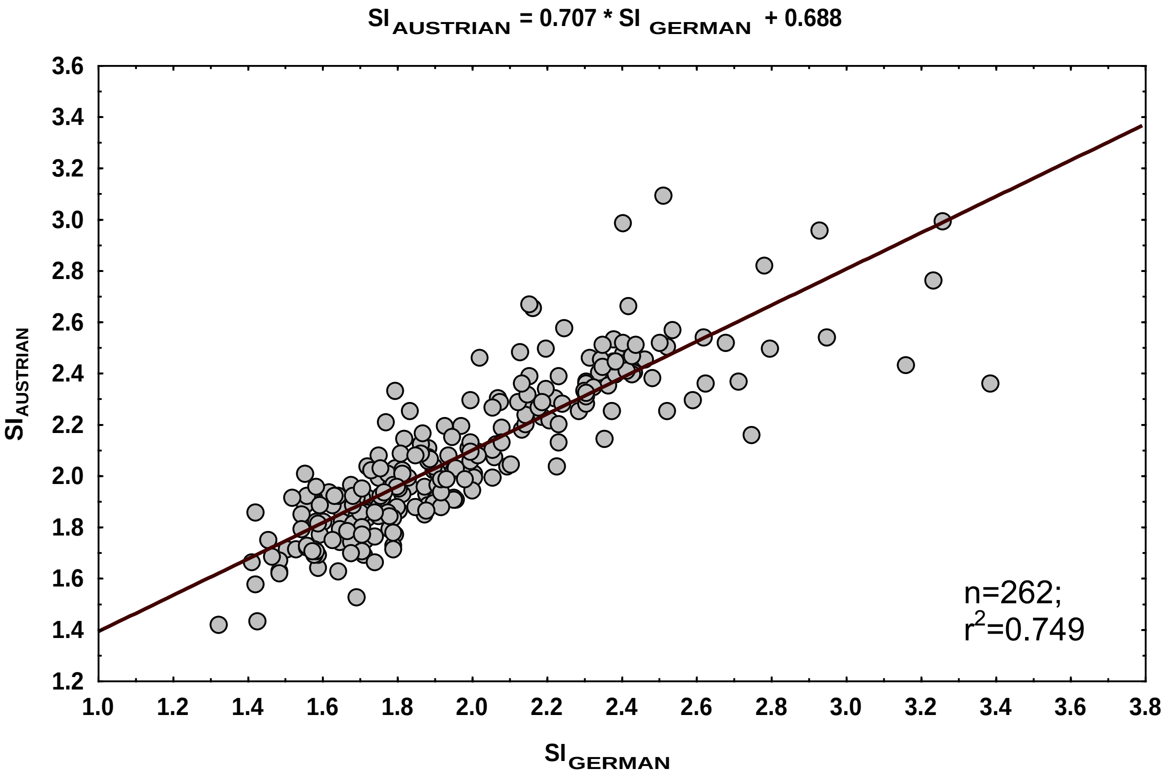

Figure 2: Scatterplot representing correlation of SI values calculated according to German and Austrian Saprobic System based on samples taken at 262 sites of the common stream-type: siliceous mid-sized streams in lower mountainous areas (200-800m a.s.l.). Formula of conversion („intercalibration factor“) is stated at the top of the diagram.

Based on these data intercalibration can be implemented in a second step, as long as no common methodology exists. According to the EU WFD the process of intercalibration shall ensure the comparability of biological monitoring results on the basis of Europe-wide agreement on what is meant by „good status“. This issue is currently addressed by the CIS (Common Implementation Strategy) Working Group 2A „Ecological Status“ of the European Commission, but practical experiences have not been gained so far. SCHMID (2000) presents a harmonised water quality map of the Danube and her tributaries based on transformed quality classes of the individual saprobic systems. BIRK & ROLAUFFS (2004) propose bilateral correlation of the results of national saprobic systems applied to common stream types. This enables the derivation of „intercalibration factors“ to convert index values of a certain national method into equivalent values of another scheme (figure 2). Nevertheless, the definition of common quality class criteria valid throughout Europe will be difficult due to strong national interests in this topic. For each monitoring site failing to meet the good ecological status countries have to raise funds for improvement.

Assessment of Ecological Status

A fundamental obstacle in implementing the WFD is represented by the lack of appropriate methods to assess the ecological watercourse status. The majority of schemes currently applied have been developed decades ago to detect the most significant impact at that time: organic pollution. With increasing awareness of other causes of reduction in watercourse quality (e.g. eutrophication or morphological degradation) different indicative parameters have been chosen. So systems have evolved which miss interconnections. Simple combination of existing methods covering diverse aspects of the river ecosystems can apparently not satisfy the premises of integrated ecological assessment.

Two basic approaches to address this issue can be observed in the Danube River Basin: Predictive modelling as conducted by the Czech PERLA system includes entire species assemblages. This enables assessment of ecosystems at community scale. However, the translation of biological data into precise conclusions concerning the cause of stress is not yet inherent to the system (WRIGHT 2000). Multimetric schemes offer decision support to water managers through stressor-specific appraisal. They aim at measuring diverse structural and functional aspects of the watercourse biota, but consider individual taxa to describe and evaluate a site's condition.

As these two different procedures perform stream type-specific assessment based on reference conditions they represent appropriate methodologies in line with the requirements of the WFD. In the future integrated ecological appraisal could be ensured by linking both approaches: a multimetric system in which the reference values of individual metrics are predicted on the basis of environmental watercourse variables.

Both subjects outlined above represent major challenges for environmental quality control in the countries of the Danube River Basin. Cooperation of individual states in this multinational catchment area is indispensable. Here, governmental institutions like the ICPDR (International Commission for the Protection of the Danube River) as well as non-governmental organisations like the IAD (International Association for Danube Research) hold key roles for the corporate overcoming of these obstacles.

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Integration of the Saprobic System into the Assessment Approach of the WFD – a Proposal for the Danube River

ILSE STUBAUER & OTTO MOOG

1. INTRODUCTION

One step of Activity 1.1.7 “Implement ecological status assessment in line with the requirements of the European Water Framework Directive using specific bio-indicators” of the UNDP/GEF Danube Regional Project is to test potentially suited assessment metrics.

Many Danubian countries use the Saprobic Index as a metric for organic water quality assessment (BIRK 2003a, waterview database): Austria, Germany, Czech Republic, Slovakia, Slovenia, Croatia, Bosnia-Herzegovina, partly Hungary, Serbia-Montenegro, Bulgaria, Romania and Moldova. As a common biological element, in many countries benthic invertebrates are used. Most of these countries use a seven class system for the water quality assessment (BIRK 2003b).

As all of them have a long tradition and an extensive experience in the use of the Saprobic System, countries will most likely be interested in integrating the system into the approach of the Water Framework Directive. Thus a comparison of further analyses and old evaluations will be assured.

The integration of the Saprobic Systems to the WFD has recently been successfully undertaken in Austria, Germany and the Czech Republic (STUBAUER & MOOG 2002, ROLAUFFS et al. 2003b, AQEM CONSORTIUM 2002a). This approach offers the possibility to inter-link the long used organic pollution assessment with the requirement of the WFD, which is to base the assessment on type specific reference conditions. The procedure followed the hypothesis of BRAUKMANN (1987), who proposed to use “saprobic basic conditions” as near-natural reference conditions of unpolluted running waters in terms of degradable organic matter. In the recent studies mentioned above it could clearly be demonstrated, that this approach leads to a successful integration of the Saprobic System into the WFD policy. The international consultants recommend the adaptation of this procedure to evaluate the saprobic water quality aspects in the Danube countries. These findings open up the possibility for the Danubian countries to overcome the challenges of the WFD in a similar manner.

The following report describes the approach of establishing type specific reference conditions for the Danube River itself.

2. METHODS

For the whole Danube River, data sets on benthic macroinvertebrates were provided by the ICPDR. These data were elaborated during the Joint Danube Survey, which was carried out in August and September 2001 by a biological expert team from the Danubian countries. The data base contains sheets with information on the sampling site and sampling conditions (location of the sample, JDS Station, River km, monitoring point code, location in profile, and village/location). The biological data sheets consist of taxonomic lists and abundances; taxa are determined to species level were possible respectively to higher taxonomic units (genus, family). At most sampling points, samples were taken on the left respectively right side and in the middle of the river (location of the sample), where possible. Due to this structure, in many cases more than one taxa list exists per sample reach.

For the purpose of calculating metrics like the saprobic index, the JDS data were imported into the PC software ECOPROF 2.5 (MOOG et al. 2001). The import of the data included biological data (taxa lists and abundances) as well as all information available on site characteristics.

We want to acknowledge the assistance of Dr. Heide Bernerth for providing unpublished environmental data of the Joint Danube Survey.

Saprobic indices were calculated for all sampling sites. Currently, no obligatory common catalogue with ecological notes exists for the Danube River or in the Danube River Basin. Recently, an attempt was made to compile a list of bioindicators for the Danube (MAKOVINSKA 2000). In this report, a preliminary list of benthic invertebrates of the Danube River Basin with saprobic values is available.

Most countries using the saprobic system have nevertheless specific lists, which serve as a basis for calculating the saprobic indices. The information which saprobic indicator lists are used in the Danubian countries is available from the water*view* database (http://starwp3.eu-star.at).

For the analyses of the JDS data, four different catalogues have been taken into account for the calculation:

- the catalogue compiled by MAKOVINSKA (2000)
- the Fauna Aquatica Austriaca (MOOG 1995, 2002)
- the Czech Standards CSN 757716 (1998)
- the German DIN 38410-1 (2003)

Three of the saprobic lists are integrated into the AQEM-assessment software (AQEM CONSORTIUM 2002b) and are thus easily available. The list provided by MAKOVINSKA (2000) is only accessible as paper version.

Saprobic indices based on the Fauna Aquatica Austriaca have been calculated in ECOPROF. For calculations based on the Makovinska-catalogue, a database has been created and linked with ECOPROF. For the calculation of saprobic indices based on German and Czech Standards, data have been exported to Excel and imported into the AQEM assessment software.

As a next step, sites have been pre-classified mainly based on morphological criteria with the help of DI Birgit Vogel, who participated in the JDS and is familiar with characteristics of the sampling sites. One hundred sites out of 148 met the criteria of reference/good sites, concerning the morphological point of view. With respect to water quality none of the investigated Danube sections meets the criteria to be regarded as reference site. The 100 sites that were pre-classified as morphologically reference/good sites were then checked according to the number of taxa present and the number of taxa that can be used to calculate a saprobic index. Those sites with less than 10 classified taxa (= taxa with a saprobic index) were removed from the evaluation. Finally, 83 sites could be used for the analyses.

For statistical evaluation and graphical visualisation the software package STATISTICA 5.5 (STATSOFT. INC. 2000) has been used.

As a spatial river typology, two different approaches were applied:

- The proposal of the JDS to separate the Danube River into three major reaches (upper, middle and lower part) (LITERÁTHY et al. 2002), and
- the ten section types for the Danube River proposed by the international consultants (SOMMERHÄUSER et al. 2003).

3. RESULTS

Saprobic indices of reference sites and good sites in the three major reaches of the Danube River

The evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the upper, middle and lower sections of the Danube by means of box-and-whisker plots is shown in Figure 1 to Figure 4. The number of sampling sites used for the calculation is given in Table1.

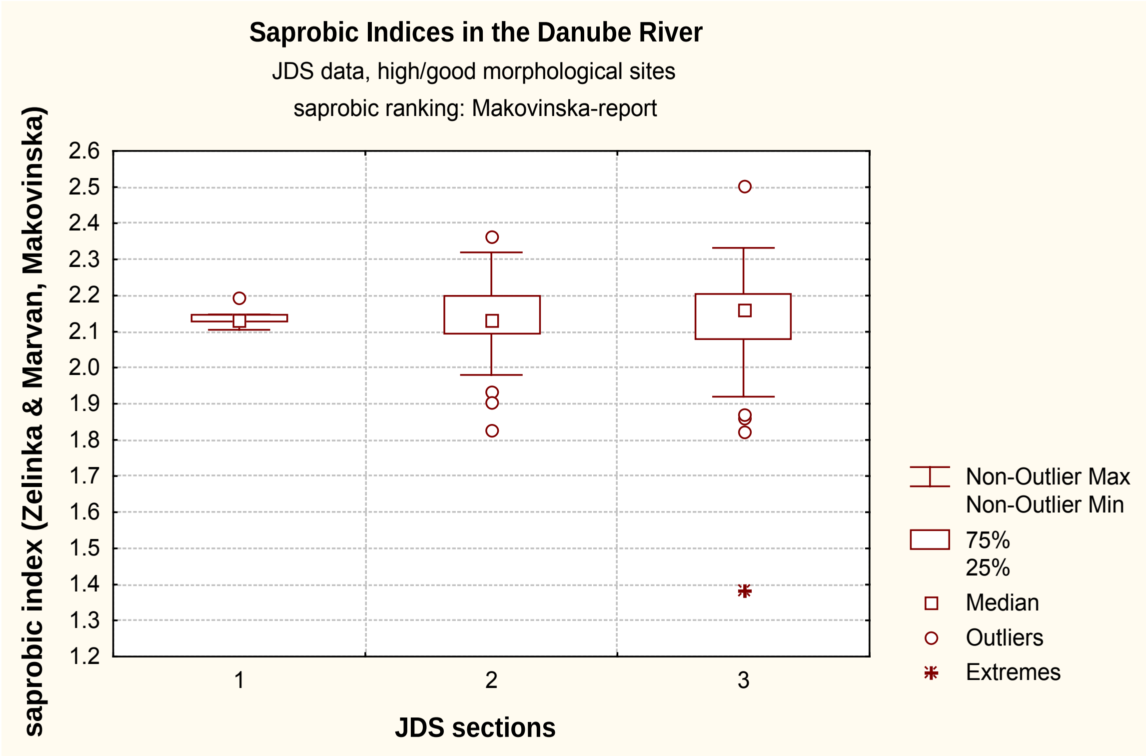

Figure 1: Evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the upper (1), middle (2) and lower section (3); saprobic rankings taken from MAKOVINSKA (2000)

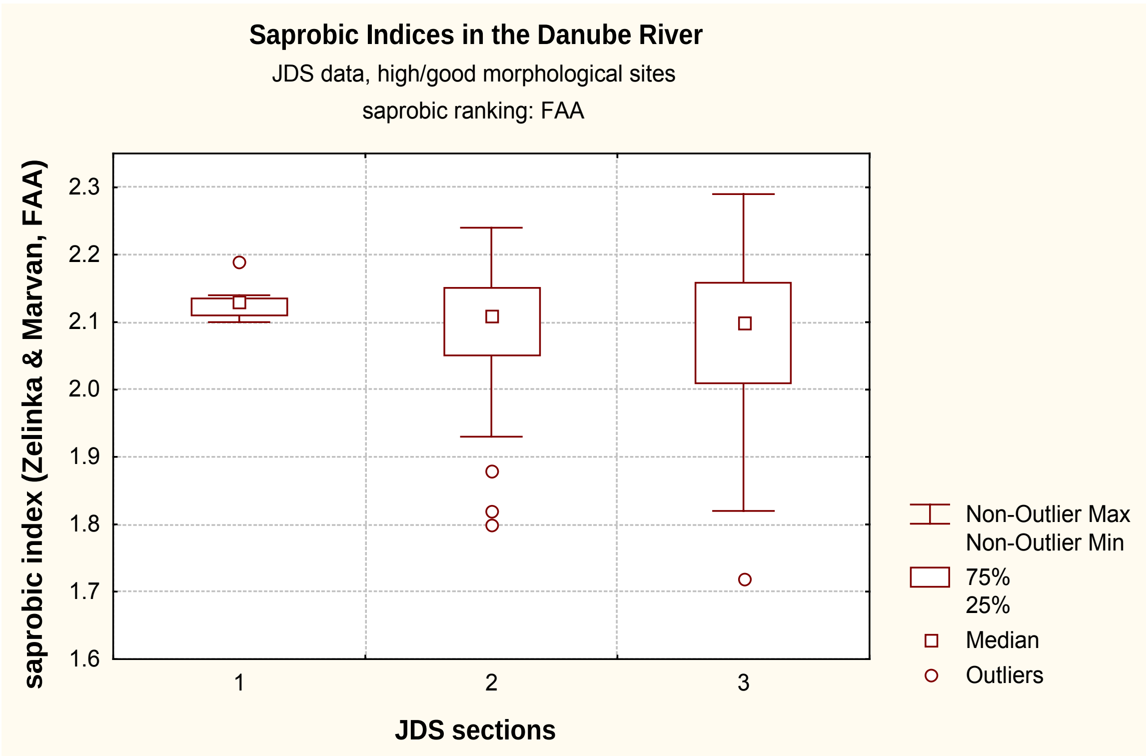

Figure 2: Evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the upper (1), middle (2) and lower section (3); saprobic rankings taken from Fauna Aquatica Austriaca (1995, 2002)

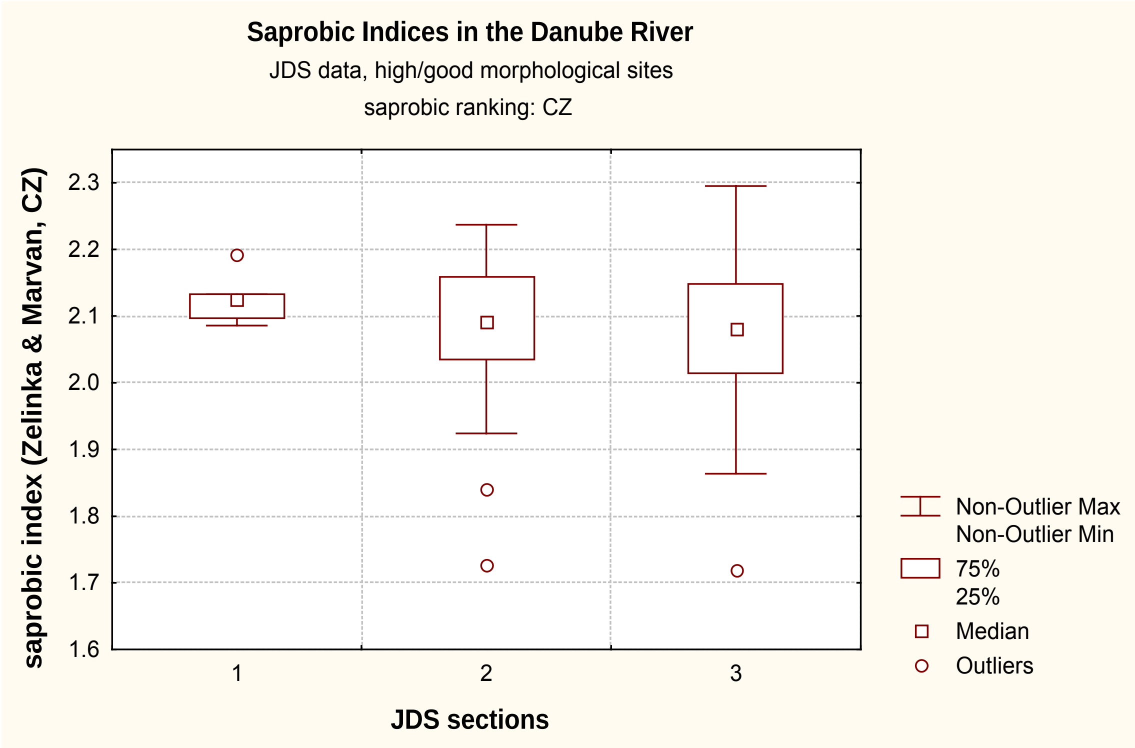

Figure 3: Evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the upper (1), middle (2) and lower section (3); saprobic rankings taken from Czech Standards (1998)

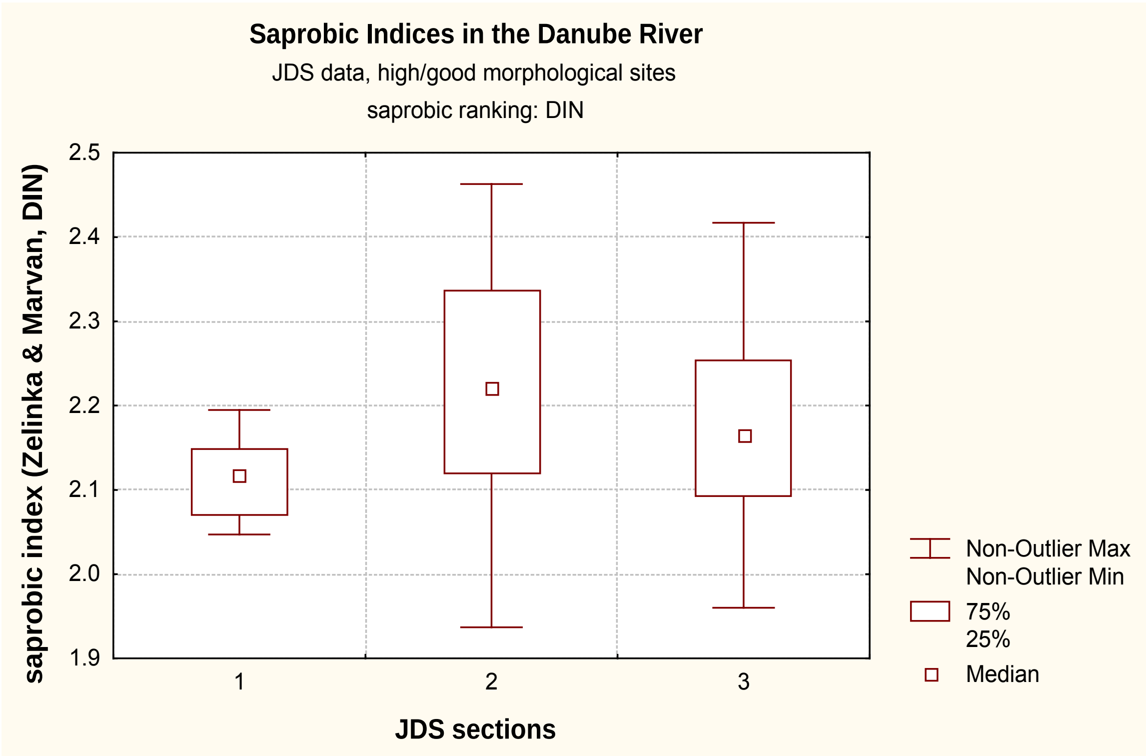

Figure 4: Evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the upper (1), middle (2) and lower section (3); saprobic rankings taken from DIN (2003)

The following table summarises the results for the calculations with the above mentioned three different saprobic ranking lists used for this purpose.

Table 1: Median (M) and 75 % percentile (P) of the saprobic indices of the upper, middle and lower section of the Danube River

saprobic ranking	upper section		middle section		lower section	
	n= 8		n= 46		n= 29	
	M	P	M	P	M	P
Makovinska	2.13	2.15	2.13	2.20	2.16	2.20
	n= 8		n= 47		n= 28	
FAA	2.13	2.13	2.11	2.15	2.10	2.16
CZ	2.13	2.13	2.09	2.16	2.08	2.15
DIN	2.12	2.15	2.22	2.34	2.16	2.25

Saprobic indices of reference sites and good sites in the ten section types of the Danube River

The evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the ten section types of the Danube River by means of box- and-whisker plots is shown in Figure 5 to Figure 8. The number of sampling sites available in the different section types is given in Table 2. For section type one (from the sources of Brigach and Breg to Neu Ulm), section type three (Passau to Krems) and section type seven (Bazias to Turnu Severin), no JDS data sets from high or good morphological sites are available.

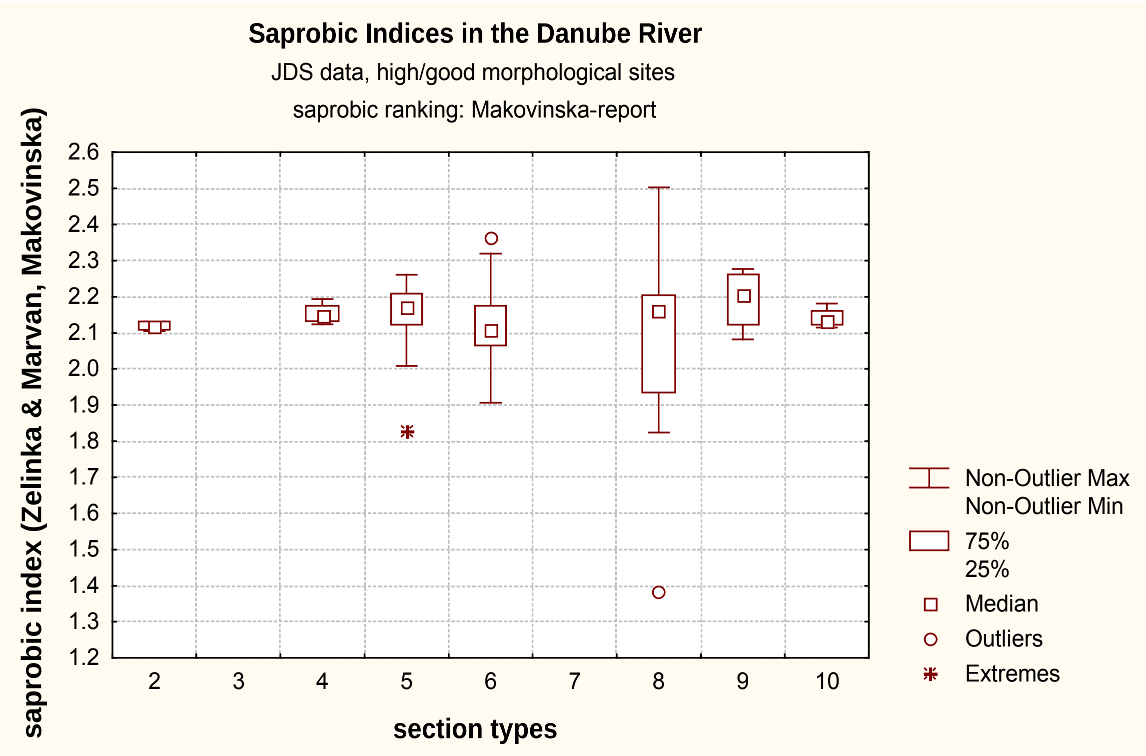

Figure 5: Evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the 10 section types; saprobic rankings taken from MAKOVINSKA (2000)

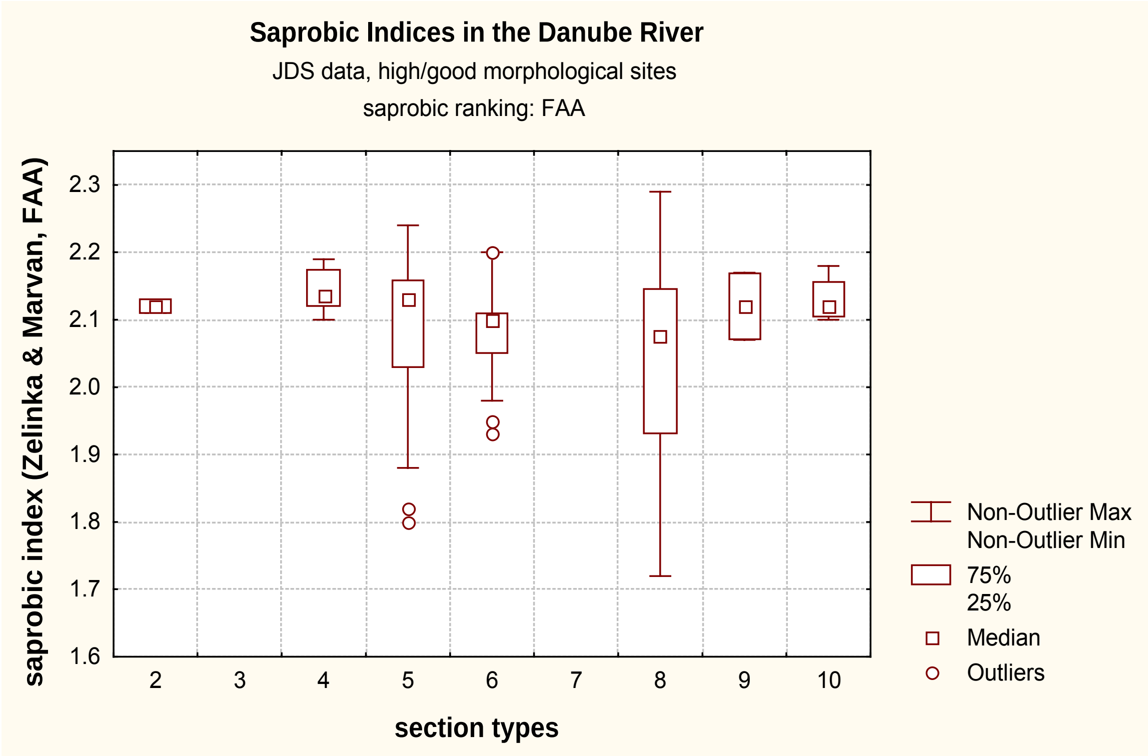

Figure 6: Evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the 10 section types; saprobic rankings taken from FAA (1995, 2002)

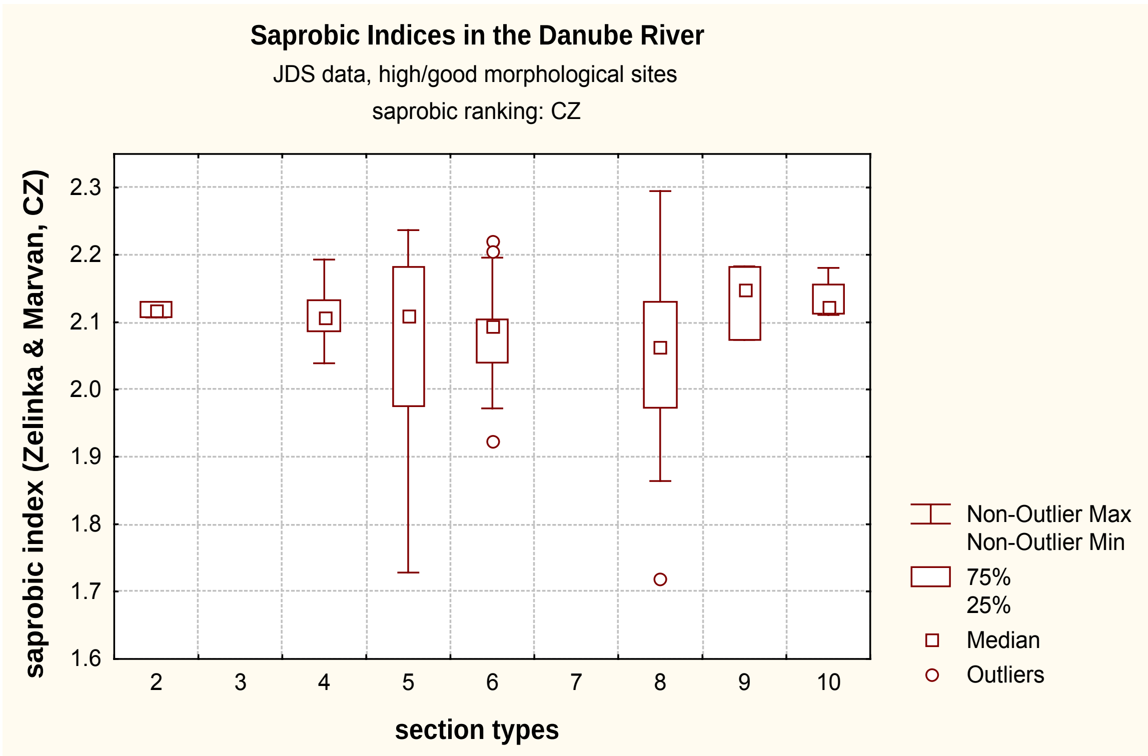

Figure 7: Evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the 10 section types; saprobic rankings taken from CZ Standards (1998)

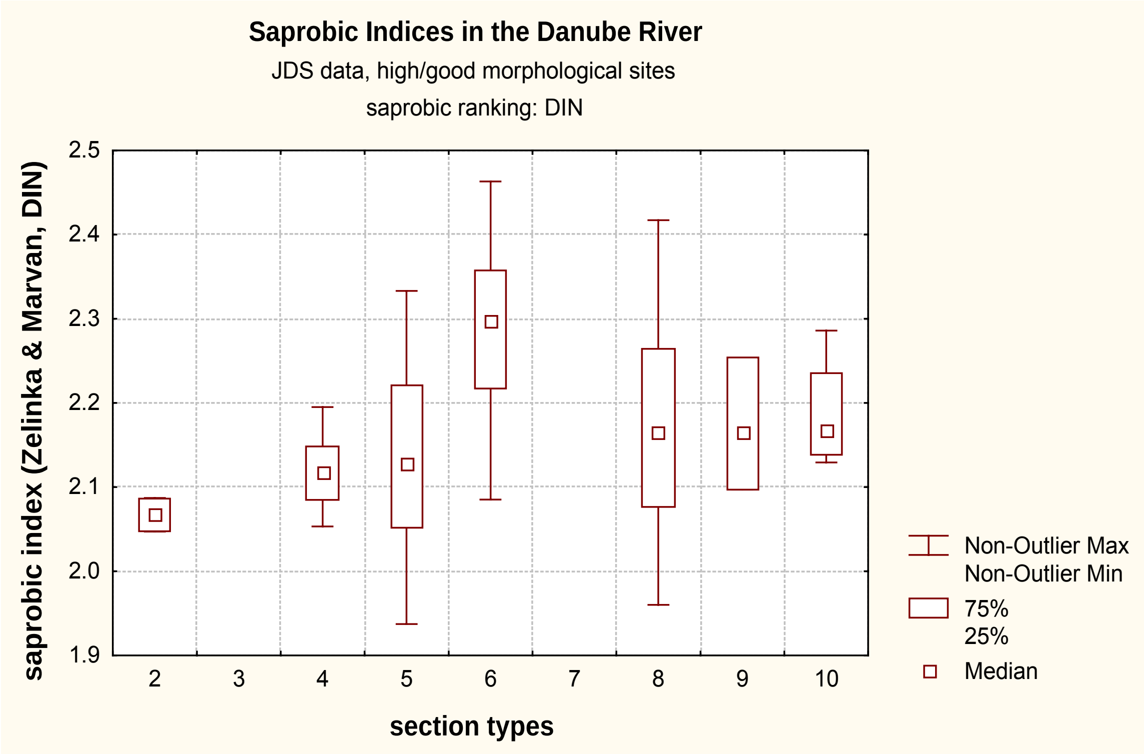

Figure 8: Evaluation of saprobic indices from JDS-sites with high or good morphological conditions in the 10 section types; saprobic rankings taken from DIN (2003)

Table 2: Median (M) and 75 % percentile (P) of the saprobic indices in the section types of the Danube River

Section types	**2**		**4**		**5**		**6**		**8**		**9**		**10**	
	n= 2		n= 8		n= 15		n= 29		n= 21		n= 4		n= 4	
saprobic ranking	M	P	M	P	M	P	M	P	M	P	M	P	M	P
Makov.	2.12	2.13	2.15	2.17	2.17	2.21	2.11	2.17	2.16	2.20	2.20	2.26	2.13	2.16
	n= 2		n= 8		n= 16		n= 29		n= 21		n= 3		n= 4	
	M	P	M	P	M	P	M	P	M	P	M	P	M	P
FAA	2.12	2.13	2.13	2.17	2.13	2.16	2.10	2.11	2.08	2.14	2.12	2.17	2.12	2.15
CZ	2.12	2.13	2.11	2.13	2.11	2.18	2.09	2.11	2.06	2.13	2.15	2.18	2.12	2.16
DIN	2.07	2.09	2.12	2.15	2.13	2.22	2.30	2.36	2.16	2.26	2.16	2.25	2.17	2.24

For the definition of saprobic reference conditions, the medians and 75 % percentiles are taken into account as a threshold value. This procedure follows the U.S. method described e.g. by BARBOUR et al. (1999), which has successfully been applied to Austrian rivers. The reference values represent the border between high and good quality and are expressed as the upper limit for high quality.

4. DISCUSSION

The definition of saprobic reference conditions has recently been carried out for Austria (STUBAUER & MOOG 2000, 2002). In this study, saprobic indices of near-natural sites showed an increasing trend with increasing catchment area. On the other hand, saprobic indices decreased with increasing altitude. Similar results were obtained in the German study by ROLAUFFS et al. (2003b).

As the spatial typology used for the evaluation of saprobic indices of the Danube includes catchment and altitude size, a similar trend was to be expected. This assumption could not be verified, neither for the detailed analysis of the ten section types, nor for the aggregated evaluation of the three main reaches.

Concerning the upper, middle and lower section of the Danube, medians of the saprobic indices of high and good morphological sites range around 2.1 for all four different saprobic lists used. The German DIN indicates slightly higher values of the medians and 75%-percentiles in the middle and lower section (Table 1). The calculation with the Makovinska-catalogue also shows somewhat higher results in the lower section.

The same pattern is detected by applying the ten section types as typological scale. The medians range between 2.06 and 2.15 using the FAA or the CZ Standards. Again the values obtained with the DIN rankings are slightly different, ranging between 2.07 and 2.31 whereby the highest median is not given in the lowest part of the Danube (Table 2). For the Makovinska list, indices range between 2.12 and 2.20, whereby no trend of increasing saprobic indices in the downstream sections can be detected.

One reason for the instability of the saprobic indices could be, that the number of evaluated sampling sites is quite different in the sections. The very upper and lower sections (section type two resp. ten) are only represented with two resp. four sites, whereas section type six and eight include more than 20 sites each.

Another possible explanation is the lack of saprobic rankings for benthic invertebrates species in the middle and mainly the lower sections. Although, on an average about 70 percent of the species detected in the JDS samples are ranked in the FAA, the remaining 30 percent might include typical Danubian species which could change the saprobic indices.

5. CONCLUSION

The investigated Danube sites cover the entire Danube stream from Regensburg to the Danube Delta. Out of a total of 148 investigated cross sections 100 section are of high or good environmental status with respect to morphological conditions. With respect to water quality none of the investigated Danube sections meets the criteria to be regarded as reference site. These findings base on a pre-classification procedure that has been conducted by DI Birgit Vogel from the Environmental Agency Austria and the BOKU team around the international consultant Otto Moog. It needs to be explicitly stated that the pre-classification status of the JDS Danube sites may change after applying more sophisticated criteria for estimating pressures and impacts on the Danube River (see activity 1.1.2, MOOG & STUBAUER 2003). Excluding sampling sites of known organic pollution (e.g. downstream Budapest and Belgrade) indicates that no significant differences of saprobic indices in high and good morphological sites of the Danube could be identified. The fact that no gradient from the upper to the lower parts of the Danube can be detected may give evidence that the middle and lower stretches of the Danube are characterised by common saprobic reference conditions.

Summarising the existing knowledge and the results of the JDS data the following saprobic reference conditions can be recommended for the Danube River. According to ROLAUFFS et al. (2003b) the saprobic reference conditions of the Bavarian Danube are characterised by saprobic indices between 1.91 and 2.01.

The saprobic reference conditions of the Austrian Danube within Ecoregion 9 (Central Highlands) are described with saprobic indices below the threshold value of 1.75 (STUBAUER & MOOG 2000). The reduction of the saprobic index is induced by the confluence of River Inn which changes the character of the Danube dramatically. The water volume of River Inn exaggerates the discharge of the Bavarian Danube, the water temperature is respectively colder. The reduction of the water temperature in the Danube after the confluence combined with the morphological features of the Austrian stretch leads to the rhithralisation and thus to a lower threshold value. After the narrow break through section “Wachau” which is a very famous world heritage due to its beautiful scenery the Ecoregion changes from 9 to 11 (Hungarian Lowlands). In accordance with the Ecoregion change the saprobic reference conditions move to a saprobic index of $\leq$2.0. Due to the lack of reference sites this threshold value was defined by an expert panel of scientists, technicians and administration. The SI of 2.0 as the highest threshold reference value seems to be a good estimate not only for the Austrian part of Danube in Ecoregion 11, but also for the Danube sections downstream. Quite similar saprobic indices around 2.1 have been observed along the entire stretch of the Danube below the borderline of Ecoregion 9 and 11. Based on these findings, a saprobic index of 2.0 is recommended as class boundary of the saprobic reference condition.

6. OUTLOOK

The international consultants recommend the adaptation of the saprobic system to evaluate the saprobic water quality aspects in the Danube countries in the above described manner. This will offer the possibility for the Danube countries to integrate the traditional system into the type specific reference approach of the WFD.

For future procedures in the Danube River Basin the following steps are recommended:

- Harmonisation of sampling techniques
- Harmonisation of saprobic lists for the Danube biota, at least benthic invertebrates
- Harmonisation of saprobic lists for the Danube tributaries
- Harmonisation of methodology to define saprobic reference conditions in the Danubian countries
- Establishment resp. harmonisation of an assessment scheme to define five ecological status classes based on saprobic reference conditions.

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The Applicability of the Multimetric Approach for Assessing the Ecological Status of the Danube River

THOMAS OFENBÖCK & OTTO MOOG

The activity 1.1.7 (Implement ecological status assessment in line with requirements of the EU Water Framework Directive using specific bio-indicators) comprises four working units:

1. Consultation of national experts (consultants) for existing hydrological and biological assessment methods presently applied to the Danube or under development;
2. Conducting an overview study on existing ecological status assessment and classification systems, from which recommendations for changes in the classification systems in the Danube River Basin will be derived in order to harmonize them with the requirements of the Water Framework Directive;
3. Test of potentially suited assessment metrics, based on the benthic invertebrate data of the Joint Danube Survey;
4. Development of a Danube specific metric index, based on the benthic invertebrate data of the Joint Danube Survey data (e.g. regarding sensitive species).

The outcomes of parts 1 and 2 have been summarized in the overview study on existing ecological status assessment methods (BIRK 2003). The results of parts 3 and 4 are delivered in the present part of the final report “The Applicability of the Multimetric Approach for Assessing the Ecological Status of the Danube River”.

1. INTRODUCTION

Metrics are defined as “Measurable parts or processes of a biological system empirically shown to change in value along a gradient of human influence” (KARR & CHU 1999). Useful metrics are

- ecologically relevant to the biological assemblage or community under study and to the specified program objectives and
- sensitive to stressors and provide a response that can be discriminated from natural variation.

Successful biological monitoring depends on precise measures of a site's fauna or flora, especially those components that are influenced most by perturbation. Thus, the spatial and temporal scale of sampling should detect and foster understanding of human influences, not document the magnitude and sources of natural seasonal or successional variation in the same system (KARR & CHU 1999).

A multimetric index combines several individual biotic metrics which are finally combined into a multimetric result. Thus, multimetric indices integrate multiple attributes of stream communities to describe and evaluate a site's condition. Aggregation of metric scores simplifies management and decision making so that a single index value is used to determine whether action is needed (KARR et al. 1986).

A requirement for developing the system is that river stressors must be estimated objectively without using biotic information to avoid circular statements. The calculation starts from a the database which contains:

- taxa lists of the macroinvertebrate fauna
- data on river morphology, physico-chemistry and catchment characteristics of the individual sites.

2. PRE- CLASSIFICATION OF SITES ACCORDING TO THEIR DEGRADATION (BASED ON THE AQEM SITE PROTOCOL DATA)

At least reference sites and impaired sites have to be distinguished for developing a classification system. Sites should be pre-classified into five quality classes based on abiotic features, but an exact differentiation between all graduations of stream quality classes cannot be done on forehand. The five pre-classified quality classes should correspond with the five ecological status classes according to the Water Framework Directive.

Calculation of metrics

Starting from the biological data (taxa lists, abundance) a large number of biological metrics are calculated to identify those metrics that are strongly associated with the parameters selected for the pre-classifications of sites.

Metrics are calculated using ECOPROF (MOOG et al. 2001) and AQEM assessment software (AQEM CONSORTIUM 2002). For the evaluation of metrics box-and-whisker-plots are used to visualize metrics values. For statistical analysis and graphical visualisation the software package STATISTICA 5.5 (STATSOFT. INC. 2000) is used.

Identification of candidate metrics

All metrics that represent ecologically relevant aspects of the assemblage and respond to the targeted stressors are potential metrics for a final index. Out of the “universe” of metrics, some have to be eliminated because of insufficient data or because the range of values is not adequate to discriminate between natural variability and anthropogenic effects.

Descriptive statistics are used to characterize metric performance within the population of reference sites of each site class. Metrics with too high variability in reference sites that do not discriminate sufficiently among sites of different condition are eliminated. The remaining metrics, which were used in further analysis, are termed as candidate metrics.

Selection of robust measures (Core Metrics)

Core metrics are those that discriminate best between good and poor quality of ecological conditions. Metrics that are highly correlated with each other and show linear gradients contribute approximately the same information (KARR et. al 1986, KARR 1991, BARBOUR et al. 1996). To avoid redundancy the pre-selected metrics are tested using pairwise correlation analysis (Pearson product-moment correlation). A correlation coefficient r = 0.75 is used as the upper limit.

Transformation of metrics into unitless scores and index calculation

Multimetric indices provide a means of integrating information from the various measures of biological metrics. For the development of an integrated index, normalizing of core metrics via transformation to unitless scores is essential. The standardization assumes that each metric has the same value and importance. The method applied in this study follows the Rapid Bioassessment Protocols of the United States - Environmental Protection Agency (BARBOUR et al. 1999): The scoring criterion for each metric is based on the distribution of values in all sites, including reference sites. The 95th percentile of the data distribution of a single metric is used to eliminate extreme outliers. From this upper percentile, the range of the metric values is standardized as the percentage of the 95th percentile value to provide a range of scores. Values that are close to the 95th percentile receive higher scores, values having a greater deviation from this percentile have lower scores. Values that exceed the 95th percentile are scored as 1. For those metrics values that increase in response to perturbation („reverse“ metrics) the 5th percentile is used to remove outliers and to form a basis for scoring. The resulting index values are calculated by simply averaging the score values (figure 1).

<table>
<tr><th>Metric</th><th>➔</th><th>Score</th><th>➔</th><th>Index</th></tr>
<tr><td colspan="2">transformation of metrics into scores (range of values between 0 and 1, standardised as the percentage of the 95th percentile to eliminate extreme outliers)</td><td colspan="3">transformation of scores into index (averaging the scores)</td></tr>
</table>

Figure 1: Scheme of transforming metrics to scores and creating a final index

Determination of the best aggregation of core measures for indicating status and change in condition

For aggregating metrics into multimetric indices special emphasis should be given to cover as many different metrics types as possible and finally to select those combinations of metrics which show the best discriminatory power to distinguish between non or slightly impaired and stressed sites. Furthermore, metrics should be selected to include - if possible - at least all four primary metrics types (KARR & CHU 1999). To evaluate the strength of the final index the discrimination efficiency (DE) values and the statistical power between classes are calculated using a one tailed t-test design with a significance level of alpha = 0.05

The DE is calculated as the percentage of stressed samples with metric values lower than the 25th percentile of reference values for decreasing metrics, and higher than the 75th percentile for increasing metrics, respectively (figure 2).

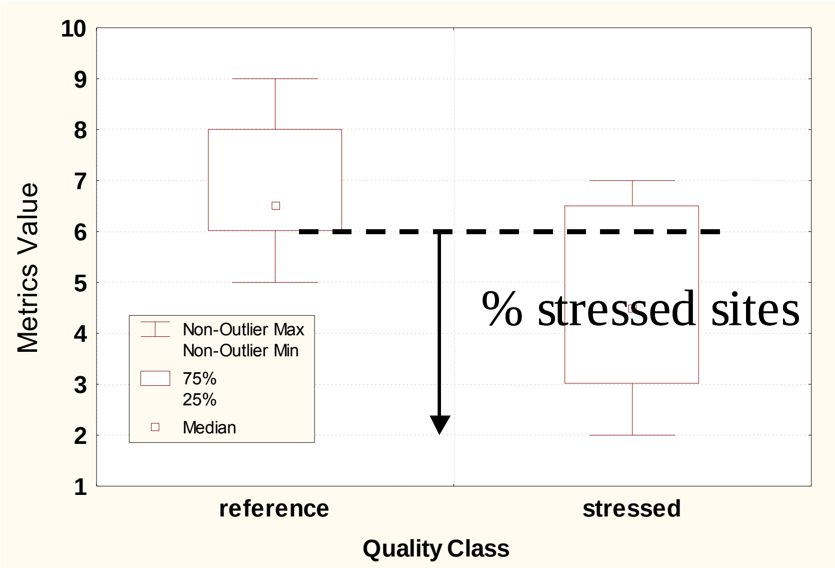


Figure 2: The discrimination efficiency is defined as percentage of stressed samples showing values lower than the 25th percentile of reference values for decreasing metrics, and higher than the 75th percentile for increasing metrics, respectively.

Definition of threshold values for ecological quality classes

The derivation of the threshold values to discriminate between different stages of stress is based on the index ranges. Different methods have been developed for defining boundaries between quality classes (see BARBOUR et al. 1999). Following the demands of the WFD, a five-class scheme is used where the 25th percentile of reference site distribution is fixed as the lower limit to separate reference sites from stressed sites. The appropriateness of the thresholds is verified with the index performance (DE) and precision estimates (statistical power analysis).

Application of the indices: evaluating new sites

Core metrics for the targeted index are calculated and converted into unitless scores. The resulting scores are averaged and used for rating and interpreting a site's condition. The component metrics can be used to aid in determination of cause and effect.

3. TESTING OF METRICS FOR DEVELOPING OF A "DANUBE SPECIFIC MULTIMETRIC INDEX"

The ICPDR provided data sets on benthic macroinvertebrates for the entire course of the Danube River. These data were elaborated during the Joint Danube Survey

(JDS), which was carried out in August and September 2001 by a biological expert team from the Danubian countries (LITERÁTHY et al. 2002).

The database contains information on the sampling site and sampling conditions (location of the sample, JDS Station, River-Kilometre, monitoring point code, location in profile, and village/location). The biological data sheets consist of taxonomic lists and abundances; taxa are determined to species level where possible resp. to higher taxonomic units (genus, family). At most sampling points, samples were taken on the left and/or right side and in some cases in the middle of the river (location of the sample). Due to this structure, in many cases more than one taxa/abundance list exists per sample reach.

As described in the methodology part for the development of a multimetric index, the calculation of as many candidate metrics as possible is a necessary must. For this purpose the JDS data were imported into the PC software ECOPROF 2.5 (MOOG et al. 2001).

ECOPROF is a software tool to store, handle and analyse field and ecological data with special emphasis on benthic algae, microfauna and macroinvertebrates. The calculation procedures focus on a large variety of biotic indices, scores and metrics. The ecological information are regularly enlarged and updated. It also includes a separate Danube taxa list comprising many benthic taxa known from the river Danube including autecological information as far as available.

According to autecological information available, taxa are ranked along gradients of environmental conditions based on the Fauna Aquatica Austria (FAA). The FAA is a comprehensive inventory that comprises a checklist of Austrian aquatic invertebrates and ciliates and also provides some ecological information like functional feeding groups, saprobic valences, and longitudinal zonation patterns (MOOG 1995, 2002). More information on the Fauna Aquatica Austria can be obtained via http://www.lebensministerium.at/wasser link to „Wassergüte“. This web page of the Ministry for Agriculture, Forestry, Environment & Watermanagement provides a free download of the whole Fauna Aquatica Austria catalogue (in German and English).

More details on the assessment software are provided at http://www.ecoprof.at. ECOPROF is based on MS-Access and is capable to calculate a wide range of metrics and is available free of any costs.

The import of the JDS data into ECOPROF included biological data (taxa lists and abundances) as well as all information available on site characteristics. The project structure for the JDS data was established on the basis of the sampling structure given, and data were imported according to this pattern. In context with the data import, the fauna catalogue which is the basis for ECOPROF needs to be extended by species that are not present in Austria. For some of the species, autecological information had to be obtained by literature research. Additionally, all data were checked for correct spelling of the taxonomic names, to be able to import them accurately. Species/genus codes provided in the JDS database were linked with the ECOPROF codes and amendments resp. corrections were necessary.

Basic information on taxa is also available from the AQEM taxa list (available on http://www.aqem.de), a result of the AQEM-project (a research project under the 5th Framework Programme of the European Union, Contract No. EVK1-CT-1999-00027). The autecological information is mainly based on ECOPROF and was extended for species not present in Austria if ecological notes were available in other catalogues.

Besides containing autecological information on all of the AQEM taxa, the taxa list is the basis for the AQEM European Stream Assessment Program and the AQEM data input program. It provides an overview of species occurring in several European countries (countries represented in AQEM). It offers taxonomic information on each species with regard to order, family, subfamily, genus, author and date of description.

The taxa list is one of the main products of AQEM and is, therefore, provided for general public use. The compilation process included the following steps: The eight AQEM partner countries (S, D, NL, CZ, A, I, GR, P) compiled draft lists of aquatic invertebrates occurring in their countries. Additional lists were created for Slovakia and - for some taxonomic groups only - for Norway, Finland and Denmark. This was done using published checklists (checklist tables); a list of those people who have compiled these literature-based „national lists". For questions concerning the national checklists please contact them. All taxa which were first recorded during the AQEM project were added to the "national lists". The resulting lists were checked by taxonomic experts (expert list) to correct nomenclature and taxonomy.

The precision of the list differs for individual countries. For central Europe countries (NL, A, D, CZ) the lists should be nearly complete while for other countries considerable gaps may remain.

Further updates on the list will be provided by the STAR consortium (Standardisation of River Classifications: Framework method for calibrating different biological survey results against ecological quality classifications to be developed for the Water Framework Directive, Contract No: EVK1-CT 2001-00089) and will be published at http://www.eu-star.at.

The database will be developed in MS ACCESS with particular attention being paid to the development of user-friendly front-end access, a simple menu of pre-programmed queries and clear, relevant data output forms. These will include simple verification forms for data-input validation.

The database will be designed to hold the results of all the sampling programs comprising the current proposal. It will contain a spatially-referenced relational set of data including information about the location, biological data comprising species names, abundances and functional roles and traits, relevant index values for each taxon (e.g. Saprobien values, Biological Monitoring Working Party scores, Mean Trophic Rank and Trophic Diatom Index values etc.), environmental information for site characterisation and prediction purposes, River Habitat Survey information, the parameter from the AQEM site protocol (http://www.aqem.de), information on the laboratories and personnel responsible for significant stages in the data acquisition processes and meta-data fields, including audit information.

The principal formats in which aquatic biological and environmental data are stored in other European and national monitoring databases, assessment systems, biodiversity databases, research programs and museums will be determined by direct enquiry and reference to the literature and the World Wide Web. This will include the principal taxonomic coding systems used to record data and the currently accepted literature.

The current project database will incorporate specific „macros“ for the direct exchange of data between the major databases including the transfer of data from the most widely used electronic spreadsheets, relational databases. The use of common data fields will maintain the referential integrity of the data transfer process.

The project database will also include facilities for the translation of each of the major European systems of taxonomic coding (Maitland/Furse Code, German DV no., ECOPROF, AQEM, TCM Code) to each of the other systems and will provide equivalent facilities for resolving taxonomic synonymies.

Concerning the JDS data, the second step after the import was an overall calculation of candidate metrics, as mentioned above. The following metrics were calculated either with ECOPROF or exported into Excel and imported into the AQEM assessment software, which calculated some additional metrics established lately in context with the AQEM project. References on the metrics are listed in the AQEM manual (AQEM CONSORTIUM 2002). A list of the calculated candidate metrics is given in table 1.

Table 1: List of candidate metrics calculated

Metric	Metric
Abundance [ind/m²]	Taxonomic group [%]
Number of Taxa	Porifera [%]
Saprobic Index (Zelinka & Marvan)	Coelenterata [%]
Saprobic Valence	Cestoda [%]
Xeno [%]	Trematoda [%]
Oligo [%]	Turbellaria [%]
Beta-meso [%]	Nematoda [%]
Alpha-meso [%]	Nematomorpha [%]
Poly [%]	Gastropoda [%]
German Saprobic Index (old version)	Bivalvia [%]
Dispersion	Polychatea [%]
Abundance	Oligochaeta [%]
Indicator Taxa	Hirudinea [%]
German Saprobic Index (new version)	Crustacea [%]
Dispersion	Araneae [%]
Abundance	Ephemeroptera [%]
Indicator Taxa	Odonata [%]
Dutch Saprobic Index	Plecoptera [%]
Czech Saprobic Index	Heteroptera [%]
Biological Monitoring Working Party	Planipennia [%]
Average Score per Taxon	Megaloptera [%]
Danish Stream Fauna Index Diversity Groups	Trichoptera [%]
Danish Stream Fauna Index (DSFI)	Lepidoptera [%]
Belgian Biotic Index (BBI)	Coleoptera [%]
Indice Biotico Esteso (IBE)	Diptera [%]
IBE Aqem	Bryozoa [%]
Mayfly Average Score (MAS)	EPT-Taxa [%]
Integr. class	EPT/OL [%]
Operational Units	EP [%]
Mayfly Total Score (MTS)	Ep ind./Total ind. [%]
MAS (Large Rivers)	Taxonomic group (number of taxa)
Integr. class	Porifera
Operational Units	Coelenterata
Diversity (Simpson-Index)	Cestoda
Diversity (Shannon-Wiener-Index)	Trematoda
Diversity (Margalef Index)	Turbellaria
Evenness	Nematoda
Acid Class (Braukmann)	Nematomorpha
Acid Index (Hendrikson & Medin	Gastropoda
Number of sensitive taxa (Austria)	Bivalvia
Zonation	Polychatea
[%] crenal	Oligochaeta
[%] hypocrenal	Hirudinea
[%] epirhithral	Crustacea
[%] metarhithral	Araneae
[%] hyporhithral	Ephemeroptera
[%] epipotamal	Odonata
[%] metapotamal	Plecoptera
[%] hypopotamal	Heteroptera
[%] littoral	Planipennia
[%] profundal	Megaloptera
[%] littoral + profundal	Trichoptera

Metric	Metric
Zonation Index	Lepidoptera
Current preference (acc. Schmedtje)	Coleoptera
[%] Type LB	Diptera
[%] Type LP	Bryozoa
[%] Type LR	EPT-Taxa
[%] Type RL	EPT/OL
[%] Type RP	Oligochaeta and Diptera -Taxa [%]
[%] Type RB	Oligochaeta and Diptera -Taxa /Total-Taxa
[%] Type IN	EP-Taxa
Microhabitat preference	EPTCOB (Eph., Ple., Tri., Col., Odo., Bivalv.)
[%] Type Pelal	Taxonomic group (abundance)
[%] Type Argyllal	Porifera
[%] Type Psammal	Coelenterata
[%] Type Akal	Cestoda
[%] Type Lithal	Trematoda
[%] Type Phytal	Turbellaria
[%] Type POM	Nematoda
[%] Type Other	Nematomorpha
[%] Type Akal + Lithal + Psammal	Gastropoda
Feeding types	Bivalvia
[%] Grazers and scrapers	Polychatea
[%] Miners	Oligochaeta
[%] Xylophagous Taxa	Hirudinea
[%] Shredders	Crustacea
[%] Gatherers/Collectors	Araneae
[%] Active filter feeders	Ephemeroptera
[%] Passive filter feeders	Odonata
[%] Predators	Plecoptera
[%] Parasites	Heteroptera
[%] Other Feeding types	Planipennia
([%] Grazers + Scrapers)/([%]GatherersCollectors + [%] FilterFeeders)	Megaloptera
[%] Xyloph. + Shred. + ActFiltFee. + PasFiltFee	Trichoptera
RETI (Rhithron Ernährungstypen Index)	Lepidoptera
Locomotion type	Coleoptera
[%] swimming/skating	Diptera
[%] swimming/diving	Bryozoa
[%] burrowing/boring	Number of Families
[%] sprawling/walking	Number of Genera
[%] (semi)sessil	
[%] others (e.g. climbing)	

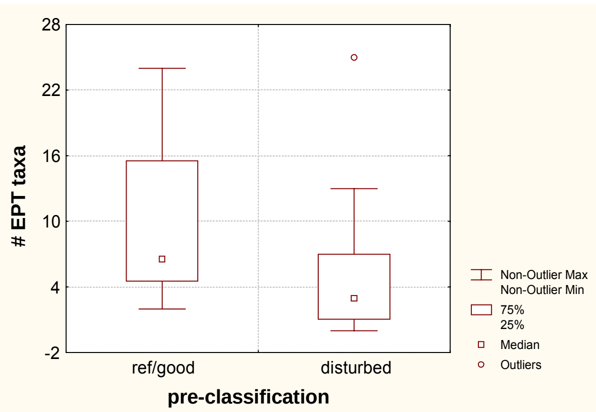
4. EXAMPLES OF METRICS THAT SHOW THE BEST DISCRIMINATORY POWER TO DISTINGUISH BETWEEN NON OR SLIGHTLY IMPAIRED AND STRESSED SITES

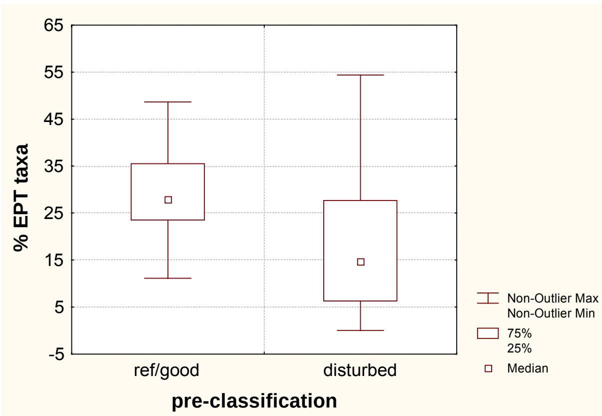
Based on the calculation of the candidate metrics listed above, core metrics as described in the methods part have to be selected. This selection should be based on real data, e.g. from the Joint Danube Survey. For this purpose a detailed pre-classification of the ecological status of all JDS sites needs to be done. The methodology of pre-classifying the JDS sites can use the criteria for pressures and impacts analyses (activity 1.1.2) as a valuable tool.

To study the reaction of selected metrics under stress a preliminary pre-classification of the JDS sites was performed by Birgit Vogel and Thomas Ofenböck. The biological data (saprobic indices only) and environmental data of the JDS report together with photographs of all sites served as the main data sources for pre-classification. The preliminary pre-classification is based on the saprobic indices and selected hydro-morphological features. For the morphological classification the general scheme for hydromorphological status assessment (WERTH 1987, SPIEGLER et al. 1989, MUHAR et al. 1996, 1998), the final report of the AQEM project and the six criteria for estimating the significance of a pressure's impact (activity 1.1.2, MOOG & STUBAUER 2003) were used.

The following two figures give evidence that a couple of metrics show a sufficiently good discrimination efficiency and can be successfully applied in developing a multimetric based assessment system for Danube River. Using box-and-whisker plots those sites that were pre-classified as reference sites or sites of good status are plotted against clearly disturbed sites.

In figure 3 only metrics from sites along the upper Danube (section types 2-4; see ROBERT et al. 2003) with a focus on the Austrian and Slovakian stretch are presented. Examples are given for: number (#) of EPT taxa, % of EPT taxa, % abundance of EPT individuals, % shredder, % grazer, % passive filter feeders, longitudinal zonation index and the Italian water quality index (IBE). Figure 4 gives some examples of metrics for the middle reach of the river Danube (section types 5-7): number (#) of EPT-Taxa, % active filter feeders, % shredder, total abundance, % type phytal living species, % type akal dwelling species. Within the "universe of metrics" the examples from the Danube River are representing each of four primary categories: (1) richness measures for diversity or variety of the assemblage; (2) composition measures for identity and dominance; (3) tolerance measures that represent sensitivity to perturbation; and (4) trophic or habit measures for information on feeding strategies and guilds.





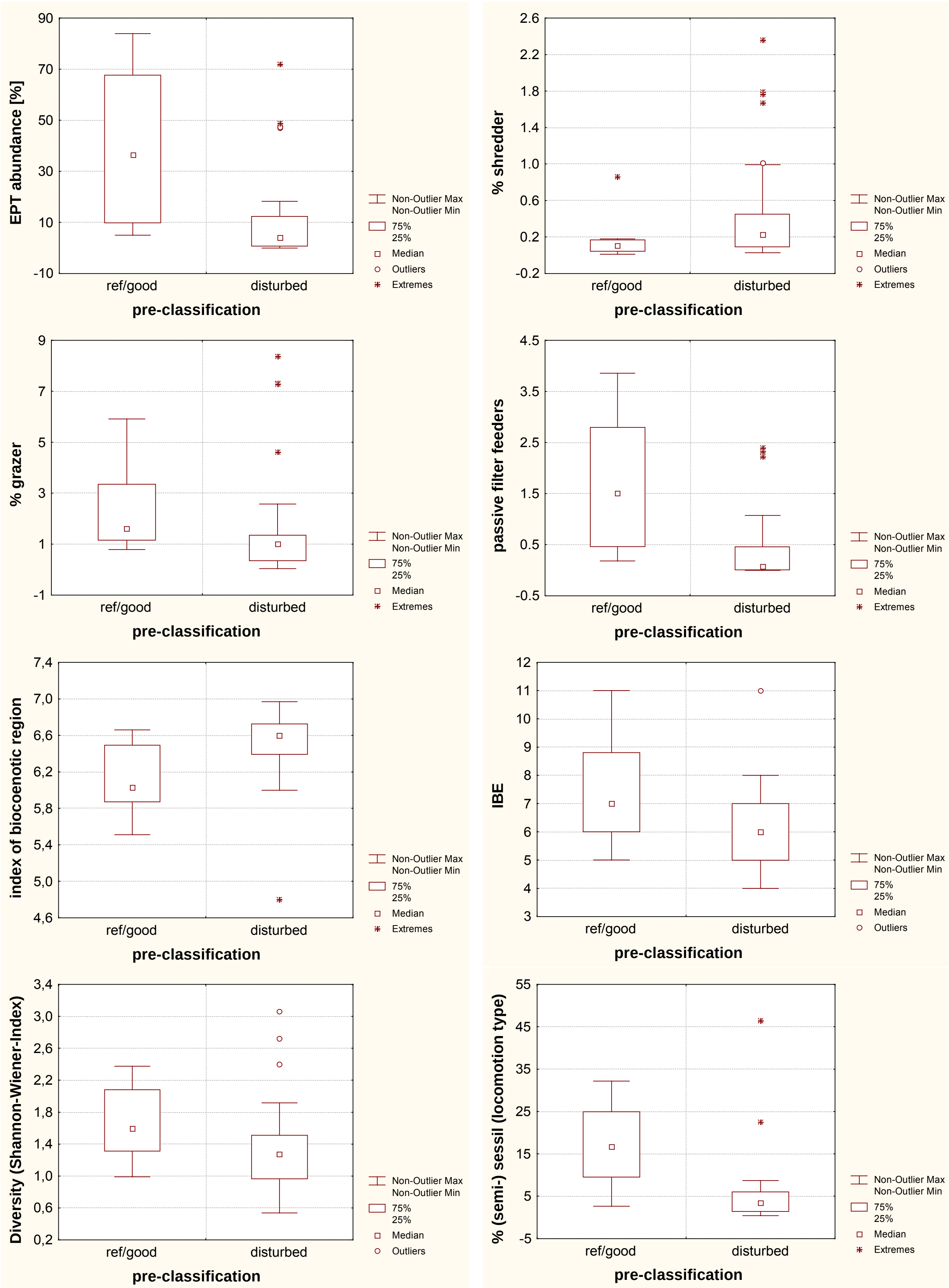


Figure 3: Examples of possibly suitable metrics for the upper reach of the river Danube (section types 2-4). Sites pre-classified as reference sites or sites of good status are plotted against clearly disturbed sites.

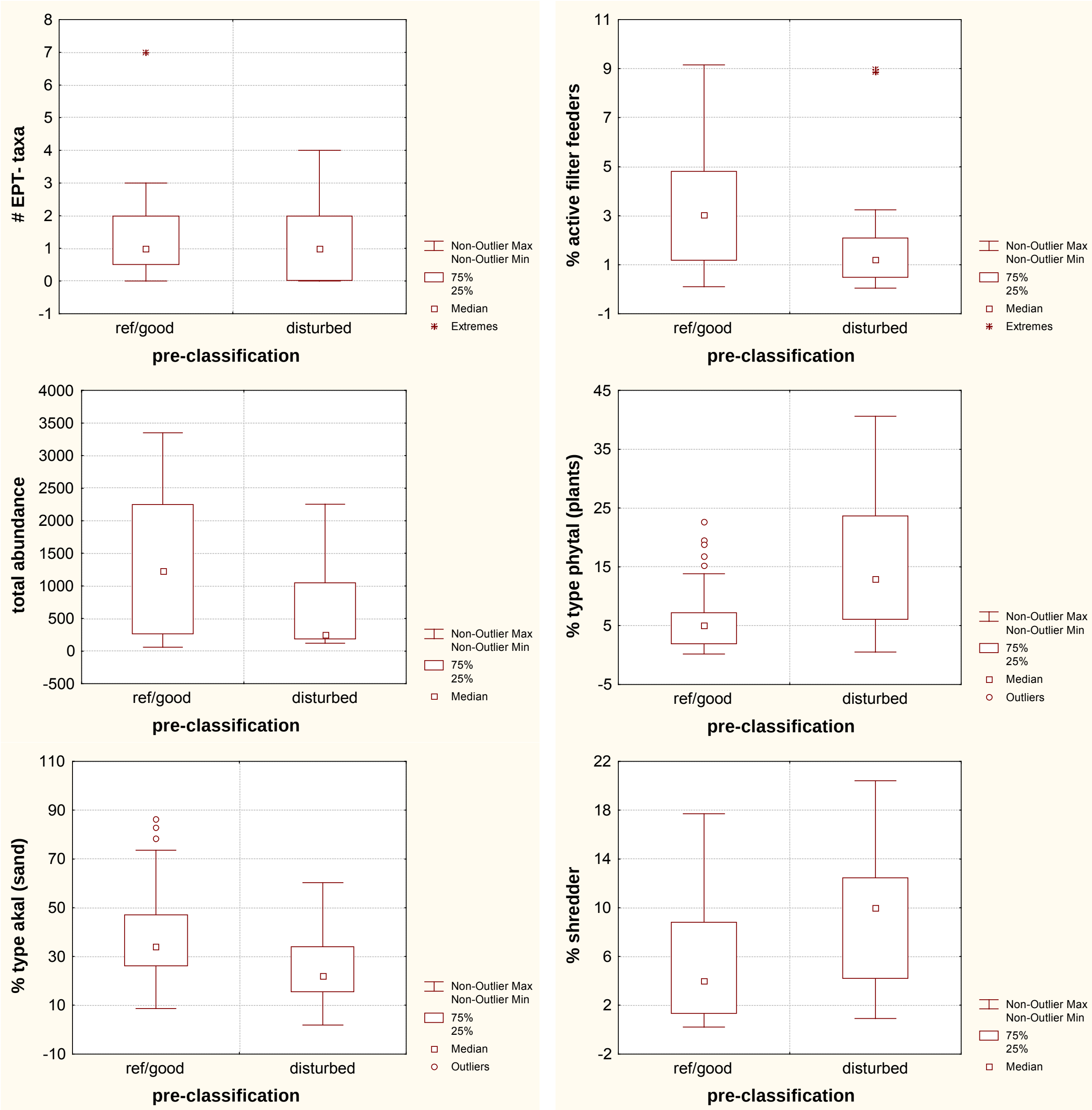


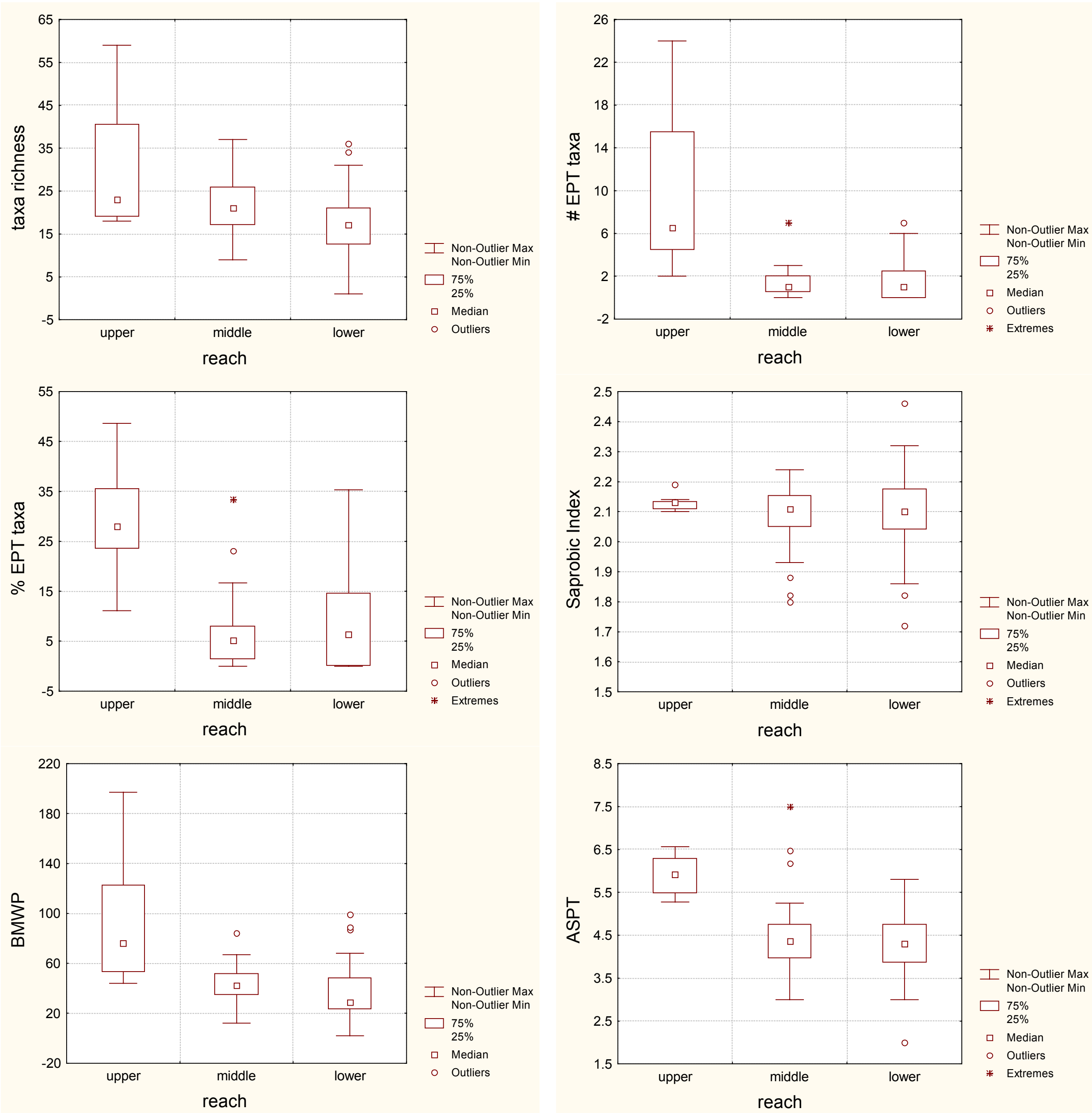
Figure 4: Examples of metrics for the middle reach of the river Danube (section types 5-7). Sites pre-classified as reference sites or sites of good status are plotted against clearly disturbed sites.

The discriminatory power of the metrics in figures 3 and 4 is promising, but needs improvement. As an important starting point the establishment of reference conditions (through actual sites or by other means) is crucial for the determination of metric (and later index) thresholds. The current process of a quick and preliminary pre-classification of JDS sites does not meet the necessary quality targets, but shows that the development of a multimetric index is on the right way.

Metric variability among Danube sections

Box-and-whisker plots of the JDS investigation sites classified by aggregated Danube section types were used to depict the natural variability of the metrics within the population of reference and good sites. The following figures plot the relationship of metric values against various Danube sections to document two effects: 1) the longitudinal development of the Danube River and 2) to validate the Danube section types.

In a first step the box-and-whisker plots of the metrics were aggregated to three groups that represent the JDS sites of the upper, middle and lower Danube. This rough grouping was chosen to gain a general prospectus of the metrics' reaction among longitudinal properties. Again the examples from the Danube River are representing each of four primary categories within the „universe of metrics“. The richness measures for diversity or variety of the assemblage are represented by the species richness (total number of taxa) and the number of EPT taxa. Unexpectedly the number of species decreases with increasing length of the river. This finding is in contradiction with limnological theories and probably due to the fact that a definite portion of the fauna typical for the lower Danube stretches could not be identified according to the necessary taxonomic resolution.



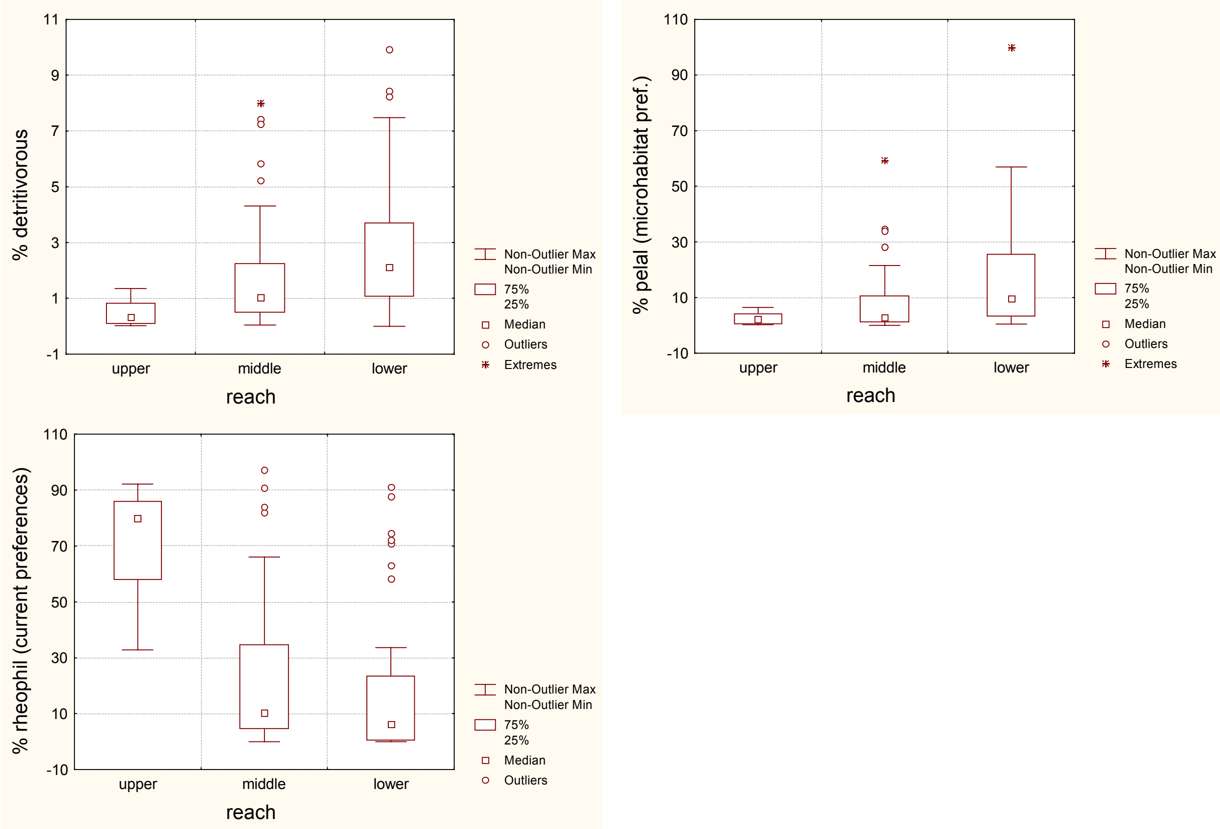


Figure 5: Distribution of metric values among Danube reaches. upper reach: section types 2-4; middle reach: section types 5-7; lower reach: section types 8-10

The percentage of EPT taxa is chosen as a representative of the composition measures for identity and dominance. The figures show a remarkably high portion of EPT taxa in the upper courses, a conspicious decrease in the middle parts and a "recovery" in the downstream sections.

Among the tolerance measures that represent sensitivity to perturbation four metrics were selected. The saprobic indices range within the same order of magnitude with median around 2.1 and thus indicating a good saprobic water quality during the JDS period. This observation does not correspond with other evaluations based on family level methods. For instance the BMWP and ASPT values start with quite low numbers and show a further decrease with increasing river length. It is not the intention of this chapter to discuss the water quality of the Danube but as a result of these analyses some questions arise that indicate the necessity for future investigations. With respect to the application of the saprobic system the need for a saprobic ranking of more Danube taxa in the middle and lower sections is evident (see also STUBAUER & MOOG 2003, this report). Figure 6 clearly demonstrates a distinct increase of taxa without saprobic ranking from stream kilometre 1000 towards the delta.

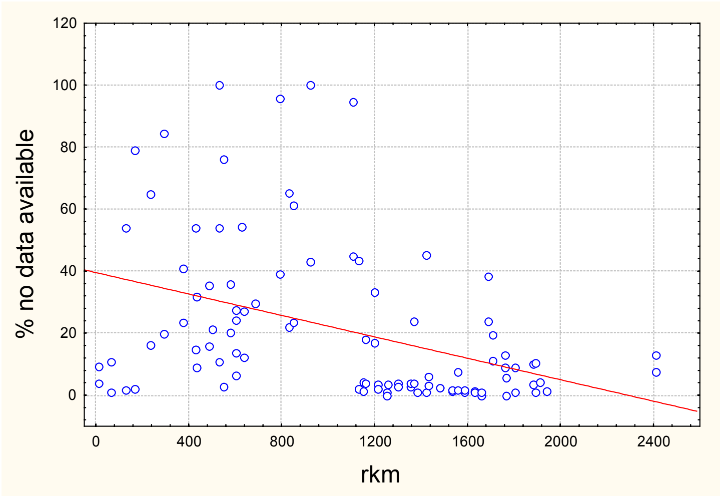
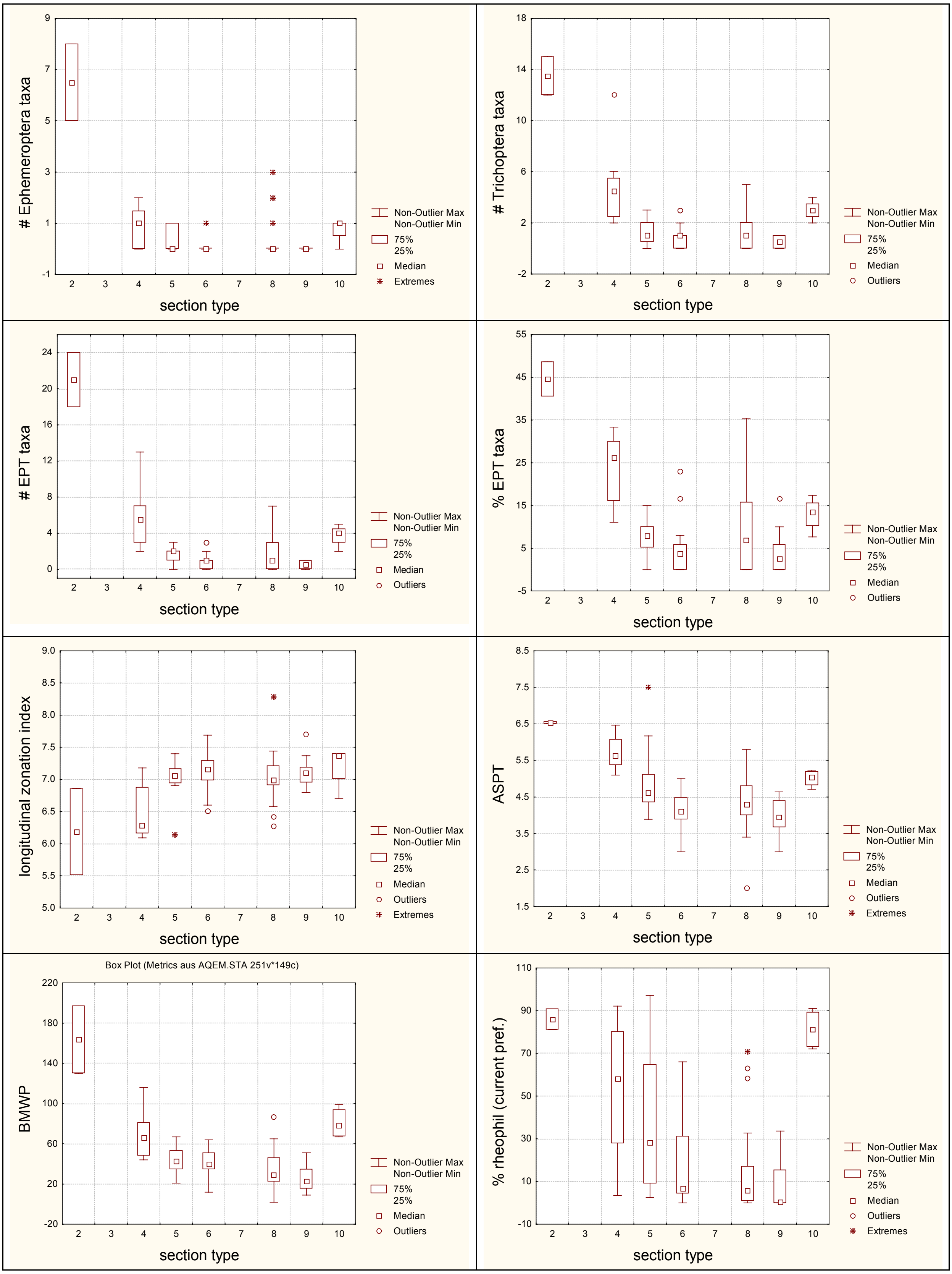


Figure 6: Percentage of individuals without saprobic ranking vs. river length (rkm).

The apparent decrease of the biological water quality as indicated by the BMWP and ASPT values may be explained by the fact that the JDS data show a tendency of decreasing taxa richness towards the delta (exceptive the delta region). With respect to this observation it might be possible that this phenomenon is a result of the fact that taxa diversity is an important input variable for BMWP calculations. To explain the validity of these BMWP results it is necessary to know if the decreasing species diversity within the longitudinal gradient is an artefact of the JDS data or reality. If the decrease in species numbers is a fact it must be clarified if this declining diversity is a typical and natural phenomenon along the Danube or if it is due to environmental impairment.

Out of the trophic or habit measures for information on feeding strategies and ecological guilds three examples from the JDS data are presented: the share of detritivorous species (% detritivorous), percentage share of mud-dwelling organisms (% pelal) and percentage share of rheophilic species (% rheophil). The amount of mud-dwelling and detritivorous organisms increase with the rivers' length, the number of rheophilic species decrease.

The variation of the metrics ranges among the three Danube sections (upper, middle, and lower course) clearly indicate that a multimetric index must be based on river types. Therefore the next step of data evaluations was to check the box-and-whisker plots of the JDS investigation sites classified by the aggregated ten Danube section types. Some Danube sections were excluded from the analysis. No samples have been taken from section type 1 during the JDS. No sites of reference character or good conditions were available from section types 2 (Western Alpine Foothills Danube) and 7 (Iron Gate Danube) due to the impacts of hydropower generation.


Ephemeroptera taxa
Trichoptera taxa
EPT taxa
% EPT taxa
longitudinal zonation index
ASPT
Box Plot (Metrics aus AQEM.STA 251v*149c)
BMWP
% rheophil (current pref.)
section type
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

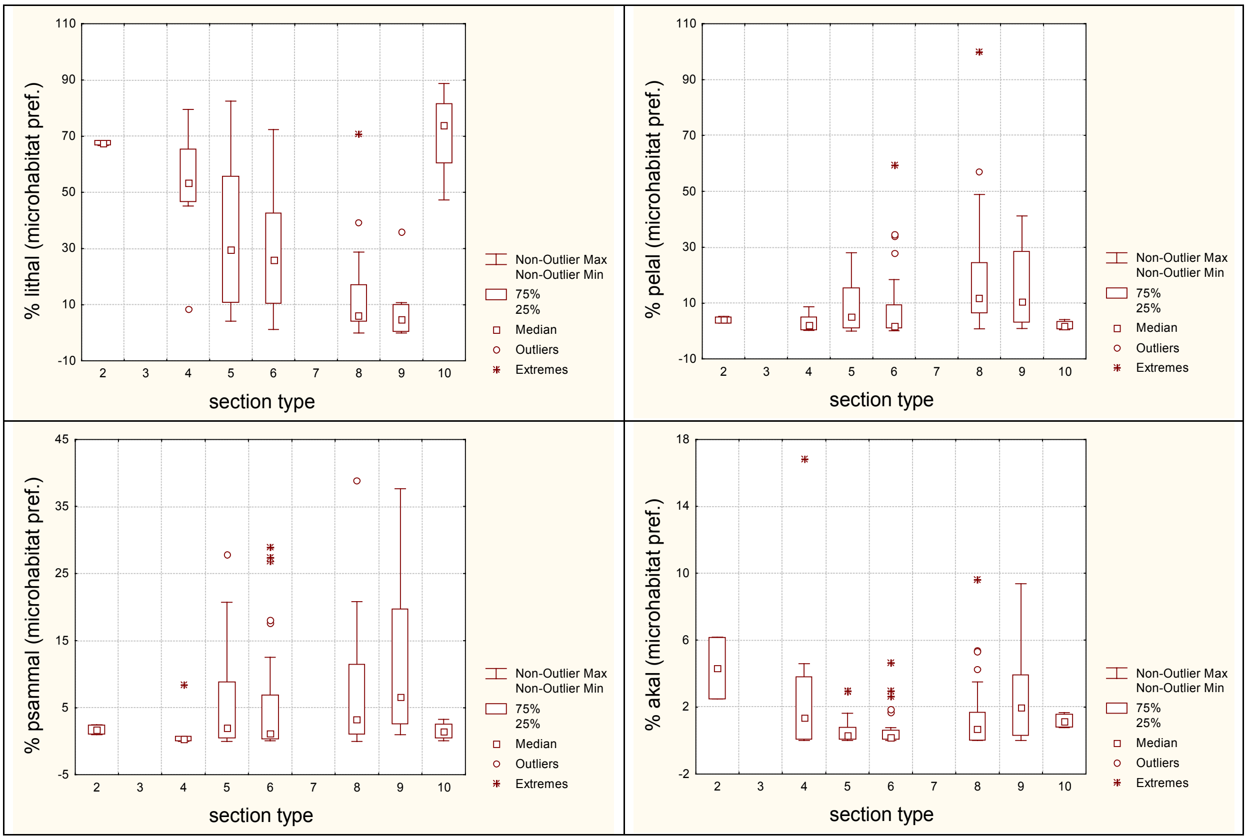


Figure 7: Distribution of metric values among Danube River section types

The richness measures for diversity or variety of the assemblage are represented by the Ephemeroptera and Trichoptera species richness (# Ephemeroptera taxa and # Trichoptera taxa) and the number of EPT taxa (# EPT taxa). All three of them show a similar distribution of the box-and-whisker plots indicating a high redundancy of information. For the final designation of core metrics only one out of the three will be taken. The phenomenon of increasing species numbers in the Danube Delta section can also be confirmed at the level of the sensitive EPT taxa.

Again the percentage of EPT taxa is chosen as a representative of the composition measures for identity and dominance. The box-and-whisker plots show a continuous decrease of the portion of EPT taxa (% EPT taxa) from the upper courses to the middle and lower Danube sections and a “recovery” in the delta reach.

The BMWP and ASPT metrics are selected as tolerance measures that represent sensitivity to perturbation. Among the trophic or habit measures for information on feeding strategies and ecologic guilds the following examples from the JDS data are chosen: percentage share of rheophilic species (% rheophil), percentage share of stone-dwelling species (% lithal), percentage share of sand-dwelling organisms (% psammal) and percentage share of mud-dwelling species (% pelal). The faunas of the first two categories show a steady decline from the source to the mouth into the Black Sea. The second two categories (amount of sand-dwelling organisms and mud-dwelling organisms) develop in the opposite direction by increasing their shares with the rivers’ length.

These evaluations clearly show that the Danube typology, especially the sub-division in ten section types is an important features for developing a type specific multimetric index.

5. SUMMARY AND OUTLOOK FOR DEVELOPING A MULTIMETRIC INDEX OF THE DANUBE RIVER

The preliminary analyses of the JDS data showed clearly that the multimetric approach can serve as a useful tool for assessing the ecological status of the Danube River. Although the ecological status of the JDS investigation sites has be pre-classified in a very rough way the metrics under test provided a remarkably high discriminatory power to distinguish between good and disturbed sites.

Out of a large set of candidate metrics the following measures proved the ability to function as core metrics:

- EPT taxa (Ephemeroptera, Plecoptera, Trichoptera-Taxa)
- % EPT-Taxa
- abundance of EPT Individuals
- % shredder
- % grazer
- % detritivorous
- % passive filter feeders
- % active filter feeders
- saprobic index
- longitudinal zonation index
- IBE (Indice biotico esteso)
- diversity index (Shannon-Weaner)
- semisessile locomotion type
- % rheophilic species
- % type phytal - microhabitat preference
- % type lithal- microhabitat preference
- % type akal - microhabitat preference
- % type psammal- microhabitat preference
- % type pelal - microhabitat preference
- total abundance

Nevertheless, the available data from the Joint Danube Survey do not reflect the real diversity in the river Danube adequately. For the future development of an assessment approach that is based on the multimetric procedure at least a second run of the Joint Danube Survey is highly recommended. The already applied sampling design which more or less reflects the longitudinal development of the Danube River needs to be adapted to a type specific and stressor based approach. For creating a new assessment system that fulfils the demands of the Directive a wide range of environmental conditions needs to be documented for each Danube type. As it is possible that reference conditions (and resultant thresholds) will need to be established on a seasonal basis it is necessary to perform a year-round sampling and assessment.

In a pre-classification process sites including reference stretches to heavily impaired sections need to be identified. As the "water bodies" will be the operative units in the future administrative system the water bodies of different types and environmental quality may serve as a source for defining sampling sites. In addition it will be helpful for the selection of according sampling sites to hark back to the presumed status information provided by the pressures and impact analysis.

The preliminary evaluations clearly show that the Danube typology, especially the sub-division in ten section types is an important feature for developing a type specific multimetric index.

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