UNDP/GEF DANUBE REGIONAL PROJECT

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

ACTIVITY 1.1.6 "DEVELOPING THE TYPOLOGY OF SURFACE WATERS AND DEFINING THE RELEVANT REFERENCE CONDITIONS"

FINAL REPORT

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INTRODUCTION

The report at hand presents the final outputs of the Activity 1.1.6 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.

Typology of the Danube River

– part 1: top-down approach

SABINA ROBERT, SEBASTIAN BIRK & MARIO SOMMERHÄUSER

INTRODUCTION

The development of a typology for the Danube River and the definition of according reference conditions is an essential part of the UNDP/GEF Danube Regional Project, considering the objectives of the Joint Action Program of the ICPDR and the Work Plans of the ICPDR Expert Groups.

Aim of this study was to compile available data on top-down typological approaches for the Danube River, to propose section types based on the available information, to possibly validate it "bottom-up" as well as to define the (morphological and biological) reference conditions for the proposed Danubian sections. A basic strategy of the project's design was a close co-operation with experts ("national consultants") from the Danube River Basin countries and to prepare an agreement among them.

Former systems subdividing the Danube River into sections

Several systems to subdivide the Danube River into „homogeneous" sections have been established before based on different abiotic parameters (e.g. geological structure, slope, geomorphology). None of these proposals meet the typological requirements of the Water Framework Directive (EU WFD) (EUROPEAN UNION 2000).

In the following the different systems are briefly presented:

a. Based on the catchment geology various authors, e.g. LÁSZLÓFFY (1965) divide the river into Upper, Middle and Lower Danube:

   - The **Upper Danube Basin** covers the area from the source tributaries in the Black Forest down to the Devin Gate east of Vienna. The regions of the Swabian and Falconian Alb, parts of the Bavarian and Bohemian Forests, and the Bohemian–Moravian Uplands form the northern border of this section, while the southern borders are composed by the Swabian-Bavarian-Austrian foothills belt, comprised by major parts of the Alps. Major tributaries from the right are Lech, Isar, Inn, Traun, Enns, and Morava from the left.
   - The **Middle Danube Basin** comprises the largest portion of the catchment. It covers the part from Devin Gate to the Iron Gate dams (Serbia-Montenegro/Romania) bordered by the Carpathians in the north and east, parts of the Dinaric mountain range in the west and south. The major tributaries in this region are (from the left) Váh, Hron, Ipel and Tisa, and from the right Raba, Sio, Drava, Sava and Velika Morava. The most important gorge section with a length of 117 kilometres is the Iron Gate which represents the downstream border of this section.
   - The **Lower Danube Basin** is formed by the Romanian-Bulgarian lowland and its upland plateaus and mountains. It is bordered by the Carpathians (north), the Bessarabian upland plateau (east) and by the Dobrogea and the Balkan (south). The important tributaries in this region are Timok, Iskar and

Jantra from the south, and Jiu, Olt, Arges, Ialomita, Siret and Prut from the north.

b. A division based on the river slope was presented by LÁSZLÓFFY (1965), resulting in six sections:
   - **Mountain section** (river km 2780 – 2497) from the confluence of the source rivers Brigach and Breg down to the confluence of river Lech (average slope = 101 cm/km);
   - **Upper Danube** (river km 2497 – 1794) from the confluence of the river Lech to the rejoining of the Danube-Mosoni at Gönyü (average slope = 40 cm/km);
   - **Middle Danube** (river km 1794 – 1048) from the confluence of river Raab to the cataract at the Iron Gate (average slope = 6 cm/km);
   - **Cataract-reach** (river km 1040 – 941) between its two borders, on a 100 km stretch there is an altitude difference of 28 m (average slope = 28 cm/km);
   - **Low Danube** (river km 941 – 80) from the Wallachian lowland to the Danube delta (average slope = 3.9 cm/km);
   - **Danube Delta** (river-km 80 – 0), with an average slope of a few millimetres on each kilometre.

c. A geomorphological division has been made for the purposes of the Joint Danube Survey conducted in August/September 2001. Nine distinct reaches have been characterised by specific geomorphological landscape features as well as anthropogenic impacts (LITERÁTHY et al. 2002):
   - **Reach 1:** Neu Ulm - confluence with the Inn River (river km 2581 – 2225). Alpine river character; impact by hydroelectric power plants;
   - **Reach 2:** River Inn - confluence with the Morava River (river km 2225 - 1880). Alpine river character; impact by hydroelectric power plants;
   - **Reach 3:** Morava River – Gabcikovo Dam (river km 1880 - 1816). Impact by the construction of Gabcikovo Dam;
   - **Reach 4:** Gabcikovo Dam – upstream Budapest (river km 1816 - 1659). Change of alpine into lowland river; Danube flows through Hungarian Highlands;
   - **Reach 5:** Budapest (upstream) – confluence with the Sava River (river km 1659 - 1202). Danube crosses Hungarian Lowlands; impact by significant emissions of untreated wastewater in Budapest;
   - **Reach 6:** The Sava River/Belgrade – Iron Gate Dam (river km 1202 - 943). As a lowland river, the Danube breaks through the Carpathian and Balkan mountains; impact by damming of Iron Gate hydroelectric power plant and significant emissions of untreated wastewater in Belgrade;
   - **Reach 7:** Iron Gate Dam – confluence with the Jantra River (river km 943 - 537). Danube flows through Wallachian Lowlands (aeolian sediments and loess); steep sediment walls of up to 150 m characterise the river bank on the Bulgarian side;
   - **Reach 8:** The Jantra River – Reni (river km 537 - 132). Lowland river; alluvial islands between two Danube arms;

- **Reach 9:** Reni – Danube Delta arms / the Black Sea (river km 132 – 12). Danube splits into three main Delta arms; characteristic wetland and estuary ecosystem; slopes decrease to 0.001 ‰.

Typology: top-down approach

The first step was the compilation of existing information concerning possible section types in the Danube River Basin countries.

The relevant data have been collected using questionnaires (described in detail in the mid-term report) which have been sent to national consultants. Additionally, other available sources e.g. maps and literature on topography, geology, geomorphology and soils were used to obtain an abiotic top-down division of the Danube into section types characterised by homogeneous hydrological and morphological features.

This „a priori“ draft typology was checked in two different ways: It was presented to the national consultants for comments. In parallel, a bottom-up validation of the section types was performed. For this „a posteriori“ step the data set of the Joint Danube Survey (benthic macroinvertebrates) was used and analysed using ordination techniques (see MOOG et al. 2003, this report)

Table 1: List of all parameters used for the definition of Danube River section types

Parameter	Alteration by human activities[1]	Origin of data
Ecoregion	-	ILLIES (1978) EUROPEAN UNION (2000)
Slope	-	LÁSZLÓFFY (1965) LITERÁTHY et al. (2002)
Geomorphology	-	LÁSZLÓFFY (1965) BREU (1989)
Lithology/Sedimentology	-	BREU (1989)
Soils	0	BREU (1989)
Bed load	+	BUSNITA (1967)
Water Temperature	+	LÁSZLÓFFY (1965)
Discharge	+	KNIE (1966)
Inundation zone	+	LÁSZLÓFFY (1965) BUSNITA (1967)
Islands	+	LASZLOFFY (1965) LITERATHY et al.(2002)

METHODS

The first criterion established was the selection of appropriate parameters for the definition of the section types: According to system B of the EU WFD parameters not altered by human activities (ecoregion, slope, geomorphology, lithology/sedimentology, soils and larger islands) as well as parameters potentially influenced by perturbance (water temperature and discharge) have been chosen. The acquisition of both types of data aimed at describing section types in near

1. [1] – = not altered by human activities, 0 = indifferent, + = probably altered by human activities

natural condition. A compilation of all parameters used to define the sections is presented in table 1.

Within the second step acquired data have been analysed to identify important changes of abiotic conditions along the course of the river.

Some examples are presented below:

- On its way to the Black Sea the Danube crosses four ecoregions (ILLIES 1978) from west to east – 9 (Central Highlands), 11 (Hungarian Lowlands), 10 (The Carpathians) and 12 (Pontic Province). According to the ecoregions the Danube can be divided into four sections (see figure 1).

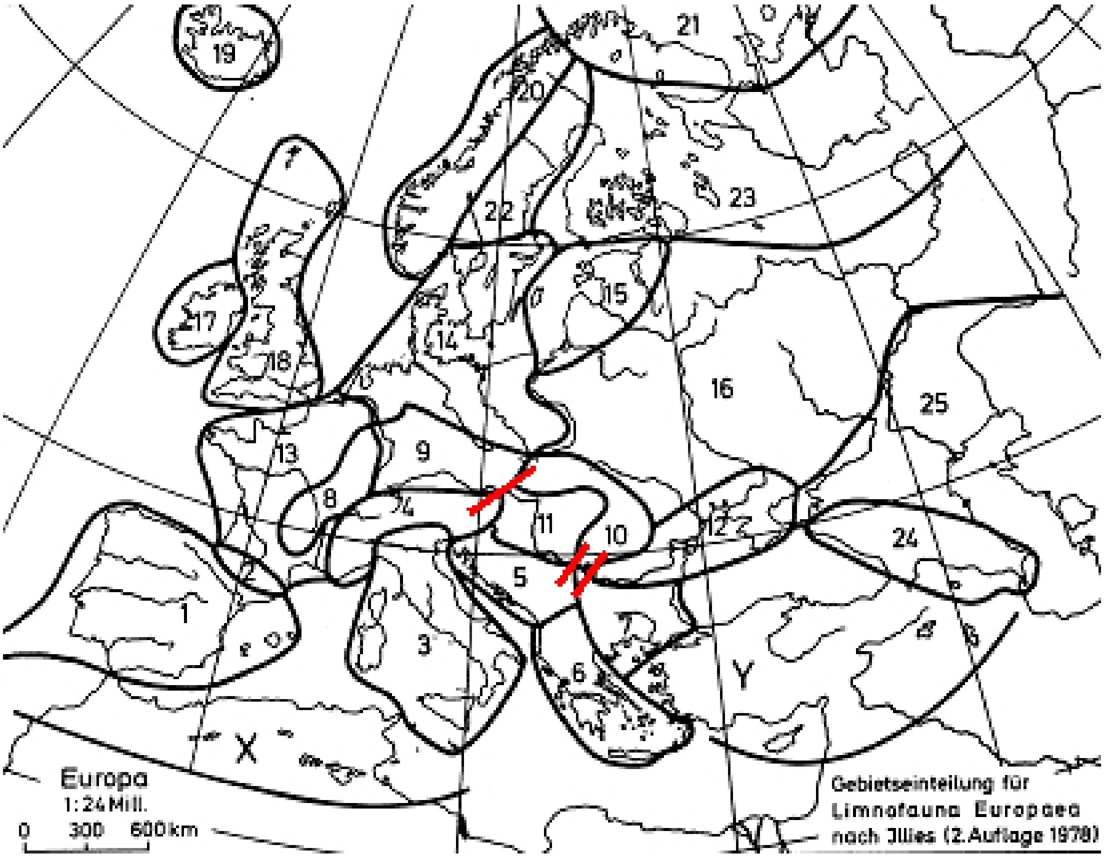

Figure 1: Division of the Danube River according to the four ecoregions (ILLIES 1978)

- Based on the slope evolution on the Danube (figure 2, LÁSZLÓFFY 1965) six major shifts in the river slope from Regensburg (km 2376) to Sulina (km 0) have been chosen as section type borders.

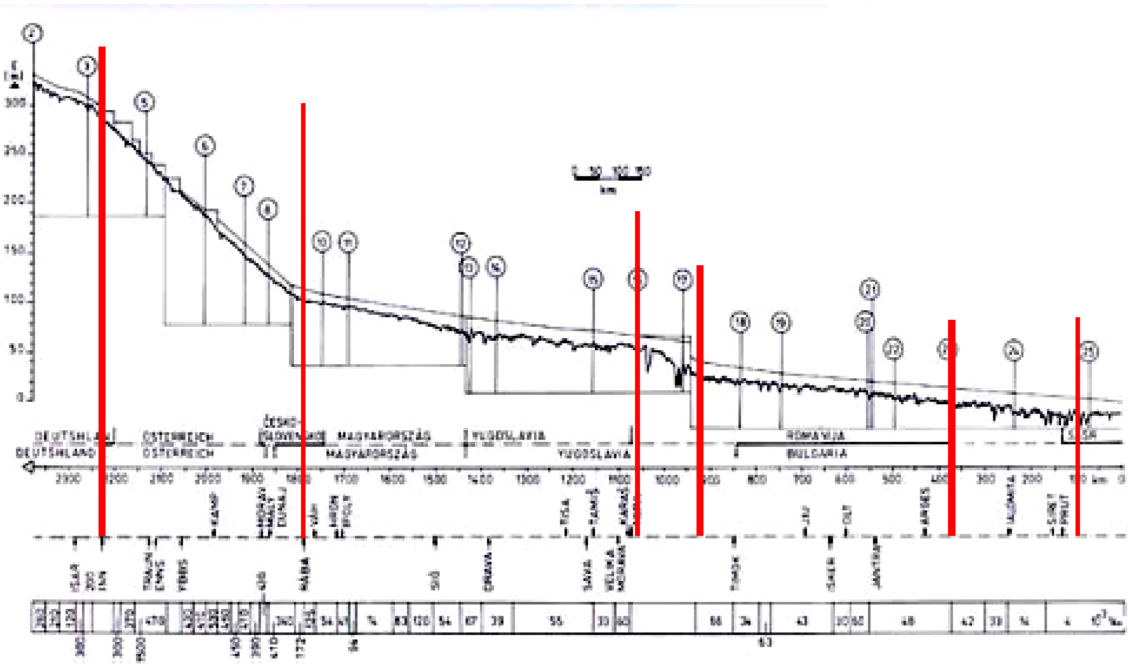

Figure 2: Six section type borders according to the slope values (LÁSZLÓFFY 1965)

- According to the geomorphological regions crossed by the Danube (figure 3, ZINKE ENVIRONMENT CONSULTING 1999) eleven borders can be defined on the river.

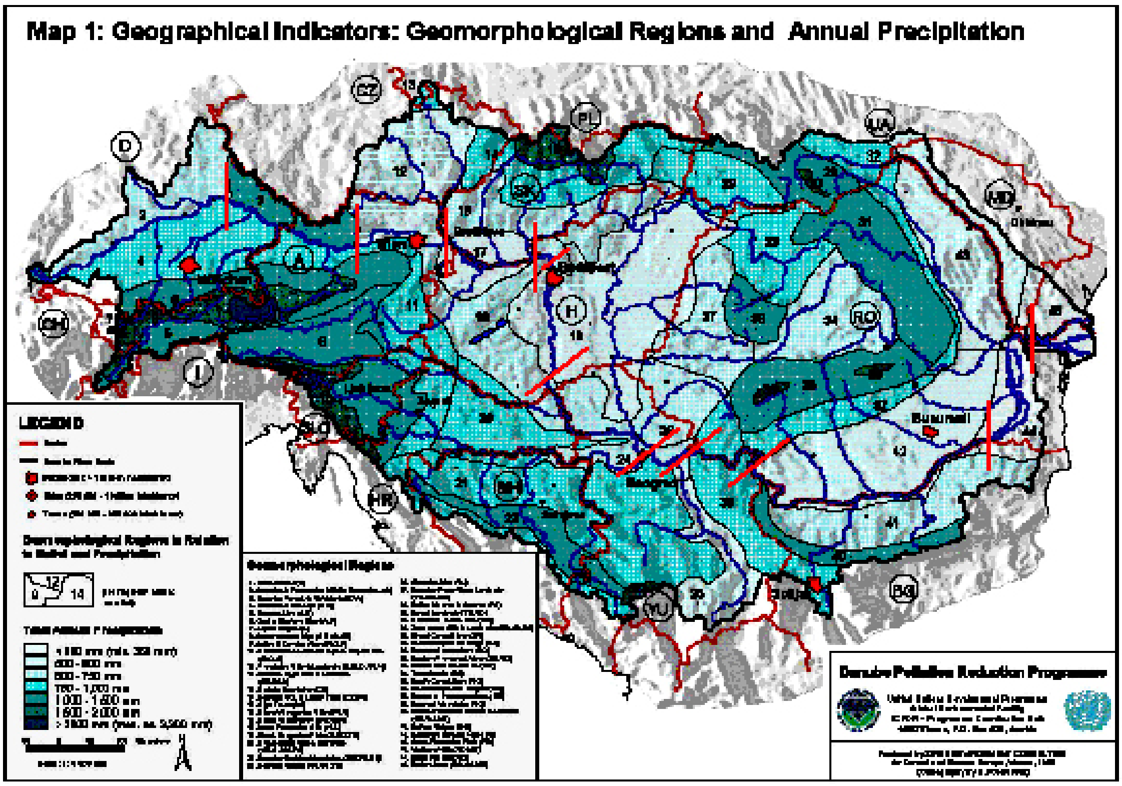

Figure 3: Eleven geomorphological borders along the Danube River considered as section and sub-section type borders (ZINKE ENVIRONMENT CONSULTING 1999)

All other parameters have been evaluated and assessed this way in order to identify the major abiotic changes and to define section borders.

In addition to the above mentioned parameters the influence of the tributaries‘ hydrological character (e.g. confluence of River Iller and Inn with the Danube) and the geomorphological variation along the river like breakthrough sections (e.g. Danube bend) and lowland areas have also been considered.

By the help of expert knowledge the major changes of one or more parameters have been considered as main borders for the section types. Less important changes form sub-section type borders.

RESULTS

The Danube River has been divided into ten homogeneous section types. According to the above mentioned criteria four of the section types (2, 4, 5 and 6) have been subdivided into two and three sub-section types, respectively.

The typology proposal was presented at the 2nd Surface Water Workshop in Zagreb in September 2003. With some constructive improvements mainly focusing on the Hungarian Danube reach it has been accepted as a framework for the Danube River Basin countries.

Names of the section types have been given according to the geographical region the Danube is flowing through (e.g. section type 6 “Pannonian Plain Danube”). This system has been chosen to simplify the areal allocation of the section. The rationales for the section type borders are as follows: confluence of the Danube with important tributaries (e.g. Iller in Neu Ulm; Inn in Passau); changes of the geomorphological structure like breakthrough sections (e.g. Kazan pass between Bazias and Turnu Severin) or lowland areas (e.g. Balta Brailei and Balta Ialomitei between Chiciu/Silistra and Isaccea); delta formation (Danube Delta from Isaccea to Sulina).

The individual section lengths differ: The average length amounts to approx. 280 km, the „Turnu Severin to Chiciu/Silistra“ section is 553 km long. The shortest section adds up to 100 km (e.g. Isaccea to Sulina).

All ten section types and the corresponding sub-section types are summarized in table 2 and figure 4. The hydromorphological and habitat characteristics of these section types are presented in detail in the “Definition of reference conditions for the section types of the Danube River” (ROBERT et al. 2003, this report).

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Table 2: The ten section types and its sub-sections

section type	1	2		3	4		5			6			7	8	9	10
section type borders	confluence of Brigach and Breg - Neu Ulm	Neu Ulm - Passau		Passau - Krems	Krems – Gönyü/ Klizska Nemá		Gönyü/Klizska Nemá - Baja			Baja - Bazias			Bazias - Turnu Severin	Turnu Severin - Chiciu/ Silistra	Chiciu/ Silistra - Isaccea	Isaccea - Sulina
river km (from - to)	**2786 - 2581**	**2581 - 2225**		**2225 - 2001**	**2001 - 1791/1790**		**1791/1790 - 1497**			**1497 - 1071**			**1071 - 931**	**931 - 378**	**378 - 100**	**100 - 0**
name of reach	**Upper Course of the Danube**	**Western Alpine Foothills Danube**		**Eastern Alpine Foothills Danube**	**Lower Alpine Foothills Danube**		**Hungarian Danube Bend**			**Pannonian Plain Danube**			**Iron Gate Danube**	**Western Pontic Danube**	**Eastern Wallachian Danube**	**Danube Delta**
sub-section type borders		**Neu Ulm - Regensburg**	**Regensburg - Passau**		**Krems - Devin**	**Devin-Gönyü/Klizska Nemá**	**Gönyü/Klizska Nemá-Esztergom**	**Esztergom - Nagymaros/Visegrád**	**Nagymaros/Visegrád - Baja**	**Baja - tr. Drava**	**tr. Drava - tr. Sava**	**tr. Sava - Bazias**				
river km (from - to)		**2581-2376**	**2376-2225**		**2001-1880**	**1880-1791/1790**	**1791/1790-1719**	**1719-1695**	**1695-1497**	**1497-1379**	**1379-1170**	**1170-1071**				
ecoregion	9	9	9	9	11	11	11	11	11	11	11	11	10	12	12	12

tr.= tributary

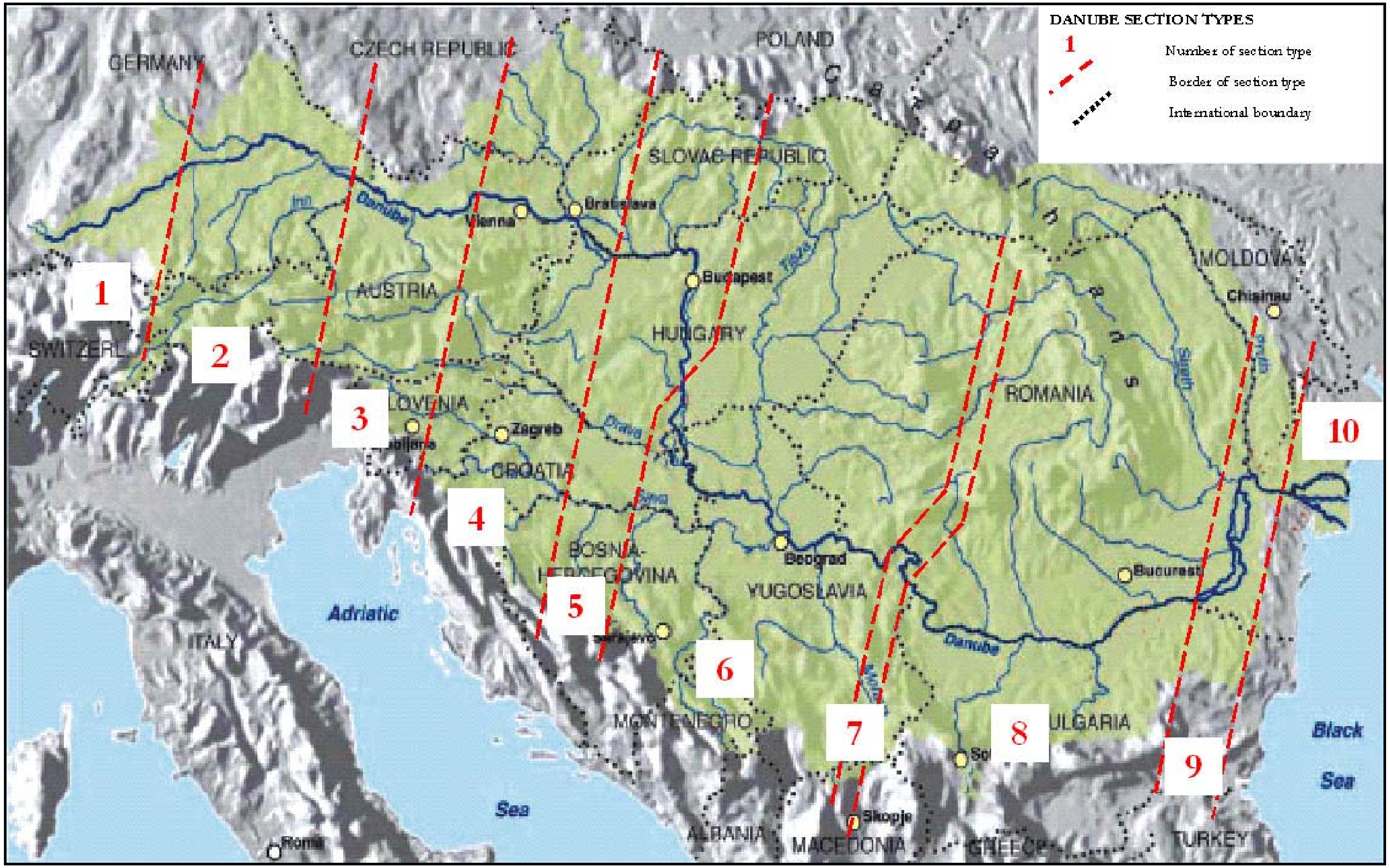

Figure 4: Map of Section Types (taken from GÜNTHER-DIRINGER 2002)

Typology of the Danube River

– part 2: bottom-up validation

OTTO MOOG, THOMAS OFENBÖCK & THOMAS BATTISTI

INTRODUCTION

The application of the Water Framework Directive's methodology to assess the ecological status of rivers needs to be based on a regional classification of river types. In regional classifications landscape elements as ecoregions (annex 11 of the WFD) or bioregions (MOOG et al. 2001) are used to create maps that allow managers to make spatially explicit statements about the biological properties characteristic of individual regions. This approach is based on the idea that the biological properties of specific aquatic ecosystems can be inferred from knowledge of the region within which aquatic ecosystems occur (HUGHES & LARSEN 1988, OMERNIK 1995, BARBOUR et al. 1996, HAWKINS & NORRIS 2000).

To classify typological units of the Danube River a spatial typology fails as large rivers show a self-contained development. Along the longitudinal gradient a large river absorbs a catchment's characteristic and finally represents a mixture of different influences. Therefore a separate typology for the Danube has been developed in an *a priori* process by ROBERT et al. (2003). In an *a posteriori* procedure the performance of this *a priori* classification system was gauged by its classification strength. Following the collaboration of freshwater scientists (HAWKINS & NORRIS 2000) the degree to which classification minimised within-class biotic similarity relative to between-class biotic similarity was determined. To describe the relationship of the benthic invertebrate communities of different sites a „non-metric multidimensional scaling“ (NMS) was performed. This method measures the biotic similarity between sites as compositional similarity by the Sørensen or Bray-Curtis coefficient. The similarity of sites can be visualised in scatterplots combined with a choice of varying overlays. To quantify the classification strength which is defined as the difference between mean within-class and mean between-class similarity the methods described by SMITH et al. (1990), VAN SICKLE (1997), and VAN SICKLE & HUGHES (2000) were used.

METHODS

Non-metric Multidimensional Scaling

The ten Danube reaches have been validated using biological data sets (benthic macroinvertebrates) from the Joint Danube Survey (LITERÁTHY et al. 2002) and comparing them by means of similarity analysis. Data from transactional station sites have been combined to represent the whole community. Due to differences in the sampling techniques presence/absence data were analysed. The objective aimed for an approval/disapproval of the ten sections by the occurrence of characteristic aquatic biocoenosis. For this purpose non-metric multidimensional scaling (NMS) was used as ordination method (MCCUNE & MEFFORD 1999). Multivariate ordination can graphically demonstrate whether the species composition reflects the set of an *a priori* classification.

Classification of species composition data usually involves ordination or clustering of sites to examine classes and structure. These require a distance or similarity measure for site pairs, calculated from the taxonomic composition of the sites. A primary requirement for a data set is taxonomic consistency, or always identifying a given taxon as the same thing (NIJBOER & VERDONSCHOT 2000).

NMS reduces the dimensionality of multivariate data in order to visualise and examine them with other, more conventional, exploratory analyses. NMS develops an ordination from any distance or similarity matrix. The procedure ranks distances in the original matrix, and then attempts to display these ranks of distances in a specified number of dimensions, usually 2 or 3. In effect, NMS produces a map of the entities from the distances among the sites. The goodness-of-fit of the estimated distances is measured by the stress statistic (indicated in the figures). Additionally a coefficient of determination (r^2) for the correlations between ordination distances and distances in the original n-dimensional space is calculated and indicated as the cumulative value of the axis shown in the figures. The computational procedure is numerical approximation, beginning with an arbitrary configuration and reducing the stress statistic in each successive approximation. When plotted in ordination space, sites with similar species composition are close together. Ordination plots are thus used to verify or falsify the *a priori* classification hypotheses. NMS is relatively robust for species composition data, and has been applied frequently in recent years to benthic macroinvertebrate data (e.g. REYNOLDSON et al. 1995, BARBOUR et al. 1996). The Sørensen/Bray-Curtis coefficient was used as distance measure. With presence/absence data only, it is equivalent to the Jaccard coefficient (LEGENDRE & LEGENDRE 1998).

Prediction of expected types can be derived from a geographic model, or with a discriminant analysis based on physical data (e.g. MOSS et al. 1987, HUGHES & LARSEN 1988, BARBOUR et al. 1996, MOSS 2000). Our approach is to check and possibly modify and adjust the *a priori* model of the section types in order to develop an optimum geographic and physical classification. NMS was performed with PC-ORD 4.1 (MCCUNE & MEFFORD 1999).

Data refer exclusively to the Danube main channel, data from the Danube tributaries were excluded. Sites with a known, significant impairment (e.g. by organic pollution or hydromorphological alteration like weirs and water abstraction) have been excluded from the analysis.

Quantifying the classification strength of the Danube Section Types (Van Sickle analysis)

Analysis were conducted using MEANSIM6 software, available from the USEPA, Western Ecology Division Web Site (http://www.epa.gov/wed). For the analysis the Sørensen coefficient is used. This Sørensen similarity is the ratio between the number of taxa common at two sites and the average number of taxa per site that was found at the two sites; the measure can be interpreted as the proportion of the assemblages found at two sites that are shared by the sites. The similarity matrix of the result file must be converted in dissimilarity (as 1 - similarity).

The strength of each classification is valued by comparing within- and between-class similarities. In a strong classification, similarities between sites in the same class tend to be substantially greater than similarities among sites in different classes.

First the mean of all between-class similarities (B_{bar}) and the within-class mean similarity (W_i) for each class is calculated. If a classification is strong B_{bar} is low, and for each class, W_i is high.

The overall weighted mean (W_{bar}) of within-class similarities can be calculated as $W_{bar} = \sum_i (n_i / N) W_i$, where n_i is the number of sites in class i, and N is the total number in all classes (VAN SICKLE 1997, VAN SICKLE & HUGHES 2000). The overall strength of all classifications can be expressed by the extent to which W_{bar} exceeds B_{bar}. For example, classification strength can be measured by the unitless ratio $M = W_{bar}/B_{bar}$. Alternatively, one may use classification strength $CS = (W_{bar} - B_{bar})$, which preserves the original units of similarity. A permutation test was used to test the null hypothesis that the CS value was not different from what might be expected from randomly assigning sites to groups (SMITH et al. 1990, VAN SICKLE 1997). The statistic CS was recalculated for each of 10,000 randomly chosen reassignments of sites to groups of the same size as the tested classification (JACKSON & SOMERS 1989).

RESULTS

Non-metric Multidimensional Scaling

The ten section types of the top-down approach (ROBERT et al. 2003) were applied as overlays, as well as the ecoregions (ILLIES 1978). As shown in figure 1 the Danube biota confirm the validity of the ecoregion approach. The similarity of benthic invertebrate assemblages within ecoregions is higher than among ecoregions.

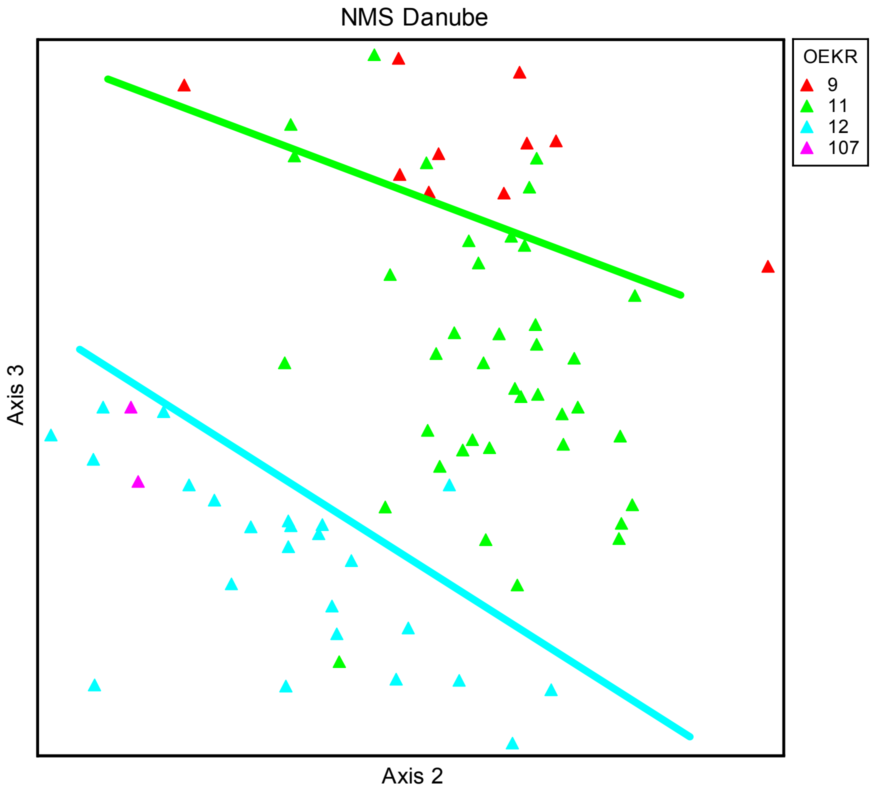

Figure 1: NMS scatterplot of JDS data. The overlay indicates the five ecoregions the Danube River is passing through (9 = Central Highlands, 11 = Hungarian Lowlands, 12 = Pontic Province, 10 = The Carpathians, 7 = Eastern Balkan) (ILLIES 1978)

Figure 2 presents a second scatterplot of the JDS data with the *a priori* (top-down) approach as overlay. Nine of the ten sections are plotted here and grouped into the three major reaches (Upper, Middle, Lower Danube). The first section type is missing due to the lacking of JDS data, whose monitoring sites start at Neu Ulm (the upstream border of section type 2).

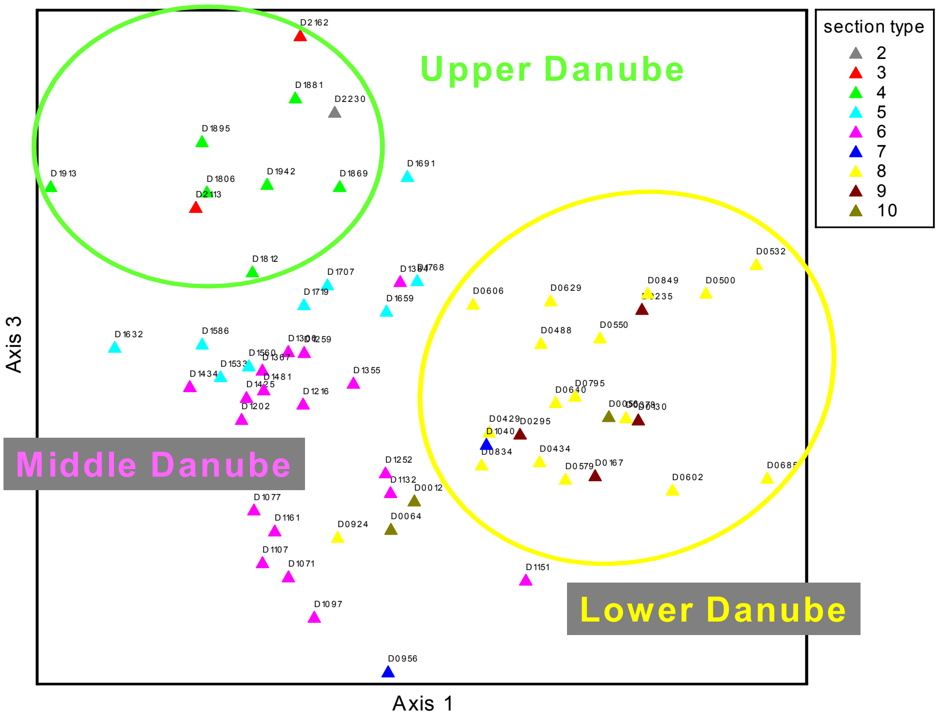

Figure 2: NMS scatterplot of JDS data for the Danube monitoring sites. The overlay indicates three major regions with the ten section types (2 = Western Alpine Foothills Danube, 3 = Eastern Alpine Foothills Danube, 4 = Lower Alpine Foothills Danube, 5 = Hungarian Danube Bend, 6 = Pannonian Plain Danube, 7 = Iron Gate Danube, 8 = Western Pontic Danube, 9 = Eastern Wallachian Danube, 10 = Danube Delta). Stress = 17.07.

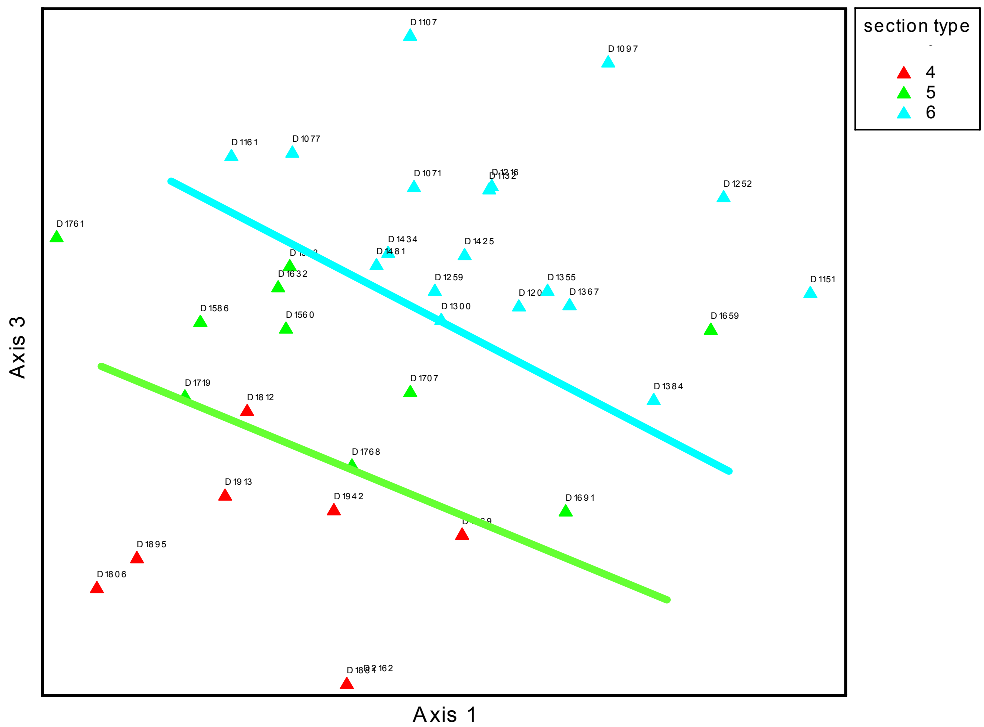

Figure 3: NMS Scatterplot of JDS data for the Danube monitoring sites. The overlay indicates three section types (4 = Lower Alpine Foothills Danube, 5 = Hungarian Danube Bend, 6 = Pannonian Plain Danube) according to the top-down typology. Stress = 18.82.

Figure 3 presents a separate analysis of the sections 4, 5 and 6. The other seven have been excluded in this plot for a much clearer separation of the remaining section types. This part of the river has intensely been discussed by the national and international consultants because of its complexity from the geomorphological (e.g. the breakthrough sections Vienna Gate, Devin Gate and Danube bend, the anabranching areas in the Vienna Basin, the large alluvial zone – “Zitny ostrov“ and “Szigetköz“ and the Hungarian plain as well as the variability of the slope values) and hydrological (e.g. the confluence of Morava, Drava, Tisa and Sava rivers) point of view. The result given in figure 3 shows a clear separation of the benthic communities in these section types and therefore provides a sound validation of the top-down classification.

Figure 4 shows the clear separation of the section types 3 and 4, whose boundary is the borderline between the ecoregion 9 (Central Highlands) and 11 (Hungarian Lowlands). The result reflects also a generally distinct differentiation between the benthic fauna in the landscape of the highlands (section 3) and the floodplains (section 4).

Summarising all results of the analyses which cannot be presented here in detail, it can clearly be stated that the top-down proposal (*a priori* approach) has generally been validated. The stream section typology of the Danube River developed within this project can be regarded as an important and sound product for further tasks of implementing the WFD.

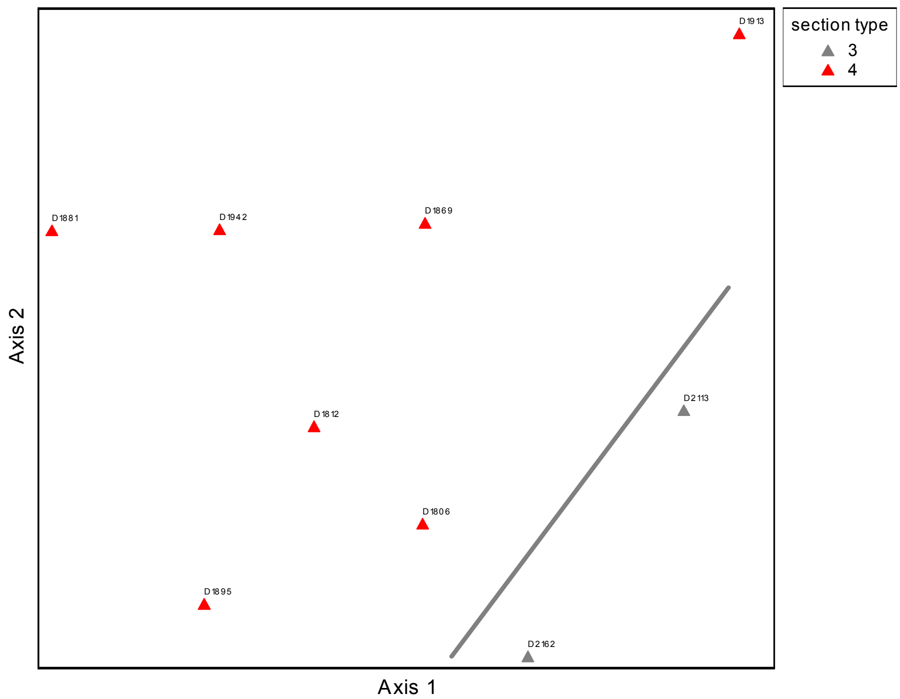

Figure 4: NMS scatterplot of JDS data for the Danube monitoring sites. The overlay indicates the section types (3 = Eastern Alpine Foothills Danube, 4 = Lower Alpine Foothills Danube) according to the top-down typology. Stress = 11.54.

Quantifying the classification strength of the Danube Section Types (Van Sickle analysis)

Two alternative current typological classifications of the Danube are compared by the use of mean similarity calculations: The nine geo-morphological Danube reaches according to the JDS report (VOGEL & PALL 2002) and the ten Danube section types proposed by the consultants of the UNDP/GEF Danube Regional Project (ROBERT et al. 2003).

Although the proposed top-down typology of the UNDP/GEF DRP comprises ten Danube River Sections for testing this typology benthic invertebrate data from only eight types were available for analysis: No data exist for the Danube section 1; due to hydropower use and ecological degradation of the according Danube reach no sufficient data were available for statistical analysis of the Danube section 2. The analyses have been carried out in two ways by considering the remaining eight main types without (DRP8) and with sub-types. By including the sub-divisions of the eight main sections into sub-section types biological data from a total of twelve reaches could be analysed (DRP12).

A similar procedure needed to be undergone within the „JDS-types“ analysis as there exist no data for JDS type 1, and not enough data for JDS type 3.

Table 1: Strength of three classifications for invertebrate communities from the Danube River (data source: JDS)

		Species P/A		
Classification	No. of classes	CS (W_{bar} - B_{bar})	M (W_{bar}/B_{bar})	W_{bar}
DRP8	8 (without subtypes)	0.114	0.778	0.517
DRP12	12 (with subtypes)	0.123	0.769	0.535
JDS-types	7	0.114	0.780	0.517

All classifications showed statistical evidence ($p<0.02$) of greater CS (W_{bar} - B_{bar}) than would be expected for randomly grouped sites (table 1). However, the observed CS values indicate a comparably slight degree of dissimilarity. DRP8 and JDS-types have the same CS values (0.114). DRP12 shows a slightly better classification (0.123). Table 1 also reports M values (W_{bar}/B_{bar}). Values of M that are only slightly less than 1.0 indicate a weak classification, and classification strength increases progressively as M decreases from 1.0 towards 0. The M-Value of the DRP12 classification is 0.769 and shows a slightly better partition than the M-Value of the Danube classification according to the JDS-types (0.780).

As the M values of this analysis are proportional high more background information can be gained by having a look at the W_i values in relation to B_{bar} (W_i- B_{bar}) in table 2.

Table 2: Comparison of „W_i- B_{bar}“ values of the three Danube typologies

DRP8	
Section	W_i- B_{bar}
3	0.203
4	0.140
5	0.145
6	0.130
7	0.042
8	0.073
9	0.114
10	0.088

DRP12	
Section/Subsec	W_i- B_{bar}
3	0.194
4/1	0.142
4/2	0.120
5/1	0.129
5/2	0.163
6/1	0.239
6/2	0.194
6/3	0.112
7	0.033
8	0.064
9	0.105
10	0.079

JDS-types	
Section	W_i- B_{bar}
2	0.153
4	0.1
5	0.2
6	0.073
7	0.069
8	0.097
9	0.006

Table 2 shows the values of classification of each section type. For a better understanding of table 2 it should be stated that „W_i- B_{bar}“-values greater than 0.2 define a very good classification with respect to higher within similarities compared to the between similarity values. Values at 0.1 define sufficient or good classification. Lower or negative values show a bad classification.

Averaging the „W_i- B_{bar}“-values of DRP8, DRP12 and JDS (0.116, 0.131, 0.109) confirms the result of table 1 by indicating the best classification strength of the DRP12 typology.

The „W_i- B_{bar}“-values of Danube Section Type 7 show only weak classifications (W_k-B_{bar}=0.042, 0.073, 0.088). This lower within similarity of the benthic invertebrate communities could be explained by the effects of the hydro-power stations in the Iron Gate section. The tailback of the barrages leads to a monotonous environment and thus to a fauna that does not represent a distinct Iron gate community. The other types show values between 0.114 and 0.203 which define a sufficient or good classification.

The subdivision of the section types 4, 5 and 6 according DRP12 also shows a sufficient or good classification with W_k-B_{bar}-Values between 0.112 and 0.239 (table 2). For JDS-types the sections 6 to 9 indicate weak classifications probably due to the impacts of the Iron Gate Section. Sections 2 to 5 show a sufficient classification with values between 0.1 and 0.2.

SUMMARY

Summarizing the results of the NMS ordination and the Van Sickle within-and-between similarity analysis the top-down division of the entire Danube into ten typological units according to the current proposal could be statistically confirmed by the according bottom-up procedure.

The international consultants recommend the use of the current UNDP/GEF DRP section typology of the Danube River as an important and sound typological tool for the further tasks of implementing the WFD (see ROBERT et al. 2003 and table 3).

Table 3: UNDP/GEF DRP Danube Section Types

# Danube Section	Danube Section Type	Stream kilometre
1	Upper Course of the Danube	2786 – 2581
2	Western Alpine Foothills Danube	2581 – 2225
3	Eastern Alpine Foothills Danube	2225 - 2001
4	Lower Alpine Foothills Danube	2001 - 1791/1790
5	Hungarian Danube Bend	1791/1790 – 1497
6	Pannonian Plain Danube	1497 – 1071
7	Iron Gate Danube	1071 – 931
8	Western Pontic Danube	931 – 378
9	Eastern Wallachian Danube	378-100
10	Danube Delta	100-0

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Definition of Reference Conditions for the Section Types of the Danube River

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WITH A CONTRIBUTION OF GERTRUD HAIDVOGL, SEVERIN HOHENSINNER, STEFAN SCHMUTZ & HERWIG WAIDBACHER

INTRODUCTION

Definition and description of type-specific reference conditions are the basis for biological river assessment according to the WFD. Due to the intense alteration of virtually all rivers the description of near-natural reference conditions is particularly difficult for large rivers (EHLERT et al. 2002, HERING et al. 2000). Here, long-lasting and exhaustive anthropogenic disturbance has taken place. For this reason historical data are best suited to provide information about morphological, hydrological and biological characteristics the Danube once featured before man exceeded substantial influence on the river.

In this chapter hydromorphological reference conditions for each of the ten section types are presented as short characteristics (RefCond-Passports) based on both historical data and expert opinion. In addition the reference fish fauna of the Austrian section of the Danube is described, and guidance is given on how to define reference communities based on historical data. These recommendations are intended to serve as guidelines for other Danube River Basin countries.

Short description of section types (RefCond-Passports)

To acquire data on historical reference conditions specifically designed questionnaires have been sent to the national consultants (see Annex 1). Within two different parts historical source references have been stated and various morphological, hydrological and habitat parameters have been described by the national consultants for each section type. Some parameters could not be confirmed by historical data, hence expert opinion of the consultants established a basis for description.

Based on information given in the returned questionnaires and additional sources such as catalogues of exhibitions of ancient river maps (GENERALDIREKTION DER STAATLICHEN ARCHIVE BAYERNS 1998, ZÖGNER 1993) the RefCond-Passports have been generated. Each passport comprises general data about the section type (borderlines, ecoregions, catchment area, section length), a historical illustration, descriptions of structural and habitat characteristics, sub-section types and important tributaries (where applicable).

Section type 1 — *UPPER COURSE OF THE DANUBE*

River km: 2786 - 2581

Borderlines: confluence of Brigach and Breg to Neu Ulm

Rationale for section type borders:

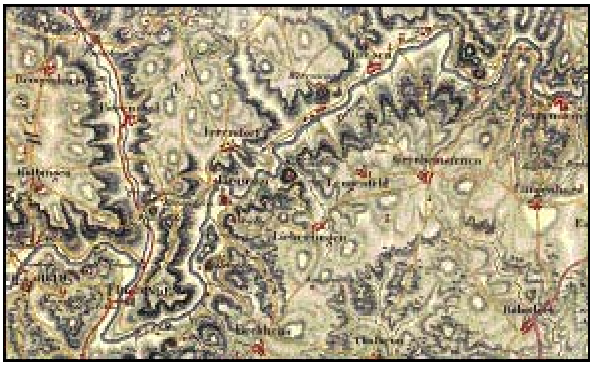
- upstream border: source of Danube River
- downstream border: confluence with river Iller

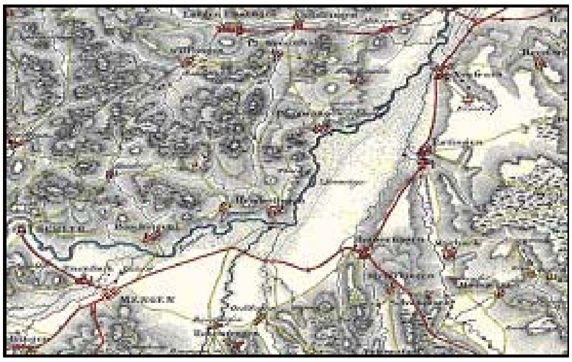
Country: Germany

Ecoregion: 9 (Central Highlands)

Catchment area:

8,100 km^2 (at Neu Ulm)





Illustrations: Map of Wirtemberg (1802) and Map of Schwaben (VON BOHNENBERGER et al. 1798-1828)

Morphological characteristics	This section type is part of the German stream type 9.1 (calcareous low mountain water course – catchment area 100 - 1000 km^2) and 9.2 (large watercourses – catchment area 1000 – 10000 km^2) (SOMMERHÄUSER & POTTGIESSER 2003a, 2003b, 2003c). Canyon reaches alternate with plain floodplain sections dominating at the right. Channel form is sinuous to meandering and braided. The slope varies between 0.75 ‰ and 1.38 ‰. The main channel substrates are composed of bedrock, head-sized boulders with a variable percentage of cobble, gravel and sand. In the floodplain section of more than 300 m width riffle and pool sections vary moderately. The bank structure is abort and sliding. Due to the karst landscape the highly dynamic discharge character is influenced by water infiltration at section Immendingen to Möhringen and sporadically until Fridingen (MNQ 3 m^3/s; MQ 7-8 m^3/s; MHQ approx. 20 m^3/s). In case of total infiltration the regeneration of the Danube River is made by the tributaries and springs. The hydrological regime shows high water level in February and March and low water level between August and September.
Habitat characteristics	The river shows a high percentage of eupotamon (AMOROS et

	al. 1982) with primarily lotic side arms on the right side of the floodplain section.
Tributaries	**right tributary:** Iller (km 2589) — average annual discharge: 68 m^3/s.
References	STAMMER (1954), SOMMERHÄUSER & POTTGIESSER (2003a, 2003b, 2003c).

Section type 2 *WESTERN ALPINE FOOTHILLS DANUBE*

River km: 2581 - 2225

Borderlines: Neu Ulm – Passau

Rationale for section type borders:

- upstream border: confluence with river Iller
- downstream border: before confluence with river Inn (mountainous region)

Country: Germany

Ecoregion: 9 (Central Highlands)

Catchment area:

8,100 km^2 (at Neu Ulm)

76,597 km^2 (at Passau)

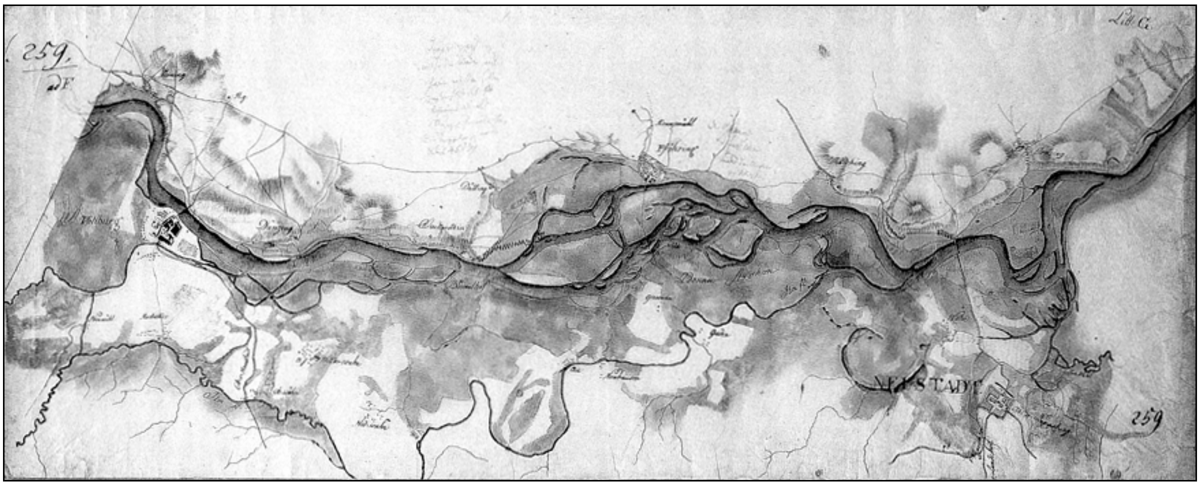


Illustration: Danube between Vohburg and Neustadt an der Donau (ca. 1807, GENERALDIREKTION DER STAATLICHEN ARCHIVE BAYERNS 1998)

Morphological characteristics	The Danube shows anabranching channel form of high intensity (more than 65 percent) interspersed with meandering morphology. Trough valley reaches alternate with meandering valley sections. A highly dynamic breadth erosion causes varying widths of the channels and shallow water depths. Gorge sections are Steppberg (km 2486 - 2478) and Weltenburger Enge (km 2422 - 2414). The channel substrates are dominated by cobbles, gravel or sand. Sporadically a mixture of sand and gravel is present. The slope varies between 1.1 ‰ at Ulm and 0.3 ‰ at Regensburg.
Habitat characteristics	The river shows a high percentage of eupotamon. The anabranching reaches are characterised by numerous side channels providing predominantly lotic habitats. Due to highly dynamic channel routing the in-channel islands are naturally unvegetated or covered by annuals. The floodplain vegetation consists of alluvial softwood and hardwood forests and wetlands (mires and swamps).

Tributaries	**right tributaries:** Lech (km 2497) – average annual discharge: 118 m^3/s; Isar (km 2282) – 176 m^3/s. **left tributaries:** Altmühl (km 2411) – 22 m^3/s; Naab (km 2386) – 49 m^3/s; Regen (km 2376) – 40 m^3/s.
Sub-section types	This section has been subdivided into two sub-section types between Neu Ulm (km 2581) and Regensburg (km 2376), and between Regensburg (km 2376) and Passau (km 2225). The rationales for this subdivision are the lithological and relief class border at Regensburg as well as the beginning of the Bavarian Forest and of the highlands landscape with erosive character.
References	GENERALDIREKTION DER STAATLICHEN ARCHIVE BAYERNS (1998)

Section type 3 *EASTERN ALPINE FOOTHILLS DANUBE*

River km: 2225 - 2001

Borderlines: Passau – Krems

Rationale for section type borders:

- upstream border: confluence with river Inn
- downstream border: end of the highlands; borderline of ecoregion 9 and 11

Country: Austria

Ecoregion: 9 (Central Highlands)

Catchment area:

76,597 km^2 (at Passau)

96,045 km^2 (at Krems)

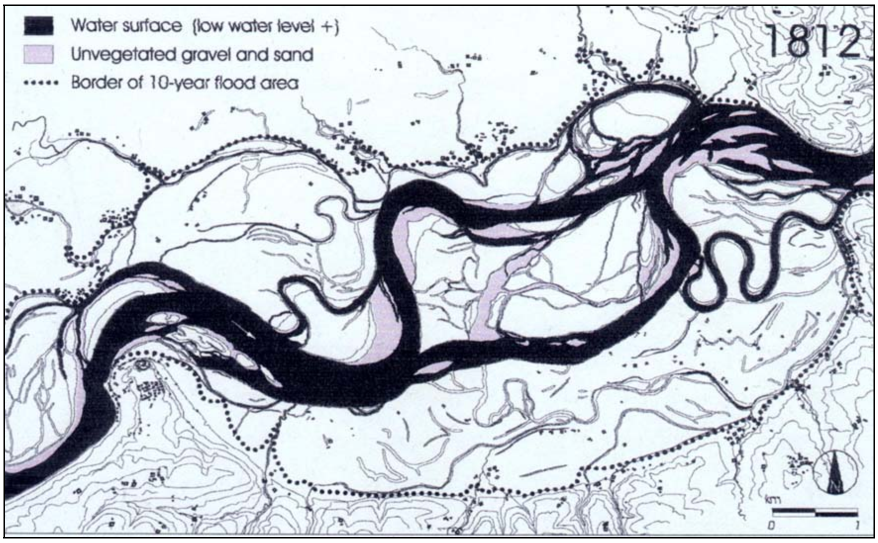


Illustration: Danube in the Machland Region in 1812 (HOHENSINNER et al. 2003)

Morphological characteristics	This section type is composed of two main parts: the breakthrough section "Oberes Donautal" (km 2225 - 2160) and the anabranching stretch "Austrian Machland region" (km 2094 - 2084). The breakthrough section is characterised by a steep, narrow incised meander valley that confines the lateral development of the river channel. Bedrocks interspersed with gravel are the dominant channel substrates. Four short river reaches with chutes formed by outcropping bedrocks (Kachlets) are present. Such reaches feature high flow velocities and complex flow patterns. Gravel areas which fall dry in times of extreme low water amount to 5 ha per km. Backwaters and some smaller floodplain forests only exist in the more spacious areas of the valley bottom. The backwaters are not a formative element in the breakthrough section. They

	are restricted to slip-off slopes, therefore their area amounts to 0.2 ha per river km. Small vegetated islands are also typical elements with a spread area of approx. 0.7 ha per river km. The average slope value for this section is 0.43 ‰. The channel system of the Machland stretch is branched by several islands and gravel bars. This reach can be designated as a gravel-dominated, laterally active anabranching section. The sinuosity of the main channel is 1.32, its mean width amounted to 550 m at low flow and 730 m at summer mean water, and mean depth could reach 3.8 m along the thalweg. Danube discharge is mainly influenced by alpine flow conditions and peaks in spring/summer due to the snowmelt in the Alps. Shallow-water zones with gentle bed gradients are a formative element. This enables a high diversity of depths, flow velocities and substrate conditions, resulting in a broad spectrum of micro- and meso-habitats with extensive shorelines.
Habitat characteristics	The gravel banks/islands and highly outcropping rocks in the breakthrough area offer a lotic environment almost throughout the whole reach. Most tributaries discharge into the Danube River at locations with large gravel bars and therefore provide valuable spawning habitats for rheophilic fish species. The backwaters offer interesting refuge habitats during floods and special lentic habitats for stagnophilic species. In the anabranching stretch the river-floodplain system is characterised by eupotamon water bodies (main channel and side arms) to a very high extend, offering a primarily lotic environment (97 percent of the overall water surface area at low flow). Para-, plesio- and palaeopotamon water bodies are less frequent in relation to eupotamon ones. They represent a great variety of distinct lentic habitats and contribute to the high extend of aquatic/terrestrial interfaces. The various floodplain elements are in constant modification and renewal due to the strong erosion/sedimentation processes.
Tributaries	**right tributaries:** Inn (km 2225) – average annual discharge: 760 m^3/s; Traun (km 2124) - 150 m^3/s; Enns (km 2112) – 230 m^3/s; Ybbs (km 2057) – 42 m^3/s.
References	HAIDVOGL et al. (2003)

Section type 4 — *LOWER ALPINE FOOTHILLS DANUBE*

River km: 2001 – 1791/1790

Borderlines: Krems – Gönyü/Kliska Nemá

Rationale for section type borders:

- upstream border: borderline of ecoregions 9 and 11
- downstream border: end of alluvial fan (Schütt/Ostrov)

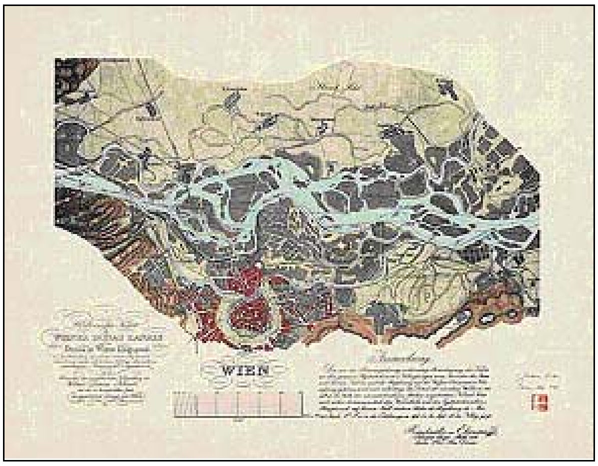
Countries: Austria/Slovakia/Hungary

Ecoregion: 11 (Hungarian Lowlands)

Catchment area:

96,045 km^2 (at Krems)

149,950 km^2 (at Gönyü)



Illustrations: (left) Danube at Vienna (1826); source: http://free.pages.at/j-orth/082vg01.jpg
(right) Schütt/Ostrov (ZÖGNER 1993)

Morphological characteristics

The section type represents the beginning of lowland reaches with meandering, anabranching and braided channels exceptive two small breakthrough valleys at the Vienna Gate (km 1949 - 1935) and Devin Gate (km 1880). Anabranching reaches are situated in the Vienna Basin and the Danube Lowland downstream Bratislava. Here, the Danube forms an inland delta with three main river branches of braided or anastomosing-meandering character: the Great Danube branch (middle), Malý (Little/Lesser) Danube (north, km 1869 - 1768), Mosoni Danube (south, up to Gönyü km 1791). These branches form a large accumulation zone composed by the Danubian islands: Large Danube Island "Zitný ostrov" (on the north side) and Little Danube Island "Szigetköz" (on the south side). Low current velocities and high groundwater levels generate a large wetland area. Some of the branches are only active during floods. The slope value decreases from 0.35 ‰ to 0.10 ‰ at Gönyü.

	The dominant main channel substrates are represented by large cobbles and gravel in the breakthrough sections, and medium to coarse gravel layered by sands and loam in the accumulation zone of the Danube Lowland. The gravel bed near Bratislava is characterised by rapid rates of lateral erosion and an extensive area of point bars and gravel bars. These bars are partially covered by incipient and older woodlands. The active floodplain varies between 10 km upstream and downstream Vienna to 6 km upstream Váh. The floodplain area of the inland delta (Schütt/Ostrov) amounts to more than 20,000 ha and is covered by one of the largest floodplain forests in central and south-eastern Europe. It represents the habitat of numerous macrophyte communities, humid willow-poplar forests, ash-elm stands and drier elm-oak formations.
Habitat characteristics	The breakthrough reaches show primarily lotic environments composed of gravel banks and islands. Backwater sections form lentic habitats during floods for stagnophilic species. In the anabranching reaches former braided segments that became disconnected from the main channel, and old meanders or similar forms resulting from another morphological type without direct connection to the main channel are frequent.
Tributaries	**left tributaries:** Kamp (km 1984) – average annual discharge: 13 m^3/s; March-Morava (km 1880) – 105 m^3/s. **right tributaries:** Raab-Rába (km 1794) – 80 m^3/s.
Sub-section types	This section has been subdivided into two sub-section types according to its complexity. The first sub-section type between Krems (km 2001) and Devin (km 1880) is composed of the two breakthrough sections: Vienna Gate and Devin Gate and their corresponding anabranching areas: The Tullner-field and the Vienna Basin. The second sub-section type is represented by the inland delta, between Devin (km 1880) and Gönyü/Kliska Nemá (km 1971/1970), the confluence of the Mosoni Danube into the Danube.
References	LÁSZLÓFFY (1965); PISUT (2002); national consultants' opinion; http://www.gabcikovo.gov.sk/doc/brown/chapters/ch2a.htm; http://www.gabcikovo.gov.sk/doc/brown/chapters/ch16a.htm

Section type 5 *HUNGARIAN DANUBE BEND*

River km: 1791/1790 - 1497

Borderlines: Gönyü/Kliska Nemá - Baja

Rationale for section type borders:

- upstream border: changing of slope characteristic
- downstream border: changing of substrate composition

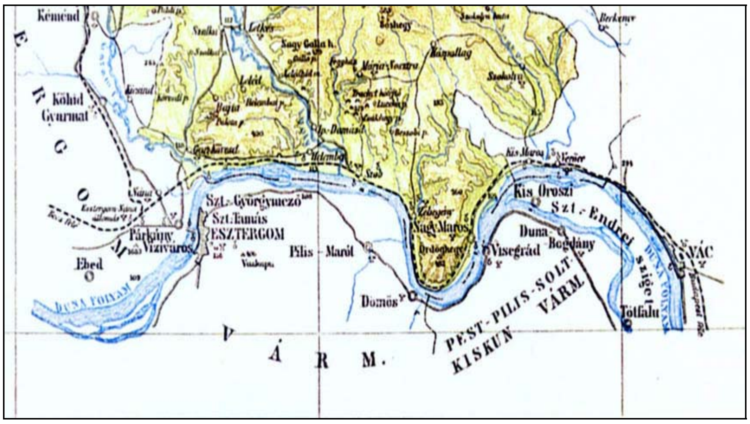
Countries: Slovakia/Hungary

Ecoregion: 11 (Hungarian Lowlands)

Catchment area:

149,950 km^2 (at Gönyü/Kliska Nemá)

207,430 km^2 (at Baja)



Illustrations: (left) Danube bend (1894);
(right) Danube in the Hungarian Plain (1897) (LAJOS et al. 1943)

Morphological characteristics	In this section the Danube passes breakthrough sections (the Danube bend) and lowland areas (Hungarian plain), and changes its watercourse from eastward to southward. In the lowland area the Danube flows in a plain floodplain valley and shows high anabranching (mainly cut-off loops) intensity (35 to 65 percent) or meandering (>1.26 sinuosity degree). The dominant main channel substrate consists of gravel in different sizes (from coarse gravel to fine and medium sized gravel), frequently interspersed with sand and hand sized cobbles, organic sludge, mud, silt and clay in small percentages. In the breakthrough section coarse blocks with variable percentages of cobble and sand are present. The average slope value varies between 0.10 ‰ at Gönyü

	and 0.17 ‰ to 0.07 ‰ in the Hungarian bend. The average width of the main channel amounts to 350 m; the mean depth is 4 to 5 m. The main channel shows moderate breadth erosion. This section is characterised by a mean current velocity of 0.5 m/s. After passing the breakthrough section (Danube bend) the Danube forms two important isles: Szentendre (km 1692 - 1657) and Csepel (km 1642 - 1586). The bank structure is variable with multiple sliding banks, isolated fallen trees, wood collections and spur banks. The floodplain is between 300 m (upstream Budapest) and 1500 m (downstream Budapest) wide. Lotic side arms and dead arms, cut off channels and oxbow lakes, temporary side arms and standing water bodies fed by the tributaries are present in the floodplain. The floodplain vegetation is represented by a dominant alluvial softwood forest. Isolated alluvial hardwood forests and mixed native forests are also present.
Habitat characteristics	The dominant aquatic habitat in this section is the eupotamon which has a mean width of 500 m. Less than 10 percent parapotamon, plesiopotamon and palaeopotamon types are present. The percent area of terrestrial habitats (e.g. banks, islands) makes up approx. 10 percent of the entire eupotamon. Biotic microhabitats are frequently formed by living parts of terrestrial plants and tree trunks, rarely accompanied by macrophytes, submerged plants, CPOM, FPOM and debris.
Tributaries	**left tributaries:** Váh (km 1766) – average annual discharge: 190 m^3/s; Hron (km 1716) – 50 m^3/s; Ipel (km 1708) – 25 m^3/s.
Sub-section types	This section has been subdivided into three sub-section types according to its geomorphological complexity. The first sub-section type between Gönyü/Kliska Nemá (km 1791/1790) and Esztergom (km 1719) is composed of an anabranching area, part of the Large Danube Island („Zitný ostrov“). The second sub-section type is represented by the Danube bend (breakthrough section) between Esztergom (km 1719) and Nagymaros/Visegrad (km 1695). In the third sub-section type between Nagymaros/Visegrad (km 1695) and Baja (km 1497) the Danube flows through the Hungarian plain representing an anabranching area.
References	national consultants' opinion (Slovakia and Hungary)

Section type 6 *PANNONIAN PLAIN DANUBE*

River km: 1497 - 1071

Borderlines: Baja - Bazias

Rationale for section type borders:

- upstream border: changes of substrate composition
- downstream border: beginning of breakthrough section "Kazan pass"

Countries: Hungary/Croatia/Serbia-Montenegro

Ecoregion: 11 (Hungarian Lowlands)

Catchment area:

207,430 km^2 (at Baja)

570,900 km^2 (at Bazias)

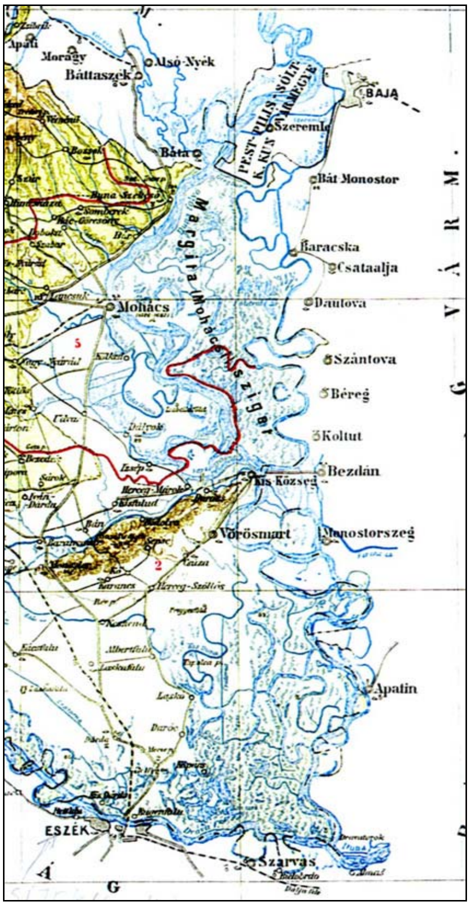


Illustration: Danube between Baja and Drava confluence (1893) (LAJOS et al. 1943, modified)

Morphological characteristics	The Danube in this section is passing through a floodplain landscape with areas of accumulation, having a meandering and plain floodplain valley with an anabranching channel (mainly cut-off loops) and meandering sections (degree of sinuosity: 1.06 – 1.25 and partially more than 2). A moderate breadth erosion is present in the main channel (average width: approx. 750 m, mean depth: 6 m). The main channel substrates are dominated by sand, and frequently fine to medium-sized gravel occurs. Mud, sludge, silt, loam, and

	clay are rare. The average slope value remains 0.04 ‰, varying between Baja and Drava from 0.07 ‰ to 0.05 ‰. Wood collection and fallen trees are frequently present on the river bank whose structure is partially sliding. The large floodplain (max. width: 30 km) is characterised by a diversity of water bodies close to the stream: lotic side arms and dead arms, cut off channels, oxbow lakes and standing water bodies fed by the tributaries. Alluvial hardwood and softwood forests are dominant. Mixed native forests represent the frequent vegetation types in the floodplain. The vegetation in few sections is sporadically composed by meadow, wetland (mire) and reeds. In the lower reach of this Danube-section (Croatia/Serbia-Montenegro) the largest tributaries with the highest runoff rate (Drava, Tisa and Sava) create an Alpine runoff character which substantially increases the catchment area. The average current velocity in this section is 0.4 m/s.
Habitat characteristics	The dominant aquatic habitat in this section is the eupotamon, frequently accompanied by para- and palaeopotamon. The percent area of terrestrial habitats (e.g. banks, islands) represents approx. 20 percent of the entire eupotamon. The biotic microhabitats are frequently represented by debris, CPOM, FPOM and sludge. Less than 30 percent submerged plants, filamentous algae, macrophytes, living parts of terrestrial plants as well as dead wood (tree trunks) are present.
Tributaries	**right tributaries:** Drava (km 1382) – average annual discharge: 622 m^3/s; Sava (km 1170) – 1800 m^3/s; Velika Morava (km 1103) – 206 m^3/s. **left tributaries:** Tisa (km 1214) – 920 m^3/s; Tamis-Timis (km 1154) – 104 m^3/s.
Sub-section types	This section has been subdivided into three sub-section types according to the discharges of the most important tributaries (Drava, Tisa and Sava) and the increase of the catchment area. The first sub-section type is located between Baja (km 1497) and Drava confluence (km 1379), the second sub-section type between the confluence of Drava river (km 1379) and the confluence of Sava (km 1170). The third sub-section type ranges from the confluence of the Sava river (km 1170) to Bazias (km 1071).
References	GAVRILOVIC & DUKIC (2002); SIKORA et al. (1988); Topographical Military-Maps (1974 and earlier); national consultants' opinion (Hungary, Croatia and Serbia-Montenegro).

Section type 7 *IRON GATE DANUBE*

River km: 1071 - 931

Borderlines: Bazias – Turnu Severin

Rationale for section type borders:

- upstream border: beginning of the breakthrough section “Kazan pass”
- downstream border: end of the breakthrough section “Kazan pass”

Countries: Serbia-Montenegro/Romania

Ecoregion: 10 (The Carpathians)

Catchment area:

570,900 km^2 (at Bazias)

578,300 km^2 (at Turnu Severin)

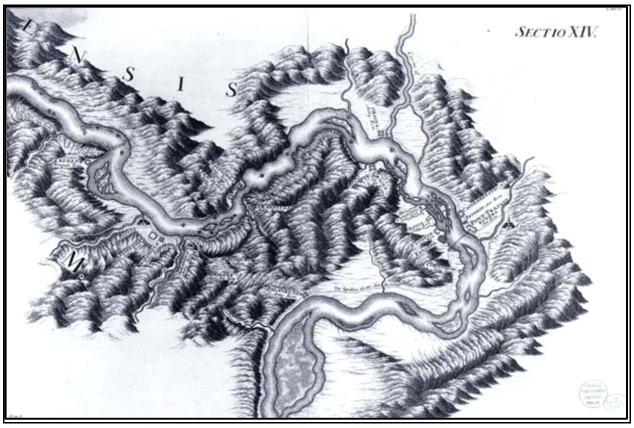


Illustration: Iron Gates **-** Donauwerk (1726) Luigi Fernando Marsigli (ZÖGNER 1993)

Morphological characteristics	Djerdap/Iron Gates canyon is composed of four canyons (necks) and three extensions. The braided channel is mostly rocky and shows areas with deposits of medium and small particles of alluvial materials (banks and islands). The main channel has an average width of about 750 m and runs in a canyon or trough valley form. Its mean depth amounts to approx. 5.5 m. Slope values range from 0.04 ‰ to 0.25 ‰. The dominant main channel substrates are represented by large cobbles, boulders and bedrocks (numerous rocks are situated directly under the water surface), and frequent coarse, medium and partial fine gravel interspersed with sand and mud in the slow-flowing parts. The river bank is isolated abort and sliding, and fallen trees and wood collections are frequently present. The breadth erosion is moderate. Spur banks are present. The section is characterised by high current velocity (1.8 to 4 m/s) and by longitudinal erosion. Shallow-water zones with gentle bed gradients are dominant.

	This enables a high diversity of depth, flow velocity and substrate condition. The flooded area is reduced to an average width of about 150 m. Temporarily flooded areas (mostly to the outflow of the Nera tributary) are present in the floodplain as well as deciduous native forest along with the hardwood alluvial forest and meadow.
Habitat characteristics	The potamon offers a primarily lotic environment. The percent area of terrestrial habitats represents only 10 percent of the entire eupotamon area. Living parts of terrestrial plants, FPOM and debris are rare.
References	ALMAZOV et al. (1963); IANOVICI et al. (1969); HYDRAULIC SERVICES OF THE HARBOR ADMINISTRATION (1934); STANESCU et al. (1967); THE INTERNATIONAL DANUBE COMMITTEE (1870); national consultants' opinion (Romania).

Section type 8 — *WESTERN PONTIC DANUBE*

River km: 931 - 378

Borderlines: Turnu Severin – Chiciu/Silistra

Rationale for section type borders:

- upstream border: south western border of ecoregion 12, slope-decrease to 0.04‰
- downstream border: beginning of wetland area

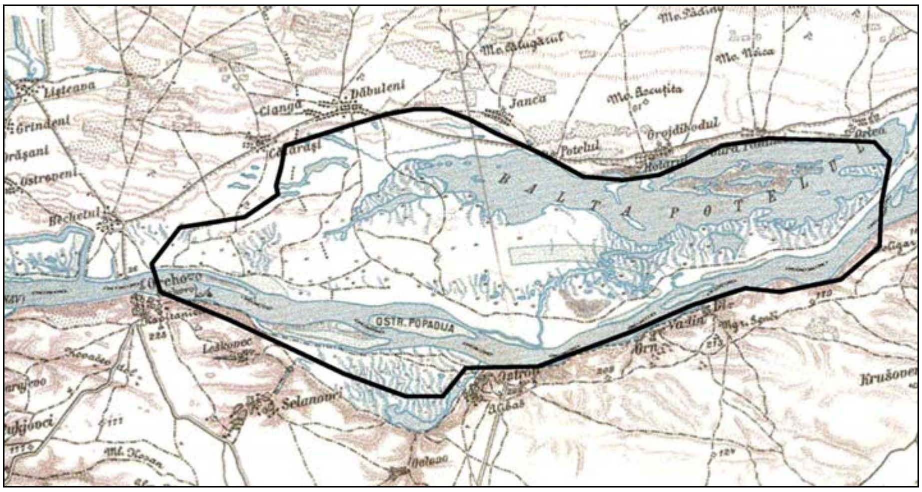
Countries: Romania/ Bulgaria

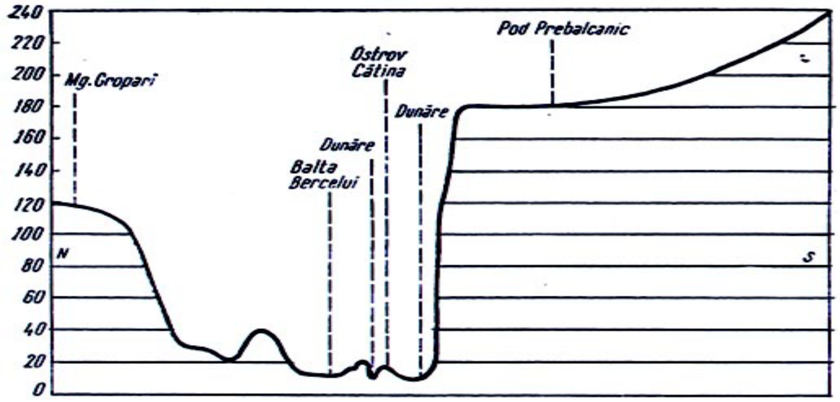
Ecoregion: 12 (Pontic Province)

Catchment area:

578,300 km^2 (at Turnu Severin)

698,600 km^2 (at Chiciu/Silistra)





Illustrations: Balta Potelu (GÜNTER-DIRINGER & WELLER 1999) and morphological profiles at the city of Turnu Magurele (BANU 1967)

Morphological characteristics	The Danube is passing a floodplain landscape with higher plains of terraced accumulation in a meander and plain floodplain valley. The right bank is high and steep, the left bank is low and terraced with wide floodplains. The channel is partially braided with bars and islands and partially anabranching (mainly cut-off loops). Meandering

	reaches are also present (degree of sinuosity 1.06-1.25). The main channel has moderate breadth erosion (average width of 830 m and mean depth of 8.5 m). Main channel substrates frequently vary from fine and medium gravel to sand accompanied by small percentages of coarse gravel and mud. The average slope values remains 0.04 ‰. Multiple wood collections and isolated fallen trees are present on the river banks. Their structure varies: abort and sliding banks are present as well as bank spurs and nest banks. This section is characterised by moderate values of current velocity (1.30 m/s). The average width of the floodplain is about 8000 m and the diversity of water bodies in this area close to the stream is large: lotic side arms connected to the main channel at both ends, cut off channels, oxbow lakes and standing water bodies fed by the tributaries. Deciduous native forest, wetland (mire) and open grass is the dominant vegetation in the floodplain, often accompanied by alluvial soft wood forest, meadow and reeds. Sporadically the vegetation is missing.
Habitat characteristics	Average width of the eupotamon is 1500 m. The percent area of terrestrial habitats represents 75 percent of the entire eupotamon. The biotic microhabitats are frequently represented by filamentous algae and macrophytes as well as CPOM and debris. In less than 30 percent living parts of terrestrial plants and FPOM are present.
Tributaries	**<u>right tributaries</u>:** Isker (km 636) – average annual discharge: 55 m^3/s; Jantra (km 536) – 40 m^3/s. **<u>left tributaries</u>:** Jiul (km 692) – 88 m^3/s; Olt (km 604) – 148 m^3/s; Arges (km 432) – 80 m^3/s.
References	BANU (1967); IANOVICI et al. (1969); STANESCU et al. (1967); national consultants' opinion (Romania).

Section type 9 *EASTERN WALLACHIAN DANUBE*

River km: 378 - 100

Borderlines: Chiciu/Silistra - Isaccea

Rationale for section type borders:

- upstream border: beginning of wetland area
- downstream border: beginning of the Danube Delta

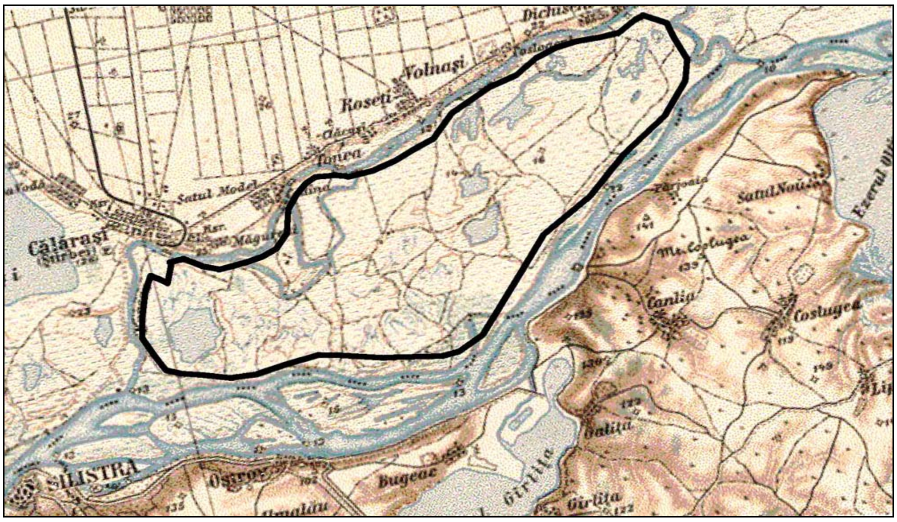
Countries: Romania/Moldova/Ukraine

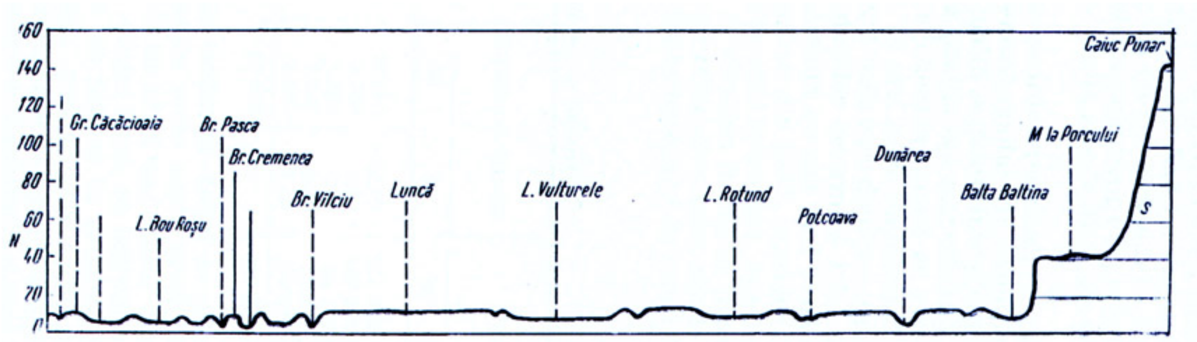
Ecoregion: 12 (Pontic Province)

Catchment area:

698,600 km^2 (at Chiciu/Silistra)

709,500 km^2 (at Isaccea)





Illustrations: Balta Calarasi (GÜNTHER-DIRINGER & WELLER 1999), Morphological profiles at Balta Braila (BANU 1967)

Morphological characteristics	The Danube changes its watercourse northward forming a wetland area with two large isles (374-248 km Balta Ialomita and 238-169 km Balta Braila) and many natural lakes. The valley form is a meander and plain floodplain valley with a braided channel (mostly long and narrow islands), composite anabranching channel and meandering sections (>1.26 of sinuosity degree).

	The main channel has an average width of 650 m, a mean depth of 10.5 m and shows moderate breadth erosion. The dominant channel substrate is sand, frequently interspersed with mud, organic sludge, silt, loam and clay. In small percentages gravel is present in fine to medium size. The bank structure is variable with multiple abort and nesting banks and bank spurs. Fallen trees and sliding banks are sporadically present. The floodplain has an average width of 5500 m. Lotic side arms and dead arms, cut off channels and oxbow lakes, temporary side arms and standing water bodies fed by the tributaries form the water bodies in the floodplain. The average slope value remains 0.04 ‰. The section is characterised by slow current velocity (0.8 m/s). More then 60 percent of the floodplain vegetation is represented by deciduous native forest, wetland (mire) and open grass frequently accompanied by alluvial softwood forest, meadows and reeds. Isolated mixed native forest and naturally unvegetated areas are present.
Habitat characteristics	Eupotamon is the dominant aquatic habitat type and shows an average width of 1000 m. The percent area of terrestrial habitats amounts to 60 percent of the entire eupotamon. Parapotamon, plesiopotamon and the palaeopotamon types are frequently present. The FPOM is the dominant biotic microhabitat in this section, frequently accompanied by macrophytes, living parts of terrestrial plants, CPOM and debris. Tree trunks, branches and roots are rarely present.
Tributaries	**<u>left tributaries</u>:** Ialomita (km 234) – average annual discharge 39 m^3/s; Siret (km 155) – 241 m^3/s; Prut (km 134) – 89 m^3/s.
References	ALMAZOV et al. (1963); BANU (1967); IANOVICI et al. (1969); THE INTERNATIONAL DANUBE COMMITTEE (1870); national consultants' opinion (Romania).

Section type 10 *DANUBE DELTA*

River km: 100 - 0

Borderlines: Isaccea - Sulina

Rationale for section type borders:

- upstream border: the beginning of the Delta, slope decrease to 0.001 ‰
- downstream border: mouth of the river into Black Sea

Countries: Romania/Ukraine

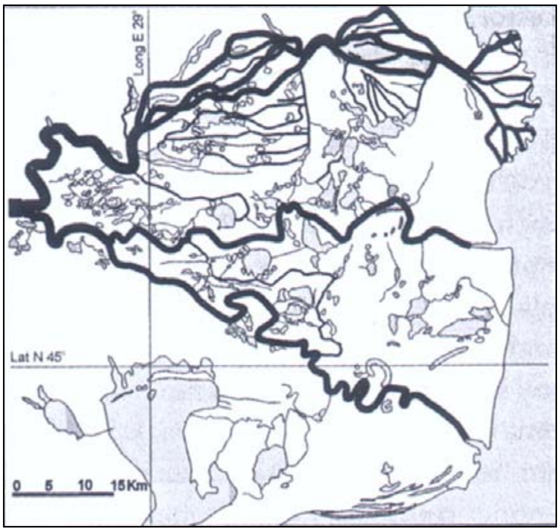
Ecoregion: 12 (Pontic Province)

Catchment area:

709,500 km^2 (at Isaccea)

807,000* km^2 at Sulina (*different figures given in the literature)

Illustration: Danube Delta about 1880 in BUIJSE et al. (2002)



Morphological characteristics	The Danube Delta is Danube's "youngest" territory having three main water channels: Kilia, Sulina and Sf. Gheorghe, and numerous canals and floating islands ("plauri"). Close to the estuary the three main branches are divided into numerous branches creating their own delta. At mean water levels 60 percent of this area is covered by waters (90 percent at high levels). The shape of the delta is triangular. A large variety of distinct lentic habitats is developed. The valley form is plain floodplain and the channel form is diverse due to the complexity of the delta: braided channel (braiding intensity 65 percent); split, sinuous and composite anabranching; meandering channel (degree of sinuosity >1.26). The average width of the main channels is 450 m at Kilia, 400 m at Sulina and 450 m at Sf. Gheorghe. The mean depth of the three branches amounts to 13 m. Slope values vary between 0.04 ‰ and 0.001 ‰. The dominant substrates are sand, mud, sludge, silt, loam and

	clay. Multiple wood collections are present on the river bank; fallen trees are sporadic. At several reaches the bank structure is abort. Lotic side arms and dead arms, cut off channels and oxbow lakes, temporary side arms and standing water bodies fed by the tributaries constitute water bodies in the floodplain. The average width of the floodplain is about 100 km. This section is characterised by a medium current velocity of 0.7 m/s (Kilia 0.7 m/s, Sulina 0.65 m/s, Sf. Gheorghe 0.68 m/s). Accumulations of sediment produce progression of the delta which is permanently shaped by maritime currents. The vegetation in this area is very complex, wetlands (mire) and reeds are dominant. Alluvial hardwood forest, deciduous native forest and open grass land are frequently present. Alluvial softwood forest, mixed native forest, meadow and naturally unvegetated areas are rare.
Habitat characteristics	The percent area of terrestrial habitats represents 40 percent of the entire eupotamon. Para-, plesio- and palaeopotamon show equal shares. Living parts of terrestrial plants, FPOM and debris as biotic microhabitats are rare.
References	ALMAZOV et al. (1963); IANOVICI et al. (1969); THE INTERNATIONAL DANUBE COMMITTEE (1870); SIKORA et al. (1988); national consultants' opinion (Romania).

Reference fish fauna of the Austrian Danube – a guideline-proposal for the definition of biological reference conditions based on historical data

The Austrian experience in describing the biological reference conditions by the use of historical data may serve as guidance for the countries in the Danube River Basin for applying, adapting or developing similar procedures.

The reference species composition of the Austrian Danube was compiled from historical publications on the fish fauna of the Austrian Danube. The procedure is described in this chapter. Data sources can be found in HAIDVOGL et al. (2003, Annex 2) which is also the foundation for this subchapter.

„Scientific“ descriptions of the fish fauna of European rivers have been published from the 18th century onwards. The earliest publications mostly deal with biological characteristics of the species. When compiling the data about the historical fish fauna of the Austrian Danube the inquiries for published data mainly concentrated on the 19th century because at that time the river could be considered as more or less natural or nature like. The main purpose of historical analyses for describing reference conditions is to gain information about the composition/distribution and abundance before major anthropogenic impacts took place (canalisation and constructions for flood protection and navigation, hydropower plants etc.). It is recommended to start historical analyses by identifying and dating these impacts for the concerned sections because of the sometimes poor quality of historical data from the 19th century which improved throughout the 20th century.

Reports dealing with the fish fauna derive from this period of time, too. However, these papers or notes must be reviewed carefully because they are sometimes written by laymen. Besides published reports material about commercial fishery registered in archives can provide important information about species occurring at a particular site or catch of certain species. Though it depends on the organisation of commercial fishery if the output was registered and traded.

Concerning abundance historical sources at the utmost allow a verbal classification of main and well-known species. Even if data from commercial fishery are available they can only indicate dominant and very frequent species but they do not exactly reflect the ecological situation. As a consequence the historical analyses of the Austrian Danube fish fauna were combined with more recent surveys and expert judgement to get the complete species composition and abundance classes. The basis for the classification of abundance in breakthrough and anabranching sections was the description of the natural morphological conditions of the Austrian Danube.

The historical Austrian Danube fish fauna is presented in table 1:

Table 1: Fish fauna of the Austrian Danube – Reference status of occurrence and abundance classes

xxxx = dominant; very large, self-sustaining populations in the Danube;
xxx = frequent; self-sustaining populations;
xx = rare;
x = very rare; only few specimen which occur only sporadically

	Occurrence	**Abundance Classes**	
	Austrian Danube section	*breakthrough sections*	*anabranching sections*
Acipenseridae:			
Sterlet, *Acipenser ruthenus*	✓	xx	xx
Ship sturgeon, *Acipenser nudiventris*	✓	x	x
Stellate sturgeon, *Acipenser stellatus*	✓	x	x
Russian sturgeon, *Acipenser gueldenstaedti*	✓	x	x
Great sturgeon, *Huso huso*	✓	x	x
Salmonidae:			
Danube salmon, *Hucho hucho*	✓	xxx	xxx
Brown trout, *Salmo trutta*	✓	xx	xx
Thymallidae:			
European grayling, *Thymallus thymallus*	✓	xx	xx
Esocidae:			
Nothern pike, *Esox lucius*	✓	xx	xxx
Coregonidae:			
Coregonen	✓	x	x
Umbridae:			
European mudminnow, *Umbra krameri*	✓		xx*
Cyprinidae:			
Zope or Blue bream, *Abramis ballerus*	✓	x	xx
White bream, *Abramis björkna*	✓	xx	xxxx
Common bream, *Abramis brama*	✓	xx	xxx
Zobel or Danubian bream, *Abramis sapa*	✓	x	xxx
Bleak, *Alburnus alburnus*	✓	xxxx	xxxx
Spirlin, *Alburnoides bipunctatus*	✓	x	x
Asp, *Aspius aspius*	✓	xx	xx
Barbel, *Barbus barbus*	✓	xxxx	xxxx
Balkanian barbel, *Barbus peloponnesius*	✓	x	x
Prussian carp, *Carassius auratus gibelio*	✓	x	x
Crucian carp, *Carassius carassius*	✓	x	xx
Nase, *Chondrostoma nasus*	✓	xxxx	xxxx
Common carp, *Cyprinus carpio*	✓	x	xx
Whitefin gudgeon, *Gobio albipinnatus*	✓	xxx	xxx
Gudgeon, *Gobio gobio*	✓	x	x
Kessler`s gudgeon, *Gobio kessleri*	✓	xx	xx
Danube gudgeon, *Gobio uranoscopus*	✓	xx	xx
Belica, *Leucaspius delineatus*	✓		xx
European chub, *Leuciscus cephalus*	✓	xxx	xxx
Ide, *Leuciscus idus*	✓	xx	xxx
Eurasian dace, *Leuciscus leuciscus*	✓	xxx	xxx
Soufie, vairone; *Leuciscus souffia agassiz*	✓	x	x
Chekhon, *Pelecus cultratus*	✓	x	x
Eurasian minnow, *Phoxinus phoxinus*	✓	xx	xx
Bitterling, *Rhodeus amarus*	✓	x	xx
Rutilus frisii meidingeri	✓	x	x
Danube roach *Rutilus pigus virgo*	✓	xx	xxx
Roach, *Rutilus rutilus*	✓	xxx	xxxx
Rudd, *Scardinius erythrophthalmus*	✓	x	xxx
Tench, *Tinca tinca*	✓	x	xxx
Vimba, *Vimba vimba*	✓	xx	xxx

	Occurrence	Abundance Classes	
	Austrian Danube section	*breakthrough sections*	*anabranching sections*
Balitoridae			
Stone loach, *Barbatula barbatula*	✓	xx	xx
Cobitidae:			
Spined loach, *Cobitis taenia*	✓	xx	xx
Wheaterfish, *Misgurnus fossilis*	✓	x	xx
Siluridae:			
Wels, *Siluris glanis*	✓	xx	xxx
Gadidae:			
Burbot, *Lota lota*	✓	xxx	xxx
Percidae:			
Balon's ruffe, *Gymnocephalus baloni*	✓	xx	xx
Ruffe, *Gymnocephalus cernuus*	✓	x	x
Schraetzer/Striped ruffe, *Gymnocephalus schraetser*	✓	xxx	xxx
Eurasian perch, *Perca fluviatilis*	✓	xxx	xxxx
Pikeperch, Zander, *Sander luciopera*	✓	xx	xxx
Volga pikeperch, *Sander volgensis*	✓	x	xx
Danube streber, *Zingel streber*	✓	xxx	xx
Zingel, *Zingel zingel*	✓	xxx	xxxx
Cottidae:			
Bullhead, *Cottus gobio*	✓	xxx	xxx
Petromyzonidae:			
Eudontomyzon mariae	✓	x	x
	57 Species		

* Westward distribution only up to the Vienna basin / Wiener Becken

A systematic summary with types of historical data and proceeding of analyses is presented below to simplify the search of information and definition of biological references. This is composed of five types of data: Recent publications; Historical publications by biologists; Historical publications by ichthyological laymen; Records in archives' and museums' material.

Type 1: Search for recent publications on the history of the biology, geography etc. of the relevant rivers, regions or cities

Before historical material is collected and analysed it should be examined if recent historical studies have already been accomplished and published. Besides ecological and biological publications the ones on geography and the history of specific regions and cities should be considered, too.

Type 2: Publications about Danube fish species and fish assemblages by biological / ichthyological experts (examples from Austria: Heckel, Heckel & Kner, Siebold, Fitzinger, Lori etc.; see list of references in HAIDVOGL et al. 2003):

Period covered:

- From the late 18th century onwards; earlier documents could be available (like e.g. MARSIGLI 1726), mainly from the 19th and early 20th century

Extend of possible information:

- Presence and absence of fish species; sometimes information about occurrence in particular stretches or sites available; verbal classification of abundance of certain species.

Quality of data:

- Information given in these publications is usually quite reliable. However data are not based on systematic surveys. Therefore information about occurring fish species and especially on distribution is likely to be incomplete.

Problems encountered during analyses:

- Fish species lists could be incomplete due to taxonomic reasons (some species might have been described only after anthropogenic impacts; e.g. some *Gobio sp*. in the Austrian Danube section). In many cases these species could be added by using more recent information.
- The taxonomic classification of some species was changed in the past. During the analyses the correct species has to be identified.
- Sometimes only "common" and/or local names for species are given. These species must also be identified during the analyses. When common names are used one also faces the problem that similar names could refer to different species in different regions (like the term Weißfisch/whitefish in the Austrian Danube).

How to find the data:

- This type of data is usually easy to find in national and scientific libraries (universities, museums). Some publications were not published as monographs - therefore systematic inquiries in relevant journals must be carried out.

Estimated efforts *(given for one person):* 2-3 weeks inquiry of relevant publications, 4-8 weeks for analyses.

Type 3: Reports published by ichthyological "laymen" in geographical and/or natural history publications (examples from the Austrian Danube: KUKULA 1874, LORI 1871, KRISCH 1900)

This type of data could be used in addition to publications by experts. Usually the material is detected anyway when searching for publications in libraries.

Period covered:

- from the 18th century onwards; also several publications from the 16th century.

Extend of possible information:

- Absence and presence of fish species, information on distribution and abundance (classes).

Quality of data:

- Must be checked more carefully than sources of the type mentioned above (authors usually not educated in biology).

Problems encountered during analyses:

- In principle the same as mentioned under type 2, experiences from Austrian rivers showed that in most cases common/regional names for fish species are the biggest problem (sometimes information cannot be used at all due to that reason).

How to find these data: see above (type 2).

Type 4: Records on commercial fishery in historical archives

Period covered:

- from the late Middle Ages onwards; but rather 16th century and later

Extend of possible information:

- Presence of species at a certain site; most dominant species in certain regions; quantitative information about amount of fish caught in a known period; however, no information about the actual fish-stocks available; possibly information of occurrence of species in specific habitat-types.

Quality of data:

- Data are usually quite reliable. However, it has to be taken into account that quantitative information does not necessarily reflect the ecological situation; it also shows the preferences for certain species.

Problems encountered during analyses:

- Only fish species which were of commercial interest are reported (however, more species were caught than nowadays; in the Austrian Danube e.g. cyprinids like nase, barbel, dace, bream or other small species like bullhead).

How to find the data:

- First of all relevant archives must be found (defined) as there are monasteries or castles which had fishing rights on the Danube or associations of commercial fishermen on the Danube.
- The next step is to verify if archive material (still) exists at all. When searching for data for the Austrian Danube valuable records from commercial fishery were detected in the big monastery Herzogenburg (at the mouth of the river Traisen). On the other hand an important monastery like Klosterneuburg in the vicinity of Vienna supplied its need for fish at the Viennese Fishery market. The monastery leased its fishing rights to commercial fishermen and hence no data were traded in the monastery archive.
- In a further step one has to find out whether the archive material is still stored in the relevant monastery/castle or if it has been incorporated into a national archive.
- One final point is that in most cases the material could only be read and analysed by people who are familiar with old handwritings.

Estimated efforts: Although hard to estimate the method described is quite time-consuming and the efforts depend on several factors especially how well the archive materials are sorted and registered.

Besides material about commercial fishery it is also recommended to analyse accounts of fish purchase, fish delivered to monasteries by fishermen or records of delivery to fish markets. For the period covered, quality of data etc. the same has to be said as for the sources described above. However, if accounts of fish-purchase or reports about fish delivered by fishermen are used one has to verify the provenience of fish. When fish market deliveries are analysed the origin of the fish must be identified. Usually especially fish markets of larger cities were provided with fish from larger areas. The Viennese market for instance was supplied with fish from Lower and Upper Austria, from Bohemia and Hungary from as far back as the 16th century.

Type 5: Specimen of fish in museum collections

Finally, museum collections can provide valuable information about the occurrence of a species on a specific site.

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Proposal of the reference communities of macroinvertebrates of the Danube River

MARIO SOMMERHÄUSER, SABINA ROBERT & SEBASTIAN BIRK

The macroinvertebrate reference communities for the individual section types have mainly been compiled from data on existing "reference" sites and from literature sources. Results of the Joint Danube Survey (JDS, LITERÁTHY 2002) have been used, not regarding data on impounded sections. In this survey more than 100 sampling sites have been investigated. As additional historical information the huge taxa list for the whole Danube compiled by DUDICH (1967) has been used which goes back beyond 1920. Many of the major hydromorphological alterations (dams, hydropower plants etc.) have been established later than DUDICH's review.

The information given in this chapter provides a first overview of macroinvertebrate reference data.

The JDS data have been analysed by checking the presence/absence and abundances of species to identify these taxa which are mainly occurring in certain sections.

Four groups of species have been distinguished:

- section type-specific species, occurring predominantly in a certain section type, e. g. the Danube Delta (example: the Venus mussel *Chamelea gallina*)
- reach specific species, occurring predominantly in a certain region, e. g. Upper Danube River (example: the snail *Ancylus fluviatilis*)
- Danube-specific species, predominantly restricted to the Danube (e. g. pontic fauna elements like the snail *Theodoxus danubialis*)
- large river-specific species, occurring predominantly in large rivers, e. g. river Rhine (example: the caddisfly *Hydropsyche contubernalis*).

To get a first impression of the macroinvertebrate fauna of a certain section type not only the 'section type-specific species' should be considered. Additionally, the taxa of the 'reach specific species', the 'Danube specific species', and the 'large river specific species' may occur.

No reference communities have been defined for the sub-sections. For the reference community of section type 1 **(Upper Course of the Danube)** refer to POTTGIESSER & SOMMERHÄUSER (2004).

The results of the analysis are presented in table 1.

Table 1: Current status of a preliminary list of macroinvertebrate "reference species" for the section types and reaches of the Danube river (in process). Species selected from data of the Joint Danube Survey (2001) and literature (DUDICH 1967, KUSEL-FETZMANN et al. 1998, RUSSEV et al. 1998). Large river type-specific species after SCHÖLL & HAYBACH (2001).

	Section type 2	Section type 3	Section type 4	Section type 5	Section type 6	Section type 7	Section type 8	Section type 9	Section type 10
river km (from – to)	2581 - 2225	2225 - 2001	2001 - 1791/1790	1791/1790 - 1497	1497 - 1071	1071 - 931	931 - 378	378 - 100	100 - 0
name of section	**Western Alpine Foothills Danube**	**Eastern Alpine Foothills Danube**	**Lower Alpine Foothills Danube**	**Hungarian Danube Bend**	**Pannonian Plain Danube**	**Iron Gate Danube**	**Western Pontic Danube**	**Eastern Wallachian Danube**	**Danube Delta**
number of taxa (JDS)	**116**	**72**	**91**	**40**	**87**	**29**	**84**	**26**	**52**
section type-specific species	*Gammarus fossarum* *Gammarus pulex* *Gammarus roeseli* *Baetis alpinus* *Baetis fuscatus* *Heptagenia sulphurea* *Potamanthus luteus* *Dinocras cephalotes* *Leuctra fusca* *Elmis maugetii* *Elmis rietscheli* *Hydropsyche contubernalis* *Hydropsyche exocellata* *Hydropsyche pellucidula-Gr.* *Rhyacophila dorsalis* *Tinodes pallidulus*	*Ephoron virgo* *Heptagenia coerulans* *Brachyptera trisfasciata* *Isogenus nubecula* *Xantoperla apicalis* *Ceraclea dissimilis* *C. annulicornis* *Hydropsyche contubernalis* *Oecetis notata* *Psychomyia pusilla*	*Erpobdella nigricollis* *Ecdyonurus aurantiacus* *Ephoron virgo* *Heptagenia flava* *Isogenus nubecula* *Brachyptera trisfasciata* *Xantoperla apicalis* *Agapetus laniger* *Ceraclea annulicornis* *C. dissimilis* *Hydropsyche bulgaromanorum* *Hydropsyche contubernalis* *Psychomyia pusilla*	*Ephoron virgo* *Heptagenia flava*	*Paludicella articulata*		*Isochaetides michaelseni* *Propappus volki* *Lithoglyphus naticoides* *Dreissena polymorpha* *Corophium curvispinum* *Pontogammarus obesus* *Pontogammarus sarsi* *Jaera sarsi* *Dikerogammarus haemobaphes* *Hydropsyche bulgaromanorum*	*Mytilus galloprovincialis* *Ostrea sublamellosa* *Pseudoanodonta complanata*	*Angulus exiguus* *Anodonta cygnea* *Chamelea gallina* *Mytilus galloprovincialis* *Ostrea sublamellosa* *Unio pictorum* *Gyraulus laevis* *Corophium volutator* *Hemimysis anomala* *Caenis horaria*

Table 1 (continued)

	Section type 2	Section type 3	Section type 4	Section type 5	Section type 6	Section type 7	Section type 8	Section type 9	Section type 10
river km (from – to)	2581 - 2225	2225 - 2001	2001 - 1791/1790	1791/1790 - 1497	1497 - 1071	1071 - 931	931 - 378	378 - 100	100 - 0
name of section	**Western Alpine Foothills Danube**	**Eastern Alpine Foothills Danube**	**Lower Alpine Foothills Danube**	**Hungarian Danube Bend**	**Pannonian Plain Danube**	**Iron Gate Danube**	**Western Pontic Danube**	**Eastern Wallachian Danube**	**Danube Delta**
	Upper Danube reach			**Middle Danube reach**			**Lower Danube reach**		
reach specific species	*Ancylus fluviatilis* *Baetis rhodani* *Ephemera danica* *Heptagenia sulphurea* *Calopteryx splendens* *Brachycentrus subnubilus* *Ceraclea dissimilis* *Hydropsyche pellucidula*	*Psychomyia pusilla* *Tinodes waeneri*		*Branchiura sowerbyi* *Stylaria lacustris* *Cordylophora caspia* *Esperiana esperi* *Lymnaea stagnalis* *Stagnicola palustris* *Theodoxus danubialis* *Theodoxus fluviatilis* *Limnomysis benedemi*	*Ephemera danica* *Calopteryx splendens* *Gomphus flavipes* *Ischnura elegans* *Brachycentrus subnubilus*		*Cordylophora caspia* *Dugesia tigrina* *Branchiura sowerbyi* *Stylaria lacustris* *Esperiana esperi* *Ferrissia wautieri* *Hydrobia ventrosa* *Lymnaea stagnalis* *Stagnicola palustris* *Theodoxus danubialis*	*Theodoxus fluviatilis* *Cardium edule* *Unio pictorum* *Limnomysis benedeni* *Caenis horaria* *Caenis robusta* *Gomphus flavipes* *Ischnura elegans*	
danube - specific species	*Cordylophora caspia, Microcolpia daudebartii, Lithoglyphus naticoides, Theodoxus danubialis, Theodoxus transversalis, Viviparus acerosus, Dreissena polymorpha, Corophium curvispinum, Dikerogammarus haemobaphes, Dikerogammarus villosus, Echinogammarus ischnus, Obesogammarus obesus, Jaera istri*								
large River-specific species	*Dina lineata, Dina punctata, Erpobdella nigricollis, Pisidium supinum, Sphaerium rivicola, Heptagenia flava, Gomphus flavipes, Gomphus vulgatissimus, Brychius elevatus, Limnius spec., Orectochilus villosus, Brachycentrus subnubilus, Ceraclea annulicornis, Ceraclea dissimilis, Hydropsyche bulgaromanorum, Hydroptila sparsa, Psychomyia pusilla*								

Section type 2 **(Western Alpine Foothills Danube).** The macroinvertebrate fauna of this section type is characterised by lithophilous species adapted to higher stream flow velocities. The macroinvertebrate community can be regarded as 'alpine-influenced'. Typical species are the Amphipods *Gammarus fossarum, Gammarus pulex, Gammarus roeseli*, the mayflies *Potamanthus luteus, Heptagenia sulphurea, Baetis alpinus* and *Baetis fuscatus*, the stoneflies *Dinocras cephalotes,* and *Leuctra fusca*, the beetles *Elmis maugetii* and *E. rietscheli*, and the caddisflies *Rhyacophila dorsalis, R. nubila, Hydropsyche pellucidula* and *Tinodes pallidulus*.

Section type 3 **(Eastern Alpine Foothills Danube)**. Also this section type is mainly influenced by prealpine features, typical species are mainly lithophilous species e. g. the mayfly *Heptagenia coerulans* which are supplemented by other species of larger rivers like the mayfly *Epheron virgo* and a Danube-specific element, the flatworm *Dendrocoelum romanodanubiale*.

Section type 4 **(Lower Alpine Foothills Danube)**. In this section type the morphological features change to a lowland situation. Beside the caddisfly *Psychomyia pusilla* several taxa which are not restricted to this section but live in all three sections of the upper Danube can be found, e. g. the sand-living mayfly *Ephemera danica*, the dragonfly *Calopteryx splendens* and some caddisfly species which are specific for larger rivers in general e. g. *Brachycentrus subnubilus*, *Ceraclea dissimilis* and *Tinodes waeneri*.

The Section types 5 – 7 are difficult to differentiate in terms of macroinvertebrate community. Specific for all three sections are taxa which inhabit finer substrate types (sand, mud) and macrophytes, e. g. the aquatic earthworms (Oligochaeta) *Stylaria lacustris* and *Branchiura sowerbyi*, the snails *Esperiana (Fagotia) esperi*, *Stagnicola palustris*, *Lymnaea stagnalis, Theodoxus danubialis* and *T. fluviatilis*, the dragonflies *Gomphus flavipes* and *Calopteryx splendens* and *Ischnura elegans*. The shrimp *Limnomysis benedemi* is an important brackish element which intruded into this area from the Black Sea via the Danube Delta.

Section type-specific for section type 5 **(Hungarian Danube Bend)** with its naturally constrained channel form and gravelly or sandy substrates are the mayfly *Heptagenia flava* and the shrimp *Dikerogammarus villosus*. In section type 6 **(Pannonian Plain Danube)** with its finer substrates (sand, loam and clay) and macrophytes e. g. the Hydrozoan *Hydra spec*. and *Paludicella articula*, a river-specific Bryozoan, are to be found. In section type 7 **(Iron Gate Danube)** with coarse blocks and gravels in the breakthrough itself most lowland and large species rivers which are usually to be found upstream and downstream of this section are lacking (most leeches, snails, shrimps, dragonflies). There are no specific taxa which are restricted to this section type.

With section type 8 **(Western Pontic Danube)** the Danube flows through the Romanian plain. This section is completely located in ecoregion 12 (Pontic Province). Only a few species are characteristic for this section, additionally a lot of species which are characteristic for the lower reach of the Danube in general are to be found, e.g. the flatworm *Dugesia tigrina*, the mussel *Unio pictorum*, the mayflies *Caenis robusta* and *C. horaria* and the snails *Theodoxus danubialis* and *Ferrissia wautieri*. With *Cardium edule, Cordylophora caspia* and *Hydrobia ventrosa* mussels from the Black Sea are intruding into these sections types.

In section type 9 **(Eastern Wallachian Danube)** the river is divided into several channels forming extended wetland areas, the dominant substrates are sand or finer substrates. Additional species for this section are the mussels *Pseudanodonta complanata, Mytilus galloprovincalis* and *Ostrea sublamellosa* which are also to be found in section type 10.

Section type 10 **(Danube Delta)** represents the Danube Delta where the Danube is divided into 3 major arms, the dominant substrates are of a very fine grain size (clay, loam). The share of brackish species invading from the Black Sea increases, beside the species mentioned above there are several species which seem to be restricted to this section type like the mussels *Chamelea gallina, Donax trunculus*, and *Angulus exiguus*, and the shrimps *Hemismysis anomala* and *Corophium volutator*. Typical insect species are the dragonflies *Gomphus flavipes* and *Ischnura elegans* and mayflies *Caenis horaria* and *C. robusta*. *C. robusta* is tolerant against higher salinity and is to be found in Delta areas in general (e. g. the Delta of the Odra at the Baltic Sea).

Danube-specific taxa: Beside the species mentioned above which are more or less specific for certain section types or certain reaches of the Danube (Upper-, Middle-, Lower Danube) there are several macroinvertebrate species which are to looked at as “Danube-specific”. They have their main distribution area within the Danube river (some of them are restricted to the Danube) e.g. the snails *Fagotia acicularis*, *Lithoglyphus naticoides*, *Theodoxus danubialis*, the isopod *Jaera istri*, and the shrimps *Corophium curvispinum*, *Dikerogammarus haemobaphes* and *Echinogammarus ischnus*.

According to SCHÖLL & HAYBACH (2001) several macroinvertebrates (most of them widespread and common in the Danube River) can be regarded as typical species for large rivers in general. They are inhabiting the different longitudinal zones of the Potamal, e. g. the leeches *Dina punctata*, *D. lineata* and *Erpobdella nigricollis*, the mussels *Pisidium supinum* and *Sphaerium rivicola*, the dragonflies *Gomphus flavipes* and *G. vulgatissimus*, the beetle *Brychius elevatus* and the caddisflies *Hydroptila sparsa, Psychomyia pusilla, Hydropsyche bulgaromanorum, Brachycentrus subnubilus, Ceraclea anulicornis* and *C. dissimilis*.

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UNDP-GEF DANUBE REGIONAL PROJECT:
ACTIVITY 1.1.6 TYPOLOGY OF AND DEFINITION OF REFERENCE CONDITIONS FOR THE DANUBE RIVER

DESCRIPTION OF REFERENCE CONDITIONS BASED ON HISTORICAL DATA AND CONSULTANT'S KNOWLEDGE

Dear …

Aim of the questionnaire in hand is to compile data on reference conditions of particular stretches of the Danube which represent the unaltered state of river. Due to long-lasting and exhaustive anthropogenic disturbance historical data are best suited to provide information about morphological, hydrological and biological characteristics the Danube once featured before man exceeded substantial influence on the river.

The historical approach to reconstruct reference conditions of large rivers has proved itself for instance at the Rhine river. Nevertheless, recent studies concerning analysis of historical conditions of the Danube are rare, available publications are limited to the Austrian section (HAIDVOGL et al., 2003[2]; HOHENSINNER et al., 2003[3]). Therefore, we rely on data you can provide by evaluation of sources in your country. In this context all documents containing information about historical conditions of the Danube are valuable, ranging from old publications and maps to antique paintings etc.. The age of relevant publications depends on the date of the first major impacts made by man: Again, only data specifying the unmodified river status are important!

How to respond to this document

In the following two parts of this questionnaire we ask you to (A) list all existent documents you can get hold of in detail, and (B) to describe the reference conditions extracted from theses sources by completing the questions (morphological, hydrological, biological and habitat characteristics).

The Danube stretch in your country is likely to show different section-types as suggested by our 'proposal for a stream-section typology'. Similar to your report of sampling sites done in a previous questionnaire, we now would like you to separately specify the historical state of each section based on information derived from publications.

2. [2] HAIDVOGL G., HOHENSINNER S., SCHMUTZ S. & H. WAIDBACHER, 2003: Typology of the River Danube and Description of Reference conditions based on historical data and expert judgement. Vienna (Dep. of Hydrobiology, Fisheries and Aquaculture University of Natural Resources and Applied Life Sciences). (unpublished)

3. [3] HOHENSINNER, S.; HABERSACK, H.; JUNGWIRTH, M. & G. ZAUNER, 2003: Reconstruction of the characteristics of a natural alluvial river-floodplain system and hydro-morphological changes following human modifications: the Danube River (1812-1991). River Research and Applications. (in press)

Please fill in two copies of this questionnaire concerning the section-types:

(…)

In case of only limited availability of historical data on morphology, hydrology or biology of the Danube River your judgement as a national consultant is in demand: Please complete the open spaces of part B to your best knowledge, but always identify your statements as consultant's knowledge, or derived from a specific source.

And please send copies of appropriate sources to us !

Where to send your information

Sabina Robert & Sebastian Birk

University of Duisburg-Essen
Faculty 9 - Institute of Ecology, Department of Hydrobiology
45117 Essen
Germany
phone (++)49 201 183 3201
fax (++)49 201 183 4442

please send your reply of this questionnaire to the following address
email: sebastian.birk@uni-essen.de

Deadline

Closing date will be

September, 1st 2003

We'd like to thank you for your efforts in advance and look forward to receiving your replies.

Sabina Robert and Sebastian Birk

INFORMATION PROVIDED BY:

Please specify below which person(s) have contributed to the information submitted.

Date:

Country :

Name (1) :

Institution :

Address :

Telephone-No.:

Fax-No. :

E-mail Address

Name (2):

Institution :

Address :

Telephone-No.:

Fax-No. :

E-mail Address

Part A

Table 1: List of existent sources describing the historical condition of the Danube River

NO.	NAME OF DATA SOURCE	TYPE OF DATA SOURCE (MAP, REPORT, ARTICLE, PAINTING ETC.)	AUTHOR	YEAR	LANGUAGE	SCALE OF MAP	RELEVANT INFORMATION (e.g. historical fish community, river morphology, discharge regime etc.)	CAN YOU PROVIDE US WITH A COPY?
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

Comments and additional sources:

- please fill in separately for each homogeneous section-type -

Part B

Name of section whose reference conditions are described in the following:

The described section ranges from stream km to stream km .

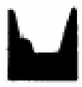
The reference state described below features the following special reference characteristics:

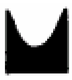
Please indicate whether provided information is based on data source (specifying the number according to table of part A), or based on consultant's knowledge **after** each question.

MORPHOLOGICAL CHARACTERISTICS

1. Valley form (Comments:)

☐ canyon 

☐ meander valley 

☐ trough 

☐ plain floodplain 

☐ other (please specify:)

ABOVE GIVEN INFORMATION IS BASED ON

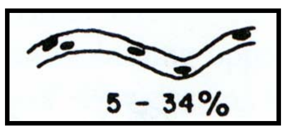
☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

2. Channel form ***– natural condition not modified by man !***

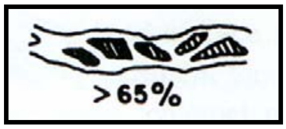
a. ☐ ***braided*** 

Braiding intensity (%) (Comments:)

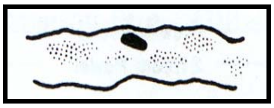
☐ 

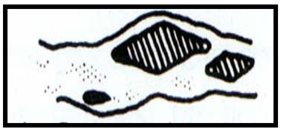
☐ 

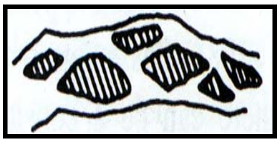
☐ 

☐ 

Character of braiding (Comments:)

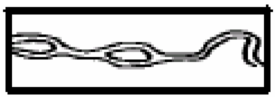
☐ mostly bars 

☐ bars and islands 

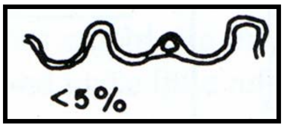
☐ mostly islands of diverse shape 

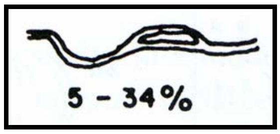
☐ mostly islands, long and narrow 

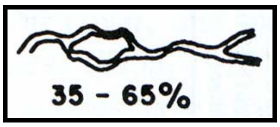
---

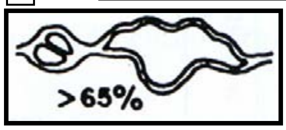
b. ☐ ***anabranching*** 

Anabranching intensity (%) (Comments:)

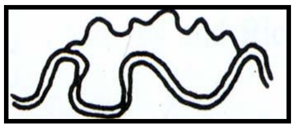
☐ 

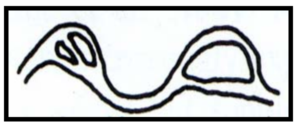
☐ 

☐ 

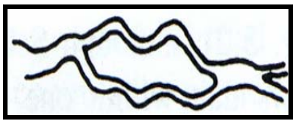
☐ 

Character of anabranching (Comments:)

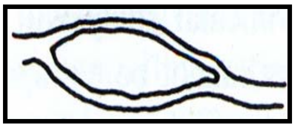
☐ **mainly sinuous side-channels** 

☐ **mainly cut-off loops** 

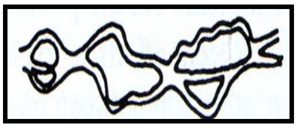
☐ **split channel, sinuous anabranching**



☐ **split channel, sub-parallel anabranching**



☐ **composite**



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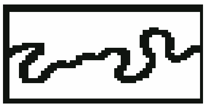
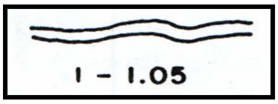
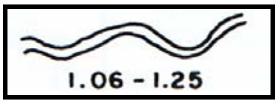
c. ☐ ***meandering***

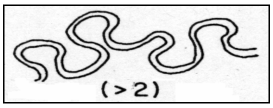


Degree of sinuosity of the main channel(s) (Comments:)

☐ 

☐ 

☐ 

☐ 

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

3. Average width of the channel(s) [m] – ***natural condition not modified by man !***

(please indicate separately for main and side channel(s) if applicable**)**

min:

mean:

max:

(Comments:)

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

4. Breadth erosion (Comments:) ***– natural condition not influenced by human activities !***

☐ high

☐ moderate

☐ none

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

5. Depth of channel(s) [m] ***– natural condition not modified by man !***

(please indicate separately for main and side channel(s) if applicable**)**

min:

mean:

max:

(Comments:)

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

6. Main channel substrates (Comments:) ***– natural condition not modified by man !***

rare < 10%	frequent 10-30%	dominant > 30%	stream substrate type	description
☐	☐	☐	**megalithal** > 40 cm	large cobbles, boulders and blocks, bedrock
☐	☐	☐	**macrolithal** > 20 cm to 40 cm	coarse blocks, head-sized cobbles, with a variable percentages of cobble, gravel and sand
☐	☐	☐	**mesolithal** > 6 cm to 20 cm	fist to hand-sized cobbles with a variable percentage of gravel and sand
☐	☐	☐	**microlithal** > 2 cm to 6 cm	coarse gravel (size of a pigeon egg to child's fist), with variable percentages of medium to fine gravel
☐	☐	☐	**akal** > 0.2 cm to 2 cm	fine to medium-sized gravel
☐	☐	☐	**psammal/** 6 µm to 2 mm	sand
☐	☐	☐	**psammopelal** 0,6 µm to 6 µm	sand and mud
☐	☐	☐	**pelal** < 2 µm	mud and sludge (organic)
☐	☐	☐	**argyllal** < 2 µm	silt, loam, clay (inorganic)

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

7. Bank structure (Comments:) ***– natural condition not influenced by human activities !***

	frequently	multiple	isolated	none
abort bank	☐	☐	☐	☐
sliding bank	☐	☐	☐	☐
fallen trees	☐	☐	☐	☐
wood collection	☐	☐	☐	☐
bank spur	☐	☐	☐	☐
nest bank	☐	☐	☐	☐

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

8. Width of former floodplain [m]: ***– natural condition not modified by man !***

min:

mean:

max:

(Comments:)

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

9. Presence of water bodies in the floodplain close to the stream (Comments:)

– natural condition not modified by man !

- ☐ arms connected to the river/stream
  - ☐ lotic side arms: both ends connected to the main channel
  - ☐ dead arms: only downstream end connected to the main channel
- ☐ cut-off channels and oxbow lakes: permanent side arms completely isolated, flooded only by high water level
- ☐ temporary side arms
- ☐ standing water bodies located in the floodplain and fed by tributaries
- ☐ other types (please specify:)
- ☐ no water bodies present in the floodplain

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

HYDROLOGICAL CHARACTERISTICS

10. Current velocity [m/s] **of main channel (**measured at water surface**):**

– natural condition not modified by man !

min:

mean:

max:

(Comments:)

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

HABITAT CHARACTERISTICS

11. Aquatic habitats (Comments:) ***– natural condition not modified by man !***

rare < 10%	**frequent** 10–30%	**dominant** >30%	**potamon types**	
☐	☐	☐	eupotamon	main channel and side/secondary channels
☐	☐	☐	parapotamon	dead arms retaining a connection to the main channel
☐	☐	☐	plesiopotamon	former braided segments that became disconnected from the main channel
☐	☐	☐	palaeopotamon	old meanders or similar forms resulting from another morphological type; without direct connection to the main channel

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

12. Width of eupotamon [m] **(**main channel plus secondary channels**):**

– natural condition not modified by man !

min:

mean:

max:

(Comments:)

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

13. Biotic microhabitats (Comments:) ***– natural condition not modified by man !***

rare < 30%	frequent < 60%	dominant > 60%	biotic microhabitats	
☐	☐	☐	Phytal	submerged plants, floating stands or mats, lawns of bacteria or fungi, and tufts, often with aggregations of detritus, moss or algal mats (interphytal: habitat within a vegetation stand, plant mats or clumps)
☐	☐	☐	Filamentous algae	filamentous algae, algal tufts
☐	☐	☐	Macrophytes	submers macrophytes, including moss and Characeae
☐	☐	☐	Living parts of terrestrial plants	fine roots, floating riparian vegetation
☐	☐	☐	Xylal (wood)	tree trunks (dead wood), branches, roots
☐	☐	☐	CPOM	deposits of particulate organic matter, coarse particulate organic matter as eg fallen leaves
☐	☐	☐	FPOM	deposits of particulate organic matter, fine particulate organic matter
☐	☐	☐	Sapropel	sludge
☐	☐	☐	Debris	organic and inorganic matter deposited within the splash zone area by wave motion and changing water levels, e.g. mussel shells, snail shells

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

14. Percent area of terrestrial habitats in the floodplain (banks, islands etc.**)**

– natural condition not modified by man !

☐ eupotamon: % of terrestrial habitats in the eupotamon

☐ entire floodplain: % of terrestrial habitats in the floodplain

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

15. Floodplain vegetation (Comments:) ***– natural condition not modified by man !***

rare < 30%	frequent < 60%	dominant > 60%	vegetation types
☐	☐	☐	alluvial forest (softwood, e.g. willow, alder etc.)
☐	☐	☐	alluvial forest (hartwood, e.g. esh, meaple, elm etc.)
☐	☐	☐	deciduous native forest
☐	☐	☐	mixed native forest
☐	☐	☐	coniferous forest
☐	☐	☐	wetland (mire)
☐	☐	☐	open grass-/bushland
☐	☐	☐	meadow
☐	☐	☐	reeds
☐	☐	☐	naturally unvegetated
☐	☐	☐	other (specify:)

ABOVE GIVEN INFORMATION IS BASED ON

☐ **DATA SOURCE NUMBER:**	☐ **CONSULTANT'S KNOWLEDGE**

BIOTIC CHARACTERISTICS

16. Please register species of benthic invertebrates characteristic for the section you have described above, adding information about abundance and recent presence.

(The following table is intended to preliminarily compile species to enable establishment of a harmonised reference taxa list within a later phase of this project**)**

(Comments:)

Taxon	abundance (indicate if abundance class or ind./m²)	present/extinct

ABOVE GIVEN INFORMATION IS BASED ON

☐ DATA SOURCE NUMBER:	☐ CONSULTANT'S KNOWLEDGE

GENERAL DESCRIPTION

17. Please describe the general character of the reference section:

(**Example:** About 1850 this Danube section was characterised to a very high extent by eupotamal water bodies (main channel and side arms), offering a primarily lotic environment (97 % of the overall water surface area at mean water). The active channel system was strongly branched by vegetated islands and gravel bars. Shallow-water zones with gentle bed gradients were dominant. This enabled a high diversity of depths, flow velocities and substrate conditions. Para-, plesio- and palaeopotamal water bodies of the floodplain were much less frequent, but represented a great variety of distinct lentic habitats. The various floodplain elements were subject to constant modification and renewal due to strong erosion/sedimentation processes.)

UNDP-GEF Danube Regional Project. Project Document Activity 1.1.6 - Typology of and Definition of Reference Conditions for the Danube River

Description of Reference Conditions of the Austrian Danube based on Historical Data with special emphasis on hydromorphology and fish fauna

Haidvogl G., S. Hohensinner, S. Schmutz & H. Waidbacher

Dept. of Hydrobiology, Fisheries and Aquaculture
University of Natural Resources and Applied Life Sciences

Version 2, August 2003

Contents

1. Introduction

The Water Framework Directive (WFD) requires Member States to differentiate the relevant surface water bodies with respect to type and to establish reference conditions for these types. Consequently the main purpose of this typology is the definition of type specific reference conditions which in turn are used as the anchor of the classification system (MLIM-EG working paper 13 May 2003).

Due to a long tradition of anthropogenic uses and influences of the Austrian Danube (mainly flood protection, navigation, hydropower generation) no river sections are left that could serve as basis for analysing the reference status. As a consequence the reference conditions must be obtained by other methods.

The aim of this paper is to present the Austrian experiences in describing reference conditions of selected Danube reaches by the use of historical data. Special emphasis is given to the fish fauna (part 1) and the hydromorphological conditions (part 2). This paper at hand may serve as a guidance for the Countries in the Danube River Basin for applying, adapting or developing similar procedures.

2. Part 1: Guidelines for the reconstruction of the target fish fauna of the Danube

In the first part of this report historical data were compiled in two ways: First to describe the species composition and to classify abundance of dominating/main fish species, in a second step the final classification of abundance was done by expert judgement for both breakthrough and anabranching sections (chapter 2.1.). This is in accordance with the differentiation of morphological subsections of the Austrian Danube which is focusing on breakthrough and anabranching sections. Chapter 2.2 deals with historical analyses and methodology to characterise the reference fish fauna of the Austrian Danube. Chapter 2.3 provides guidance for collecting and analysing historical fish data to describe reference conditions.

2.1. Fish ecological reference conditions of the Austrian Danube

The reference species composition of the Austrian Danube was compiled from historical publications on the fish fauna of the Austrian Danube. The procedure is described in chapter 2.2, the data sources are cited in the list of references in appendix 1. Adequate reports are available mainly from the 19th and in parts from the 20th century. Apart from the species composition they allow for a rough estimation of abundance classes for dominating species and those which were important for commercial fishery. However, the historical reports do not provide sufficient information for a clear differentiation of species composition and abundance classes in breakthrough and anabranching section. Hence occurrence and abundance as listed in table 1 below was finally classified by expert judgement.

Table 1: Fish fauna of the Austrian Danube – Reference status of occurrence and abundance classes

Abundance classes: xxxx = dominant; very large, self-sustaining populations in the Danube;
xxx = frequent; self-sustaining populations
xx = rare
x = very rare; only few specimen which occur only sporadically

	Occurrence *Austrian Danube-Section*	**Abundance Classes** *Breakthrough sections*	*anabranching sections*
Acipenseridae:			
Sterlet, *Acipenser ruthenus*	✓	xx	xx
Ship sturgeon, *Acipenser nudiventris*	✓	x	x
Stellate sturgeon, *Acipenser stellatus*	✓	x	x
Russian sturgeon, *Acipenser gueldenstaedti*	✓	x	x
Great sturgeon, *Huso huso*	✓	x	x
Salmonidae:			
Danube salmon, *Hucho hucho*	✓	xxx	xxx
Brown trout, *Salmo trutta*	✓	xx	xx
Thymallidae:			
European grayling, *Thymallus thymallus*	✓	xx	xx
Esocidae:			
Nothern pike, *Esox lucius*	✓	xx	xxx
Coregonidae:			
Coregonen	✓	x	x
Umbridae:			
European mudminnow, *Umbra krameri*	✓		xx*
Cyprinidae:			
Zope or Blue bream, *Abramis ballerus*	✓	x	xx
White bream, *Abramis björkna*	✓	xx	xxxx
Common bream, *Abramis brama*	✓	xx	xxx
Zobel or Danubian bream, *Abramis sapa*	✓	x	xxx
Bleak, *Alburnus alburnus*	✓	xxxx	xxxx
Spirlin, *Alburnoides bipunctatus*	✓	x	x
Asp, *Aspius aspius*	✓	xx	xx
Barbel, *Barbus barbus*	✓	xxxx	xxxx
Balkanian barbel, *Barbus peloponnesius*	✓	x	x
Prussian carp, *Carassius auratus gibelio*	✓	x	x
Crucian carp, *Carassius carassius*	✓	x	xx
Nase, *Chondrostoma nasus*	✓	xxxx	xxxx
Common carp, *Cyprinus carpio*	✓	x	xx
Whitefin gudgeon, *Gobio albipinnatus*	✓	xxx	xxx
Gudgeon, *Gobio gobio*	✓	x	x
Kessler`s gudgeon, *Gobio kessleri*	✓	xx	xx
Danube gudgeon, *Gobio uranoscopus*	✓	xx	xx
Belica, *Leucaspius delineatus*	✓		xx
European chub, *Leuciscus cephalus*	✓	xxx	xxx

	Occurrence *Austrian Danube-Section*	**Abundance Classes**

Ide, *Leuciscus idus*	✓	xx	xxx
Eurasian dace, *Leuciscus leuciscus*	✓	xxx	xxx
Soufie, vairone; *Leuciscus souffia agassiz*	✓	x	x
Chekhon, *Pelecus cultratus*	✓	x	x
Eurasian minnow, *Phoxinus phoxinus*	✓	xx	xx
Bitterling, *Rhodeus amarus*	✓	x	xx
Rutilus frisii meidingeri	✓	x	x
Danube roach *Rutilus pigus virgo*	✓	xx	xxx
Roach, *Rutilus rutilus*	✓	xxx	xxxx
Rudd, *Scardinius erythrophthalmus*	✓	x	xxx
Tench, *Tinca tinca*	✓	x	xxx
Vimba, *Vimba vimba*	✓	xx	xxx
Balitoridae			
Stone loach, *Barbatula barbatula*	✓	xx	xx
Cobitidae:			
Spined loach, *Cobitis taenia*	✓	xx	xx
Wheaterfish, *Misgurnus fossilis*	✓	x	xx
Siluridae:			
Wels, *Siluris glanis*	✓	xx	xxx
Gadidae:			
Burbot, *Lota lota*	✓	xxx	xxx
Percidae:			
Balon's ruffe, *Gymnocephalus baloni*	✓	xx	xx
Ruffe, *Gymnocephalus cernuus*	✓	x	x
Schraetzer/Striped ruffe, *Gymnocephalus schraetser*	✓	xxx	xxx
Eurasian perch, *Perca fluviatilis*	✓	xxx	xxxx
Pikeperch, Zander, *Sander luciopera*	✓	xx	xxx
Volga pikeperch, *Sander volgensis*	✓	x	xx
Danube streber, *Zingel streber*	✓	xxx	xx
Zingel, *Zingel zingel*	✓	xxx	xxxx
Cottidae:			
Bullhead, *Cottus gobio*	✓	xxx	xxx
Petromyzonidae:			
Eudontomyzon *mariae*	✓	x	x
	57 Species		

* Westward distribution only up to the Vienna basin / Wiener Becken

2.2. Methodology for describing the reference fish fauna of the Austrian Danube

Short overview of historical publications

“Scientific” descriptions of the fish fauna of European rivers have been published from the 18th century onwards. The earliest publications mostly deal with biological characteristics of the species. If they refer to species distribution this is rather done for larger areas than for particulate rivers (e.g. Bloch, 1782-84, “Ökonomische Naturgeschichte der Fische Deutschlands, or Meidinger, 1785-94, “Icones piscium Austriae indigenorum”). However, one of the earliest more detailed descriptions of the Danube fish fauna dates as far back as 1726 (Marsigli “Danubius pannonico myscius” 1726).

When compiling the data about the historical fish fauna of the Austrian Danube the inquiries for published data mainly concentrated on the 19th century because at that time the river could be considered as more or less natural or nature like. Nevertheless channelisation of longer stretches was already carried out in the first half of the 19th century (stretches in Upper Austria) and a bit later in Vienna (1860ies and 70ies).

In the 19th century the number of studies dealing with the fish fauna of the Danube in general and the Austrian Danube in particular increased. In 1832 Fitzinger published the Fauna of Lower Austria, considering also distribution and information on abundance of fish (Fitzinger, 1832). Several years later Fitzinger and Heckel characterised the Acipenseridae and their distribution in the Danube (Fitzinger & Heckel, 1835). In 1858 Heckel and Kner published an overview of the fish species of the Austrian monarchy including information about the distribution and abundance of species. Siebolds valuable description of the fish species of central Europe dates from 1863. It also contains an overview of the status of ichthyological publication in parts of the Hungarian Monarchy.

Moreover in the 19th century reports dealing with the fish fauna of the Austrian Danube were also published in several journals. Examples are Kornhuber (1863, 1900), Lori (1871), Kukula (1874) or Jeitteles (1862). There are even small notes in fisheries journals, which can give hints on the occurrence of fish species in a particulare place (for Austria the “Mitteilungen des Österreichischen Fischereivereins” was revised). However, these papers or notes must be reviewed carefully because they are sometimes written by laymen. Additional information is available in publications about commercial fishery and fish markets too (e.g. in Peyrer, 1874 or in Krisch, 1900). In the 1950ies two papers on the history of fish markets and trading in Upper Austria were published (Kerschner, 1956, Wacha, 1956). The latter also lists many regional names for fish species, which are a useful basis for the correct identification of fish species, named in non-scientific historical publications.

The literature mentioned above provides important information about the fish fauna of the Austrian Danube in the 19th century. Further publications from the 19th and early 20th century which refer to downstream sections as well (e.g. Mojsisovics, 1886/87 and 1897; Jeitteles, 1862) are listed in Appendix 1, References. Besides published reports material about commercial fishery registered in archives can provide important information about species occurring at a particulate site or catch of certain species. Though it depends on the organisation of commercial fishery if the output was registered and traded (see chapter 2.3. for details).

Combination of historical information and expert judgement to obtain the reference situation

The analyses of the historical publications allow a compilation of the historical fish species composition of the Austrian Danube. However, there are some exceptions. This is at first due to the late taxonomic description of some species as e.g. *Gobio albipinnatus* (Lukasch, 1933) or *Gymnocephalus baloni* (Holcik & Hensel, 1974) which have been added to the list according to more recent surveys. Additionally some species have been listed which are described only for tributaries of the Austrian Danube in historical sources (*Umbra krameri*, *Rutilus frisii meidinger*, *Leuciscus souffia* and *Sander volgensis*). In this context it has to be stressed that historical analyses hardly ever result in a complete species list of a particular river. In many cases species which were identified later or which are hard to detect must be amended according to more recent surveys.

Concerning abundance historical sources at the utmost allow a verbal classification of main and well-known species. Even if data from commercial fishery are available they can only indicate dominant and very frequent species but they do not exactly reflect the ecological situation. As a consequence the historical analyses of the Austrian Danube fish fauna were combined with more recent surveys and expert judgement to get the complete species composition and abundance classes. The basis for the classification of abundance in breakthrough and anabranched sections was the description of the natural morphological conditions of the Austrian Danube (see part 2).

2.3. Guidance on collecting, reviewing and analysing historical information

The main purpose of historical analyses for describing reference conditions is to gain information about the composition/distribution and abundance before major anthropogenic impacts took place (channelisation and constructions for flood protection and navigation, hydropower plants etc.). Hence data collection for the Austrian Danube should concentrate on the middle of the 19th century, in some areas in Upper Austria on the first third of this century. It is recommended to start historical analyses by identifying and dating these impacts for the concerned sections because of the sometimes poor quality of historical data from the 19th century which improved throughout the 20th century.

Types of historical data and proceeding of analyses

Type 1: Search for recent publications on the history of the biology, geography etc. of the relevant rivers, regions or cities

Data type 1: Recent publications

Before historical material is collected and analysed it should be examined if recent historical studies have already been accomplished and published. Besides ecological and biological publications the ones on geography and the history of specific regions and cities should be considered too.

Type 2: Publications about Danube fish species and fish assemblages by biological / ichthyological experts (examples from Austria: Heckel, Heckel & Kner, Siebold, Fitzinger, Lori, etc.; see list of references in Appendix 1):

Data type 2: Historical publications by biologists

Period covered:

- From the late 18th century onwards; earlier documents could be available (like e.g. Marsigli, 1726), mainly from the 19th and early 20th century

Extend of possible information:

- Presence and absence of fish species; sometimes information about occurrence in particular stretches or sites available; verbal classification of abundance of certain species.

Quality of data:

- Information given in these publications is usually quite reliable. However data are not based on systematic surveys. Therefore information about occurring fish species and especially on distribution is likely to be incomplete.

Problems encountered during analyses:

- Fish species lists could also be incomplete due to taxonomic reasons (some species might have been described only after anthropogenic impacts; e.g. some *Gobio sp.* in the Austrian Danube section). In many cases these species could be added by using more recent information.

- The taxonomic classification of some species was changed in the past. During the analyses the correct species has to be identified.
- Sometimes only “common” and/or local names for species are given. These species must also be identified during the analyses. When common names are used one also faces the problem that similar names could refer to different species in different regions (like the term Weißfisch/whitefish in the Austrian Danube).

How to find the data:

- This type of data is usually easy to find in national and scientific libraries (universities, museums). Some publications were not published as monographs - therefore systematic inquiries in relevant journals must be carried out.

Estimated efforts (given for one person):

- 2-3 weeks inquiry of relevant publications, 4-8 weeks for analyses.

Type 3: Reports published by ichthyological “laymen” in geographical and/or natural history publications (examples from the Austrian Danube: Kukula, 1874, Lori 1871, Krisch 1900)

Data type 3: Historical publications by ichthyological laymen

This type of data could be used in addition to publications by experts. Usually the material is detected anyway when searching for publications in libraries.

Period covered:

- from the 18th century onwards; also several publications from the 16th century;

Extend of possible information:

- Absence and presence of fish species, information on distribution and abundance-(classes).

Quality of data:

- Must be checked more carefully than sources of the type mentioned above (authors usually not educated in biology).

Problems encountered during analyses:

- In principle the same as mentioned under 1, experiences from Austrian rivers showed that in most cases common/regional names for fish species are the biggest problem (sometimes information cannot be used at all due to that).

How to find these data:

- see paragraph in 1,

Type 4: Records on commercial fishery in historical archives

Data type 4: Records in archvies

Period covered:

- from the late Middle Ages onwards; but rather 16th century and later

Extend of possible information:

- Presence of species at a certain site. Most dominant species in certain regions; quantitative information about amount of fish caught in a known period; HOWEVER: no information about the actual fish-stocks available; possibly information of occurrence of species in specific habitat-types.

Quality of data:

- Data are usually quite reliable. However, it has to be taken into account that quantitative information does not necessarily reflect the ecological situation; it also shows the preferences for certain species.

Problems encountered during analyses:

- Only fish species which were of commercial interest are reported (however more species were caught than nowadays; in the Austrian Danube e.g. cyprinids like nase, barbel, dace, bream or other small species like bullhead);

How to find the data:

- First of all relevant archives must be found (defined), as there are monasteries or castles who had fishing rights on the Danube or associations of commercial fishermen on the Danube.
- The next step is to verifiy if archive material (still) exists at all. When searching for data for the Austrian Danube valuable records from commercial fishery were detected in the big monastery Herzogenburg (at the mouth of the river Traisen). On the other hand an important monastery like Klosterneuburg in the vicinity of Vienna supplied its need of fish at the Viennese Fishery market. The monastery rented its fishing rights to commercial fishermen and hence no data were traded in the monastery archive.
- In a further step one has to find out whether the archive material is still stored in the relevant monastery/castle or if it has been incorporated into a national archive.
- One final point is that in most cases the material could only be read and analysed by people who are familiar with old handwritings.

Estimated efforts:

- Although hard to estimate the method described is quite time-consuming and the efforts depend on several factors especially how well the archive materials are sorted and registered.

Besides material about commercial fishery it is also recommended to analyse accounts of fish purchase, fish delivered to monasteries by fishermen or records of delivery to fish markets. For the period covered, quality of data etc. the same has to be said as for the sources described above. However, if accounts of fish-purchase or reports about fish delivered by fishermen are used one has to verify the provenience of fish. When fish market deliveries are analysed the origin of the fish must be identified. Usually especially fish markets of larger cities were provided with fish from larger areas. The Viennese market, e.g., was supplied with fish from Lower and Upper Austria, from Bohemia and Hungary from as far back as the 16th century (see e.g. Schmeltzl, 1548).

Type 5: Specimen of fish in museum collections

Finally Museum collections can provide valuable information about the occurrence of a species on a specific site.

Data type 5: Museum materials

3. Part 2: Guidance on collecting and analysing historical information regarding former hydromorphological conditions

3.1. Morphological data

Data sources - morphology: Maps and surveys

Historical maps and surveys provide a valuable basis to obtain morphological parameters describing the natural state of a river-floodplain system. For the Austrian Danube section a wealth of these resources is available. Some of the most interesting ones for river analysis are listened in the following. Analogue historical resources may also be available for the Danube River sections up- and downstream of Austria.

- Military-topographical surveys

  in Austria: "Franziszeische Landesaufnahme" mostly prior to channelisation (1806-1869, scale: 1: 28.800, Austrian State Archives / War Archive) and "Franzisko-josephinische Landesaufnahme" (1869-1887, scale: 1 : 25.000) during river-channelisation. These maps provide an overview of the former river-landscape, but may lack of accuracy.

- River-surveys and maps for river-channelisation / navigation

  e.g. in Austria: "Allgemeine Donau-Aufnahme" (in Upper Austria, 1817-1819) and "Nieder-Oesterreichische Donau-Stromkarte" (in Lower Austria, 1805 from Porta, 1816-1817 from Lorenzo), scales: 1: 7.200 – 1 : 28.800. These maps built the basis for future channelisation measures and therefore are surveyed rather accurately. Besides morphological information, they also offer some hydrological data, e.g. water surface levels, flow velocities,….

- Maps and surveys from aristocratic and monastery archives

  Several surveys along running waters were evoked by property and hunting-ground border conflicts between different landowners following major floods. As a result, some accurate land surveys may be found that enable good impressions of former river-landscape conditions. In Austria, from 1700 onwards detailed maps exist (e.g. for the floodplains near Vienna, Melk and in the Machland region, 1714-1730 from Marinoni).

3.2. Hydrological data on the historical flow regime

Data sources - hydrology

As pointed out, river-surveys in many cases show usable hydrological information like characteristic water surface levels, flow velocities and water depths. Besides the maps, historical records of stage heights at gauging stations may also provide valuable data.

For example, in Austria from 1821 onwards, systematically recorded water levels are available for three sites along the Danube River. The interpretation of these data may be difficult due to channel changes and changing profiles (erosion/sedimentation) at the gauging station. For this reason, exact knowledge of the changes and the history of the gauging station are necessary. Since 1893, a broad spectrum of hydrological data exists but only refers to time periods after river channelisation.

3.3. Analysis of river-morphology on basis of historical surveys

Analysis of river morphology

In the following, some examples for morphological data that can be obtained by analysing historical maps are listed:

1. **Planform Properties:**
   - ⇒ sinuosity, bend radius of curvature, braiding, anabranching,
   - ⇒ meander planform geometry
   - ⇒ lengths of the shoreline (water-land-interfaces)
   - ⇒ single instream structures: length, width, length of shoreline
2. **Longitudinal Profile:**
   - ⇒ river depths in relation to the line of maximum velocity
   - ⇒ pool-riffle-sequences
   - ⇒ channel slope, water surface slopes
3. **Cross Section:**
   - ⇒ widths of the river system, profile areas
4. **Area Calculations:**
   - ⇒ water areas (main channel, side-channels, connected abandoned channels, tributaries, isolated backwaters)
   - ⇒ areas without vegetation (gravel, sand)
   - ⇒ bays, islands, areas with pioneer vegetation
5. **Heights of the Terrain:**
   - ⇒ areas without vegetation, areas with pioneer vegetation
   - ⇒ higher terrain areas of the floodplain, vegetated islands
   - ⇒ heights of the river banks

Based on these analyses the following parameters can be determined in order to describe the characteristics of the specific river sections (examples):

• Morphological river classifications	(e.g. Leopold & Wolman 1957, Silva 1991, Rosgen 1994)
• Braiding Indices	(e.g. Howard et al. 1970, Bridge 1993, Thorne 1997)
• Total Sinuosity	(Richards 1982, Bridge 1993, Robertson-Rintoul and Richards 1993)
• Fractal Dimensions (Box-counting method)	(Nikora 1991, Nikora et al. 1997)

3.4. Methodology of historical map analysis

Analysis of historical maps - methodology

First, selected maps have to be scanned and georeferenced with the help of GIS/CAD-programs. The planform accuracy has to be computer-checked and the errors in selected maps must be digitally rectified in order to eliminate errors of surveying and distortions of the maps due to air humidity. In a next step, the scanned and rectified maps are vectorized and further evaluation and analysis of individual parameters are performed with the help of CAD- and GIS-programs.

By overlaying several maps in a chronological order it is possible to visualize and calculate the channel dynamics. The compiled data are used to describe the former river hydromorphology and to define an appropriate typology of the analysed river sections.

3.5. Hydromorphological criteria to describe typological features and reference conditions

- General morphological parameters:

  Sinuousity of the main channel, meander development, braiding intensity, total sinuosity, widths of the floodplain area and the river channels, channel slopes, channel substrate, calculated area values of typical river structures, hydrological regime,…

- Characteristic water body types:

  Classified due to their connectivity at specific water levels (e.g. Amoros et al. 1982, 1987, Amoros and Roux 1988), area calculations of the various water bodies, duration and character of connection with the discharge regime of the main channel

- Expansion of aquatic habitats due to flooding and lateral connectivity:

  Water covered areas at characteristic hydrological events (e.g. at low and mean flow, bankfull level, mean annual flood), areas that are effected by “flow pulse” and “flood pulse” (Junk et al. 1989, Puckridge et al. 1998, Tockner et al. 2000a, 2000b), widths of flooded areas, flooded unvegetated and vegetated areas

- Channel dynamics:

  Area changes of typical morphological features, river bank migration, volume calculation of erosion and aggradation (by comparison of different temporal situations)

3.6. Current status of historical information and analysis regarding the hydromorphology of the Danube River

Literature and actual knowledge

Specific studies on the historical morphology of the Danube River are rare in Austria and also for other sections outside from Austria. Many studies and articles are focused on historical-geographical issues and do not provide accurate information for deriving reference conditions. Nevertheless, some studies exist for specific Danube River reaches, e.g. for the anabranched section in the Austrian *Danube Floodplain National Park* downstream of Vienna (e.g. Reckendorfer and Schiemer 2001) and near Vienna (Stummer 1982). More detailed information regarding former hydromorphology are available for the anabranching Danube River in the alluvial zone of the Machland region (Upper/Lower Austria). Besides two-dimensional investigations (between 1715 and 1991), in this study, also three-dimensional aspects that describe the former status of the whole floodplain in 1812 prior to regulation are analysed (Hohensinner et al. in press a, b). Specific information concerning the former river-morphology also exists for some German Danube sections (e.g. Kern 1994).

For break-through sections of the Danube River, historical analyses are also rare. In Austria, only one study is available for the section "Obere Donautal" between Passau and Aschach (65 km length; Hohensinner 1995). This study primarily provides area calculations of typical riverine elements in a canyon-stretch of the Danube River in 1850.

3.7. Typological overview of the Austrian Danube River

Austrian Danube Typology

The preliminary typology of the Austrian Danube sections shall be based on the ecoregions and nine geomorphological sections used in the Joint Danube Survey. Further, the Austrian stretch will be subdivided into break-through sections and anabranching sections (e.g. based on the geomorphological and palaeo-geographical criteria according to Kohl 1966).

According to the accuracy of the used historical sources, an additional subdivision of these two types may be possible. For the break-through sections:

- Chutes/cataracts/rapids

  River reaches with bedrock-channels, high flow velocities, outcropping bedrocks within the channel that determine flow patterns, so-called "Kachlets"
- Break-through-sections without chutes

  River-bottom characterised by gravel substrate and lower flow velocities

For the anabranching sections:

- Transition from break-through to anabranching sections

  (upstream end of the alluvial floodplain)

  characterised by large shallow flooded boulders at the river-bottom, these boulders derive from the upstream break-through sections and were deposited in the upper end of the floodplain, so-called "sphaeres" (Kugeln)
- Free anabranching sections without any influence of the break-through sections

Situated in the center of the anabranching sections with well developed lateral connectivity, great widths of the river-system and the floodplain, gravel/sand/silt as substrate

- Transition from anabranching to break-through sections

  (downstream end of the alluvial floodplain)

  hydrologically and also morphologically affected by the downstream break-through section, augmented backwater flooding effects at higher discharges due to the flow restriction of the following canyon-reach, increased "flood pulse" effect as a consequence of backwater flooding

These subdivisions mentioned above need some further discussion if they are applicable as well as reasonable from the hydromorphological and ecological point of view.

3.8. Examples for analysing historical hydromorphological reference conditions

Basic characteristics of a break-through section:

The Danube River in the Austrian "Obere Donautal"

(Hohensinner 1995)

Austrian Danube I: break-through section

The Danube River between Passau and Aschach (river-km 2225-2160) is characterised by the steep narrow canyon of the "Obere Donautal" that confines the lateral development of the river channel. The Danube`s original state in the "Obere Donautal" had been almost completely preserved until 1850. While the construction of the two hydropower plants Jochenstein (1956) and Aschach (1964) was progressing, most of the typical river structures disappeared.

!! Methodology - Proceeding

The former natural morphological conditions of this Danube section were analysed on the basis of river-survey maps from 1850 - 1860 (e.g. so-called "Pasetti Karte", scale 1: 28.800). Planform accuracy was checked by superimposing over current river maps. In order to improve planform accuracy, the study river section was divided into subsections for which specific scale-correction factors were determined. In a following step, the area extensions of certain river/floodplain structures were manually measured using a planimeter.

Because of the narrow river-canyon with a comparatively high channel slope, gravel banks/islands and highly outcropping rocks (Kachlets) dominated the Danube River and accordingly offered a lotic environment almost throughout the whole study area. Backwaters and some smaller floodplain forests only existed in the more spacious areas of the valley bottom. In 1850, gravel areas, which fell dry in times of extreme low water, amounted to 5 ha per river-km. Most tributaries discharged into the Danube River at locations with large gravel bars and therefore provided valuable spawning habitats for rheophilic fish species. Originally, this type of specific habitat showed approximately 30 m per river-km.

Though backwaters were not a formative element in break-through sections, the total area of such water bodies amounted to 0,2 ha per river-km. They provided interesting refuge habitats during floods and special lentic habitats for stagnophilic species.

The former "Obere Donautal" was characterised by four short river reaches with chutes that were formed by outcropping bedrocks (Kachlets). Such reaches featured high flow velocities and complex flow patterns. Small vegetated islands were also typical elements. In 1850, ca. 0,7 ha of vegetated islands existed per river-km.

Analysing the time period before 1850 reveals that they evolved out of gravel bars at the inner riverbank within some years. The further human-induced development showed proceeding aggradation that led to the formation of backwaters between former islands and the outer riverbanks.

Up to today, shallow water areas with fine sediments forming the channel substrate have been highly increasing as a consequence of damming. The loss of original river structures becomes apparent in the absence of adequate habitats above all for the rheophilic fish fauna. Accordingly, the live stock of the rheophilic fauna has been decreasing, while indifferent species are getting stronger.

Basic characteristics of an anabranching section:

The Danube River in the Austrian Machland region (Hohensinner et al. in press a, b)

Austrian Danube II: anabranching section

This historical reference for an anabranching section of the Danube River is located in the eastern Machland (river-km 2094-2084) along the border of Upper and Lower Austria. The Machland is the most eastern of three tectonic Danube basins in Upper Austria, which are separated by the Bohemian Massif. Danube discharge is mainly influenced by alpine flow conditions and peaks in spring/summer due to the snowmelt in the Alps (Mader et al. 1996). The 33.8 km² large study area coincides with the present 10-year flood area, which is delimited to the north by the terrace of the Würm glaciation and to the south by the Tertiary hill country. Prior to channelisation, in 1812, 22.2 km² (66 %) belonged to the active zone. In this context the active zone (AZ) includes the active channel system (water bodies and unvegetated gravel/sand areas), vegetated islands and morphologically young floodplain sections that were formed during Modern times since approx. 1500 A.D. Originally, the AZ was partially flooded at mean annual flood, and total inundation occurred every 3-5 years. On average the width of the whole study area (10-year flood area) is 3200 m, that of the AZ 2100 m. The first channelisation measures along this Danube reach were initiated around 1826 and the major phase of river straightening was already completed in 1859. In the 20th century two hydropower plants, Ybbs-Persenbeug (1957, 23 km downstream) and Wallsee-Mitterkirchen (1968, at the upstream border of the study area) were constructed when most floodplain waters were separated from the main channel by dikes.

!! Methodology - Proceeding

From 1714 onwards, exact surveys of the river landscape were conducted in order to determine property and hunting-ground borders after major floods. Moreover, plans to improve navigation were initiated early, giving rise to a series of detailed river maps of this Danube stretch from 1812 onwards. 120 historical maps (land surveys, estate maps, river surveys, navigation maps,…) of this river reach have been found in various Austrian archives. Gathering the most accurate ones, 45 selected maps were superimposed over current detailed topographical surveys using AutoCAD Overlay. Planform accuracy was checked by means of benchmarks, e.g. churches, farms, streets and unchanged terrain structures. For this study, the most accurate map (river survey from the former k.k. Landesbaudirection, scale 1: 6900) dating to 1812 was selected to describe the natural state of the river landscape. In order to eliminate planform inaccuracies and map distortions, the map was digitised, geometrically corrected using the benchmarks and vectorised.

First results regarding the hydromorphological conditions in 1812 were gathered by analysing the historical surveyed spot heights of the terrain and the water levels (Hohensinner et al. in press a). Additionally, three-dimensional *digital terrain models* (DTM) were generated in form of *triangulated irregular network*s (TIN: model based on triangles) using the CAD/GIS-program Autodesk Land Desktop for modelling the natural reference situation in 1812 (Hohensinner et al. in press b). One of the great advantages of these vector-based models is that breaklines of the terrain surface as well as shorelines can be accurately edited. In a first step, the historically mapped spot heights of the terrain surface and the water surfaces at different stages were used to build TINs for each of these surfaces. In order to estimate the level of the groundwater table between the channels in the floodplain in 1812, the mapped spot heights of the water surfaces were interpolated and incorporated into the TINs. In a following work step, water cover at different water levels was calculated based on the intersection of TINs of the terrain surface and specific water/groundwater surfaces. Additionally, surface water volumes were computed by advanced intersection-methods for specific flows.

In 1812, the Danube River channel system in the Machland was branched by several vegetated islands and gravel bars. Mean total width of the channel system amounted to 550 m at low flow (LW) and 730 m at summer mean water (SMW). A main channel was clearly recognisable, but in some reaches split into two morphologically similar anabranches with mean widths of 340 m at LW and 450 m at SMW. The sinuosity of the main channel - measured along the northern arm was 1.32. According to the classification of Leopold and Wolman (1957), the main channel of the Danube River was sinuous.

Because the Danube River also featured several small side arms, additional parameters may be used to describe past conditions. The ratio of total active channel length to valley length yields a total sinuosity of 5.22 (Richards 1982, Bridge 1993, Robertson-Rintoul and Richards 1993).

Based on 42 transects with a regular spacing of 250 m, the braiding index for 1812 is 4.10 (Bridge 1993, Thorne 1997). Based on the river classification of Nanson & Knighton (1996), the studied Danube River reach can be designated as a *gravel-dominated, laterally active anabranching river*. According to depth soundings at LW in 1812, the mean depth of both main channel arms along the thalweg reached 3.8 m, whereas the minimum depth was only 1.9 m. The analysis of the historical bed level by means of the longitudinal profile measured in 1812 shows a mean slope of 0.00055 m per m over the total river reach.

In 1812, this Danube River-floodplain system was characterised to a very high extent by eupotamal water bodies (main channel and side arms), offering a primarily lotic environment (97 % of the overall water surface area at LW, 94 % at SMW); shallow-water zones with gentle bed gradients were originally a formative element. This enabled a high diversity of depths, flow velocities and substrate conditions, resulting in a broad spectrum of micro- and meso-habitats with extensive shorelines. Para-, plesio- and palaeopotamal water bodies of the floodplain were much less frequent in relation to eupotamal ones. Nevertheless, they represented a great variety of distinct lentic habitats and contributed to the high extent of aquatic/terrestrial interfaces. The various floodplain elements were subject to constant modification and renewal due to strong erosion/sedimentation processes. Relic elements persevered longer solely on the older and higher terrace of the “lower postglacial valley floor“.

At mean water (MW) 41 % of the AZ were flooded and 57 % at bankfull water level which approximately corresponds to the 1-year flood (Q_1). At Q_1, flooding did not overtop the bank slopes and occurred only in the deeper, partly vegetated areas of the floodplain. Thus, 16 % of the AZ were directly affected by water level fluctuations between MW and Q_1. Thereby, the water surface expanded from the main channel over the AZ, enabling lateral connections to habitats more than 2 km away from the main channel. When water level rose above Q_1, the whole floodplain was gradually inundated. Total inundation of the AZ occurred during floods with return periods of 3-5 years ($Q_{3\text{-}5}$).

The intensive lateral connectivity of the former Machland river landscape is also reflected by the calculated volumes of surface water within the total study site (10-year flood area). Based on the modelled DTMs for the natural situation in 1812, the water volume amounted to 24.3 Mio. m³ at MW and 38.5 Mio. m³ at approximately Q_1. When the floodplain was entirely inundated at Q_{3-5}, water volume totalled c. 117.6 Mio. m³.

The highly dynamic hydromorphological processes of the former floodplain resulted in permanently changing and complex connectivity-conditions and therefore provided a high diversity of aquatic, semi-aquatic and terrestrial habitats. In the former floodplain, backwaters and vegetated abandoned channels served as transport and migration pathways for dissolved material, sediments, biomass and organisms at high runoff and flood events. The original aquatic/terrestrial transition zones and permanently changing habitat compositions point to the key role of fluvial dynamics and hydrological connectivity to sustain ecological integrity of natural river-floodplain systems.

Appendix 1, References historical fish fauna

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