Typology of the Danube River based on „top-down“ and „bottom-up“ approaches

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Introduction

Since December 2000 the European water management is ruled by a new common legislative construct establishing a „Framework for Community Action in the Field of Water Policy“ (European Commission 2000). In setting ecological targets for surface waters, the Commission has recognized the need for an integrated approach to assess the ecological status of water bodies. The bio-monitoring design of the „Water Framework Directive“ (WFD) intends that the ecological status must be determined with respect to the near-natural reference conditions, which represent a „high ecological status“. To describe reference conditions and to conduct a reference based quality assessment a typological framework is needed (Verdonschot & Nijboer 2004).

The development of a typology for the Danube River and the definition of according reference conditions is an essential part of the UNDP/GEF DRP (Danube Regional Project), considering the objectives of the Joint Action Program of the ICPDR and the Work Plans of the ICPDR Expert Groups. A basic strategy of the project’s design was the close co-operation with experts („national consultants“) from the Danube River Basin countries and to prepare an agreement among them.

Methods

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 for individual regions. To classify typological units of the Danube River a spatial (ecoregion-based) 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 River needed to be developed.

The methodological background 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

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information, to possibly validate it bottom-up as well as to define the (morphological and biological) reference conditions for the proposed Danube sections. The *a priori* procedure is based on a survey of existing typological descriptions.

The outcome of this top-down procedure has been validated using biological data sets (benthic macroinvertebrates) from the Joint Danube Survey (Literáthy et al. 2002) and comparing them by means of ordination and similarity analysis.

To describe the relationship of the benthic invertebrate communities of different sites a non-metric multidimensional scaling (NMS) was performed using PC-ORD 4.1 (McCune & Mefford 1999). 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 Van Sickle (1997) and Van Sickle & Hughes (2000) were used. Analyses were conducted using MEANSIM6 software, available from the USEPA, Western Ecology Division Web Site (http://www.epa.gov/wed).

Data refer exclusively to the Danube main channel. Data from the Danube tributaries as well as sites with a known, significant impairment (e.g. by organic pollution or hydro-morphological alteration like weirs and water abstraction) have been excluded from the analysis.

Results

The chapter summarizes the results of the top down analysis. Several systems to subdivide the Danube River into „homogeneous“ sections or types have been established before, most of them based on different eco-geographic parameters (e.g. geological structure, slope, geomorphology, hydrology). None of these proposals meet the typological requirements of the European Water Framework Directive (WFD) (European Union 2000).

The following different systems were used for creating the top-down typology:

1) The **Upper**, **Middle** and **Lower Danube** concept of various authors (e.g. Lászlóffy 1965) based on the catchment geology

2) A division based on the river slope presented by Lászlóffy (1965), resulting in six sections (**M**ountain section, Upper Danube, Middle Danube, Cataract-reach, Low Danube, Delta)

3) A JDS *a priori* division of nine sections, characterised by specific geo-morphological landscape features as well as anthropogenic impacts is given by Literáthy et al. (2002)

4) Eleven sections based on the geo-morphological regions crossed by the Danube Zinke Environment Consulting 1999)

5) Division of the Danube River according to the ecoregions of Illies (1978): Central Highlands, Hungarian Lowlands, Pontic Province, The Carpathians, Eastern Balkan.

Based on the categories discussed above the Danube River could be grouped into ten homogeneous Danube Section Types (Table 1). The resulting Danube reaches have been validated using biological data sets (benthic macroinvertebrates) from the Joint Danube Survey (Literáthy et al. 2002). For more details on the methodology please consult http://www.undp-drp.org/drp/en/activities_1-1_eu_wfd_implementation_fr_phase1.html.

Table 1: *A priori* derived top down 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

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 aerial allocation of the section. The rationales for the section type borders are as follows: confluence of the Danube with important tributaries (e.g. River Iller at Neu Ulm; River Inn at Passau); changes of the geo-morphological 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).

Discussion:

The discussion chapter summarizes the biological validation of the top-down typology. In a first step the validity of the WFD ecoregion approach was checked. The five ecoregions that are covered by the Danube catchment (Central Highlands, Hungarian Lowlands, Pontic Province, The Carpathians, Eastern Balkan) were applied as overlays. As a result of the NMS analysis the benthic invertebrate Danube biota clearly confirm the validity of the ecoregion approach. The similarity of benthic invertebrate assemblages within ecoregions is definitely higher than among ecoregions. Figure 1 gives the scatterplots for investigation sites in the ecoregions 9, 11 and 12 (one symbol represents one investigation site; figure gives only the two-dimensional view although the calculation was done three-dimensional).

In a second step the scatterplot of the JDS data was analysed with the results of the *a priori* (top-down) approach as overlay. Only nine of the ten Danube 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) could be verified because the first section type is lacking of JDS data, whose monitoring sites start at Neu Ulm (the upstream border of section type 2). Again the NMS analysis indicates that the similarity of benthic invertebrate assemblages within Danube section types is higher than among Danube section types. Figure 2 gives an example of the scatterplots for the section types 4, 5 and 6 (see legend).

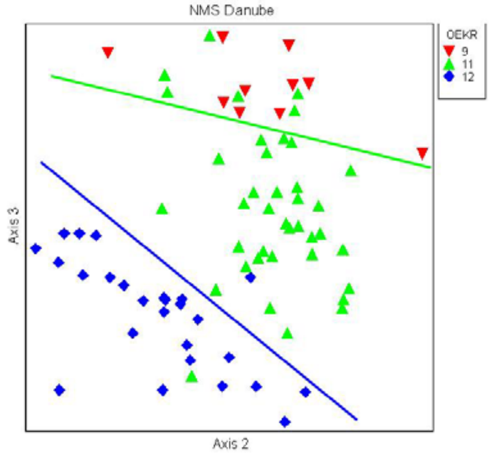

Figure 1: NMS scatterplot of JDS data. The overlay indicates the five ecoregions the Danube River is passing through (9 = Central Highlands, 11 = Hungarian Lowlands, 12 = Pontic Province; ecoregions according to Illies (1978)

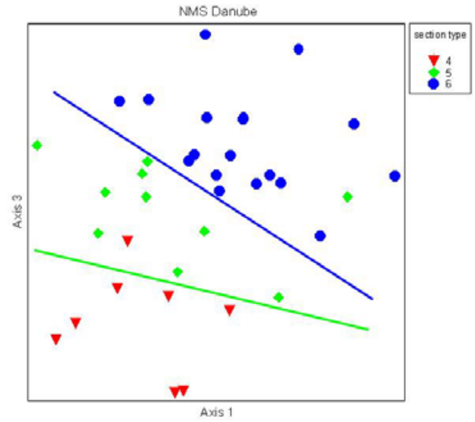

Figure 2: NMS Scatterplot of JDS data for the Danube monitoring sites. The overlay indicates three section types (4 = Lower Alpine Foothills Danube, 5 = Hungarian Danube Bend, 6 = Pannonian Plain Danube) according to the top-down typology.

Besides these promising results the three traditionally separated major reaches among the Danube Section Types could be clearly distinguished by the composition of the benthic invertebrate fauna: the Upper Danube (section types 2-4), the Middle Danube (section types 5-6, and the Lower Danube (section types 7-10).

In a last step a detailed NMS ordination analysis was performed to define the exact borders of the Danube section types. The borderline between some section types could be clearly defined due to apparent eco-geographic and biotic differences. E.g. there was a clear separation of the section types 3 and 4, whose boundary corresponds with the borderline between the ecoregion 9 (Central Highlands) and 11 (Hungarian Lowlands). In those cases where the eco-geographic features along a Danube stretch were not so obviously different a clear separation has been performed primarily on the basis of the benthic communities.

Summary:

As a result 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 (Table 1) could basically be statistically confirmed by the according bottom-up procedure. The delineation of the exact borders of the Danube section types was based on eco-geographic criteria and the benthic invertebrate assemblages. The stream section typology of the Danube River is recommended as an important and sound product for further tasks of implementing the WFD.

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