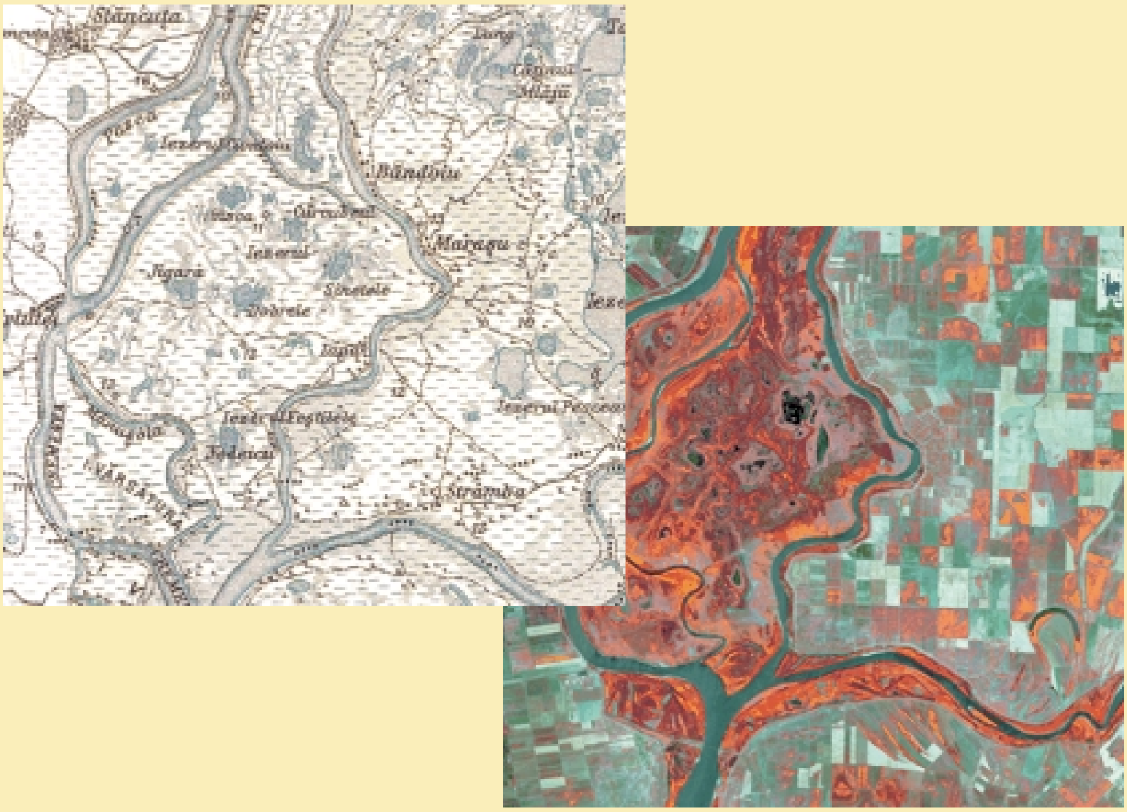
# DANUBE POLLUTION REDUCTION PROGRAMME

# EVALUATION OF WETLANDS AND FLOODPLAIN AREAS IN THE DANUBE RIVER BASIN FINAL REPORT

## MAY 1999




**Programme Coordination Unit**
**UNDP/GEF Assistance**

*prepared by*

**WWF Danube-Carpathian-Programme**
**and WWF-Auen-Institut (Germany)**

WWF

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# Preface

The "Evaluation of Wetlands and Flkoodplain Areas in the Danube River Basin" study was prepared in the frame of the Danube Pollution Reduction Programme (PRP). The Study has been undertaken to define priority wetland and floodplain rehabilitation sites as a component of the Pollution reduction Programme.

The present report addresses the identification of former floodplains and wetlands in the Danube River Basin, as well as the description of the current status and evaluation of the ecological importance of the potential for rehabilitation. Based on this evaluation, 17 wetland/floodplain sites have been identified for rehabilitation considering their ecological importance, their nutrient removal capacity and their role in flood protection. Most of the identified wetlands will require transboundary cooperation and represent an important first step in retoring the ecological balance in the Danube River Basin.

The results are presented in the form of thematic maps that can be found in Annex I of the study. The study was prepared by the WWF-Danube-Carpathian-Programme and the WWF-Auen-Institut (Institute for Floodplains Ecology, WWF-Germany), under the guidance of the UNDP/GEF team of experts of the Danube Programme Coordination Unit (DPCU) in Vienna, Austria.

Wetland experts were selected in each participating Danube country to ensure full participation at the national level while taking into account local priorities in identifying the potential for wetland restoration. Moreover, the wetland sites were discussed in the frame of National Planning Workshops and projects were identified for restoration activities. In the frame of the Transboundary Analysis Workshop in January 1999 held in Hernstein, the preliminary results of the study have been presented, An additional four wetlands sites have been identified and included in the presentation of the thematic maps.

The conceptual preparation and the organization of activities were carried out by Joachim Bendow, UNDP/GEF Project Manager and Andy Garner, UNDP/GEF Environmental Specialist who also followed and coordinated the development of the project. The report has been edited by Michael Sokolnikov.

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WWF would like to express their thanks to all scientific colleagues who have contributed to this project by providing data.

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# Summary

The potentially important role that natural floodplains can play in flood reduction, water quality improvement and maintaining biodiversity in the Danube River Basin has been documented in a number of studies and reports. There has, however, never been a comprehensive and systematic evaluation of the existing extent of natural floodplains in the Danube River Basin and the potential for restoration of former wetlands. UNDP/GEF commissioned this study as part of the Danube River Pollution Reduction Programme to address this shortcoming and to provide the basis for evaluation of the potential for wetland restoration to form a part of the strategies identified for bringing about environmental improvement in the Danube River Basin.

The study was conducted by the WWF Germany Floodplain Institute together with the WWF Danube Carpathian Programme Office and evaluated the potential for wetland restoration along the main channel of the Danube River and 5 main tributaries, the Prut, Tisza, Sava, Drava, and Morava.

Given the Danube catchment area's heterogeneous structure and the well known eventful historical conditions, homogeneous data/maps over the entire area are only to a very limited extent available. This is also true for data on recent and historical floodplain areas. On the basis of extensive investigation, however, the deliniation of both the morphological and the recent floodplain could, in a first step, be determined for the whole Danube and for its larger tributaries (Morava, Drava, Tisza, Sava and Prut) (map 1).

The total area of historical floodplain wetlands in the area of investigation was 41,605 $km^2$. The study found that the total area of remaining floodplain wetlands in the area of investigation was only 7, 845 $km^2$. The remarkable extent of floodplain loss in the study area is therefore in excess of 80%.

To evaluate the floodplains investigation area with respect to their ecological value and their rehabilitation potential, they had to be divided into sections. The segmentation resulted from a combination of various factors: the first and determining factor was the floodplain width. This factor is in turn determined by geomorphological, river morphological and hydrological factors. Detailed landuse data have been used for a further refinement of the segmentation. The minimum size for segments was fixed to 15 km (map 3).

Selected bioindicators were expected to contribute to the estimation of the ecological value of the investigated floodplains. Extensive investigation in the Danube catchment area of bioindicator data demonstrated, that geographically extensive and current data are not available, or only very limited, for this area. For certain species only local or regional information exists on their occurrence (map 5/6).

To create an evaluation consistent throughout the whole area, factors that were available everywhere had to be chosen. In addition to the data on floodplain size and type, surface-covering landuse data were also available. They existed in the form of current CORINE-LandCover data for the major part of the investigation area. For the other areas of the Danube catchment area (Ukraine, Moldova, Slovenia, Croatia, Bosnia-Herzegovina, FR Yugoslavia, Albania), current landuse data had to be elaborated through satellite image classification.

An evaluation procedure based on the following factors has therefore been developed:

- floodplain type (recent floodplain (4), outlet section/polder (2), former floodplain (1)),
- floodplain width (> 5 km(4), 2,5-5 km (3), 1-2,5 km (2) and 0-1 km (1)),
- landuse data (forest (4), swampland/water (4), meadows (3), farmland (2/1), settlements (0)).

The evaluation resulted from a classification of the three factors according to the values in brackets. Floodplain type and width appear as multipliers of the actual landuse in the specific section. The landuse was valued and calculated percentally in a first step. The results have been grouped in four classes from a low to a very high ecological value. 450 sections have been evaluated. The result has been represented in the map 4 "Ecological Potential of Floodplains in the Danube River Basin".

Besides the ecological value, the nutrient reduction potential had to be studied as well. It is an uncontested fact, that recent, inundated floodplains have a positive effect on water quality improvement and nutrient input reduction if they are not subject to intensive agricultural use. This is why one may suppose that all areas of the ecological potential map that have been considered as being valuable or very valuable have a high nutrient reduction potential (map 4). The reduction extent however cannot be definitely quantified at the moment due to insufficient and inhomogeneous available data. The required data and the methodology to do this have been described in the text. It can be argued, however, based upon review of the studies mentioned above and the general knowledge on all factors influencing the Danube basin, that a range of values for nutrient reduction can be proposed. They may be represented as follows:

- kg total N/ha/year: 100-150
- kg total P/ha/year: 10-20

As a result of numerous alterations to the Danube and the other rivers investigated, there is a general problem of deepening of the channel which has an important influence on the restoration potential. In particular the deepening of the channel reduces the frequence of flooding. This problem has to be addressed and measures to prevent this deepening as well as remedial measures are necessary.

The evaluation of the rehabilitation potential considered only former floodplains with a width of more than 1 km. Both the existing segmentation and the landuse data have again been used. The evaluation have been classified in four classes. The main factors used in the evaluation were:

- unsettled or scarcely settled areas
- connected areas
- large old floodplain structures

Experience shows that political and socio-economical conditions (property structure, status of the area, political decision-makers) play a far more important role in the realization of rehabilitation projects than the actual landuse. These factors, however, have not been examined in detail and require further investigation. The results are represented in the map 7, "Restoration of Former Floodplains in the Danube River Basin". The areas recommended for restoration are areas with a high or very high rehabilitation potential. The selection of these areas is based on criteria such as realizability, transboundary character and regional knowledge of ecological value.

The 17 sites identified are as follows:

***Upper Danube:***

1. floodplains near Ingolstadt (Germany)
2. Isar mouth (Germany)

***Morava:***

3. Drösing forest/Sierndorf (Austria)
4. North of Hodonin (Czech Republic)

***Central Danube:***

5. Area from Gemenc to Kopacki Rit (Hungary, FR Yugoslavia, Croatia)

***Drava:***

see central Danube, Kopacki Rit

***Sava:***

6. Drina mouth area (FR Yugoslavia, Bosnia-Herzegovina and Croatia)
7. Mokro Polje area (Croatia)

***Tisza:***

8. Upper Tisza/Bodrog mouth (Hungary)
9. Lower Tisza (FR Yugoslavia)

***Lower Danube:***

As can be seen on the map, many areas with a very high and high rehabilitation potential exist along the Romanian Danube. In principle, these areas should all be analyzed with respect to their actual rehabilitation potential. In order to facilitate progress we propose four areas, one in Romania, the others in the transboundary area:

10. Balta Potelu (near Oriakovo)
11. Bulgarian Danube islands and opposite area in Romania
12. Balta Greaca (Romania)/Tutrakan (Bulgaria)
13. Balta Calarasi

***Prut***

14. Lower Prut

***Danube Delta:***

15. Liman lakes (Ukraine)
16. Pardina polder
17. Ukrainian part of the Danube Delta

In the following table an overview of the proposed restoration areas with a first rough application of the nutrient potential and its potential value is visible.

As a final word we recommend that in addition to further examination and investigation of the proposed restoration sites, the following aspects should be considered for future work:

- Application of the methodology to additional rivers (e.g. Inn, Wag, Mures, Siret etc.)
- Elaboration of protected area concepts for ecologically valuable areas
- Publication of the results in a form that makes them accessible to a broader public
- Organization of a digital information system to make the extensive information of the floodplains in the Danube River Basin and the evaluation results in digital form available all over the world.

**Table 1** **List of proposed restoration areas**

| | Site | Country | Proposed study area for future restoration | Area of recent floodplains included in proposed study area | Proposed study area, only former floodplains | Estimated portion of restorable area in the former floodplains | Potential Rest. Area (min.) | Potential Rest. area (max.) | N-reduction (min) | N-reduction (max) | P-reduction (min) | P-reduction (max) | Value of potential nutrient reduction (min) | Value of potential nutrient reduction (max) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | ha | ha | % | ha | ha | t/y/site | t/y/site | t/y/site | t/y/site | US $ | US $ |
| | | | | | | | | | (100 kg/y/ha) | (100 kg/y/ha) | (10 kg/y/ha) | (10 kg/y/ha) | (250 US$/ha/y) | (250 US$/ha/y) |
| 1 | Floodplains next to Ingolstadt | D | 1.500 | 0 | 1.500 | > 75 % | 1.125 | 1.500 | 113 | 150 | 11 | 15 | 281.250 | 375.000 |
| 2 | Mouth of Isar | D | 1.700 | 400 | 1.300 | 50 – 75 % | 650 | 975 | 65 | 98 | 7 | 10 | 162.500 | 243.750 |
| 3 | Drösing forest | A | 3.000 | 800 | 2.200 | 50 – 75 % | 1.100 | 1.650 | 110 | 165 | 11 | 17 | 275.000 | 412.500 |
| 4 | Floodplains next to Strasnize | CZ | 2.200 | 200 | 2.000 | 50 - 75 % | 1.000 | 1.500 | 100 | 150 | 10 | 15 | 250.000 | 375.000 |
| 5 | Area between Gemenc and Kopacki Rit | H/HR/YU | 250.000 | 70.000 | 180.000 | 25 - 50 % | 45.000 | 90.000 | 4.500 | 9.000 | 450 | 900 | 11.250.000 | 22.500.000 |
| 6 | Area of Drina mouth | YU/BIH/HR | 60.000 | 10.000 | 50.000 | 25 - 50 % | 12.500 | 25.000 | 1.250 | 2.500 | 125 | 250 | 3.125.000 | 6.250.000 |
| 7 | Makro Polje | HR/BIH | 12.400 | 1.000 | 11.400 | 50 – 75 % | 5.700 | 8.550 | 570 | 855 | 57 | 86 | 1.425.000 | 2.137.500 |
| 8 | Mouth of Bodrog | H | 10.000 | 7.000 | 3.000 | > 75 % | 2.250 | 3.000 | 225 | 300 | 23 | 30 | 562.500 | 750.000 |
| 9 | Lower Tisza | YU | 36.000 | 3.000 | 33.000 | 25 – 50 % | 8.250 | 16.500 | 825 | 1.650 | 83 | 165 | 2.062.500 | 4.125.000 |
| 10 | Balta Potelu | RO/BG | 27.000 | 7.500 | 19.500 | > 75 % | 14.625 | 19.500 | 1.463 | 1.950 | 146 | 195 | 3.656.250 | 4.875.000 |
| 11 | Area of Bulg. Danube Islands | RO/BG | 27.000 | 7.000 | 20.000 | > 75 % | 15.000 | 20.000 | 1.500 | 2.000 | 150 | 200 | 3.750.000 | 5.000.000 |
| 12 | Balta Greaca/ Tutrakan | RO/BG | 54.000 | 9.000 | 45.000 | > 75 % | 33.750 | 45.000 | 3.375 | 4.500 | 338 | 450 | 8.437.500 | 11.250.000 |
| 13 | Kalarasch | RO | 10.000 | 0 | 10.000 | > 75 % | 7.500 | 10.000 | 750 | 1.000 | 75 | 100 | 1.875.000 | 2.500.000 |
| 14 | Lower Prut | RO/MD | 51.000 | 20.000 | 31.000 | 50 – 75 % | 15.500 | 23.250 | 1.550 | 2.325 | 155 | 233 | 3.875.000 | 5.812.500 |
| 15 | Liman Lakes | UA | 38.000 | 12.000 | 26.000 | > 75 % | 19.500 | 26.000 | 1.950 | 2.600 | 195 | 260 | 4.875.000 | 6.500.000 |
| 16 | Polder Pardina | RO | 27.000 | 0 | 27.000 | > 75 % | 20.250 | 27.000 | 2.025 | 2.700 | 203 | 270 | 5.062.500 | 6.750.000 |
| 17 | Ukr. Part of Danube Delta | UA | 27.000 | 7.000 | 20.000 | 25 – 50 % | 5.000 | 10.000 | 500 | 1.000 | 50 | 100 | 1.250.000 | 2.500.000 |
| | | ∑ | 637.800 | 154.900 | 482.900 | | 208.700 | 329.425 | 20.870 | 32.943 | 2.087 | 3.294 | 52.175.000 | 82.356.250 |

# 1. Introduction

On its 2800 km journey from the Black Forest to the Black Sea, the Danube crosses ten European states. Its catchment area, with a surface of 805,300 $km^2$, includes 17 states. Like no other European river it links different natural and cultural landscapes. In addition to important capitals such as Vienna, Budapest and Belgrad one also finds remarkable floodplain areas along the Danube. Among these are the area of the Isar mouth between Straubing and Vilshofen (Germany), the Danube floodplains situated East of Vienna up to Hainburg, the Gemenc-Beda floodplain forest in Southern Hungary and the Bulgarian Danube islands near Belene and Svistov up to the Danube Delta in Romania/Ukraine. Within the frame of its 'Green Danube Programme' (part of the Danube-Carpathian programme), WWF, together with local partners has fought for the protection, conservation, rehabilitation and sustainable use of these floodplain areas along the Danube.

The areas listed above make up merely a small part of the former floodplain areas situated along the Danube and its tributaries. To obtain a general, global and transboundary view of the Danube's floodplain areas, the WWF-Auen-Institute conducted the present study on all existing and former wetland areas along the Danube river and its large tributaries (Morava, Drava, Sava, Tisza and Prut). The study has included an ecological evaluation that will be relevant with regard to future nature conservation projects in the Danube river basin.

This study has been conducted on behalf of UNDP/GEF which is part of the Programme Coordination Unit (PCU) of the Environmental Programme for the Danube River Basin. The programme has brought together international organizations (GEF, UNDP, EU, etc.) for the purpose of achieving environmental improvement in the Danube river basin. Although the PCU has existed since the early 1990's. A consistent, common database of the wetland areas situated along the Danube river and its tributaries was lacking. The elimination of this deficiency is among the major objectives of this project. On the basis of this mutually elaborated database, it is expected that specific rehabilitation projects can be prepared and implemented.

# 2. Background and Methodology

To evaluate the recent and historical floodplain areas along the studied rivers the first step was to develop unequivocal definitions regarding generally accepted deliniation of the areas. The following definitions were developed:

Morphological floodplain: the whole area of the floodplain that was formerly flooded without major anthropogenic influence. It is generally marked by a terrace. The period referred to dates from about 300 years ago.

Recent floodplain: floodplain areas that are flooded recently during flood events. The maximum extension of this recent floodplain usually corresponds to the inundation area of a centennial flood event. Its deliniation may however only be defined with accurate contour data of the attending dykes. This is why the deliniation has been fixed with respect to the present dyking system.

Former floodplain: the area of the morphological floodplain that is no longer inundated, in general cut off from the recent floodplains by dykes.

Attending lowlands: lowlands that are no longer part of the actual morphological floodplain, where the flood influence may however be noted, e.g. from groundwater.

Given the Danube river basin's heterogeneous structure and the well-known eventful history, sufficient homogeneous data covering the entire area were not available. This is why extensive investigations had to be carried out to record the selected floodplain areas.

Investigations were concentrated on the following fields:

- Historical maps: deliniation of the morphological floodplain and recording of the former floodplain areas
- Current topographical maps: to record the recent floodplain areas, topographical maps at a scale of 1:50.000 to 1:200.000 with registered dyking systems have been studied
- Investigations have been made of available digital data as well as adequate satellite images to obtain the necessary landuse data for the recording of the floodplain area structure. The landuse data could be obtained with an appropriate classification of these data.
- Natural structure data: to achieve a wise classification of the floodplain areas, the present natural structure of the Danube river basin has been studied.
- Hydrological data.
- Bioindicators: To substantiate the ecological value, intensive discussions and data investigations have been carried out in this field.
- Existing large-scale protected areas.
- Nutrient load data.
- Data for an economic evaluation of the floodplain areas.

## 2.1. General Spatial Data

### 2.1.1. Historical Maps

The necessary historical maps had to date from the time before the major river engineering measures had been implemented in the investigation area. Moreover, they had to show an appropriate cartographical-geometrical quality to allow an overlaying with recent spatial data in the course of the processing of the maps.

This is why the maps of the Austrian-Hungarian Imperial and Royal monarchy dating from the last century turned out to be appropriate. The 'General map of Central Europe' revealed to be a good basis for this project. On the one hand it was of outstanding quality, elaborated from 1889-1915, i.e. before the implementation of the major river training measures on the Danube. On the other hand, it covered an extensive area at a medium scale of 1:200.000.

More than 70 maps have been scanned, georeferenced and put into a mosaic to create a homogeneous historical map.

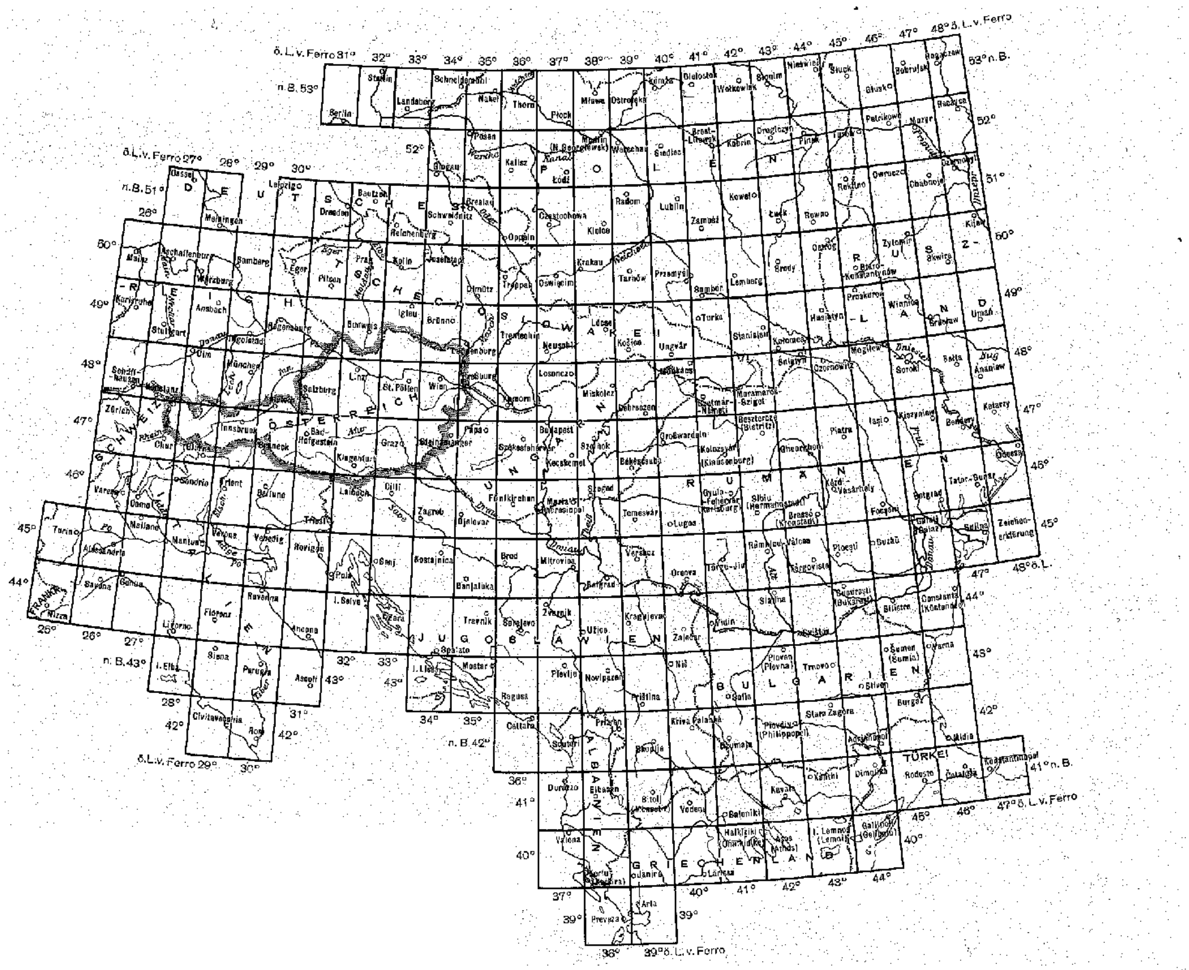


**Figure 1** **Overview of the “Generalkarte von Mitteleuropa”**

## 2.1.2. Current Maps

### 2.1.2.1. Topographical maps

An attempt was made to obtain easily comparable maps for all of the countries involved. For the withdrawal of essential data (dam courses, deliniation of morphological/recent floodplains, settlements, landuse), topographical maps at a scale of 1:50.000 - 1:200.000 were needed.

The procurement of current maps proved to be difficult, even though 8 years have passed since the political opening of the Eastern European countries. **Table 2** shows the heterogeneity of the maps for every country and the time gaps between the various cartographical updates (Romania since 1964, Germany 1997). To evaluate the dyking systems (many dams have been erected in the 1970's only) current satellite data (Landsat for Serbia/Croatia) and local specialists (e.g. for Romania) had to be consulted. In establishing the dyking systems, the training measures (e.g. flood protection for 5-year, 10-year and centennial events) could not be considered, as this information is only available for a few countries.

**Table 2 Overview of the Topographic Maps used.**

| Country | Designation | Recording period | Map sheets used | Scale |
|---|---|---|---|---|
| Germany | TK 50 | 1990-1997 | Baden- Württem-berg/Bayern (digital) | 1: 50 000 |
| Austria | ÖK 50 | 1988-1997 | 12, 13, 30-33, 37-41, 51-55, 59-62 | 1: 50 000 |
| Czech Republic | Základnà mapa CR | 1988-1990 | 24-4-2(-3,-4), 25-1-1(-3),<br>34-2-2(-3,-4), 34-4-1 | 1: 50 000 |
| Slovak Republic | Slowakia | 1985- 1991 | 34-2-4(-4-1,-3), 44-2-1(-3,-4), 45-3-3(-4)<br>45-4-3(-4) | 1: 50 000 |
| Hungary | Magyar Nekoztarasag | 1988- 1996 | 15,17,25,27,35,37,45, 47,55,57,65,67,68,72-75,78,82,88,89,99,710 ,711,810,811,910 | 1: 100 000 |
| FR Yugoslavia | Jugoslavija | 1972-1988 | L-34-: 65,73- 77, 85-91, 97-101, 109-118, 128-130 (alle A-D) | 1: 50 000 |
| Romania | Romania | 1964-1975 | Not available | 1: 50 000 |
| | Romania<br>AMS (USA) | 1960/61 | 4385 I, 4386 I,III, 4387 I,III | 1: 50 000 |
| Bulgaria | Bulgaria | 1964- | 3882 III,IV,<br>4982 I,II | 1: 50 000 |
| Molodova/Ukraine<br>(former. USSR) | SSSR | 1986-1990 | L-35-IV,-X,-XI,-XVII,<br>M35XXIII,-XXIV | 1: 200 000 |

#### 2.1.2.2. Thematic Maps

The thematic maps used consist of both single maps and country atlas. The maps are available at a scale between 1:300 000 and 1:750 000. The maps from country atlas usually are at a scale between 1:750 000 and 1:million. The following country listing once again shows the heterogeneous although comparable data of the individual countries. The thematic maps served to deliniate the morphological floodplain, with preference for use responding to the following ranking:

- pedological maps
- geomorphological maps
- (quartary)-geological maps.

In addition, special inundation maps were available for some countries. These require, however, a precise analysis: the deliniation criteria reach from extreme flood events (current map for the Czech Republic) to historical inundation areas of various types in Hungary.

To define the limits of the morphological floodplain, one has to consider the last 300 years. One may suppose that the flow regime has not substantially changed since that time (systematical gauge recordings are however only available since the middle of the last century). "Grown settlements" without a systematical flood protection that were constructed later in some lower situated locations (e.g. Szigetköz in Hungary/Slovak Republik) may serve as deliniation indicators, especially in undifferentiated lowlands.

Moreover, the broad lowlands of the pannonian basin (particularly along Tisza and Danube) that are inundated every year by lateral tributaries, have not been considered.

**Table 3 Overview of the geological/geomorphological maps used.**

| Country | Subject | Scale |
|---|---|---|
| Germany | geomorphology, soils<br>(special inundation maps) | 1: 25 000-1: 100 000 |
| Austria | pedological maps | 1: 200 000 |
| Czech Republic | geomorphology, soils<br>(special inundation maps) | 1: 750 000 |
| Slovak Republic | geomorphology, soils | 1: 1 000 000 |
| Hungary | quartary geology, geomorphology, soils<br>(special inundation maps) | 1: 300 000,<br>1: 1 000 000 |
| Yugoslavia | geology | 1: 500 000 |
| Romania | geomorphology | 1: 300 000 |
| Bulgaria | geomorphology | 1: 1 000 000 |
| Molodova/Ukraine | geology, geomorphology | 1: 1 500 000 |

### 2.1.3 Landuse data

The project benefitted from the availability of the CORINE-Landcover-data for most of the Eastern European countries. The CORINE project was initiated in the European Union in the late 1980's with the objective to elaborate a homogeneous, recent and comparable database for all EU member states. The landuse data were produced on the basis of satellite classifications. Since the early 1990's, the CORINE-methodology has as well been applied to many Eastern European countries. The areas from the Baltic states to Bulgaria have been completed within the frame of a PHARE-project under the sponsorship of the European Environmental Agency. For the countries of FR Yugoslavia, Slovenia, Croatia, Bosnia-Herzegovina as well as for Albania, Moldova and Ukraine, the data were not available.

The Corine data are presented in 44 landuse classes and in different digital raster- and vector-based formats. For further processing, the data were reclassified in 11 main classes:

1. Settlements
2. Gravel and sand pits
3. Intensively used agricultural land
4. Farmland of heterogeneous structure
5. Grassland
6. Mixed forests
7. Coniferous forests
8. Vegetation-free areas
9. Wetlands
10. Water courses
11. Water bodies

For further evaluation the raster data were used with a 100 m ground resolution.

### 2.1.4. Remote Sensing Data

As CORINE Landcover data are not available for the whole Danube catchment area, satellite images had to be interpreted to obtain the landuse data.

The satellite images have been taken between 14.9. and 6.10.1997 by the Indian IRS-1C satellite. Each satellite scene comprises a size of 800 x 800 km with a spatial resolution of 188 m for the two channels 'near-infrared' and 'infrared'. Given the high spatial resolution per scene, it was possible to capture the major part of the Danube catchment area with 4 satellite images at a relatively low cost.

The satellite images have been worked over by GAF company, Munich, i.e. rectified, adjusted radiometrically and georeferenced.

The landuse classification has been elaborated within the frame of Franz Diegruber's diploma thesis at FH-Karlsruhe, in the cartography/geoinformatics course of studies. The classification has been obtained with the processing software Erdas Imagine 8.3 used on a Unix workstation.

Given the low spatial resolution of 180 m, the mixed pixel problem was serious. Several small structured landuse forms within a pixel of 180 x 180 m were proportionately mixed to obtain a spectral value for the whole pixel. This spectral value was then assigned to a certain class with a lower probability. The higher the number of small-structured elements in a pixel, the more difficult it is to assign them to a certain class.

In the course of classification one had to realize, that given an intensive spectral dispersion of constructions, the latter distinctly overlapped for its farmland and grassland classes. This is why this class has finally been dropped. The cultivated areas were mainly assigned to the 'farmland' class, but also to the 'grassland' one.

Because the various landuse forms distinctly overlap in some parts with merely two spectral channels, misclassifications occurred for some areas. Among these problematic areas are: shallow areas, shadow areas around clouds, and valleys.

The probabilities of an accurate assignment to the different classes may, if compared to the neighbouring CORINE-data, be estimated as follows:

| | |
|---|---|
| Clouds | 95% |
| Water | 88% |
| Forests | 83% |
| Grassland | 70% |
| Farmland | 75% |

Given the low spatial resolution of the photos, two additional satellite photos of the American Landsat satellite have been purchased for especially important regions in Croatia and Serbia (30 m x 30 m ground resolution, 180 km x 180 km per scene). A total coverage of the investigation area by means of these high-resolution satellite images would have necessitated purchase of more than 50 scenes which would have by far exceeded both the financial recources of the whole project and lengthened its duration.

### 2.1.4.1. Landsat Evaluation Methodology

Two Landsat TM 5 satellite scenes dating August and October 1997 were available for the evaluations. To integrate these data within the GIS framework, several pre-processing steps had to be carried out.

To transform the satellite data to a coordinate system, the data was georeferenced to topographical maps at a scale of 1:50 000. This rectification process was realized by means of ground control points using an affine transformation.

The Landsat satellite orbit is at about 705 km altitude above ground. The atmosphere between satellite sensor and ground surface affects the radiometric quality of the different spectral bands by absorption and scattering processes. To reduce these effects a correction was performed, based on a 5-S Radiation-Transfer-Model developed by TANRÉ et al. (1985, 1990).

For statistical and practical reasons a principal component analysis was completed on the datasets. This led to a reduction of the data size while keeping 98 % of the initial information. These datasets were used for the classification process.

The landuse classification was performed using a hybrid classification concept, based on a combination of a super- and unsupervised technique (RICHARDS 1994). Representative prototype pixel were collected for each landuse class and separated by means of an unsupervised classification. The resulting spectral signatures were used as input for a supervised Maximum-Likelihood-Classification.

#### 2.1.4.2. Evaluation of the Landsat Classification Results

Given the satellite's repetition rates and the weather conditions in Europe, it proved to be difficult to find the optimum combination of a cloudless scene and the phenological situation of the agricultural landuse. To maintain the satellite data consistent and comparable to the CORINE data, the satellite scenes had to date from 1997. Unfortunately, only one completely cloudless scene was available for this region in 1997. This scene has been shot on October 7th, 1997 and covers the Danube basin in Serbia and Eastern Croatia. The late date of this photo, however, created a number of problems for the data analysis.

On the one hand, the harvest had already been brought in at the moment of the shooting, so many fields appear as fallow land, bare soil. The spectral signature of bare soil, however, because it has the same mineral composition (clay minerals, sand, silt) corresponds to that of cultivated land. A spectral separation is therefore very difficult if not impossible in many cases. The settled areas have thus been digitalized and interpreted manually. This process is a visual interpretation and because some villages may not have been recorded, may thus lead to an underestimation of the settled areas.

On the other hand the low sun position in October caused negative illumination effects. Small or very high valleys may be shadowed, which leads to classification errors and an overestimation of forest areas, especially of coniferous woods. Because the investigation areas are however mainly located in lowlands, these illumination effects may be neglected for the project purposes.

The second satellite scene was obtained on August 11th, 1997, it comprises images of mostly Croatian areas and parts of Eastern FR Yugoslavia. Both the illumination effects and the phenological situation are better, even though this scene is not totally cloudless. Cloud shadows lead to a weakening of the spectral signals on the ground and thus imply misinterpretations and overestimations of water and forest areas. Some areas along the Danube were flooded at the moment of the shooting which resulted in an overestimation of water areas and wetlands.

For the evaluation of the Danube floodplains, the landuse data must not be as detailed as the CORINE data. This is why despite the restrictions on the data quality their use is justified. All important landuse classes for the evaluation could be separated out and classified.

## 2.2. Geographical Subdivision

Ecological classifications comprise delineable landscape units that are characterized by their geological, climatological, geomorphological, geobotanical and, in a broader sense, landscape ecological forms (see MEYNEN, SCHMITHÜSEN,1953, LESER, 1976).

The approach to the actual area of interest, i.e. the Danube floodplains and its larger tributaries, was orientated by the natural and physiogeographical classifications of the various countries. Existing classifications of Germany, Austria, Hungary, Bulgaria and Romania could be directly taken over. The objective of this classification is the deliniation and combination of area sections and single areas. The area sections have therefore been subdivided into 5 different morphological types:

1. Lowlands (river attending lowlands)
2. Plains/Terraces (areas adjacent to the river attending lowlands)
3. Hills
4. Mountains
5. Narrow gorges

In the map these 5 types have been visualized with orographic colours (green for lowlands up to brown for mountains).

The third classification level corresponds to a phyto-climatological large-scale classification subdividing the catchment area into 6 large units.

For the topographical and thematical maps, the following data was used for the different countries:

**Table 4 Overview of the used basis material used**

| Country | Designation | Source/Basis | Scale |
|---|---|---|---|
| Germany | Biogeographical subdivision | MEYNEN, SCHMITHÜSEN | 1: 200 000<br>1: 1 000 000 |
| Austria | Landscape Types | HASSINGER | 1: 500 000 |
| Czech Republic | Geographical Subdivision | ATLAS CESKOSLOVENSKE SOCIALISTICKÉ REPUBLIKY | 1: 1 000 000 |
| Slovak Republic | | ATLAS SLOVENKEJ SOCIALISTICKEJ REPUBLIKY<br>(+ topographical maps) | 1: 1 000 000,<br>1: 300 000 |
| Hungary | Landscape Types | MAGYARORS-ZAG NEMZETI ATLAS | 1: 1 000 000 |
| FR Yugoslavia | | (+ topographical maps) | 1: 50 000-<br>1: 500 000 |
| Romania | Landscape Types | ATLAS DER REPUBLICA SOCIALISTA ROMANIA | 1: 100 000 |
| Bulgaria | Geographical Subdivision | BULGARIAN NATIONAL-ATLAS | 1: 500 000 |
| Molodova/ Ukraine | Geographical Subdivision | ATLAS CCCP | 1: 1 500 000 |

## 2.3. Hydrological Data

The characteristics and the current state of the floodplains are mainly due to the various hydrological factors that will be gathered for the whole catchment area. Among these factors are the water regime and the flow situation in the respective catchment areas that are already characterized by very complex elements (precipitation, evapotranspiration, geology, relief, soils, vegetation, landuse). Moreover, the major dams and hydropower plants will be listed and briefly described.

## 2.4. Bioindicators

### 2.4.1. Basics

In the floodplain's natural framework of ecological effects, the hydrological and morphological dynamics play an essential role. They determine the natural structure and dynamics of the habitats and are decisive for the classified mosaic of habitats and the spatial distribution of the species characteristic of these habitats. Training measures and the loss of morphological dynamics have, in certain sections, contributed to a dramatic decrease of floodplain habitats and their characteristic species composition. The existence of characteristic plant and animal species serves as indicators of dynamics (water level fluctuations, substrate dynamics), development states of vegetation and animal settlements, nutrient dynamics, sedimentation, water quality but also certain exploitations. Using bioindicators one can determine the habitat's site quality and the degree of man-caused alterations.

Some representatives of flora and fauna with bioindicator value have been chosen among the whole spectrum of floodplain characteristic species. By means of these species one may, even in altered habitats, rapidly carry out an evaluation.

Unfortunately, however, a complete zoo- or phytoecological registration and evaluation of the area or parts of it, with its complex framework of ecological effects, is not realizable. Even the indicator method will merely lead to an exemplary representation of complex ecosystems. The statements that may be obtained are thus limited.

The evaluation of indicator species has thus to be judged with respect to what was realizable within the frame of this project and what could be of future interest. The indicator species were useful in the determination of the ecological value and with regard to possible rehabilitation projects.

The availability of data on species in the Danube river basin played a decisive role in choosing the indicator species. Distribution data exist for many species, but they have been elaborated differently for the various countries and are, in many cases, rather old dated. Some indications merely consider large areas and thus do not allow a distinct assignment to certain river stretches.

Numerous species, given their natural occurrence, may merely be considered for certain river stretches and not as indicators for the whole investigation area (see also chapter 2.4.3, comp to ELLENBERG et al. (1991), KREEB (1990)).

## 2.4.2. Selection Criteria

The selection of various species as bioindicators were based on the following criteria:

1. The species have to show characteristic floodplain habitat conditions and qualities.
2. The chosen bioindicator species are autochthonous in the Danube catchment area.
3. The bioindicator species basically occur in floodplains (but they do not have to be exclusively bound to them).
4. The occurrence of bioindicator species will not be falsified through artificial stocks or plantations, e.g. fish stocks or plantation of species that are not characteristic of the sites.
5. Taxonomically the bioindicator species are distinctly defined and may be reliably determined.

The following species have thus been chosen as bioindicators and have been subject to closer research:

***Higher plants***

German tamarisk (Myricaria germanica)
Grey willow (Salix elaeagnos)
Tamarisk (Tamarix ramosissima)
White willow (Salix alba) / only surface-covering natural succession
Black poplar (Populus nigra) / surface-covering natural succession
Narrow-leaved ash (Fraxinus angustifolia; incl. ssp. pannonica)
Wild vine (Vitis sylvestris)
Greek liana (Periploca graeca)
Summer snowflake (Leucojum aestivum)
Limosella aquatica
Cyperus species (Cyperus flavescens, c. fuscus, c. michelianus)
Water chestnut (Trapa natans)
Clematis integrifolia
Viola persicifolia

***Butterflies***

Danubian Purple Emperor (*Apatura metis*)
Large Copper (*Lycaena dispar*)

***Fish***

European mud-minnow (*Umbra krameri*)
Streber (*Zingel streber*)
Blue bream (*Abramis ballerus*)
Crucian carp (*Carassius carassius*)
Mud load (*Misgurnus fossilis*)

***Birds***

White-tailed eagle (*Haliaeetus albicilla*)
Little Ringed Plover (*Charadrius dubius*)
Bird colonies (Cormorant, Heron)

Given the lack of appropriate distribution maps for the investigation surface area it was necessary to use qualitatively different information sources, to record the distribution of certain species along the rivers. Quotations from relevant recent publications and, as far as they exist, data from distribution atlas' have been considered. In addition, at least one or more specialists (botanists, entomologists, ichthyologists, ornithologists) have been questioned for each country on their species distribution knowledge.

For the plants, some species that serve as good indicators for floodplain habitat quality have also been selected even though their distribution data was only available for certain stretches. They could thus not be represented on the maps. These indicator species may, however, serve at least for certain stretches and will be considered in close analysis of certain sections.

The varying state of information has been represented in the cartographical elaboration. A differentiation between spots, sections and surface-covering information is possible. Sectional or surface-covering information reflects the fact that the respective species occurs in a respective section or area but a precise localization could not be made. The punctual information however locates a distinct occurrence, even though this has still to be differentiated with respect to the various species. For the white-tailed eagle, a spot stands for a breeding pair. For the little ringed plover it represents the breeding-place which may be occupied by various breeding pairs. For higher plants, butterflies and fish the spot represents a location where one or more species have been found. River sections for which no data were available are also represented.

Given the necessary differentiation of the data one may merely make restricted statements and thus draw only restricted comparisons between the various river stretches. Because systematic and surface-covering investigations are, with few exceptions, not available, a classification of the different information levels may only be gathered in one homogeneous way if the working scale was lowered. A reduction of information does however not correspond to the purpose of the project, as the best possible, present state of the species' distribution should be represented. This representation will also reflect the country-specific current knowledge on the distribution of certain species along the rivers. More intensive research and local investigations on chosen spots would have provided more precise results. The longer time and financial cost were however considered.

### 2.4.3. Description of the Selected Bioindicator Species

***Higher plants***

Both in the cross section of the floodplain and in the longitudinal section from the upper to the lower river course, the occurrence of certain species implies the presence of habitats with a varying hydrological or morphological dynamics. Among these are e.g. German tamarisk (*Myricaria germanica*) and the willow *Salix elaeagnos*. They are both characteristic of dynamic stretches with coarse substrates. They imply erosion, aggradation and substrate dynamic processes.

Whereas on the upper Danube the German tamarisk is characteristic of dynamic sites with coarse-grained substrates, on the lower Danube the same site is characterized by the tamarisk *Tamarix ramosissima*. It is typical on fine-grained substrates, partly with a low salt content as a consequence of the continental climate, a high evaporation and the salinization coming along with it.

Black poplar (*Populus nigra*), white willow (*Salix alba*), other willow species such as the purple willow (*S. purpurea*), the almond-leaved willow (*S. triandra*) and the willow *S. fragilis* also play an important role as bioindicators for dynamic habitats. These species require very specific germination conditions that only exist on vegetation-free protosoils brought up by the river dynamics, if these are sufficiently moist at the moment of the seed rain. If these conditions are given, a large-scale succession may take place. Whereas the black poplar may be found on dynamic medium/coarse-grained substrates, the white willow (*Salix alba*) occurs on more fine-grained substrates.

Ephemeral pioneer species such as *Limosella aquatica* and Cyperus species (*Cyperus flavescens, C. fuscus, C. michelianus*) are characteristic of fine-grained floodplain soils where falling water levels (below the mean water level) leave free areas in the minor bed for a short term. They may grow in great number and form what is characteristic for the Danube in certain stretches: *Limosella aquatica* stands. Due to the water level, their development is not guaranteed in every year.

The ecological conditions for near-natural hardwood floodplain forests, mainly of the lower and central hardwood floodplain, may (even though only partly) be supported by the presence of the narrow-leaved ash (*Fraxinus angustifolia*). It is characteristic of warm summer floodplain habitats.

In the Danube river basin, the narrow-leaved ash is attended by summer snowflake (*Leucojum aestivum).* It characterizes wet to periodically wet and periodically flooded habitats of the lower hardwood floodplain and transitory habitats of the softwood forest. This species also appears in inundated meadows and indicates potential floodplain forest habitats. But *Leucojum aestivum* may also be found outside the floodplains, on habitats that have been temporarily flooded by high groundwater levels. On the central and lower Danube, the wild vine *Vitis sylvestris* is characteristic of structured floodplain forests, that naturally occur along water courses and flood channels. It is also an indicator for human intervention in the forest and does thus not really serve as an indicator for natural floodplains. Another characteristic species of structured, near-natural floodplain forests and bushes in the lower and central hardwood forest of the lower Danube is the Greek liana (*Periploca graeca*).

The clematis *Clematis integrifolia* is a typical species of flooded, moderately eutrophic habitats and extensively used floodplain meadows.

The network of eutrophic and relatively clean old branches is characterized by the presence of the water chestnut (*Trapa natans*). These waters are partly connected to the river and are adapted to the dynamics of the water levels. If the water chestnut appears in floodplains, it provides, together with other bioindicators, valuable hints on the quality of its environment. But the water chestnut also occurs outside the floodplain in ponds and lakes. These habitats have however not been considered in this project.

### Butterflies

Danubian Purple Emperor (Apatura metis)

The danubian purple emperor is an indicator species for completely structured white willow fringes in softwood forests situated along large rivers and streams.

Total distribution: South-Eastern Europe and Russia. The aereal map BY TOLMAN & LEWINGTON (1998) shows no distinct deliniation of the distribution area in the East.

The caterpillar lives on white willows (*Salix alba*) and on other narrow-leaved willows. Its development stages are closely linked to its nutrition and its need of certain microclimatic conditions and habitat structures. Young caterpillars winter in the fissured bark of white willows on the side of the tree that is not exposed to the sun (according to WEIDEMANN, 1998).

Large Copper (Lycaena dispar)

The large copper is an indicator for temporarily flooded swamp and floodplain meadows in river valleys with herbaceous floodplain plants.

The development of the area indicates decreasing inundation and swamp meadows in the whole distribution area of this species. The comparison of its presence over the last 10 years with its occurrence in the preceding decades documents that this butterfly disappeared in some parts of its total European area (see distribution maps BY PULLIN ET AL. 1998). Recent occurrence changes show that the species does not disappear everywhere. Its stock is in danger where wetland habitats are supplanted by agricultural landuse. The species is however threatened in its whole distribution area.

Habitat: "Swampy border areas of lakes, rivers, ditches" (TOLMAN & LEWINGTON, 1998).

The caterpillar lives on large sorrel species such as *Rumex hydrolapatum*, *Rumex crispus* and *Rumex aquaticus*. According to literature, the caterpillar survives temporary floods without damage (e.g. EBERT, 1991).

Original ecological habitats of the large copper are wetlands such as thistle, purple molinia, lacustrine meadows and sedge stands (EBERT, 1991). But the species may as well be found outside the large floodplains in secondary habitats such as moist ditches, clay and gravel pits, the borders of dredging pools, moist fallow land, moist bushes and waysides, borders of artificial lakes with periodical wetting.

Distribution: Europe, Northern Turkey. "Extremely local in largely distributed populations" (TOLMAN & LEWINGTON, 1998). This statement considers its West-European presence and its occurrence in the lowlands of Northern Germany and Poland.

### Fish

European mud-minnow (Umbra krameri)

Its presence in alluvial river valleys indicates the existence of a rich vegetation in former branches with stagnant or slowly flowing waters and pools. These waters are subject to dramatic water level fluctuations and may even dry out.

Blue bream (Abramis ballerus)

Its presence in undammed, flowing river sections of the inundation areas indicates a well-operating surface connection between the river and its former branches.

Crucian carp (Carassius carassius)

Its presence in alluvial river valleys indicates the existence of silted-up, strongly drying and cut-off former branches. It may also be found in temporary pools with frequent oxygen deficiencies in the inundation area.

Mud load (Misgurnus fossilis)

Its presence in alluvial river valleys indicates the existence of cut-off former branches and pools with a rich vegetation. These waters are frequently silted up, are subject to dramatic water level fluctuations and may even dry out.

Streber (Zingel streber)

Its presence indicates dynamic and rapidly flowing river stretches with open gravel banks in shallow and deep waters.

***Birds***

White-tailed eagle (Haliaeetus albicilla)

Its occurrence in alluvial river valleys indicates the existence of broad, old growth floodplains characterized by little human intervention (silviculture, hunting, recreation), adjacent to eutrophic waters with rich fish and bird populations (river, old branches, fish ponds, lakes and coastal waters).

Little ringed plover (Charadrius dubius)

Its presence in river areas is an indicator for bare or scarely covered gravel or sand aggradations in the river bed resp. bare or hardly covered even though mainly dry swamp or mud areas. It does however definitely prefer gravelly spots in open grounds.

It is considered as a pioneer bird species and as an indicator for initial biotopes created by the river morphological dynamics.

Bird colonies

Breeding conglomerates composed of herons and cormorants are grouped and represented unspecifically as bird colonies.

Heron (Ardea cinerea), night heron (Nycticorax nycticorax), great white egret (Egretta alba), little egret (Egretta garzetta), purple heron (Ardea purpurea) and squacco heron (Ardeola ralloides) belong to the heron species group. Among the cormorants there are Phalacrocorax carbo and the pygmy cormorant (Phalacrocorax pygmeus).

Their presence in alluvial river valleys indicates sections with abundant feeding grounds, i.e. fish (rivers, former branches, fish ponds etc.). Their use may however differ very much depending on the bird species and the characteristics of the area.

**Table 5** **Habitat use with respect to the requirements of the selected indicator bird species in the studied river sections.**

| Species | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| White- tailed Eagle (Haliaeetus albicilla) | | N | N | N | | B |
| Little Ringed Plover (Charadrius dubius) | NB | | | | | |
| Bird Colonies (Cormorant, Heron) | | N | N | N | NB | B |

| | | | |
|---|---|---|---|
| 1 = | gravel, sand or sludge bank | B = | breeding place |
| 2 = | main river bed / lateral branch | N = | feeding ground |
| 3 = | former river branch | | |
| 4 = | fish pond | | |
| 5 = | reed | | |
| 6 = | floodplain forest (mostly recent) | | |

## 2.5. Inventory of Selected Protected Areas (incl. the Ramsar Convention)

An inventory of protected area types was undertaken for the whole investigation area of the recent and former floodplains. Additionally, all wetlands declared within the frame of the Ramsar Convention will also be listed. On the one hand, this listing reflects the actual state of protection of particularly valuable areas in the various countries. On the other hand it uncovers nature protection deficiencies and the necessity for future action.

Because comparison of the various countries' protected area programmes proved to be impossible (country-specific nature protection laws, different nomenclature for protected categories etc.), an appropriate concept for a homogenization, i.e. a common basis, had to be elaborated. The internationally recognized IUCN criteria have therefore been considered, as they allow an assessment of the various protection categories and thus a comparability in substance.

The categorization has mainly been extracted from the protected area data bank of the WCMC (World Conservation Monitoring Centre). The surface-area of the different sites has been determined with the help of cooperation partners in every country. By doing so, we tried to consider only those protected area types that show a distinct nature protection task. The IUCN categories I, II and IV are relevant for the area (see below). Within the frame of category IV however, only areas of more than 500 ha have been recorded. This appears to be justified, because this project only considers large-scale units. Protected areas of category V (protected landscapes) were recorded in a first step, but they have not been considered in the final list because as this category is a 'melting pot' for types with comparably low nature protection contents (landscape protection areas, natural parks etc.). A country-specific differentiation (study of the specific legal conditions) would provide more distinct results. Within the frame of this project it could not be undertaken because of both financial and time considerations.

Areas that were declared on the basis of relevant international programmes and agreements for the different countries have also been considered (here: Ramsar Convention sites, biosphere reserves within the frame of the UNESCO MaB programme). The majority of the data was taken from the documents of the Ramsar Convention Bureau and the WCMC database.

For the sake of completeness the protected areas have always been considered and represented in their entirety, even if, in certain cases, large areas were not of interest for the project (e.g. the major part of the Duna-Ipoly or Djerdap/Iron Gate national parks are alpine national parks).

**Recorded protected area categories and Ramsar sites (map 1)**

The following IUCN categories have been considered with respect to their relevance for the investigation area and their importance from the point of view of nature protection:

IUCN category I: Scientific reserve/strictly protected areas
IUCN category II: National park
IUCN category IV: Nature reserve (> 500 ha)
IUCN category IX: Biosphere reserve
Additional sites are those of the Ramsar Convention.

## Table 6 Recorded protected areas and Ramsar sites

| Nr | Country | River | Site | IUCN category and Ramsar-site | Area (ha) | Date of designation |
|---|---|---|---|---|---|---|
| 1 | Germany | Danube | Donau-Auen & Donau Moos | R | 8000 | 1976 |
| 2 | Germany | Danube | Lech-Donau Winkel | R | 239 | 1976 |
| 3 | Germany | Danube | NR Flußlandschaft Donauwiesen I | IV | 530 | |
| 4 | Germany | Danube | NR Flußlandschaft Donauwiesen II | IV | 560 | |
| 5 | Germany | Danube | NR Pfatter | IV | 680 | |
| 6 | Germany | Danube | NR Isar Mündung | IV | 980 | |
| 7 | Austria | Danube | NP Donau-Auen | II | 9300 | 1996 |
| 8 | Austria | | Untere Lobau | BR | 1039 | 1977 |
| 9 | Austria | | Untere Lobau | R | 1039 | 1982 |
| 10 | Austria | Danube-Morava | Donau-March-Auen | R | 38500 | 1982 |
| 11 | Austria | Morava | NR Untere March-Auen (WWF Reservat) | IV | 1166 | 1978 |
| 12 | Czech Republic | Dyje | Palava | BR | | |
| 13 | Czech Republic | Dyje | Mokrady dolního Podyjí (floodplains of lower Dyje river) | R | 11500 | 1993 |
| 14 | Czech Republic | Morava | Litovelské Pomoraví | R | 5122 | 1993 |
| 15 | Slovakia | Danube | NR Cícovské mrtve rameno | R | 135 | 1990 |
| 16 | Slovakia | Danube | NR Súr | IV | 568 | 1952 |
| 17 | Slovakia | | NR Súr | R | 1137 | 1990 |
| 18 | Slovakia | Danube | Dunajské luhy (Danube floodplains) | R | 14335 | 1993 |
| 19 | Slovakia | Morava | Moravské luhy (Morava floodplains) | R | 4971 | 1993 |
| 20 | Slovakia | Morava | NR Horny les | IV | 543 | 1981 |
| 21 | Hungary | Danube | Gemenc-Béda-Karapancsa | R | 18023 | 1997 |
| 22 | Hungary | Danube | NP Duna-Ipoly | II | 60314 | 1997 |
| 23 | Hungary | | Szentendrei-sziget | II | 1300 | 1997 |
| 24 | Hungary | Danube | Ocsa | R | 1078 | 1989 |
| 25 | Hungary | Danube | NR Császártöltési Vörös-mocsár | IV | | |
| 26 | Hungary | Danube | NR Szelidi-tó | IV | | |
| 27 | Hungary | Danube | NR Kiskörösi turjános | IV | | |
| 28 | Hungary | Danube-Drava | NP Danube-Drava | V | 49479 | 1996 |
| 29 | Hungary | Drava | Szaporca | R | 257 | 1979 |
| 30 | Hungary | Tisza | Pusztaszeri | R | 5000 | 1979 |
| 31 | Hungary | Tisza | Mártélyi | R | 2232 | 1979 |
| 32 | Hungary | | NP Kiskunsági | II | 35860 | 1975 |

*Table 6 continued*

| | | | | | | |
|---|---|---|---|---|---|---|
| 33 | Hungary | | NP Kiskunsági | BR | 22095 | 1979 |
| 34 | Hungary | | NP Kiskunsági | R | 3903 | 1979 |
| 35 | Hungary | Tisza | Lakitelek Töserdö | II | 600 | 1975 |
| 36 | Hungary | | NP Hortobágyi | II | 52213 | 1973/1996 |
| 37 | Hungary | | NP Hortobágyi | BR | 53099 | 1979 |
| 38 | Hungary | | NP Hortobágyi | R | 23121 | 1979 |
| 39 | Hungary | Tisza | Tiszacsegeihullámtér | II | 1263 | 1996 |
| 40 | Hungary | Tisza | Tiszalake | II | 5000 | 1996 |
| 41 | Hungary | Tisza | Tiszalake | R | 2500 | 1979 |
| 42 | Hungary | Tisza | NR Tiszatobi ártér | IV | 1000 | 1977 |
| 43 | Hungary | Tisza | Tokaj-Bodrog-zug | R | 3782 | 1989 |
| 44 | Hungary | Tisza | NR Tiszatelek-Tiszaberceli-ártér | IV | 1263 | 1978 |
| 45 | Croatia | Danube-Drava | Special Zoolog. Reserve Kopacki Rit | Ia | 7000 | 1993 |
| 46 | Croatia | Drava-Mur | Ornith. Reserve Veliki Pazut | IV | 17770 | 1983 |
| 47 | Croatia | Kupa | Special Ornith. Reserve Crna Mlaka | IV | 625 | |
| 48 | Croatia | Kupa | Special Ornith. Reserve Crna Mlaka | R | 625 | 1993 |
| 49 | Croatia | Sava | Lonjsko & Mokro Polje | R | 50650 | 1990 |
| 50 | Yugoslavia | Danube | Special NR Karadjordjevo | IV | 2955 | 1997 |
| 51 | Yugoslavia | Danube | Special NR Koviljsko-Petrovaradinski Rit | IV | 4841 | 1998 |
| 52 | Yugoslavia | Danube | NP Djerdap | IV | 63608 | 1974/1993 |
| 53 | Yugoslavia | Tisza | Special NR Stari Begej-Carska Bara | IV | 1767 | 1986 |
| 54 | Yugoslavia | Tisza | Special NR Stari Begej-Carska Bara | R | 1767 | 1996 |
| 55 | Yugoslavia | Sava | Special NR Zasavica | IV | 671 | 1997 |
| 56 | Yugoslavia | Sava | NR Obedska Bara | IV | 9820 | 1968/1994 |
| 57 | Yugoslavia | Sava | NR Obedska Bara | R | 17501 | 1977 |
| 58 | Bosnia | Sava | Ornith. Reserve Bardaca | IV | 700 | |
| 59 | Romania | Danube | Donau-Delta | BR | 580000 | 1990 |
| 60 | Romania | Danube | NR Small Braila Island | IV | 14983 | 1997 |
| 61 | Bulgaria | Danube | NR Persin island | IV | 1714 | 1981 |
| 62 | Bulgaria | Danube | NR Srébarna | IV | 1143 | 1948 |
| 63 | Bulgaria | | NR Srébarna | R | 902 | 1975 |
| 64 | Bulgaria | | NR Srébarna | BR | 600 | 1977 |
| 65 | Moldova | Prut | Prutul de jos | Ia | 1691 | 1991 |
| 66 | Moldova | Prut | Padurca Domneasca | Ia | 6032 | 1993 |
| 67 | Ukraine | Danube | Dunaiskie Plavny Donau-Delta | BR | 46400 | 1998 |
| 68 | Ukraine | Danube | Ismail Islands | R | 1366 | 1996 |
| 69 | Ukraine | Danube | Kugurluy Lake | R | 6500 | 1995 |
| 70 | Ukraine | Danube | Kartal Lake | R | 500 | 1995 |

## 2.6. Nutrient Reduction Potential in Waters

The Danube's nitrate and phosphorus input to the Delta and the Black Sea has dramatically increased over the last decade (WACHS, 1997). The negative symptoms of eutrophication may be observed from the Central Danube in Hungary to the North-Western part of the Black Sea. Studies conducted by the catchment area countries (TU Vienna and University of Technology, Budapest, 1997) show that 60% of the nitrogen compounds and about 40% of the phosphorus compounds originate from diffuse sources.

The new sewage purification technology allows a reliable and cost-effective nutrient decomposition in sewage treatment plants. The input from diffuse sources can be reduced by purposive measures in agriculture and landscape management, they can, however, not be completely stopped. The high efficiency of floodplains, situated between farmland and water courses, in the reduction of nutrient/suspended matter input (CASTELLA, E ET AL., 1994) found consequences as for the transformation of the river banks in Baden-Württemberg and Bavaria. Nutrients may be decomposed in floodplains both in dry periods and during floods. The self-purification in floodplains is a complex of physical (sedimentation, filtration, absorption), microbiological (denitrification) and biological processes (nutrient reduction through aquatic micro- and macrophytes and the roots of terrestrial vegetation). According to numerous studies and calculations, floodplains retain up to 90% of nitrates and up to 50% of phosphorus that inundations transported into the floodplain (GUILLIAM, 1994).

The absolute numbers on nutrient reduction in wetlands differ significantly. RICHARDSON (1990) states, that American forest wetlands (comparable to European floodplain forests) hold back 38 kg total N/ha/year and 15 kg total P/ha/year. VAN OORSCHOT (1996) noted a reduction of 169 kg total N/ha/year and 17,4 kg total P/ha/year in UK floodplain meadows while the reduction capacity of Australian floodplain meadows has been estimated to 80,8 kg total N/ha/year and 12,5 kg total P/ha/year (RAISIN 1996).

Nutrient reduction in floodplains depends on numerous factors. Nutrient reduction is higher in vegetation periods, outside this period nutrient input occurs into the river. In floodplain meadows the decomposition intensity is influenced by flood duration and height (VAN OSCHROOD, 1996). High efficiency has been established for the hardwood forest's climax state (Querceto-Ulmetum) (SANCHÉZ-PÉREZ et al., 1991). The river's most important and most effective self-purification processes proceed in the shallow litoral zones. Any shortening of the river, i.e. embankments, steeper banks and particularly the cutting-off of the floodplains by dams, reduce its self-purification capacity.

The self-purification processes described may in no case replace sewage treatment plants. A revitalization of all former floodplains would not bring a significant improvement of the current nutrient load of the Danube, if 'hot spots' remain and continuously pollute the Danube waters. Only a simultaneous action of sewage treatment plant construction and revitalization of floodplains will stop the gradual eutrophication of the central and lower Danube sections and improve the water quality of both the Danube and the Black Sea.

## 2.7 Data for an Economical Evaluation

The economical evaluation required extensive and comparable data on the floodplains of 13 riparien states (e.g. agricultural, silvicultural and fishery data, data on power generation, drinking water withdrawal, tourism etc.). This study has therefore used data from an investigation dating 1994 (KREN, 1994). No additional detailed data have been gathered.

## 2.8. Methodology

The methodology for evaluation, as it this was dependent upon available data, could only be determined after the data collection had been completed.

On the basis of the historical and recent maps the limit between recent and morphological floodplain could be recorded according to the definition in Chapt. 2. On this basis the deliniation of the investigation area has been fixed.

To evaluate the floodplain areas with respect to their ecological value and rehabilitation potential, they had to be divided into different sections. The segmentation could be obtained by various methods:

- river kilometre marking (sections of equal length): this kind of segmentation is arbitrary and does not consider ecological or natural factors, it has therefore not been considered.
- river morphology: every river may be divided into erosion and sedimentation stretches or sections with a balanced sediment household. This proceeding would however produce large-scale sections that would not allow a distinct differentiation.
- natural segmentation: as has been described in detail in Chapt. 3.2, the investigation area may be structured in 170 units, a structure that could provide a homogeneous and understandable segmentation. This approach has therefore been intensively discussed. While superposing these sections with the areas of the recent and morphological floodplain and combining them to the landuse data one found out that optimum evaluation units could not be formed. Areas with both no morphological floodplain and large, well-structured floodplains were found within one natural section on the lower Danube, in Hungary. In a common evaluation the two extremes situated within one evaluation section would be averaged and thus the actual state would be falsified.
- the floodplain width: to avoid the problems described above one needed to consider the variable floodplain width factor. The floodplain width is characterized by geomorphological, river morphological and hydrological factors. It thus represents a combination of the segmentation factors described above. One section has been defined for each significant alteration in the width of the recent and morphological floodplain. A minimum of 15 km was fixed per section, even though on the upper river sections the sections sometimes remain below this limit.

To use the floodplain width method for segmentation the width of the recent and morphological floodplain had to be classified into different widths for each side of the river. Starting from the middle of the river, the following width classes were identified:

class 1: 0 -1 km
class 2: 1 - 2.5 km
class 3: 2.5 - 5 km
class 4: > 5 km

A smaller first class of e.g. 0 - 0,5 km has been considered, but could not be evaluated given the spatial resolution of the available data (see chapt. 2).

In areas where the studied rivers are divided into several large branches, the centre of the main branch has been determined as the centre of the whole river. One bank thus consists not only of the immediately adjacent floodplain area, but also the two floodplain areas of the lateral branch situated on the respective river bank. This was mainly significant for areas situated along the lower Danube. The same procedure was adapted to the Danube islands.

The classification and its subsequent segmentation constitued, on the one hand, the geometrical basis for the evaluations described below. On the other hand it could be used for the cartographic representation of the results. Because the natural extension of the floodplains is relatively small compared to the total catchment area (see map 1) and as the evaluation results could only be visualized on this basis, the described classification of the floodplain width also served as a symbolic representation of the floodplains. They do not show the exact extent as in map 1, but the superelevation of the floodplain width with factor 3 to 5. This representation immediately provides an impression of the ratio of the different floodplains along the studied rivers to the map user (see map 2).

Besides the described advantages of this methodology, a number of disadvantages also appeared and should not be left unmentioned:

- If, through classification, the recent floodplain and the limit of the former floodplain appear in the same section, only the recent floodplain will be represented. For areas, where the recent floodplain occupies the whole morphological floodplain, this is correct. For other areas however, where the recent floodplain ranges at the lower edge of the class and the border of the former floodplain at the upper edge of the same class, certain areas will not be evaluated (e.g. recent floodplain = 200 m; former floodplain = 900 m).

  This is the case for most of the upper river areas that are naturally more narrow.
- Another problem area regards to class 1 (0 - 1 km floodplain width). Given the available data, a more detailed large-scale representation, e.g. 0-10 m, 100-500 m and >500, was impossible. This is why narrow floodplains with less than 100 m width are not differentiated, the same is true for areas with up to 1 km. This information could be obtained from satellite images with a resolution of 20 -30 m. As has been described in Chapt. 2.1.4, more than 50 satellite images would have been necessary to cover the whole investigation area. This was not possible for reasons of time and cost.
- This is also why the upper river areas of the studied rivers have been removed from the evaluation. Their floodplains are too narrow to allow a classification on the basis of the developed methodology.

### 2.8.1. Evaluation of the Ecological Potential

The evaluation of the ecological potential occurred on the basis of a floodplain segmentation, both for the right and the left river bank and for the recent and former floodplain.

For a closer characterization of the obtained sections, the CORINE data represent the only available database covering the main areas. The use of this database has been supplemented with classification from Landsat and IRS satellite data in the areas where Corine dat did not exist. Further surface-covering data were available from the mapping of the recent and morphological floodplains. The hydropower plant sites and their sphere of influence have been previously recorded. The following data were thus available for the whole area and could be directly integrated in the evaluation:

- width of the recent and morphological floodplains
- sections disturbed by hydropower plants and dams (backwater, outlet sections/polder)
- landuse (forest, waters, swampland, grassland, extensive agriculture, farmland, settlements/constructions)

The evaluation occurred by means of a simple weighting of the three main factors: floodplain type, floodplain width and landuse. Type and width appear as multipliers of the actual landuse in each section (see evaluation scheme on the following page). Landuse will be proportionally evaluated and calculated in a first step (see example 1-4). Areas of less than 1 km width may, according to the chosen evaluation scheme, not reach the highest evaluation class. This proved to be problematic, particularly for the upper river areas. On the other hand, the objective of this project was to study the floodplains of the Danube and its major tributaries, these few 'critical' factors could thus be disregarded. The consideration of another factor, i.e. the ratio between morphological and recent floodplain, has been dropped for reasons of clarity. In total, more than 450 sections have been evaluated.

**Start conditions:**

Floodplain segmentation by width and section length
of recent and former floodplains

***1. Floodplain Type***

recent floodplain *(4)* polder/diversion stretch *(2)* former floodplain *(1)*

↓

***2. Floodplain Width***

I 0- 1 km *(1)*
II 1- 2,5 km *(2)*
III 2,5- 5 km *(3)*
IV over 5 km *(4)*

↓

**3. Landcover (CORINE- Data)**

forests *(4)* swamp/waters *(4)* meadows *(3)* heterogeneous agriculture *(2)* farmland *(1)* settlements *(0)*

$$\mathbf{FPT \bullet FPW \bullet \sum (AFC \bullet PAT) = EPF}$$

FPT: floodplain type
FPW: floodplain width
AFC: assessment factor CORINE- data
PAT: percentage of area type
EPF: ecological potential of floodplain

**Assessment range:**
0- 69 pt.: low EPF
70- 149: moderate EPF
150- 319: high EPF
320- 640: very high EPF

***Sample 1:***

**1. Floodplain type**
recent floodplain ................................ 4

**2. Floodplain width**
II 1- 2,5 km ......................................... 2

**3. Landcover**

| | | | |
|---|---|---|---|
| forests | 30% | ...... | $4 \cdot 3 = 12$ |
| meadows | 20% | ....... | $3 \cdot 2 = 6$ |
| het. agriculture | 20% | ....... | $2 \cdot 2 = 4$ |
| farmland | 20% | ....... | $1 \cdot 2 = 2$ |
| settlements | 10% | ........ | $0 \cdot 1 = 0$ |

--------------

$24 \cdot 2 \cdot 4 =$ **192** **(high EPF)**

***Sample 2:***

**1. Floodplain type**
former floodplain ............................... 1

**2. Floodplain width**
III 2,5- 5 km ....................................... 3

**3. Landcover**

| | | | |
|---|---|---|---|
| forests | 20% | ...... | $4 \cdot 2 = 8$ |
| het. agriculture | 20% | ....... | $2 \cdot 2 = 4$ |
| farmland | 40% | ....... | $1 \cdot 4 = 4$ |
| settlements | 20% | ....... | $0 \cdot 2 = 0$ |

--------------

$16 \cdot 3 \cdot 1 =$ **48** **(low EPF)**

The area evaluated according to this methodology provides a representation of the present state of the ecological value of the studied floodplain areas in the Danube basin. The result, rather than being described as ecological value has deliberately been designated as ecological potential. This is due to the limitations of the data available for the evaluation (see above). One may suppose that broad inundated and wooded floodplain areas have a far more significant ecological value than dammed and agriculturally intensively used areas. The described bioindicator evaluations have complemented this statement (see chapter 3.4).

## 2.8.2. Evaluation of the Rehabilitation Potential

The evaluation of the rehabilitation potential only considered the former floodplain with more than 1 km width. Based on the present segmentation, the landuse data available for the whole area (CORINE data, proper classifications) were again used. The evaluation occurred selectively on a 4-level scale. The main factors were:

- areas with few or no settlements
- connected areas
- large former floodplain structures

Experience shows that political and socio-economical conditions (property structure, status of the area, political decision-makers) play a far more important role in the realization of rehabilitation projects, than the actual landuse. On the other hand, agriculturally used areas may also be appropriate for rehabilitation, in some cases even more than poplar monocultures or grassland areas.

### 2.8.3. Evaluation of Nutrient Reduction Potential

According to today´s knowledge, various factors obstruct the development of a homogeneous methodology for the evaluation of the nutrient reduction potential in the Danube floodplains.

For certain countries, absolute numbers on nutrient concentrations are difficult to access, and the evaluation criteria for water quality in the different countries are not comparable (VITUKI Budapest, 1997).

The positive function of floodplains on nutrient decomposition is undisputed. It is, however difficult to reliably quantify, given the actual state of the data, the analytical methods used and the situation of the measuring points in the Danube catchment area. Compared to the floodplains along other rivers, few studies dealing with nutrient cycling exist for the Danube floodplains (e.g. PENKA et al., 1985, POSTOLACHE et al., 1997, GARKAVAYA et al., 1997) and cannot directly contribute to a quantitative evaluation.

The only landuse data from the CORINE mapping merely provide coarse information on the forest and grassland types and no information on the macrophyte vegetation of the floodplain waters. The vegetation type plays an important role in nutrient reduction. The decomposition of nutrients differs in swamp forests, softwood or hardwood floodplain forests, near-natural meadows and broad reed stands, and waters with or without macrovegetation.

For the recent floodplains of the Danube and its tributaries detailed hydrological data on height, duration and timely distribution of the floods are lacking. These factors are also among the determining aspects of nutrient reduction.

The methodological approaches for the estimation of the nutrient reduction potential may be summarized as follows:

- to provide a control of the different literature citations on the reduction of nitrogen and phosphorus in the recent Danube floodplains, distinct investigations should be completed on 1 ha ground for each of the following habitat or vegetation types:
  - floodplain waters with a rich macrophyte vegetation
  - broad reed stands
  - near-natural floodplain meadows
  - softwood floodplain forests
  - hardwood floodplain forests
  - swamp forests
- the recorded data could be transferred to existing habitat and vegetation types and be mapped in the recent floodplain
- the necessary hydrological data have to be evaluated and included in the classification of the areas
- the calculated nutrient reduction potential should be compared to the nutrient input in the floodplains. They should then be represented on the basis of homogeneous criteria for nutrient load in the water.

### 2.8.4. Economical Evaluation

The economical evaluation of wetlands has presently gained both in importance and acceptance, geographically speaking it reaches from Swedish wetlands to African floodplains and Indonesian mangroves.

Three major evaluation groups can be described (see also BARBIER et al., 1996):

1. Evaluations carried out before, during and after an intervention (e.g. hydropower plant construction)
2. Partial evaluation of certain aspects depending on the respective problem
3. Global evaluations (e.g. estimation of the financial value)

The evaluation mainly consists of three elements:

- abiotic and biotic **components** (silviculture, fishing, gravel extraction...)
- **functions** (nutrient decomposition, groundwater regeneration, flood retention...)
- **essential characteristics** (species diversity, natural heritage,...)

The main utility values in the Danube catchement area could be:

1. **Direct utility values:**
   - fishing, hunting
   - silviculture
   - agriculture
   - gravel and sand extraction
   - recreation
   - navigation
   - power generation
2. Indirect utility values:
   - nutrient retention and decomposition
   - pollutant decomposition and fixing
   - groundwater regeneration
   - flood protection
   - regional climatic stabilization
   - ecological networks
3. Optional utility values:
   - future use
   - formation, information
4. No utility values are:
   - biodiversity
   - natural heritage
   - cultural heritage

A simple estimation of the financial value as has been realized 5 years ago for the Danube floodplains (KREN, 1994) has been carried out in further detail within the frame of this project. The following values have been considered:

- fishing
- silviculture
- grassland farming
- recreation
- nutrient retention and decomposition
- flood protection

However, data heterogenity and extensive investigations represent a major obstacle: the 12 major riparian states of the Danube catchment area have very different economic and social levels.

# 3. General Description of the Danube River Basin

## 3.1. Description of the Geographical Subdivision (Map 2)

The Danube is the only large European stream with a distinct West-East extension. From a geological and morphological point of view, the entire catchment area reflects a relatively young history, reaching from the alpine folding to the periglacial age. Abundant morphological forms that, due to varying climatic conditions, led to extremely different landscape types emerged in the Danube catchment area.

The most characteristic landscape elements of the Danube river and its major tributaries are the various basin landscapes: inneralpine and prealpine basin (Klagenfurt basin, Graz basin) and the broad basin plains, such as the pannonian basin on the one hand and the highland gorges on the other hand (Swabian and Franconian Alb, Austrian Alpine foothills, Visegrad Danube knee upstream of Budapest and Djerdjap/Iron Gate). The upper courses of the Danube tributaries mainly show the characteristics of alpine or subalpine rivers as they originate in the Alps, Tatra, Carpates and Dinaric mountains. The majority of the broad floodplain forests are limited to the lowlands.

Thanks to its West-East expansion, the Danube crosses areas with differently influenced atlantic resp. continental climates. According to WALTER and LIETH (in HORVAT et al., 1974), the Southern European climate types merely prove a typically continental climate (dry summers, frosty winters with little snow) in the most Eastern part of the Danube basin (Balta area = flood prone area of the Danube, Danube Delta). The subcontinental area with relatively poor precipitation in winter and dry late summers in some years however reaches far into the pannonian lowlands. In the South they are followed by central European-submediterranean areas, while in the West, in the Alp´s rain shadow and the high Carpate bend a subcontinental-central European climate with abundant summer precipitations and moderately cold winters is predominating.

In a first step - as has been described above - natural structure classifications have been combined and completed for the countries where this classification is lacking. In a next step and with the inclusion of topographical and morphological data, the 170 areas have been differentiated in 5 morphological types:

1. lowlands (river attending lowlands)
2. plains/terraces (areas adjacent to the river attending lowlands)
3. hills
4. mountains
5. narrow gorge sections

**Table 7 Overview of the defined geographical subdivisions**

| Country from West to East | Morphological type | unit | ID-number in map (only visible in map with scale 1:1.500.000) |
|---|---|---|---|
| Germany | | | |
| | 4 | Östlicher Schwarzwald | 1 |
| | 4 | Baar | 2 |
| | 5 | Albdurchbruch zwischen Tuttlingen und Siegmaringen | 3 |
| | 4 | Schwäbische Alb | 4 |
| | 4 | Riesalb | 5 |
| | 1 | Donau-Iller-Lech-Niederung | 6 |
| | 3 | Donauried | 7 |
| | 1 | Unteres Lechtal | 8 |
| | 1 | Donaumoos | 9 |
| | 5 | Weltendorfer Enge | 10 |
| | 3 | Hallertau | 11 |

*Table 7 continued*

| | | | |
|---|---|---|---|
| | 4 | Untere Frankenalb | 12 |
| | 4 | Falkensteiner Vorwald | 13 |
| | 1 | Dungau | 14 |
| | 3 | Donau-Isar-Hügelland | 15 |
| | 1 | Unteres Isartal | 16 |
| | 4 | Vorderer Bayrischer Wald | 17 |
| | 4 | Passauer Abteiland und Neuburger Wald | 18 |
| | 3 | Isar-Inn Hügelland | 19 |
| | 1 | Unteres Inntal | 20 |
| Austria | | | |
| | 4 | Sauwald | 21 |
| | 3 | Grieskirchener Hügelland | 22 |
| | 4 | Mühlviertler Hochland | 23 |
| | 1 | Erferdinger Becken | 24 |
| | 1 | Ager-Traunauen | 25 |
| | 2 | Traun-Enns-Platte | 26 |
| | 1 | Freistadt-Feldaist-Senke | 27 |
| | 1 | Linz-Mauthausener-Becken | 28 |
| | 1 | Unteres Ennstal | 29 |
| | 1 | Machland | 30 |
| | 2 | Neustädter Platte | 31 |
| | 1 | Unteres Ybbstal | 32 |
| | 1 | Strudengau | 33 |
| | 4 | Waldviertler Hochland | 34 |
| | 4 | Dunkelsteiner Wald | 35 |
| | 4 | Wachauer Bergland | 36 |
| | 5 | Wachau | 37 |
| | 1 | Tullnerfeld | 38 |
| | 1 | Unteres Traisental | 39 |
| | 2 | Krems-Stockerauer-Feld | 40 |
| | 3 | Tullner H3gelland | 41 |
| | 3 | Bisamberge | 42 |
| | 4 | Sandstein- Wienerwald | 43 |
| | 2 | Feuchte Ebene / Wiener Becken | 44 |
| | 3 | Poysdorfer Hügelland | 45 |
| | 3 | Weikersdorfer Hügelland | 46 |
| | 1 | Moravafeld | 47 |
| | 1 | Leithamulde | 48 |
| | 4 | Leithagebirge | 49 |
| | 4 | Hainburger Berge / Porta Hungarica | 50 |
| | 1 | Neusiedlersee | 57 |
| Czech Republic | | | |
| | 1 | Morava-Thaya-Winkel | 51 |
| Slovak Republic | | | |
| | 1 | Unteres Moravatal | 52 |
| | 2 | Moravaabdachung | 53 |
| | 4 | Kleine Karpaten | 54 |
| | 2 | Podunajska | 55 |
| | 1 | Nizina Maly Dunaj | 56 |
| | 3 | Pohronska Hügelland | 63 |
| | 1 | Lowers Grantal | 65 |
| | 3 | Ipel Hügelland | 66 |
| | 1 | Unteres Ipolytal | 67 |
| Hungary | | | |
| | 2 | Becken von Györ | 58 |
| | 1 | Rábaköz | 59 |
| | 1 | Komárom-Kisber-Becken | 60 |
| | 1 | Szigetköz | 61 |
| | 3 | Bakonyalja | 62 |
| | 4 | Dunazug-Bergland | 64 |
| | 4 | Börzsöny-Gebirge | 68 |
| | 4 | Visegrader Gebirge | 69 |
| | 5 | Visegrader Danube-Knie | 70 |
| | 2 | Pest-Hordalékkup-Ebene | 71 |
| | 1 | Vác-Pest-Niederung | 72 |
| | 3 | Keleti-Cserhat | 73 |
| | 3 | Tapio-Galga-Zagyva-Gebiet | 74 |
| | 4 | Cserhat-Berge | 75 |

*Table 7 continued*

| | | | |
|---|---|---|---|
| | 3 | Gödöllö-Hügelland | 76 |
| | 1 | Csepel-Niederung | 77 |
| | 1 | Solt-Niederung | 78 |
| | 2 | Danube-Tisza-Zwischenstromland | 79 |
| | 1 | Zagyva-Tisza-Ebene | 80 |
| | 1 | Überschwemmungsgebiet Borsod | 81 |
| | 1 | Szolnok-Tür -Ebene | 82 |
| | 1 | Hortobagy | 83 |
| | 1 | Taktaköz | 84 |
| | 1 | Bodrogköz | 85 |
| | 2 | Eszakkelet-Nyirség Sandebene | 86 |
| | 2 | Ebene von Bereg-Szatmár | 87 |
| | 1 | Also-Tisza-Raum | 88 |
| | 1 | Lower Tisza | 89 |
| | 1 | Offene Tonebene von Kalocsa | 93 |
| | 1 | Mohács-Insel | 94 |
| | 1 | Offene Dravaebene | 95 |
| | 1 | Centrals Drava/Drava-Tal | 98 |
| | 3 | Zalaer Hügelland | 99 |
| Croatia | | | |
| | 1 | Kopacki Rit/ Baranja | 96 |
| | 1 | Podravina | 97 |
| | 1 | Murebene | 100 |
| | 2 | Medijemure | 101 |
| | 1 | Dravafeld | 102 |
| | 4 | Bilogora | 103 |
| | 4 | Papuk | 104 |
| | 3 | Moslavacka | 105 |
| | 3 | Psunj | 106 |
| | 4 | Pozeska | 107 |
| | 3 | Dilj | 108 |
| | 1 | Posavina | 109 |
| | 1 | Lonjskopolje / Makropolje | 110 |
| | 2 | Syrmische Ebene | 112 |
| Bosnia- Hercegovina | | | |
| | 1 | Prosara | 111 |
| | 1 | Molaika | 113 |
| | 1 | Savina | 114 |
| | 1 | Malva | 115 |
| FR Yugoslavia | | | |
| | 1 | Banat | 90 |
| | 1 | Bacska | 91 |
| | 2 | Lössebene der Bacska | 92 |
| | 4 | Fruska Gora | 116 |
| | 3 | Podluzje | 117 |
| | 2 | Srem | 118 |
| | 2 | Pocerina | 119 |
| | 3 | Cer | 120 |
| | 3 | Madija | 121 |
| | 3 | Podunavlje-Hügelland | 122 |
| | 2 | Kincstari Homok Puszta | 123 |
| | 1 | Pomoravje | 124 |
| | 3 | Dumacia | 125 |
| | 4 | Avola Kosmay | 126 |
| | 4 | Homoljske-Gebirge | 127 |
| | 4 | Lokva | 128 |
| | 4 | Slarica | 129 |
| | 4 | Almaj | 130 |
| | 4 | Miroc | 131 |
| | 4 | Mehedinti Gebirge | 132 |
| | 3 | Danceu | 133 |
| | 5 | Eisernes Tor | 134 |
| | 3 | Mehedinti Hochland | 135 |
| | 3 | Krajna | 136 |
| Bulgaria | | | |
| | 3 | Greben | 137 |
| | 2 | Zlatiata | 140 |
| | 2 | Tschernopolje | 141 |
| | 3 | Dunavskaravnin | 146 |

*Table 7 continued*

| | | | |
|---|---|---|---|
| | 3 | Luaokorie | 147 |
| Romania | | | |
| | 1 | Untere Donauniederung | 138 |
| | 2 | Bailesti | 139 |
| | 1 | Lower Jiu | 142 |
| | 2 | Romanati | 143 |
| | 1 | Lowerr Olt | 144 |
| | 2 | Boian | 145 |
| | 2 | Burnaz | 148 |
| | 1 | Arges-Tiefland | 149 |
| | 2 | Mostistea | 150 |
| | 2 | Ialomita-Tiefland | 151 |
| | 1 | Untere Ialomita | 152 |
| | 1 | Balta der Lowern Danube | 153 |
| | 1 | Balta Ialomitei | 154 |
| | 1 | Balta Brailei | 155 |
| | 3 | Cobadin | 156 |
| | 2 | Dorobantu | 157 |
| | 3 | Babadag-Hügelland | 158 |
| | 3 | Macin-Gebirge | 159 |
| | 1 | Lagunenkomplex Razim/Ratelm-See | 160 |
| | 3 | Tulcea | 161 |
| | 2 | Braila-Ebene | 162 |
| | 1 | Siret-Niederung | 163 |
| | 3 | Covurlui-Hügelland | 164 |
| | 3 | Falciu-Berge | 165 |
| | 1 | Unterer Prut | 166 |
| | 1 | Tulcea Vordeltastrecke | 168 |
| | 1 | Danube-Delta | 169 |
| Molodova | | | |
| | 3 | Westmoldawisches Hügelland | 167 |
| Ukraine | | | |
| | 2 | Nizina Czernamorska | 170 |

The arrangement of habitats on various substrates that depend on the hydrological dynamics and thus on the aggradation of various grain sizes is the same both in the cross section of the floodplain and along the whole Danube. Despite their dependency on dynamic floodplain factors the different Danube stretches are also subject to the influence of immediately adjacent areas. With respect to geomorphological, climatic, botanic and general biogeographic aspects of the Danube-adjacent areas, a phytoclimatic classification of the Danube has been carried out. By doing so, the numerous small and differentiated area sections have been gathered as follows in 6 broad sub-units, or respective areas:

I. Alpine-prealpine area
II. Subalpine-central European area
III. Pannonian area
IV. Illyric area
V. Balkan-moesian area
VI. Pontic-danubian area

I. The alpine-prealpine upper Danube comprises the headwater region of the Eastern Black Forest, the upper Danube valley, the Swabian Alb section and the Riesalb, an area with precipitations of 738 mm where the Danube is a characteristic highland river. In this area one may find vegetation-free gravel banks, narrow brook floodplains with grey alders, broad Calthion and Polygono-Trisetion meadows and, in the narrow rocky gorge valleys, Aceri pseudoplatani-Fraxinetum and narrow black alder-ash floodplain forests. The influence of adjacent calcareous beech forests with alpine species such as *Carex alba*, *Lilium martagon* and *Lunaria rediviva* is also visible. The occurrence of *Salix elaeagnos*, characteristic of dynamic areas, is rare.

II. The subalpine-central European area consists of the whole Danube section which is characterized by its alpine tributaries on the one hand and the highlands on the other hand. Its landscape has been shaped by the Glacial Age, with reeds, peats and moraine areas of the last glaciation (Würm). Despite differences between some of the sections, i.e. the Danube up to the Bavarian Forest and the Austrian Danube, they have many things in common. Characteristic of this area are those species that arrived from the Alps with the water, they cover large areas of the foothills of the Alps and indicate deposits of coarse alluvions. *Salix elaeagnos* stands and grey alder floodplain forests are characteristic of the Danube tributaries. The German tamarisk (*Myricaria germanica*) occurs here even though it has dramatically decreased over the last decades due to river regulation. The grey alder (*alnus incana*) is an important component of the grey alder forest dominating on sandy substrates along the Danube. The numerous dry, so-called "Brennen" sites where, in addition to numerous thermophilic species, oak, pine, common juniper and *Berberis vulgaris* are also characteristic. The juniper reflects ist former use as sheep-walk.

III. In the pannonian section with the Small and Large Alföld, the Danube is characterized by the continental climate which is reflected by the habitats´species composition and the occurrence of numerous pontic-pannonian and continental, but also of submediterranean species. A postglacial relict is the pontic Plantago maxima which has ,however, almost completely disappeared due to drainage. The floodplain forests along the pannonian Danube section are characterized by the pannonian narrow-leaved ash (*Fraxinus angustifolia* ssp. *pannonica*) and *Crataegus nigra*. The broad lowlands are characteristic of extended peat meadows and swamp forests (Thelypteridi-Alnetum), however only few remains of them are left.

IV. A submediterranean-illyric influence may be observed in the Southern pannonian lowlands, both along the Danube valley and the lower Drava and Sava. The narrow-leaved ash-elm floodplain forest is thus also characterized by a number of Southern, thermophilic species. In addition to *Crataegus nigra* and the frequent occurrence of *Vitis sylvestris* one also finds the thermophilic atlantic-submediterranean liana *Tamus communis* as well as *Ruscus aculeatus* and *Carpesium abrotanoides*. Broad lilac bush forests, Syringo-Cotinetum stands, *Acer monspessulanum* and *Celtis australis* grow in the forests of the Danube valley near the Danube gorge at the Iron Gate. The transition to the Balkan-moesian area is fluid and cannot be considered as a strict limit. There are differing points of view as to this delimitation (SEE BORZA & BOSCAIU 1965, HORVAT, GLAVAC & ELLENBERG 1979).

V. The Balkan-moesian Danube comprises the area downstream of the Iron Gate up to the confluence of the Olt. It is characterized by a submediterranean, even though Balkan-influenced climate, with more distinct dryness than in the illyric section. The few remaining hardwood floodplain forest stands show a more dense occurrence of the ash *Fraxinus holotricha* and the oak *Quercus pedunculiflora*. These species are quite frequent in the forests along the Southern Olt. Large-scale sand dune areas (near Caracal) with numerous xerophytes may be found in this section, immediately adjacent to the Danube lowland.

VI. The area downstream the Olt mouth up to the Danube Delta may be considered as the pontic-danubian section. This delimitation mainly corresponds to the statements of CALINESCU (1969). The section is characterized by the gradually increasing influence of the continental climate, which is reflected by its vegetation and fauna. Just as for the Balkan-moesian area, the limits of which have been fixed further to the East by some authors (see BORZA & BOSCAIU, 1965), remaining hardwood floodplain forests may also be found in the pontic-danubian section, *Quercus pedunculiflora* and *Fraxinus holotricha* play an important role. There are also *Acer tataricu*, which occurs along the Danube tributaries, the Greek liana *Periploca graeca* and the tamarisk *Tamarix ramosissima* which exists along the Danube up to its mouth in the Black Sea. The latter occurs predominantly in forests composed of *Quercus pedunculiflora* and swamp ashes (*Fraxinus pallisae*) in the Danube Delta. The lakes and oxbow lakes of the lower Danube floodplains and the Delta are characterized by a frequent occurrence of water chestnut (*Trapa natans*) stands, *Salvinia natans* and broad reed belts that also form floating reets ("Plaur").

## 3.2. Hydrological Description

**Table 8** represents the main hydrological parameters for the Danube (upper, central und lower course), Morava, Drava, Sava, Tisza and Prut rivers. The data originate from the hydrological Danube monography (IHD, 1986) and reflect a relatively undistorted view. Except for Prut and Danube, the gauges are exclusively situated on the lower courses of the rivers, so that no major changes occur until their mouth.

**Table 8 Selected hydrological parameters for the examined rivers**

| River | Catchment area in km$^2$ | Gauge | Average discharge in m$^3$/s *Extreme values 1931-1970)* | | | Minimum and maximum water levels in the ice-free period in cm * | |
|---|---|---|---|---|---|---|---|
| | | | MNQ | MQ | MHQ | Min. | Max. |
| Danube | 805 358 | | | | | | |
| Upper Danube | 101 700<br>(up to Vienna) | Vienna- Nuß-dorf | 804<br>*(504)* | 1943 | 5500<br>*(9600)* | 107<br>[72] | 607<br>[862] |
| Central Danube | 513 338<br>(up to Beograd) | Pancevo | 2242<br>*(1273)* | 5490 | 10072<br>*(13378)* | 7<br>[-130] | 574<br>[754] |
| Lower Danube | 717 388 _<br>(up to Braila) | Vadu Oii-Hirsova | 2621<br>*(1540)* | 6216 | 10812<br>*(14950)* | 24<br>[-93] | 408<br>[727] |
| Delta | 87 970 _ | <br>Sf.<br>Gheorghe<br>Sulina<br>Vilcov | -<br>-<br>-<br>- | 6550<br><br>1324<br>1130<br>4096 | <br>-<br>-<br>- | | |
| Morava | 26 643 | Moravsky Jan | 29<br>*(8)* | 110 | 629<br>*(1508)* | 140<br>[80] | 484<br>[579] |
| Drava | 40 076 | Donji Miholjac | 235<br>*(167)* | 554 | 1581<br>*(2025)* | -29<br>[-62] | 322<br>[460] |
| Mur | 14 410 | Letenye | 80 | 195 | 750<br>- | - | - |
| Tisza | 157 186 | Senta | 174<br>*(80)* | 766 | 2119<br>*(3730)* | -88<br>[-198] | 619<br>[907] |
| Sava | 94 694 | Sr. Mitrovica | 390<br>*(194)* | 1613 | 4272<br>*(5515)* | 59<br>[0] | 678<br>[780] |
| Prut | 28 395 | Cernovci | 7 - | 61 | 1213 - | -146<br>[-168] | 144<br>[638] |

** Annual average 1941-70 the absolute values [ ] refer to the periods*

Vienna-Nußdorf: 1893-1970
Pancevo: 1876-1970
Vadu Oii-Hirsova: 1920-1970
Moravsky Jan: 1914-1970
Donji Miholjac: 1890-1970
Senta: 1892-1970
Sr. Mitrovica: 1920-1970
Cernovci: 1940-1970

The discharges are very different for the various catchment areas. Smaller alpine tributaries such as Lech, Traun or Enns provide up to 30 l/skm$^2$. The larger, partly alpine tributaries such as the Drava and Sava provide 15-18 l/skm$^2$ whereas the Morava, a highland river with 3,9 l/skm$^2$ and the Prut with a steppe regime in certain sections and 2,7 l/skm$^2$ are not large tributaries. The ratio of HHQ to NNQ amounts to about 30 for the upper course and remains to about 10 for the central and lower Danube course. The discharge strongly varies both for the catchment area and the water level amplitude in Tulcea. Just before reaching the Delta it still amounts to 5 m.

Extremely varying water regime systems are overlaid in the Danube catchment area. In the upper course, the alpine tributaries and Northern tributaries from the highlands result in a balanced regime with a moderate maximum from April to June. Nevertheless, the alpine tributaries (Inn, Traun, Enns) considerably determine the water regime downstream Passau (maximum discharge in June/August, however a distinct minimum in winter). The Morava as well as the Slovak Republic and Hungarian tributaries merely weaken this regime to some extent. Low precipitations, high evaporation rates and extremely absorbing gravel bodies imply a decrease in the total discharge, even though the catchment area is growing. The June maximum will merely be deferred to May downstream the Prut mouth. The Sava river which has - even more than the Drava - both an alpine upper course and a very mediterranean discharge regime, leads to an extra maximum in winter. As a consequence of this, downstream the highest discharge rates are recorded in April and May, while the low water period lasts from August to October.

From a river morphological point of view and given the different longitudinal sections of the rivers there is a wide range of morphological characteristics. Among these are trained river courses, not only in the alpine mountains, that branch out when they leave the mountains. Furcation zones of considerable extensions are situated on the Danube East of Vienna and Bratislava as well as along the central courses of its large East-alpine and Carpathian tributaries. The Danube merely meanders in the section just before reaching the delta. The Tisza, however, shows a well developed lowland river system with originally broad meandering zones. By comparison, the lower Danube course has typical islands that gradually grow with decreasing gradient. A similar phenomenon may be observed upstream the Iron Gate, where relatively stable islands of different sizes formed before the training. Moreover, special formations such as the Liman lakes on the lower Danube emerged in depressions and lateral valleys after the cutting-off from the main stream. They are naturally connected to the main stream during floods.

The following representation of the headworks primarily serves the localization of the major hydraulical interventions. The continuum ratios along the rivers also have a considerable influence on the river sections upstream and downstream (bed load deficiency e.g. in the lower courses of Drava and Mur, aggravation of the flood situation, migration obstacles for sturgeons in the Danube etc.).

The cartographical representation merely considers the headworks of the studied rivers even though, additionally to the sites in the areas of the broader floodplains, the upper courses with few floodplains are shown as well. The respective use of the upper river sections may thus be well illustrated (e.g. Danube, Drava and Mur).

Further hydrologically based evaluations (influence of the headworks on the hydrological regime and the bed load household of the river sections downstream, construction degree of the banks etc.) are desirable. They could however, for reasons of time and lack of adequate data, not be carried out within the frame of this project.

### 3.2.1. Problem of Deepening

As a result of numerous alterations to the Danube and to the other rivers investigated, there is a general problem of deepening of the channel which has an important influence on restoration potential. In particular the deepening of the channel reduces the frequence of flooding. This deepening is caused by dams on the one hand, limiting the particle and sediment transport, on the other hand by the cutting of the meanders reducing the river length.

In general all of the free flowing parts of the rivers investigated have the problem of deepening but it is a particular problem in the areas that follow:

- on the Central Danube South of Budpest (see map 1). The rate of channel deepening has been found to be 1-2 cm/year.
- on the Drava below the confluence with the Mur. According to Croatian studies the deepening is occuring at a rate of 1,7 cm/year. Over the last 65 years the Drava channel has deepened by 1,1 m.
- on the Tisza, the problems of deepening are caused by a reduction of the river length by 32%. From this follows an increase of the river slope from 3,7 cm/km to 6 cm/km.

In order to ensure that existing and potential restoration areas are flooded it is essential to address this deepening problem. Measures to prevent this deepening are needed as well as remedial measures (artificial input of bed load transport material) in some of the above-mentioned areas.

**Table 9 Hydro power plants along the studied rivers**

| River | Country | Hydro power plant type and other functions | Situation |
|---|---|---|---|
| **Danube** | Germany | L | Ulm- Böfingerhalde |
| | | L | Upperichingen |
| | | L | Leipheim |
| | | L | Günzburg |
| | | L | Offingen |
| | | L | Gundelfingen |
| | | L | Faimingen |
| | | L | Dillingen |
| | | L | Höchstädt |
| | | L | Taphheim |
| | | L | Donauwörth |
| | | L | Lechsend |
| | | L | Bertholdsheim |
| | | L | Bittenbrunn |
| | | L | Bergheim |
| | | L | Ingolstadt |
| | | L | Vohburg |
| | | L | Bad Abbach |
| | | L | Regensburg |
| | | L | Geisling |
| | | L | Straubing |
| | | L | Kachlet |
| | Austria | L | Jochenstein |
| | | L | Aschach |
| | | L | Ottensheim/Wilhering |
| | | L | Abwinden- Asten |
| | | L | Wallsee- Mitterkirchen |
| | | L | Ypps- Persenbeug |
| | | L | Melk |
| | | L | Altenwörth |
| | | L | Greifenstein |
| | | L | Freudenau |

*Table 9 continued*

| | | | |
|---|---|---|---|
| | Slovak Republik | L/(S) | Gabcikovo |
| | Yugoslavia | L | Djerdap I (Eisernes Tor I) |
| | | L | Djerdap II (Eisernes Tor II) |
| Ráckeve- Soroksár-lateral channel of Danube | Hungary | L | Kvassay |
| | | L | Tassi |
| **Drava** | Austria | L/S | Strassen- Amlach |
| | | L/S | Paternion |
| | | L/S | Kellerberg |
| | | L/S | Villach |
| | | L/S | Rosegg- St. Jakob |
| | | L/S | Feistritz- Ludmannsdorf |
| | | L/S | Ferlach- Maria Rain |
| | | L/S | Annabrücke |
| | | L/S | Edling |
| | | L/S | Schwabeck |
| | | L/S | Lavamünd |
| | Slovenia | L/S | Dravograd |
| | | L/S | Vuzenica |
| | | L/S | Vuhred |
| | | L/S | Ozbalt |
| | | L/S | Fala |
| | | L/S | Mariborski otok |
| | | S/L | Zlatolicje |
| | | S/L | Formin |
| | Slovenia/Croatia | S/L | Varazdin |
| | Croatia | S/L | Cakovec |
| | | S/L | Dubrava |
| Mur | Austria | L | Bodendorf- Mur |
| | | L | St. Georgen |
| | | L | Fisching |
| | | L | Dionysen |
| | | L | Pernegg |
| | | L | Laufnitzdorf |
| | | L | Rabenstein |
| | | L | Peggau, Deutschfeistritz |
| | | L | Friesach |
| | | L | Weinzödl |
| | | L | Mellach |
| | | L | Lebring |
| | | L | Gralla |
| | | L | Gabersdorf |
| | | L | Obervogau |
| | | L | Spielfeld |
| Prut | Moldova | B/L/S/W | Costesti – Stinca |
| Sava | Slovenia | L | Moste |
| Thaya | Czech Republik | L | Mavcice |
| | | L | Medvode |
| | | L | Vrhovo |
| | | T/B/W/S | Vranov |
| | | T/B/L | Znojmo |
| | | <br>B/W<br>B/W<br>B/W/L | Nove Mlyny<br>Upper dam<br>Central dam<br>Lower dam |
| Tisza | Hungary | B/L | Tiszalök (Tisza I) |
| | | B/W/L | Kisköre (Tisza II) |

The short characterization of 'hydropower plant type and other functions' has been graded according to the priority of the various plants' functions:

| Hydropower plant type: | Other functions: |
|---|---|
| L = river power plant | B = irrigation |
| S = hydropower plant with peak operation mode | T = drinking water reservoir |
| | W = water retention |
| A = diversion cannel | |

## 3.3. Occurrence of Bioindicator Species

In the following text, statements regarding the results of bioindicator analysis will be presented with respect to the different species.

***Higher plants***

Both the German Tamarisk (*Myricaria germanica)* and the willow *Salix elaeagnos* occur resp. occurred along the mountain sections of the Danube and its tributaries. This follows from the distribution data which have not been verified from current data for the whole Danube. While 10 year-old data from a raster mapping are available (HAEUPLER & SCHÖNFELDER, 1988) for the German Danube, comparable data do only partly exist for other Danube countries. Information is available in the flora works of the various countries, nevertheless this data is too general to allow a spot-like carthographical representation.

The general distribution map of the **German tamarisk** *(Myricaria germanica)* (MEUSEL et all., 1978) and the willow *Salix elaeagnos* distinctly shows the focal points of their distribution along the alpine and carpathian tributaries of the Danube with coarse-grained substrates. Both species dramatically decreased with river regulation and are now severely threatened. On the German Danube, the German Tamarisk predominantly occurs along Lech and Isar; it is however also present along Iller, Inn and Salzach (HAEUPLER & SCHÖNFELDER, 1988). In Austria it is limited to only a few Danube tributaries. On the Hungarian section its occurrence has been proven along Raba, Drava and Mur. In Romania its distribution area is limited to the carpathian tributaries of the Danube, where it occurs at various distances outside the mountain area. Generally speaking, it has drastically decreased with river regulation.

The distribution of the **grey willow** *Salix elaeagnos* is comparable to that of the tamarisk. Along the German Danube section however, it occurs more frequently, along the main stream (HAEUPLER & SCHÖNFELDER, 1988). On the Austrian Danube it may be found on alluvial sediments of the tributaries, due to river regulation it disappeared gradually (ADLER, OSWALD & FISCHER 1994). In Hungary it is limited to the Small Alföld (Ráb) and may be found along the upper and central course of Drava and Sava. On the lower course of the Danube its occurrence is comparable to that of the German tamarisk and is mainly limited to the hilly area of the tributaries. In the Southern Carpathian it occurs along the Danube tributaries Olt, Ialomita and in their catchment area up to the pre-carpathian area.

In the Romanian lowlands the tamarisk *Tamarix ramossisima* occurs along the Danube's tributaries Ialomita, Siret, Prut and along other tributaries in the lowlands, in places where the river dynamics uncovered protosoils where tamarisk successions grow under favourable moisture conditions. Along the Bulgarian/Romanian Danube it may be found downstream of Zimnicea and the Danube up to its mouth in the Black Sea.

In the frame of this project a full analysis of the occurence of **black poplar** and **white willow** in the whole distribution area was not possible**.** It is necessary, however to have an idea of their distribution in sections of the Danube catchment area and their possible large-scale succession. This kind of development is not guaranteed along the regulated Danube. Willow and black poplar successions only exist along the Bavarian Danube between Straubing and Vilshofen. Natural willow succession occurs in an even smaller area along the short untrained section near Riedlingen (between Zell and Zwiefaltendorf). The conditions for a natural succession of black poplar and white willow are present only downstream on longer sections, of the central and lower Danube (see map). Large-scale softwood stands of the same age develop and integrate into natural gallery forests on these new accretions along the banks of the Danube and on newly emerging islands. This is the case along the Romanian/Bulgarian border. Sections with finer sediments are favourable to the white willow. In some places it covers broad surfaces and it may be found up to the sea-adjacent area of the delta.

Few studies exist on the pioneer species in the low water bed, their distribution is only proven for certain sections along the Danube. This is the case e.g. for the German Danube (HAEUPLER & SCHÖNFELDER, 1988), sections of the Hungarian Danube, in the Kopacki rit/Croatia (SCHNEIDER, 1991 unpubl.) as well as for parts of the lower Danube and the Danube Delta (SCHNEIDER, 1991 unpubl.).

The narrow-leaved ash (*Fraxinus angustifolia*) has its distribution centre in the central and lower Danube basin which follows from the representation of its general distribution (MEUSEL et al., 1978). In Austria it may be found in the floodplain forests East of Vienna and the lower Morava (ADLER, OSWALD & FISCHER, 1994). In Hungary it mainly occurs in the Gemenc-Beda-Mohacs floodplain forest. It appears as well on the lower Sava and Drava and along the tributaries of the lower Danube in the Romanian section.

In Austria, the distribution of *Leucojum aestivum* is limited to the pannonian area (ADLER, OSWALD & FISCHER, 1994). Along the Morava it is characteristic of temporarily inundated floodplain meadows, it appears along the Hungarian Danube, along Sava and Drava, the Bulgarian/Romanian Danube section, the Balta and in some cases in the Danube Delta.

The wild vine may be found along the central and lower Danube in very structured floodplain forests and moves up to the Danube Delta (MEUSEL & NIEDERMAYER, 1985).

The **Greek liana** (*Periploca graeca*) occurs along the lower Danube from Giurgiu up to the sea-adjacent delta area.

The distribution of the **clematis** *Clematis integrifolia* reaches from the lower Morava and the area of the Morava mouth to the central Danube area and the lower Sava and Drava rivers. In smaller areas it may as well be found along the lower Danube, it has however dramatically decreased given the eutrophication of its habitats and the cutting off of meadows from the flood regime. Because of this it is severely threatened.

The **water chestnut** (*Trapa natans*) has ist centre of distribution downstream of the Hungarian Danube. It distinctly occurs in the Hungarian lowland along Danube and Tisza (FELFÖLDY, L., 1990). On the lower Danube the former areas where it was found have not been recently confirmed except for those in the Balta Brailei and the Danube Delta.

***Butterflies***

Danubian Purple Emperor (*Apatura metis*)

No proof exists for the upper Danube section.

Austria: it has been mentioned for the Austrian Danube (TOLMAN & LEVINGTON, 1998). The Austrian butterfly distribution atlas (REICHL, 1992) comprises a map for Apatura metis, but no recent occurrences have been recorded.

Slovak Republik: no proof of existence

Hungary: according to statements by RAKONCZAY (1990) and UHERKOVICH (written note, 1998), many specimen have been found along the Danube downstream Csepel island. Numerous specimen have been found at the confluence of Drava and Danube, on the Drava along the Hungarian/FR Yugoslavian border. The species has also been mentioned for the lower Tisza (RAKONCZAY, 1990).

Slovenia: no data

Romania: proofs of existence are available for the lower Nera, the lower Danube near Ostrov, the lagoon area Razelm-Sinoe near Enisala (oral message L. RAKOSY, Nov 1998), several spots in the Danube Delta and the lower course of the Siret (proper oberservations, SCHNEIDER 1997, 1998). The Tolman & Lewington aerial map does not include occurrences on the lower Danube.

Bulgaria: the species appears in isolated populations. According to the distribution map by ABDJIEV (1995, p 18), the majority of the occurrences have been proven along the Danube tributaries rising in the Balkan mountains. The absence of proof of occurrence for the Danube floodplains is probably due to the lack of field studies.

Moldova: no data, the occurrence on the lower Prut is very likely.

Ukraine: according to KOTENKO (written message, 1998) *Apatura metis* is characteristic of the floodplain forests in Ukraine's steppe zone. It has also been mentioned for the Ukrainian part of the Danube Delta, where it does not appear in great number.

*Large Copper (Lycaena dispar)*

According to the distribution map by EBERT (1991, p. 214), in Baden-Württemberg the large copper exclusively appears in the upper Rhine plain and along its major tributaries. It is lacking along the upper Danube up to Austria.

The next occurrence was recorded in the Eastern part of Austria (REICHL, 1992), in Slovenia; (written note by Lidja Globevnik, Nov 1998) and Southern Slovak Republik. The highest raster frequence shows the species in the pannonian section of the Danube lowlands in Hungary, Croatia and Serbia.

The areal map of the present distribution in Europe shows that occurrences have been proven for the pannonian section of the Danube lowland and along the lower Danube (Balta area, Danube Delta).

Little proofs of ist occurrence exist for the Romanian/Bulgarian Danube. The reason for this probably are insufficient entomological investigations in this border area which has been inaccessible over the recent decades.

According to the map of the present large copper distribution in Europe (PULLIN et al., 1998), the species exists on a large scale in the inundation areas of the Balta, Danube Delta and along the Prut and Siret rivers. In the Ukrainian Danube Delta, which presents the same conditions as the Romanian part, *Lycaena dispar* is considered as a "common and relatively frequent hygrophilous species" (KOTENKO, written message, 1998).

Observations made in the Danube Delta show that the species is relatively frequent in the whole Delta area. It appears wherever its forage plants, i.e. sorrel species, are growing. The species was especially frequent on reflooded and wet, periodically moistened rehabilitation areas in the Northern part of the Delta (Ostrowa, Babina and Cernovca). After the reflooding of the polder areas (1994) it was the most spectacular, frequent and characteristic diurnal species.

***Fish***

European mud-minnow (*Umbra krameri*)

Streber (*Zingel streber)*

Blue bream (*Abramis ballerus*)

Crucian carp (*Carassius carassius)*

Mud load ((*Misgurnus fossilis*

A description of the fish bioindicators distribution may be found in chapter 4.1.1 – 4.1.9.

***Birds***

*White-tailed eagle (Haliaeetus albicilla)*

The distribution map of the white-tailed eagle largely corresponds to its total expansion in the Danube catchment area, as breeding pairs have also been recorded beyond the river area. The very good knowledge of the occurrence of this bird allowed a very detailed analysis which revealed interesting results plotted on the map. The white-tailed eagle appear as a string of pearls both along the larger rivers of the pannonian lowlands and along the lower Danube. Their highest breeding density is concentrated in the largely intact, broad floodplain areas along Sava (Lonjsko Polje), Danube (Gemenc-Béda-Karapancsa), the Drava-Danube mouth (Kopacki Rit) and the Danube Delta. Regular inundations allow only an extensive use of these largely wooded areas which has a positive effect on this species´ need of rest. Moreover, broad inundation areas (flooded meadows, grazing land etc.) and various water types (river, oxbow lakes, floodplain lakes etc.) as well as floodplain-adjacent and extensively used fish ponds (particularly in Croatia and Hungary) provide adequate feeding grounds.

If the combination of broad quiet forests with old wood stands and adequate feeding waters (most of all fish ponds) is available, the bird may also appear in a higher density as breeding bird. This is for example one of the reasons for a relatively dense breeding occurrence in the South-Hungarian Komitat Somogy. The limited occurrence of the white-tailed eagle in the broad Danube-Morava-Thaya area is due to a still relatively intensive human interference in the breeding habitats (e.g. Czech Republic) respectively the lack of adequate feeding grounds (e.g. Austria).

The selection of the white-tailed eagle as a bioindicator primarily undermines the faunistic information - already based on the dyking system and CORINE data - on the broad remaining floodplain areas along the studied rivers.

*Little ringed plover (Charadrius dubius)*

The distribution of this bird species is not nearly as well-known as that of other species. One may generally say that, given the qualitatively differing information, only restricted statements can be made on the total distribution of the little ringed plover. Because, one can only deduce its occurrence, a reliable localisation of its breeding habitats and thus its connection with pioneer habitats is impossible. The data on its distribution in the Romanian/Bulgarian Danube section indicates that there are adequate breeding habitats for the whole section, however without a distinct localization. Additional information (based on the experience of local ornithologists,) is that it occurs as a breeding bird on almost all larger gravel and sand banks. The information of the CORINE Landcover data on large-scale pioneer habitats could not be used in this case. This information is not relevant for the project and, even though it will not be represented cartographically, it serves at least as a complementary information to the report.

Information on the little ringed plover also exists for the Croatian Sava. Its total population amounts to less than 10 breeding pairs. The little ringed plover may thus be considered here as a sporadical breeding bird (MIKUSKA, 1998). Its continuous and localized occurrence along Drava and Mur proves a relatively high density of adequate initial habitats (gravel and sand banks) on these river sections.

The available data shows that its main distribution areas are situtated in natural habitats along Drava and Mur, in the Morava-Danube area and on the Romanian/Bulgarian Danube section. These areas present a relatively high density of gravel and sand banks. Secondary breeding places (gravel and sand pits etc.) have not been considered. They are indeed relevant for the distribution of the little ringed plover, but not useful in the bioindicator analysis.

These indicator species primarily provided complementary information to prior knowledge. As statements on the morphological situation, the bird´s activity or pioneer habitats along certain river sections are lacking, this information is valuable. It represents a first approach in the recording of pioneer habitats and, in a broader sense, of recent morphologically active river sections. The habitat type "pioneer habitat" has to be considered on selected plants.

*Bird colonies (cormorant, heron)*

The representation of the breeding colonies´ distribution has to be analysed in a differentiated manner. As the data do not throw light upon the colonies' size in the different habitats they lead to a slightly falsified representation in some cases, e.g. in the case of an area of the size of Kopacki Rit. At first sight the potential, e.g. fish abundant feeding grounds, are not proportionate to the number of represented colonies. These, however, are very rich in specimen, e.g. the cormorants with about 2000 breeding pairs (SCHNEIDER-JACOBY, 1996). While establishing comparative evaluations of the various habitats, further problems may arise due to lack of statements regarding size. Several colonies in one habitat do not necessarily indicate richer feeding grounds in comparison to a habitat with one single colony. Here again, the size of the colony is significant.

As for the little ringed plover, the weight of the statement depends on the investigation level, i.e. on the data basis. The differing state of information, from spot-like, sectional, large-scale to no information at all, has been represented cartographically.

The distribution scheme may generally be compared to that of the white-tailed eagle, at least for its occurrence in the broader floodplain areas. However, the distribution of the colonies is much denser and does not bear gaps. Numerous colonies (mainly characterized by the heron) do e.g. exist along the German and Austrian Danube. Moreover, besides the colonies of the immediate river area, i.e. of the recent floodplain, those of the adjacent areas (oxbow lakes, fish ponds) have also been recorded. The river area is also among the feeding grounds of the latter.

The statements of this indicator species provide, just as for the little ringed plover, complementary information to prior knowledge. The statements however mainly stand as an indicator for habitat quality. But one has to consider that bird colonies also exist along anthropogeneously altered river sections (e.g. in German and Austrian backwater areas) and not merely in recent floodplain areas. This point may be analysed in further detail with the help of the hydropower plant site data.

# 4. Evaluation of Area Sections

## 4.1. Ecological Evaluation Classified According to River Catchment Areas

The investigation area has been divided in the various catchment areas studied. The Danube itself has been divided into Upper (source up to the Porta Hungarica near Hainburg), Central (Porta Hungarica to the Iron Gate) and Lower Danube (Iron Gate to Tulcea) and the Danube-Delta.

The described methodology of the ecological evaluation (s. 2.8.1) largely ensured that the the important wetlands described in the national reports of the GEF-Danube River Basin Pollution Reduction Programme are covered along the studied rivers.

### 4.1.1. Upper Danube

#### a) Evaluation description

As can be seen on map 3, the Upper Danube, with the exception of few unregulated sections, is influenced by a a series of weirs and hydropower plants. Two larger freely flowing sections may be found in the highland gorges where floodplains do not exist naturally. On the dammed sections, the natural inundation areas are cut-off from the river. A few inundations occur at the ends of the dammed sections, in small areas where the river is not or only minimally dammed. In addition, there are small, near-natural areas, for example the practically unregulated section between Zell and Zwiefaltendorf (upstream of Ulm). The small size of these areas, however, makes them irrelevant for the purposes of this study. In addition to the almost total regulation of the upper Danube, the relatively narrow former floodplains in these areas are subject to intensive agricultural use. These factors are the basis for the generally low evaluation of the ecological potential.

The only exceptions are the two larger, freely flowing sections. They are situated in Bavaria, between Straubing and Vilshofen (inclusive of the Isar mouth area) and in Austria near Hainburg, East of Vienna (East of the Morava mouth). By central European standards, both areas comprise floodplain areas of outstanding quality. This has been confirmed by bioindicator studies.

#### b) Exemplary bioindicator results

***Plants***

Along the German Danube, the main distribution area of the German Tamarisk (*Myricaria germanica*) is situated along Lech and Isar, it also appears however along other larger alpine tributaries such as Iller, Inn and Salzach (see HAEUPLER & SCHÖNFELDER 1988). In Austria it is limited to merely a few Danube tributaries. The distribution of the willow *Salix elaeagnos* is comparable to that of the German tamarisk, along the Bavarian Danube it occurs however more frequently along the main stream than the German tamarisk (see HAEUPLER & SCHÖNFELDER 1988). On the Austrian Danube, *Salix elaeagnos* occurs on the alluvions of the tributaries, it has however been dramatically reduced as a consequence of river regulation (see also ADLER, OSWALD & FISCHER 1994).

The lack of morphological dynamics is also distinctly reflected by the decrease in pioneer sites for the natural succession of the black poplar (*Populus nigra*) and the white willow (*Salix alba*). Willow and black poplar succession can only be found along the Bavarian Danube between Straubing and Vilshofen. Natural willow succession occurs in an even smaller area along an untrained section on the Upper Danube near Riedlingen (between Zell and Zweifaltendorf).

The narrow-leaved ash (*Fraxinus angustifolia*), mainly present on the central Danube, occurs only in the border area of the upper Danube. In the floodplain forests East of Vienna it is an indicator for a more or less large-scale presence of inundated hardwood floodplain sites.

***Butterflies***

The European distribution area of the large copper shows a distribution gap between the Upper Rhine and the populations in the Eastern part of Austria. Starting from the pannonian area of the Danube plain, the species occurs everywhere in its respective habitats.

The occurrence of the Danubian Purple Emperor is presumed for the Danube floodplains East of Vienna, however, no distinct indications of where it has been found are available (REICHL,1992).

***Fish***

European mud-minnow

An intact population of this fish species has been recorded in the Danube floodplain national parc (WANZENBÖCK, SPINDLER, 1992). The oxbow lakes of the Vienna basin form the Western deliniation of the European mud-minnow distribution. The distribution area of this species is limited to the central and lower Danube.

Streber

Along the upper Danube its habitats have been destroyed by dams. Island-like populations still appear at the end of the dammed sections (ZAUNER, 1996). The main distribution area is limited to the river´s freely running waters in the Wachau East of Vienna.

Blue bream

The natural Western deliniation of its distribution area is Passau. Given the loss of floodplain waters that are naturally connected to the main stream, the species decreased on the regulated Austrian Danube section (SPINDLER, 1997). East of Vienna the blue bream is a dominating species in the section with open former channels (SCHIEMER et al., 1994).

Crucian carp

The species occurs along the entire German Danube section. It may well survive oxygen deficiencies in shallow, cut-off waters of the former inundation areas. The populations of the Danube floodplains in the Vienna basin have decreased (SCHIEMER et al., 1994).

Mud load

The mud load has dramatically decreased on the upper Danube as appropriate habitats have been destroyed by river regulation and pollution. Significant populations only occur in the Vienna basin.

***Birds***

White-tailed eagle

No breeding occurrence is presently known for the upper Danube (the area of the Isar mouth and the Tullner field). This is due to a lack of adequate habitats and a significant disturbance by man in suitable habitats. The floodplains situated East of Vienna may be considered as potential breeding habitats even though the last breeding attempt dates from 1983.

Little ringed plover

The present occurrence of the few breeding pairs is limited to the undammed river sections with few remaining open substrate banks along the Bavarian Danube (and the area of the Isar mouth) and the Danube East of Vienna. Due to the lack of gravel banks it does not occur in the section of the river through the Tullner field. No data were available for the upper Danube section.

Bird colonies

The bird colonies occuring along the Bavarian and - to some extend - also along the Austrian Danube are mainly grey heron colonies. Colonies have also been located in the Isar mouth area and the Tullner field. No data were available for the upper Danube section.

## 4.1.2. Morava

### a) Evaluation description

Contrary to the upper Danube, no hydropower plants are situated along the Morava. Hydrological measures of different quality have been implemented (weirs etc.), but their consequences are far less dramatic than on the upper Danube. Ecologically most valuable areas are situated on the confluence of Morava and Thaya (Soutok). On the lower Morava they are situated on the Austrian (WWF reserve Moravaauen-Moravaegg) and the Slovak side (Záhorie). The upper Morava shows unusually broad inundation areas for an upper river course (Litovelské Pomoraví) near Olomouc.

### b) Exemplary bioindicator results

***Plants***

The narrow-leaved ash (*Fraxinus angustifolia*) has its main distribution centre in the central and lower Danube area (see MEUSEL et all., 1978). On the lower Morava its presence indicates favourable sites for pannonian hardwood floodplain forests (see ADLER, OSWALD & FISCHER, 1994). An additional indicator of highly structured floodplain forests is the wild vine *Vitis syslvestris*.

*Leucojum aestivum* appears as an indicator species for periodically inundated floodplain meadows and hardwood floodplain forests.

Along the lower Morava and the Morava mouth, the clematis *Clematis integrifolia* occurs frequently as an indicator species for extensively used, moderately eutrophic floodplain meadows; it has its main distribution area in this region.

***Butterflies***

The occurrence of the large copper has been proven many times for this area (REICHL, 1992). The Danubian Purple Emperor has not yet been proven here; its occurrence however is probable.

***Fish***

European mud-minnow

In the North, its occurrence has been proven in the small waters of the Slovak inundation area along the lower Morava (BARUS, OLIVA, 1995). Despite intensive investigations, the species could not be proven nor on the Slovak (SPINDLER et al., 1992) nor on the Austrian side of the river. (WANZENBÖCK, SPINDLER, 1992).

Streber

Up to the 1920's, the streber occurred in the central section of the Morava river near Olomouc. Due to river regulation and river pollution it disappeared completely. Adequate habitats may still be found nowadays upstream of the city of Hodonín.

Blue bream

The natural occurrence of the blue bream in the lower Morava reaches up to the confluence with the Thaya (BARUS, OLIVA, 1995). Its actual distribution between the Morava-Thaya mouth and the Morava-Danube mouth (SPINDLER et al., 1992, ZAUNER, 1993) indicates a well-operating connection between the stream and its tributaries.

Crucian carp

Recent studies confirm the occurrence of the Crucian carp on the upper Morava (HOHAUSOVÁ, JURAJDA, 1997), on the lower Morava (JURAJDA, PENÁZ, 1993) and in oxbow lakes. It is probable that it also occurs in the numerous oxbow lakes of the central part between the two studied sections. In numerous waters of the lower Morava the Crucian carp does not occur at all, even though the waters are appropriate.

Mud load

Only one proof is known for the central Morava in the floodplains of the nature reserve Litovelské Pomoraví (STERBA, oral message). Several populations have been found in the floodplains of the lower Morava.

***Birds***

White-tailed eagle

In the broad floodplains of the Morava-Thaya area it is known only as a potential breeding bird, due to a too high human interference in the breeding habitats (in Czech Republic for example) and due to the lack of sufficient feeding grounds (e.g. in Austria).

Little ringed plover

Depending on the respective water levels of the river, the breeding sites are available in certain sections on pioneer sites along the entire Morava and the lower Thaya.

Bird colonies

Breeding sites may be found in the whole Morava-Thaya area. The colonies consist mainly of grey herons and a lower number of cormorants (e.g. in the Austrian-Slovak section). On the Czech Morava, data on colonies could only be found for certain sections.

### 4.1.3. Central Danube

#### a) Evaluation description

The beginning of the central Danube is characterized by the Gabcikovo hydropower plant and its subsequent and far-reaching hydrological interventions in the natural landscape. The major part of the inner delta´s (Szigetköz) waters have been withdrawn because of the construction of the more than 40 km long outlet channel and the management plan (1/3 of the water remains in the Danube river bed, 2/3 of the water is diverted into the hydropower plant channel). This project and its subsequent ecological consequences have been analysed in many studies. An analysis of the Gabcikovo problem is far beyond the scope of this project.

In general, the Szigetköz has a very high ecological value. However, due to the Gabcikovo hydropower plant the situation constantly deteriorates. An improvement of the situation could be reached by an adequate change of the management plan in favour of the water regime of the former Danube (e.g. 2/3 of the water remains in the Danube , 1/3 is diverted).

Along central Danube up to Budapest, narrow or intensively used farmland and densely settled areas are characteristic. Downstream of Budapest the Danube reaches the Hungarian lowlands (Alföld). On its Eastern side an adjacent lowland extends along the river up to the Tisza. A concise deliniation of the morphological floodplains very difficult for this section. Up to the first extremely valuable area, the Gemenc floodplain forest in Hungary, the river flows along intensively used farmland with numerous settlements. This image changes as the river flows to the south. From the Gemenc floodplain forest in Hungary up to the Drava mouth (Kopacki-Rit/Croatia, FR Yugoslavia) areas with a high ecological potential are characteristic. This is confirmed by investigations completed on bioindicators.

Further valuable areas may be found downstream in the central Danube, their extent, however, is smaller. The 130 km backwater section of the Iron Gate dam negatively affects the results of the evaluation in the last section of the central Danube. The dam has influences on the floodplains up to Beograde (see map 2), which is why the large-scale areas downstream of Beograde can not be evaluated as having higher values.

## b) Exemplary bioindicator results

***Plants***

On the central Danube, indicator species such as German tamarisk and *Salix elaeagnos* occur sparsely. The German tamarisk (*Myricaria germanica*) has been found on the Hungarian Raba. On the central Hungarian Danube, the distribution of *Salix elaeagnos* is limited to the small Alföld (Ràb).

Thanks to a natural morphodynamics in certain sections, adequate conditions for the natural succession of black poplar (*Populus nigra*) and white willow (*Salix alba*) have still been preserved on the central Danube. Large-scale softwood stands of the same age may develop on new accretions, both along the Danube border and on the islands.

On the central Danube, the narrow-leaved ash (*Fraxinus angustifolia*) is an indicator of periodically inundated hardwood floodplain forest habitats. Additionally there is *Vitis sylvestris*, occurring in highly structured floodplain forests in this Danube section.

The indicator species *Leucojum aestivum* is characteristic of hardwood forest floodplains along the central Danube and also indicates potential sites of the pannonian oak-elm forest on inundated, moderately eutrophic floodplain meadows. The habitat quality of moderately eutrophic floodplain meadows that are subject to an extensive use may also be deduced from the occurrence of *Clematis integrifolia*, even though this species dramatically decreased during recent years.

The presence of numerous oxbow lakes in the central Danube area of the Hungarian lowland, which are still subject to regular water level fluctuations, provides ideal conditions for the occurrence of the water chestnut (*Trapa natans*). This characteristic species of eutrophic, even though unpolluted water sections, has dramatically reduced as a result of intensive farming and nutrient input into the waters.

***Butterflies***

The large copper has a connected distribution in the pannonian lowland and occurs in the majority of the flood prone areas along the Danube (PULLIN et al., 1998). Today, the Danubian Purple Emperor has been proven to occur in the area from the Csepel island up to the Drava mouth. An especially dense occurrence has been proven along the Drava and its confluence with the Danube. The broad white willow floodplains present the best conditions for its occurrence.

***Fish***

European mud-minnow

Before the construction of the Gabcikovo dam, the European mud-minnow was among the common fish species of the Szigetköz floodplain waters (GUTI, 1995). Nowadays, only two suitable habitats are known for the Hungarian side. On the other sections of the Hungarian Danube, its distribution was dramatically reduced. Former habitats along the Szigetköz in Slovak Republik (BARUS, OLIVA, 1995) no longer exists with only one exeption. (HOLCÍK, oral message). No data are available for the Croatian-Serbian area as well as for the rest of Serbia.

Streber

Before the construction of Gabcikovo, the streber commonly occurred in the main river and in the flowing side arms of the Szigetköz (HENSEL, 1979). The streber may still be found in the undammed Slovak and Hungarian sections. In Croatia and Serbia it is limited to two sites. Because adequate habitats are available, we assume that the main reason for the disappearance of this fish species are water quality problems. The streber habitats in the gorge section of the Iron Gate have been destroyed by building of the two Iron Gate-dams.

Blue bream

The blue bream´s occurrence throughout the whole section indicates good communication between main stream and branches. Its incomplete distribution in Croatia and Serbia (MALETIN et al., 1997) is due to insufficient mapping, as many intact floodplains exist in this section.

Crucian carp

The presence of numerous oxbow lakes and ponds in the central Danube´s recent and morphological floodplains allows a regular distribution of the Crucian carp. Its actual, island-like presence is the result of two factors: first is competition with the congenial species *Carassius auratus*, second, the distribution data are very poor for some countries.

Mud load

Its present distribution is island-like, even though a sufficient number of appropriate habitats exists on the central Danube. Downstream the Visegrad Danube mouth it occurs more frequently than on the section influenced by Gabcikovo. The recent distribution data available for the Slovakian-Hungarian section require urgent actualization (HOLCÍK, oral message). Only incomplete data are available for the Croatian and Serbian river stretches.

***Birds***

White-tailed eagle

The mainly intact, broad floodplains of the Gemenc-Béda-Karapancsa area, the Kopacki Rit and the Yugoslavian Danube are the centre of the white-tailed eagle´s breeding occurrences along the Danube. These are the most important breeding areas in the whole Danube catchment area. Due to regular inundations, these areas are only subject to extensive landuse which in turn has a positive effect on this bird species. In addition to the extended flood prone areas, various water bodies and extensively used fish ponds (mainly in Croatia and Hungary) provide adequate feeding grounds. Potential breeding occurrences exist as well in the Szigetköz area of the Slovakian Danube floodplains.

Little Ringed plover

The known breeding occurrence is limited to the Hungarian/Slovakian river section of the Szigetköz (outlet section of the Gabcikovo hydropower plant), which has larger, still open pioneer sites and smaller stretches along the Hungarian Danube. No breeding on natural sites occurs along the Yugoslavian Danube. The temporary inundation of the gravel banks in the very extended backwater area of the Iron Gate hydropower plant, especially during the breeding time, certainly is the reason for this. No breeding is known for the Kopacki Rit.

Bird colonies

On the central Danube, colonies are mainly situated in the larger floodplains of the Gemenc-Béda-Karapancsa and the Kopacki Rit area, as well as along the Yougoslavian Danube. Colonies may also be found in the floodplains along the Szigetköz.

No data were available for the central section of the Hungarian Danube.

### 4.1.4. Drava

#### a) Evaluation description

In the section downstream of its confluence with the Mur and in the lower Mur area, the Drava is characterized by its relatively near-natural recent floodplains. The lack of dams in this section has a positive effect on the ecological evaluation. However, the gradual deepening of the river is a problem. As a consequence, the recent floodplain area is rarely inundated if compared to the past. If progressive deepening is not stopped, the riverbed will be so deep, that the areas between the dykes will no longer be flooded. As a consequence, they would no longer be a part of the recent floodplain, even though no new dams would obstruct the water flow.

The former floodplain area contains numerous settlements and is subject to more or less intensive agricultural landuse. The upper section of the studied portion of the Drava is characterized by dams with outlet sections in between and a correspondingly low ecological potential.

#### b) Exemplary bioindicator results

***Plants***

Both on the upper and central Drava and along the Mur, some dynamic habitats are indicated by the presence of the German tamarisk (*Myricaria germanica*) and the willow *Salix eleagnos*.

Along the central and lower Drava and Mur, small-scale possibilities for natural black poplar (*Populus nigra*) and white willow (*Salix alba*) succession are present.

The presence of the narrow-leaved ash (*Fraxinus angustifolia*) indicates characteristic, periodically inundated habitats of the hardwood floodplain. Together with *Leucojum aestivum* they constitute characteristic *Leucojum aestivum*-ash floodplain forests on the lower Drava.

*Vitis sylvestris* is an indicator for the rich structure of these forests on the lower Drava. Extensive use and moderate eutrophication of the habitats is indicated by *Clematis integrifolia*.

On the lower Drava, the presence of the water chestnut (*Trapa natans*) is an indicator for large eutrophic old channels that are subject to water level fluctuations.

***Butterflies***

The raster mapping of the Large Copper shows a wide distribution in this area. The Danubian Purple Emperor also occurs continuously along the Drava.

***Fish***

All studied fish species have been found in the Drava-Mur river system (POVZ, 1991, MAJER, 1995, MRAKOVCIC, 1996). Streber and blue bream could not be found in the Slovenian part (GLOBEVNIK, oral message). A more detailed mapping would certainly show a denser distribution, as these floodplains are very natural.

***Birds***

White-tailed eagle

On the lower Drava its breeding habitats are spread along the whole Croatian-Hungarian border section and in the area of the Danube-Drava floodplains. The occurrence is closely linked to the relatively dense breeding areas in the broad and calm South-Hungarian forests with old wood stands and rich feeding grounds (mainly fish ponds). It has also been proven as a breeding bird in the Drava-Mur area. A potential breeding area is the section upstream the Mur close to a Drava outlet channel. No breeding places have recently been proven on the lower Mur.

Little ringed plover

Along the Drava, it is both a breeding bird on the remaining gravel banks in the Slovenian hydropower plant outlet channels (no data were available for the Croatian outlet sections) and downstream of the Mur confluence, on the unregulated section along the Croatian-Hungarian border area. The breeding habitat are concentrated on the numerous gravel and sand banks downstream the Mur-Drava confluence up to the area where the Drava finally forms the border between Croatia and Hungary. Along the Mur river, the present breeding habitats are mainly situated in the Slovenian-Croatian-Hungarian border section with its relatively numerous pioneer habitats.

Bird colonies

A concentration of heron breeding habitats is situated in the Croatian-Hungarian border area. Grey heron colonies are known for the Slovenian and Slovenian-Croatian Mur.

### 4.1.5. Sava

#### a) Evaluation description

The Sava is the Danube´s second largest subcatchment area after the Tisza. Based on its discharge, the Sava is by far the largest tributary of the Danube. On its central course, downstream of Zagreb, it is characterized by a large-scale morphological floodplain, the so-called Poljen. These include not only the Sava, but also smaller waters flowing parallel to the Sava. The large hatched areas are used as polders and may be subject to controlled flooding. On the other hand, the flooding of the two dark-green areas occurs uncontrolled over the two tributaries. Further broad former floodplain areas may be found downstream, even though they are subject to a more or less intensive anthropogenic use. Other large-scale recent floodplains may be found in the Drina mouth area and along the Northern Sava border in Yougoslavia.

#### b) Exemplary bioindicator results

***Plants***

The willow Salix elaeagnos occurs on the upper and central Sava. The German tamarisk (Myricaria germanica) has not been proven to be present here. Appropriate conditions for white willow (Salix alba) and black poplar (Populus nigra) exist on the lower Sava. The available incomplete data do not allow a higher degree of detail. The distribution of the narrow-leaved ash (Fraxinus angustifolia) indicates large-scale hardwood floodplains along the Sava. Leucojum aestivum is characteristic of the hardwood floodplain forests of the lower Sava. Where it occurs in extensively used floodplain meadows it also indicates potential hardwood floodplain habitats. Clematis integrifolia occurs in the moderately eutrophic, extensively used inundation meadows of the lower Sava.

The water chestnut (Trapa natans) is an indicator for eutrophic oxbow lakes with water level fluctuations on the lower Sava.

***Butterflies***

The large copper occurs in the area, but no proof exists for the occurrence of the danubian purple emperor (Globevnik inf.).

***Fish***

European mud-minnow

It does not occur on the upper Sava in Slovenia. Distribution data for Croatia and the border area between Croatia and Bosnia-Herzegovina are not available. Its presence in Serbia corresponds to the good conditions of the floodplains along the Northern bank of the lower river course.

Streber

Data exist only for Serbia.

Blue bream

Distribution data are lacking. The blue bream does not occur in Slovenia (Globenik, oral message). Given the relatively good conditions of the recent floodplain one may suppose that the species also occurs on the central and lower Sava.

Crucian carp

Its distribution on the upper course of the river in Slovenia and single observations in Serbia allow the supposition, that the species is largely present along the Sava.

Mud load

Evidence from the upper, central and lower river course indicate, that a more detailed mapping of the floodplain waters would bring up new evidence of occurrence, because appropriate habitats exist.

***Birds***

White-tailed eagle

The white-tailed eagle occurs as a breeding bird in the larger recent floodplain areas along the lower Sava, a distinct centre for its distribution being the extended floodplains of Lonjsko Polje. This area is not only significant for the Sava, but it is also among the most important breeding areas of the white-tailed eagle in the whole Danube catchment area.

Little ringed plover

On the Croatian and Croatian-Bosnian side, it may merely be found as a sporadic breeding bird of the pioneer sites, as the total stand of this area is estimated at less than 10 breeding pairs.

Bird colonies

The distribution of the grey heron colonies is mainly limited to the broad floodplain area of Lonjsko Polje.

## 4.1.6. Tisza

### a) Evaluation description

Due to numerous drainage projects, the formerly very large floodplain areas have been reduced to narrow recent floodplains. Drainage also affects the adjacent lowlands between Danube and Tisza, the Mur arriving from the East, the upper Tisza confluents from Slovakia (Bodrog) and the Somes from the South-East. In the 18th and 19th century, these formerly broad wetland areas have been drained and made agriculturally usable. This is why nowadays only narrow recent floodplain areas may be found along the Tisza. They are, however, relatively valuable from an ecological point of view thanks to their structure and their extensive anthropogenic use. The reservoir near Tiszaczsege is important as well. Its shallow backwaters are far from natural, dynamic floodplains, but it has become an important breeding and feeding habitat for birds.

Just as for the Drava, the dramatic deepening problem exists also for the Tisza. The consequence of this is a gradual disappearance of the natural dynamics of the recent floodplains.

### b) Exemplary bioindicator results

***Plants***

The German tamarisk (Myricaria germanica) occurs in the catchment area of the upper Tisza (e.g. along the Somes).

The central and lower Tisza offers, on some stretches, conditions for a black poplar (Populus nigra) and white willow (Salix alba) succession. However, the emergence of new dynamic sites has been dramatically reduced because of the regulation of the Tisza. The lower Mures, the largest tributary of the Tisza, still contains broad pioneer habitats where natural black poplar and white willow succession may occur.

The narrow-leaved ash in its pannonian form (Fraxinus angustifolia ssp. pannonica) indicates the habitats of the pannonian hardwood floodplain forest. Vitis sylvestris also occurs in these forests that are rich in structure and species.

The water chestnut (Trapa natans) is an indicator for the numerous old channels of the Large Alföld, which is still partly linked to the river.

***Butterflies***

The large copper has a large-scale distribution area along the Tisza (Pullin et al., 1998). The Danubian Purple Emperor has been proven to exist on the lower Tisza (Rakonczay, 1990). The available data however do not provide information on the upstream distribution.

***Fish***

European mud-minnow

It occurs on the entire Hungarian part of the Tisza. The Tisza and its tributaries from Eastern Slovakia are among its central distribution areas.

Streber

It occurs in the sections of the upper Tisza, where dynamic river sections exist.

Blue bream

It is present in the central and upper sections with intact floodplains.

Crucian carp

Its occurrence along the entire Tisza indicates the existence of numerous small waters in recent and morphological floodplains.

Mud load

The species regularly occurs along the whole river and indicates the presence of conditions similar to those that have already been mentioned for the Crucian carp.

***Birds***

White-tailed eagle

This species likely breeds, although sparsely along the whole Tisza in the larger floodplain areas. It is also breeding in the large reservoir basin Kisköre.

Little ringed plover

With one exception in Hungary, breeding has not been proven for this species along the Tisza.

Bird colonies

Colonies, mainly composed of grey heron, exist along the whole Tisza, e.g. in the area of the Hungarian reservoir basin Kisköre. In addition, many colonies may be found on the Yugoslavian Tisza section. No data were available for the upper river.

## 4.1.7. Lower Danube

### a) Evaluation description

Downstream of the gorge at the Iron Gate, the lower Danube is characterized, on the Bulgarian side, by relatively narrow floodplains with very marked slopes and, on the Romanian side, by a large-scale morphological floodplain up to 15 km wide. In the 1960s and ´70s, the areas on the Romanian side have been dyked and drained for agricultural purposes. As a consequence their ecological value decreased dramatically. Large remaining floodplain areas exist only in the mouth areas of the Romanian tributaries. The gradually reduced velocity of the Danube waters allows the formation of constantly growing islands on the lower Danube. Because these islands are merely used in part, they increase the ecological potential of the area. The three largest islands near Calarasi, Balta Jalomita and Balta Braila with the Large and Small Braila islands are, however, mainly subject to intensive agricultural use. The ecologically highly valuable areas of this section mainly refer to the undammed areas immediately upstream and downstream of the islands. Another valuable area is the small Braila island situated immediately upstream of the Danube bend, close to the Prut mouth. The 5 km wide recent floodplain is the largest on the lower Danube. This represents, however, only about 10 % of the formerly recent Balta Braila floodplain. Given the different classes due to different floodplain widths (class 3: 2,5 -5 km, class 4: > 5 km) the actual surface of this area has been represented in a somewhat distorted way. While representing these large island areas one also has to consider, that the repartition in the right and left floodplain areas has been affected from the main stream.

Two large Liman lakes with large-scale adjacent wetlands are situated on the Ukrainian side of the lower Danube, downstream of the Prut mouth. On the Romanian side however, natural floodplain areas still exist and have already been declared as core areas of the Danube Delta biosphere reserve.

### b) Exemplary bioindicator results

***Plants***

On the lower Danube, the distribution of the German tamarisk (Myricaria germanica) is limited to the carpathian tributaries of the Danube. Its seeds are deposited relatively far along the lowland.

The distribution of the willow Salix elaeagnos is comparable, even though it exclusively occurs in the alpine section of some tributaries. In the Southern Carpathes it occurs along Olt and Ialomita as well as along their alpine tributaries up to the pre-carpathian mountains.

In the lower Danube lowland, the German tamarisk is replaced by Tamarix ramosissima. It occurs both on pioneer sites along the main stream, downstream Zimnicea, and along the Danube´s tributaries in the lowlands. It exists along the river up to the Danube Delta.

Good conditions for a natural black poplar (black poplar) and white willow (salix alba) succession are given on longer stretches along the lower Danube. On fine sediments, the white willow has an advantage over other plants. It forms dense riparian fringes on certain stretches and exists along the Danube almost up to the sea.

On the lower Danube, the narrow-leaved ash indicates the presence of the small-scale hardwood floodplain habitats. These exist on part of the Bulgarian Danube islands and the Romanian Danube downstream of Giurgiu.

*Vitis sylvestris* is a characteristic element of well-structured floodplain stands on the whole lower Danube (see MEUSEL & NIEDERMAIER, 1985). They usually exist in transitory forests from softwood to hardwood floodplain forests and in hardwood floodplain forests.

On the lower Danube downstream of Giurgiu, the liana *Periploca graeca* is characteristic of well-structured hardwood floodplain forests.

The presence of *Leucojum aestivum* indicates the existence of small-scale hardwood floodplain forests along the whole lower Danube. Its distribution is limited to some Bulgarian Danube islands (Persin, Vardim) and on remains of hardwood floodplain forests along the Danube downstream of Giurgiu.

On the lower Danube *Clematis integrifolia* has almost completely disappeared due to plowing and the eutrophication of habitats. Today it only occurs on few spots in the lower Danube catchment area. It's presence indicates extremely valuable habitats on moderately eutrophic inundation meadows.

Early evidence of the water chestnut (*Trapa natans*) which occurred frequently in floodplain lakes and old channels on the lower Danube have not recently been confirmed. A large-scale occurrence of the water chestnut has only been found in the Balta Brailei area.

***Butterflies***

Until now, the large copper has been found on the central section of the Romanian-Bulgarian Danube. An extensive distribution occurrence is supposed for the Balta area. Curiously, the recorded occurrence of the danubian purple emperor in Bulgaria are exclusively available for the Danube tributaries, whereas on the Danube itself it has not been found. One may suppose, however, that this fact is due to insufficient investigations in the border Danube floodplains.

***Fish***

Only limited distribution data is available for the lower Danube. Particularly for the Romanian side, a new mapping of fish distribution is desirable (BANARESCU, oral message). It is hard to believe that, with the exception of the floodplain waters of the Belene island where the fish fauna has been studied on the Bulgarian side, the Crucian carp does not occur on the lower Danube.

Potentially, all of the studied species could occur in this area, because appropriate aquatic habitats are available both in the recent and in the morphological floodplain.

***Birds***

White-tailed eagle

It occurs with single breeding pairs on the larger floodplain areas along the river, i. e. on the Bulgarian-Romanian border section. There is at least one breeding pair in the Belene island area and it is known as well as a breeding species in the Siret, Prut and Danube area.

Little ringed plover

The little ringed plover mainly occurs on the larger gravel and sand banks of the whole Romanian/ Bulgarian border section and on the substrate banks of the Belene islands. It is also present in the area of the Braila island and the Danube Delta. No data were available for the major part of the Romanian Danube.

Bird colonies

The majority of the known colonies are located in the Bulgarian-Romanian river section. They mainly consist of mixed colonies composed of various heron species and/or cormorants. This is true as well for the Belene islands. Data are also available for the major part of the Romanian Danube, the colonies are ,however, not localized.

## 4.1.8. Prut

### a) Evaluation description

Other rivers that have not been studied, are larger than the Prut, e.g. Inn, Mures and Siret. The Prut river, however, given its importance as a transboundary river between Romania and Moldova, has thus been considered in the evaluation. It has a relatively constant morphological floodplain on its meandering course to the Danube. A large reservoir is situated near Stanca-Costesti on the upper Prut. Downstream, the Prut is untrained. Major parts are, however, cut-off from the river by dams which is why its floodplains are relatively small and narrow. Given a less dense settling and the border situation, extremely valuable areas have nevertheless been preserved here. Two natural floodplain lakes are of major importance on the lower Prut, they are among the most valuable areas. Large areas of the lower Prut and close to its mouth have been dammed and drained, e.g. the larger part of the Brates lake. Dramatic changes of the local climate have occured with the decrease in wetland area and have led to steppe-like conditions and large brackish areas.

### b) Exemplary bioindicator results

***Plants***

The tamarisk *Tamarix ramosissima* occurs on virgin soil habitats along the lower Prut. This area also offers narrow riparian pioneer areas that are favourable to white willow (*Salix alba*) succession.

The water chestnut (*Trapa natans*) occurs on the lower Prut, due to water eutrophication it has dramatically decreased and counts among the Red List species of this area.

***Butterflies***

The distribution map of the large copper shows many occurrences along the central Prut valley, a continuous occurrence along the whole river is very probable. The occurrence of the Danubian Purple Emperor is very probable for the lower Prut, because it has been found in both the adjacent lower Siret floodplains and in the Danube Delta.

***Fish***

European mud-minnow

It occurs on the lower Prut where the floodplains provide sufficient adequate habitats.

Streber

This species does not occur in the Prut.

Blue bream

It occurs regularly in the river downstream of the dam Costesti-Stinca. A well-operating communication between the river and its floodplain waters is guaranteed in this section.

Crucian carp

Its spot-like occurrence in the lower river course probably reflects reality. Adequate aquatic habitats for the Crucian carp have been preserved.

Mud load

A similar situation as for the Crucian carp exits for this species. A more detailed fish mapping would certainly remedy the lack of distribution data.

***Birds***

White-tailed eagle

No present breeding occurrence on the Prut.

Little ringed plover

No data available for the Prut.

Bird colonies

Colonies exist along the Prut, but the occurrences have not been localized.

## 4.1.9. Danube Delta

### a) Evaluation description

The description of the Danube Delta´s ecological diversity, with its unique natural world heritage, is beyond the scope of this study. In the Delta one may find various forms of landuse: in addition to areas used traditionally by agriculture, silviculture and fishery there are also relatively broad polder areas used by agriculture and fishery. Moreover there are large-scale, unspoiled areas, with a natural water dynamics. The repartition of the areas is shown in map 3. First results of successful rehabilitation of former polder areas have been obtained and are to be continued in other areas of the Delta.

In comparison to the other floodplain areas studied, those of the Delta have extremely broad extensions. Because of this a classification according to the chosen width classes has not been considered, and a scaled representation has been used. This is why the representation of the Danube Delta on the map appears in another, smaller scale compared to the other floodplain areas.

### b) Exemplary bioindicator results

**• *Plants***

The tamarisk *Tamarix ramosissima*, which also occurs on slightly saline pioneer sites exists along the Danube up to the coast. Large-scale natural succession occurs in some spots of the Delta (Chilia branch, Babina, Popina).

Favourable conditions for new white willow *(Salix alba*) gallery forests that move on to the sea-adjacent Delta area may be found on the ever re-emerging sand and sludge banks along the main branches and on the emerging islands.

The narrow-leaved ash (*Fraxinus angustifolia*) indicates higher situated habitats along the Delta branches where narrow stretches of hardwood floodplain forests may grow. This is also where *Vitis sylvestris*, which forms real curtains along the gallery forests, may regularly be found.

The Greek liana (*Periploca graeca*) is characteristic of the Delta´s hardwood floodplain forests and tree vegetation. Its occurrence is concentrated on the dune forests of Letea and Caraorman. In the North of the Danube it may also be found in the Jebriansk (Ukraine) dune area.

In the Delta, *Leucojum aestivum* occurs only in dune areas (Letea, Caraorman). It grows in low inundation meadows which, if they were subject to no use at all, would grow into forests.

The water chestnut (*Trapa natans*) occurs in eutrophic water courses and delta lakes with intensive water level fluctuations.

***Butterflies***

The Large Copper is among the most characteristic and most frequent butterflies of the Danube Delta. It has been proven to exist on many permanently wet spots and sites with varying moisture in flood prone and riparian areas where the feeding plants for its caterpillar grow. Given the evidence of the Danubian Purple Emperor´s existence on various spots in the Danube Delta one may suppose that it is distributed throughout the area.

***Fish***

With the exception of the streber, all studied fish species occur in the Danube Delta. A multitude of appropriate habitats still exist here for these species.

***Birds***

White-tailed eagle

On the lower Danube the centre of its breeding occurrence is distinctly situated in the Danube Delta which also counts among the most important breeding areas in the entire Danube catchment basin.

Little ringed plover

There exists a small breeding occurrence which has not been exactly localized.

Bird colonies

Colonies of various sizes and species composition may be found in the whole delta area. The mixed breeding colonies of the Danube Delta are among the most representative in the whole Danube basin.

## 4.2. Evaluation of Nutrient Reduction

Recent, inundated floodplains have a posititve effect on the improvement of water quality and nutrient reduction if the area is not agriculturally used. The areas indicated dark-green and light-green on the map 3, the evaluation of the ecological potential, possess a high existing nutrient reduction capacity. Sections of the studied area with these potentially large self-purification capacities are situated on the upper Danube downstream of Vienna, on the central Danube in the mouth areas of Drava, Tisza and Sava, on the lower Danube downstream of the Iron Gate, and particularly in Dobrudza and the Delta. Comparable areas exist along the tributaries, the lower Morava, the Drava, the central and lower Sava, the central Tisza and the lower Prut.

The nutrient reduction efficiency in the above mentioned areas cannot be fully estimated, because no data are available on nutrient concentrations downstream and upstream of these ecologically valuable floodplains. Nevertheless, it is clear that without these areas, the nutrient input into the Black Sea would be higher than it is today.

The border section of the lower Morava is one area where detailed water quality data can be linked to the existence of natural floodplains self purification. On the Slovak side, the section downstream of the Thaya/Morava mouth has been evaluated - based on CORINE data (mapping 1992-94) and according to the inundation area width - as an ecologically moderate and, on a smaller section, as an ecologically valuable area. Larger ecologically valuable areas exist on the Austrian side. The total area of the recent floodplain covers 88 $km^2$. Permanent water quality monitoring stations are situated on the Slovak side. The Moravsky Ján monitoring station is situated in the Northern part of the area, the Devínská Nová station 66 km downstream Moravsky Ján. On both sides, the recent floodplains form a mosaic of near-natural meadows, hardwood floodplain forests and oxbow lakes with a rich macrovegetation. On the Slovak side there are fallow areas of the former `LPG´ (agricultural production cooperative) that are slowly beeing transformed into grassland or are left to natural succession. NH-4, NO3-N and PO4-P are analysed once a month.

Even though two organically polluted tributaries, Zaya and Malina, flow into the river, the table below shows a reduction tendency of nitrogen and phosphorous compounds. With more detailed data (e.g. recordings on both stations of levels of flow and input concentrations of the two tributaries) the positive effect of the 66 km long floodplain section could be much better analysed.

**Table 10 Examples of nutrient levels on the lower Morava**

| Nutrient | NH4-N (mg/l) | | NO3-N (mg/l) | | PO4-P (mg/l) | |
|---|---|---|---|---|---|---|
| Surveying spot | Mor. Ján | Dev. N. Ves | Mor. Ján | Dev. N. Ves | Mor. Ján | Dev. N. Ves |
| | Km 67,1 | Km 1,5 | Km 67,1 | Km 1,5 | Km 67,1 | Km 1,5 |
| Year | | | | | | |
| 1990 | 0,40 | 0,30 | 3,81 | 3,71 | 0,86 | 1,44 |
| 1991 | 0,63 | 0,48 | 3,40 | 2,90 | 0,72 | 1,02 |
| 1992 | 0,45 | 0,28 | 3,30 | 3,61 | 0,42 | 0,39 |
| 1993 | 1,05 | 1,11 | 3,20 | 3,85 | 0,48 | 0,44 |
| 1994 | 0,42 | 0,32 | 4,30 | 2,65 | - | - |
| 1995 | 0,37 | 0,33 | 3,95 | 2,91 | 0,40 | 0,30 |

A quantitative estimation of the yearly nutrient reduction for a particular area of floodplain is difficult. This is because of the methodological problems mentioned in chapters 2.6 and 2.8.3. Based on a review of literature from European and North American temperate zone wetlands, the values found for nutrient reduction of wetlands are between two logarithmic orders (see table 10).

**Table 11 Nutrient reduction in floodplains**

| Type of wetland | Nutrient reduction | | Data source |
|---|---|---|---|
| | kg ges.N/ha/Jahr | kg ges.P/ha/Jahr | |
| | | | |
| Floodpl. Meadows (UK) | 289 | 17,4 | Van Ooorschot, 1996 |
| Floodpl. Meadows (Sweden) | 250-680 | - | Jansson et al., 1994 |
| Hardwoodforest (CZ) | 224 | 18 | Klimo, 1985 |
| Floodp. Forest (USA) | 38-52 | 1,5 | Richardson, 1990 |
| Wetland (not spec.) | 100 | - | Andreasson-Gren, 1995 |
| | Summer | Summer | |
| Reed (Danube-Delta) | 50-100 | 0 | Drost, oral message |

The reduction value of 20 kg total P/ha/year that has been used in the Danube Water Quality Model Simulation (VAN GILS, 1999) approaches the other values published on European floodplains.

The values described in **table 11** originate from divergent geographic regions. This results in dramatic differences for the factors that are relevant for nutrient reduction, e.g. climate, hydrology, pedology, vegetation etc. A scientifically defensible average nutrient reduction capacity cannot be obtained from the available studies. It can be argued, however, based upon review of the studies mentioned above, and the general knowledge on all factors influencing the Danube basin, that a range of values for nutrient reduction can be proposed. They may be represented as follows:

- kg total N/ha/year: 100-150
- kg total P/ha/year: 10-20

## 4.3. Evaluation of the Restoration Potential

To estimate the rehabilitation potential in further detail, the following table, showing the morphological and recent floodplains, has been elaborated. It must be noted, that the river itself has been integrated in these values.

The values of the recent floodplain along the German and Austrian sections, which are influenced by dams require a more detailed evaluation.

**Table 12 Overview of the calculated morphological and recent floodplains area**

**Morphological floodplains in km²**

| | **∑ per state** | **∑ per river** | Com. |
|---|---|---|---|
| **Morava** | | | |
| Austria | 141 | | |
| Czech Republic | 778 | | |
| Slovak Republic | 173 | | |
| | | | |
| ∑ Morava | | 919 | |

**Recent floodplains in km²**

| | **∑ per state** | **∑ per state** | Com. |
|---|---|---|---|
| **Morava** | | | |
| Austria | 47 | | |
| Czech Republic | 318 | | |
| Slovak Republic | 38 | | |
| | | | |
| ∑ Morava | | 403 | |

| | | | |
|---|---|---|---|
| **Donau** | | | |
| Germany | 625 | | |
| Austria- | 1137 | | |
| ∑ **Upper Danube** | | 1762 | |
| | | | |
| | | | |
| Slovak Republic | 1515 | | |
| Hungary | 3114 | | |
| Croatia | 500 | | |
| FR Yugoslavia | 3033 | | |
| ∑ **Central Danube** | | 8161 | |
| | | | |
| | | | |
| Romania | 5951 | | |
| Ukraine | 510 | | |
| Bulgaria | 1401 | | |
| ∑ **Lower Danube** | | 7862 | |
| | | | |
| **Danube-Delta** | | | |
| Romania | 4507 | | |
| Ukraine | 593 | | |
| ∑ **Danube-Delta** | | 5100 | |
| | | | |
| ∑ **Danube** | | | 22885 |

| | | | |
|---|---|---|---|
| Danube | | | |
| Germany | * | | |
| Austria | 95 | | East of Vienna |
| ∑ Upper Danube | * | | |
| | | | |
| | | | |
| Slovak Republic | 245 | | |
| Hungary | 663 | | |
| Croatia | 282 | | |
| FR Yugoslavia | 818 | | |
| ∑ **Central Danube** | | 2008 | |
| | | | |
| | | | |
| Romania | 1653 | | |
| Ukraine | 5 | | |
| Bulgaria | 541 | | |
| ∑ **Lower Danube** | | 2200 | |
| | | | |
| **Danube-Delta** | | | |
| Romania | 3675 | | |
| Ukraine | 124 | | |
| ∑ **Danube-Delta** | | 3799 | |
| | | | |
| ∑ **Danube (East of Vienna)** | | | 8101 |

| | | | |
|---|---|---|---|
| **Prut** | | | |
| Romania | 1139 | | |
| Moldova | 526 | | |
| ∑ **Prut** | | 1665 | |

| | | | |
|---|---|---|---|
| **Prut** | | | |
| Romania | 241 | | |
| Moldova | 178 | | |
| ∑ **Prut** | | 419 | |

| | | | |
|---|---|---|---|
| **Drava** | | | |
| Croatia | 1229 | | |
| Hungary | 666 | | |
| Slovenia | 129 | | |
| ∑ **Drava** | | 2023 | |

| | | | |
|---|---|---|---|
| **Drava** | | | |
| Croatia | 312 | | |
| Hungary | 182 | | |
| Slovenia | | | |
| ∑ **Drava** | | 494 | |

| | | | |
|---|---|---|---|
| **Mur** | | | |
| Slovenia | 152 | | |
| Austria | 150 | | |
| Croatia | 81 | | |
| Hungary | 67 | | |
| ∑ **Mur** | | 449 | |
| | | | |
| ∑ **Drava/Mur** | | | 2472 |

| | | | |
|---|---|---|---|
| **Mur** | | | |
| Slovenia | 62 | | |
| Austria | 5 | | |
| Croatia | 12 | | |
| Hungary | 51 | | |
| ∑ **Mur** | | 130 | |
| | | | |
| ∑ **Drava/Mur** | | | 624 |

| | | | |
|---|---|---|---|
| **Sava** | | | |
| Croatia | 3563 | | |
| Bosnia-Hercegovina | 1037 | | |
| FR Yugoslavia | 1401 | | |
| Slovenia | 121 | | |
| ∑ **Sava** | | 6122 | |

| | | | |
|---|---|---|---|
| **Sava** | | | |
| Croatia | 675 | | |
| Bosnia-Hercegovina | 165 | | |
| FR Yugoslavia | 384 | | |
| Slovenia | 108 | | |
| ∑ **Sava** | | 1332 | |
| ∑ Sava + Poljen | | | 1827 |

| | | | |
|---|---|---|---|
| **Tisza** | | | |
| FR Yugoslavia | 2392 | | |
| Hungary | 4637 | | |
| Ukraine | 200 | | |
| Romania | 313 | | |
| ∑ **Tisza** | | 7542 | |
| | | | |
| ∑ **of evaluated morph. floodplains** | | 41605 | |

| | | | |
|---|---|---|---|
| **Tisza** | | | |
| FR Yugoslavia | 142 | | |
| Hungary | 914 | | |
| Ukraine | 159 | | |
| Romania | | | |
| ∑ **Tisza** | | 1215 | |
| | | | |
| ∑ **of evaluated recent floodplains** | | 7845 | |

** Due to the scale used in this project, the area calculation of the small sized German and Austrian recent floodplains were not to be calculated with the necessary accuracy. It can be said, that the value is smaller than 20 % of the morphological floodplains in this area.*

### 4.4.1. Upper Danube

Because of the numerous hydropower plants there are only few possibilities for restoration in this section.

Along all upper river courses we had to face problems of scale. The precision of detail for this area has been reduced because of the area´s extension. As a consequence, some small-scale floodplain areas along the upper courses were below the required minimum size. This is why the results of the "Inventory of Potential Small Scale Wetland Restoration Sites in the Danube River Basin"-report are also important.

1. Ingolstadt: only the area between Ingolstadt and Neuburg responds to the requirements of size. Improvement measures could be taken along the dam section.
2. Isar mouth: according to evaluations, the inundation area of the Isar mouth is very valuable and could still be enlargened.

### 4.4.2. Morava

3. Drösing forest/Sierndorf: is a relatively small area, but the only possibility for Austria to take restoration measures along the studied rivers. This area is potentially important with respect to its connection to the Morava-Thaya-mouth and the floodplains there.
4. Next to Starznice: this area could compliment the already rehabilitated Morava-Thaya area. The areas is already inundated thanks to the fact that height of the dams are very low here. Many improvement and protection measures could be taken for the sake of the adjacent villages.

### 4.4.3. Central Danube

5. Area between Gemenc and Kopacki Rit (Hungary, Croatia, FR Yugoslavia). In additon to existing well preserved areas, this region presents large-scale rehabilitation possibilities. The present settlement structure requires a detailed investigation to determine a concise deliniation. This is also the case for the Northern Drava area which is adjacent to Kopacki Rit and should be integrated into the protected area.

### 4.4.4. Drava

See central Danube, Kopacki Rit.

### 4.4.5. Sava

6. Drina mouth area: well-structured areas on both sides of the Sava; FR Yugoslavia, Bosnia-Herzegovina and Croatia could be connected to this area.
7. Mokro Polje area: due to the given forest structure, large-scale areas downstream Mokro Polje could be connected to the already existing inundation area of the Polje.

### 4.4.6. Tisza

8. Upper Tisza/Bodrog mouth: the area of the Bodrog mouth still comprises valuable old structures that could easily be connected.
9. Lower Tisza: Given their low settlement density, existing old structures could be connected along the left river bank.

### 4.4.7. Lower Danube

As can be seen on the map, many areas with a very high or high rehabilitation potential still exist. All of these areas should be basically analysed with regard to the possibilities of implementation of rehabilitation mesures.

To achieve a step-by-step progress, we propose four areas, one of them in Romania, the others in the transboundary area as initial priorities:

10. Balta Potelu (near Oriakovo) and Bulgarian area: this is among the few areas where the large Romanian agricultural polders could be reconnected to the river and to similar adjacent Bulgarian areas.
11. Bulgarian Danube islands and opposite area: all Bulgarian islands still have a high ecological potential and could accelerate a rapid rehabilitation when the Romanian polder on the opposite would be opened.
12. Balta Graeca (RO) / Tutrakan (Bulg.): the former fish ponds of Tutrakan and the large agricultural polder on the Romanian side.
13. Kalarasch: is the first and 'smallest' of the three Balta islands. Given the high ecological value at the Danube branching upstream and the area downstream of the island, there is a high near-natural potential at close range.

### 4.4.8. Prut

14. Lower Prut: the map distinctly shows two existing natural lakes along the lower course and the adjacent agricultural areas. Due to the existing natural lakes with their high ecological value a good possibility is given to restore the large agricultural areas on the Romanian and Moldawian part by connecting them with the near natural areas.

### 4.4.9. Danube Delta

15. Liman lakes in Ukraine: connection of the lakes to the Danube
16. Polder Pardina: extended agricultural polder in the Delta with over 30.000 ha
17. Ukrainian part of the Danube Delta: there are some areas in the same conditions like the succesful restored areas in the Romainain part of the Danube Delta. Hey could be restored in the frame of the now existing Ukrainian Danube Delta Biopshere Reserve.

Additional proposals for restoration sites were discussed at the Transboundary Analysis Workshop in January 1999. Four additional areas were identified at this workshop. They are visible on map 7:

18. Obedska Bara (FR Yugoslavia)
19. Mouth of Yrbas (Bosnia-Hercegovina)
20. Crna Mlaka Pokubje (Bosnia-Hercegovina)
21. Palic/Lados (FR Yugoslavia)

Based on the nutrient reduction estimation (s. 4.2) a first rough application of the nutrient reduction potential in the proposed restoration areas and its potential value is visible in the following table 12:

**Table 13 List of proposed restoration areas**

| | Site | Country | Proposed study area for future restoration | Area of recent floodplains included in proposed study area | Proposed study area, only former floodplains | Estimated portion of restorable area in the former floodplains | Potential Rest. Area (min.) | Potential Rest. area (max.) | N-reduction (min) | N-reduction (max) | P-reduction (min) | P-reduction (max) | Value of potential nutrient reduction (min) | Value of potential nutrient reduction (max) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | ha | ha | % | ha | ha | t/y/site | t/y/site | t/y/site | t/y/site | US $ | US $ |
| | | | | | | | | | (100 kg/y/ha) | (100 kg/y/ha) | (10 kg/y/ha) | (10 kg/y/ha) | (250 US$/ha/y) | (250 US$/ha/y) |
| 1 | Floodplains next to Ingolstadt | D | 1.500 | 0 | 1.500 | > 75 % | 1.125 | 1.500 | 113 | 150 | 11 | 15 | 281.250 | 375.000 |
| 2 | Mouth of Isar | D | 1.700 | 400 | 1.300 | 50 – 75 % | 650 | 975 | 65 | 98 | 7 | 10 | 162.500 | 243.750 |
| 3 | Drösing forest | A | 3.000 | 800 | 2.200 | 50 – 75 % | 1.100 | 1.650 | 110 | 165 | 11 | 17 | 275.000 | 412.500 |
| 4 | Floodplains next to Strasnize | CZ | 2.200 | 200 | 2.000 | 50 - 75 % | 1.000 | 1.500 | 100 | 150 | 10 | 15 | 250.000 | 375.000 |
| 5 | Area between Gemenc and Kopacki Rit | H/HR/YU | 250.000 | 70.000 | 180.000 | 25 - 50 % | 45.000 | 90.000 | 4.500 | 9.000 | 450 | 900 | 11.250.000 | 22.500.000 |
| 6 | Area of Drina mouth | YU/BIH/HR | 60.000 | 10.000 | 50.000 | 25 - 50 % | 12.500 | 25.000 | 1.250 | 2.500 | 125 | 250 | 3.125.000 | 6.250.000 |
| 7 | Makro Polje | HR/BIH | 12.400 | 1.000 | 11.400 | 50 – 75 % | 5.700 | 8.550 | 570 | 855 | 57 | 86 | 1.425.000 | 2.137.500 |
| 8 | Mouth of Bodrog | H | 10.000 | 7.000 | 3.000 | > 75 % | 2.250 | 3.000 | 225 | 300 | 23 | 30 | 562.500 | 750.000 |
| 9 | Lower Tisza | YU | 36.000 | 3.000 | 33.000 | 25 – 50 % | 8.250 | 16.500 | 825 | 1.650 | 83 | 165 | 2.062.500 | 4.125.000 |
| 10 | Balta Potelu | RO/BG | 27.000 | 7.500 | 19.500 | > 75 % | 14.625 | 19.500 | 1.463 | 1.950 | 146 | 195 | 3.656.250 | 4.875.000 |
| 11 | Area of Bulg. Danube Islands | RO/BG | 27.000 | 7.000 | 20.000 | > 75 % | 15.000 | 20.000 | 1.500 | 2.000 | 150 | 200 | 3.750.000 | 5.000.000 |
| 12 | Balta Greaca/ Tutrakan | RO/BG | 54.000 | 9.000 | 45.000 | > 75 % | 33.750 | 45.000 | 3.375 | 4.500 | 338 | 450 | 8.437.500 | 11.250.000 |
| 13 | Kalarasch | RO | 10.000 | 0 | 10.000 | > 75 % | 7.500 | 10.000 | 750 | 1.000 | 75 | 100 | 1.875.000 | 2.500.000 |
| 14 | Lower Prut | RO/MD | 51.000 | 20.000 | 31.000 | 50 – 75 % | 15.500 | 23.250 | 1.550 | 2.325 | 155 | 233 | 3.875.000 | 5.812.500 |
| 15 | Liman Lakes | UA | 38.000 | 12.000 | 26.000 | > 75 % | 19.500 | 26.000 | 1.950 | 2.600 | 195 | 260 | 4.875.000 | 6.500.000 |
| 16 | Polder Pardina | RO | 27.000 | 0 | 27.000 | > 75 % | 20.250 | 27.000 | 2.025 | 2.700 | 203 | 270 | 5.062.500 | 6.750.000 |
| 17 | Ukr. Part of Danube Delta | UA | 27.000 | 7.000 | 20.000 | 25 – 50 % | 5.000 | 10.000 | 500 | 1.000 | 50 | 100 | 1.250.000 | 2.500.000 |
| | | $\sum$ | 637.800 | 154.900 | 482.900 | | 208.700 | 329.425 | 20.870 | 32.943 | 2.087 | 3.294 | 52.175.000 | 82.356.250 |

## 4.5. Economic Evaluation

A concise example for the estimation of the financial value of the Danube floodplains was elaborated in 1994 (GREN), it can be summerized as follow:

1. Basic direct values
   - Forests (silviculture) 250.- DM/ha*
   - Grassland (forage/litter) 100.- DM/ha*
   - Water (fishing) 260.- DM/ha*
2. Recreation factor: ca. 380.- DM/ha (240.- DM/ha in "Eastern countries")
3. Nutrient reduction: 440.- DM/ha (this factor has been somewhat overestimated according to the study, on the other hand factors such as flood protection and groundwater regeneration have not been considered.)

** Reduction factor for "Eastern countries" according to OECD criteria (Eastern countries are compared to Turkey): about 2/3 of the direct values for Germany and Austria (state 1991).*

The distribution of forests, grassland and waters refers to the Austrian Danube National Park (61% forest, 13% grassland, 21% water). For a total floodplain area of 1 738000 ha (only Danube floodplains), the estimation amounts to a total value of about 1,33 billion DM. (Values and Calculations of GREN, 1994)

A continuation of this approach should include:

- distinct area values for the recent floodplains
- a detailed landuse in the recent floodplains
- a new evaluation (estimation of the financial value) of each factor and of the reduction factor for "Eastern countries"
- addition of further values (e.g. flood protection, groundwater regeneration, biodiversity)
- special expansions of financial value estimations for the rehabilitation potential

Besides this general information on the economical value of the studied floodplain areas, different wetland restoration projects of the Danube River Basin and their costs are listed in the following:

| Country | Project | Area | Total (US$) |
|---|---|---|---|
| Germany | Building of an ecological polder next to the hydropowerplant Iffezheim at the upper Rhine | ca. 1000 ha | ca. 70 million US$ |
| Austria | Danube downstream of Vienna (national park: reconnection of side-arms) | ca. 800 ha | ca. 4.6 million US$ |
| Romania | Danube Delta: restoration of poldered islands | 3.800 ha | ca. 380.000 US $ |

In this listing the fact has to be taken into account, that neither the individual projects and the respective measures carried out, nor the size of the project areas, are comparable. This table, however, provides preliminary information on the potential range of costs. The restoration cost per acre varies from 70000 US$/ha (including costs buying some land in the study area) in Germany in an area, where many hydrotechnical measures have to be carried out, because the area is situated parallel to the back water area of a hydropower plant. A middle value of costs is given in the Austrian project 5750 US$/ha. The lower end of the costs is decribed by the Romanian experience in the Danube Delta with ca. 100 US$/ha. This low value based on both the relative small area and the information, which was given befor the restoration have started. For the other areas along the lower Danube (Proposed area 10 – 17) a range of costs from 100 – 200 US$ could be estimated. The proposed areas along the Central Danube (areas 5-9) are in other, more complicated circumstences than the areas at the Lower Danube. The range of cost varies from 200 – 2000 US$. Proposed areas 2 – 4 , along the Upper Danube, can be compared with the experience in the Austrian national parc: range from 2000 – 6000 US$. For the proposed area Nr. 1, the floodplains next to Ingolstadt, the value of the Upper Rhine may be an example for the upper limit of costs.

Detailed information may only be obtained with a subsequent investigation, as the areas are not comparable and as varying solutions have to be worked out for each of them.

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