4 Results of landscape analyses

4.1 Physico-geographical description of the Bojana-Buna Delta

In this section a short introduction is given to the process of delta formation, followed by a description of the specific situation in the Bojana-Buna delta and the main landscape units of the project region.

4.1.1 Delta formation

The formation of deltas is attributed to three forcing factors:

- eustatic variations (sea level), which control the available volume for sedimentation and the position of the general base level (shelf).
- sediment transport to the delta, which depends on the climatic variability and on human activities in the catchment basin, as well as on the capacity of transfer of the river channel.
- tides and coastal currents, which are important in the meso- and macro-tidal zones, but which are relatively minor factors in the Mediterranean Sea.

The delta in the context of sediment flux and littoral processes. (source: http://www.pangaea.de/Projects/EURODELTA/)

Figure 1: The delta in the context of sediment flux and littoral processes. (source: http://www.pangaea.de/Projects/EURODELTA/)

Figure 1 shows the close relationship between the influences of hydrology, sedimentology and marine development in the deltaic zone.

During the past 10,000 years, following the end of the last Ice Age, deltas worldwide, including the Bojana-Buna delta, have been in the phase of formation. However, most of the deltas in industrial countries have, during the past 150 years, been converted by man to a destruction phase, triggered by water regulation and dam building that have disrupted the balance between sediment influx, by the erosive effects of coastal processes, and by subsidence. Symptoms of the destruction phase include accelerated coastal erosion and straightening of the shoreline, reduction in wetland size and increased landward incursion of saline groundwater. To re-establish some level of natural hydrologic and sedimentologic conditions is the only credible solution for achieving equilibrium between sediment accretion on the delta plain to offset subsidence, progradation along the coast to offset erosion, and sufficient water influx to flush out and remove the high levels of salt and pollutants from the system.

The Bojana-Buna delta has the characteristics of Shovel deltas such as the Ebro delta and, in part, the Po delta. The Po in its lower course transports mostly sand whereas, during heavy floods, the Bojana Buna transports a lot of gravel too. This type of delta grows by lateral accumulation and the separation of shallow lagoon lakes and pools. This can be seen in particular in the eastern half of the Bojana-Buna delta over the last 100 years. The process is related to a strong coastal influence (dune and lagoon development stages), whereas the radial ridges and swales of the delta are built mainly by river accumulation. Due to the massive reduction of bed load and suspended load following the construction of the dams in the upper Drin basin, the delta is today more and more eroded by the coastal regime. Together with reduced discharges of the rivers and the slight raising of sea level due to climate change, the erosion phase will be intensified.

4.1.2 The Bojana-Buna delta complex and its landscapes

The Bojana-Buna river and delta region comprises a small and recent river delta, several different lagoon complexes and freshwater lakes, as well as typical riverine and coastal
Changes in Bojana-Buna Delta: 1900 (a), 1972 (b) and 2002 (c).
Map 1: Physio-geographical overview

Legend
- Delta development since 1900
- Former river courses of the Bojana / Buna over the last 300-500 years
- Border
- Other rivers
- Rivers and fresh water lakes
- Lagoon, brackish water

Explanation (see also chapter 1.2)
1: Recent Bojana-Buna delta
2: Drin delta (not part of this study)
3: Fluvial and coastal accumulation plain with lagoon formations
4: Bojana-Buna (transition from braided to meandering river type)
5: Drinasa (typically braided gravel river type)
6: Bifurcation of the Drin (today reservoir and water abstraction)
7: Drin reservoir (hydro power generation and irrigation)
8: Skutari lake (shallow floodplain lake)

Map Credit: Ulrich Schwarz, FLUVIUS 2004
Schneider-Jacoby et al. 2006

The development of the whole delta complex could be described as a dynamic short- and long-term process based on:

- high sediment loads from the mountainous catchment of the Drin River
- the hydrographical variability of Lake Skadar and the Drin River
- variability of the wave activity and sea level, based on short-term events (storm waves and tides) and long-term processes (sea transgressions)
- tectonic processes associated with the uplift and abatement of tectonic plates (several earthquakes have been recorded for the area).

The low tidal currents in the Adriatic Sea (about 20 cm in the project area), as well as the high sediment load of the Drin river, support delta formation, whereas the growth of the Bojana-Buna delta by 1 to 1.5 km in the last 100 years is relatively slow compared with other Mediterranean deltas such as the Rhone and Po deltas (about 4 km in 100 years).

The deltaic landscape, in particular the lagoon waters and the coastline, is formed by high flood events, from both the river and the sea. Along the lower Bojana-Buna a natural river levee has formed. During floods, the coarser sandy sediment particles accumulate first, producing a low ridge along the bank with a height of about 1-2 m. Intensive sea waves on the other hand may cause strong currents and erosion that sweep sediment along the shoreline.

As indicated in Map 1 the whole delta complex can be divided into several morphological units:

- The active Bojana-Buna delta. Between 1910 and 1980 the delta grew by 1 to 1.5 km, especially in the eastern part, which is explained by the main discharge through the eastern branch of the river. Since the 1980s, following construction of the Drin reservoir, the sediment load has decreased and the delta front is being partly destroyed.
- The Drin delta: The Drin delta is located 20 km south-eastwards and was not part of this study. But the Drin is important in understanding the whole discharge complex of the region. Between 1846 and the end of the 19th century, the present connection of the old Drin River and the Bojana-Buna River was formed (Drinisa/Drinjaca). Since then the water of the old Drin River is discharged via the Drinisa and the Bojana-Buna to the sea.
- A fluvial and coastal accumulation plain with lagoon formation: This part of the complex is relatively young. It comprises the slow flowing lower Bojana-Buna delta reach, with two huge lagoon complexes (the Montenegrin lagoon was mostly altered into a Salina), littoral and fluvial accumulation forms such as small dune bars and river levees, and irrigated fresh water swamps.
- A fluvial accumulation plain with the braided to meandering Bojana-Buna (a huge floodplain due to the narrow breakthrough and former river courses).
- The braided river Drinisa/Drinjaca (branch of the Drin) leaves the mountains and provides a broad gravel bed with multiple channels.
- Bifurcation of the Drin river into the Drinisa/Drinjaca and Drin, today used for a reservoir and for irrigation, respectively.
- The Drin reservoir (hydropower generation, irrigation).
- Lake Skadar, floodplain lake with annual water oscillation of 2 to 5 m.

4.2 Hydrographic description of the project area

As indicated in Chapter 4.1, the whole landscape complex is influenced by the discharge of the Drin river, the different water stages in Lake Skadar and by the corresponding groundwater levels. Unfortunately, the acquisition of hydrographical data from Albania and Montenegro is still very difficult and existing information has to be reviewed carefully.

At the confluence of the Drin River (Drinisa) with the Lake Skadar outflow (Bojana-Buna) the total catchment comprises about 19.600 km² and the average discharge is 672 m³/s. The river basins are divided into the following sub-basins and discharges (Table 1):

Table 1: River basins, size and discharges of Drin, Skadar Lake and Bojana–Buna

<table>
<thead>
<tr>
<th>Name</th>
<th>Mean discharge</th>
<th>100 year flood</th>
<th>Basin area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Skadar with the main tributary Moraca (50% discharge to the lake)</td>
<td>320 m³/s</td>
<td>3,930 m³/s</td>
<td>5,180 km²</td>
</tr>
<tr>
<td>Drin river with Beli Drin and Crn Drin plus Ohrid and Prespa lakes</td>
<td>351 m³/s</td>
<td>6,530 m³/s</td>
<td>15,540 km²</td>
</tr>
<tr>
<td>Bojana-Buna</td>
<td>672 m³/s</td>
<td>8,500 m³/s</td>
<td>20,720 km²</td>
</tr>
</tbody>
</table>

The average altitude above sea level of both sub-basins is 1.000 m and includes alpine landscapes such as the Montenegrin and Albanian Dinaric Alps, and the Prokletije massif with ridges up to 2.693 m. Gravel and coarse sand are the main sediments of the Drin river, whereas the Skadar lake...
Map 2: Flooded Areas in the Project Region

Legend:
- Border
- International Roads
- Main Roads
- Local Roads
- Railway
- Major rivers
- Other rivers
- Permanent canals
- Small canals
- Embankments

Flood observations and origin:
- January 26 2004 (local rainfall)
- November 5 2003 (Skutari catchment)
- (Flooded during both event)
- January 20 1966 (Drin catchment, data only for the eastern part available)
- Potentially flooded areas in 1900 (based on historical maps)

Background layer: Landsat 7 panchromatic, June 2002, ground resolution 15 m

Map Credit:
Ulrich Schwarz.
FLUVIUS 2004

1: 150,000
accumulates a lot of fine and organic matter. The longitudinal connectivity of rivers of the Lake Skadar catchment and the Bojana-Buna River is high, as no major dams have been built there.

The seasonality of discharge is influenced by the Mediterranean conditions, with high floods during the winter (November - April) and low water levels from June to August. The water and sediment regime of the Drin River is strongly influenced by a huge hydropower reservoir and by water abstraction for irrigation (see also Map 1, Drin bifurcation).

The average fluctuation of the water level of Lake Skadar is about 5 m, with a maximum amplitude of 9.4 m. These fluctuations are very characteristic of the lake with its broad floodplain on the northwestern shoreline. The high water levels of the Drin river (Drinisa) regularly block the discharge of Lake Skadar. Consequently the water level of the lake regularly fluctuates, with the total lake surface varying between 320 km² under low water conditions and more than 500 km² during major floods.

The powerful hydrological and sedimentological prerequisites lead to very active flood and accumulation dynamics of the rivers. Before intensive drainage and melioration of the area, almost 50% of the whole region was regularly flooded (over 28,000 ha). Map 2 shows the results of a preliminary survey of flooded areas within the project region. According to our mapping of flooded areas in November 2003 and January 2004, nearly 9,000 ha are still regularly flooded. As we saw in January 2004, following heavy rainfalls in the delta, flooding in coastal and lagoon areas depends on regional precipitation in the lowlands.

As noted in section 4.1.2 the lower Bojana-Buna has built a river levee. In consequence, large areas adjacent to the river floodplain gallery are regularly flooded. In combination with high river water or sea water levels within the coastal zone, the occurrence of local floods is not infrequent. The still regularly flooded areas includes the most important wetlands, as discussed in section 4.3.

4.3 Habitats of the Bojana-Buna Delta

4.3.1 Classification methodology

A total area of about 878 km² was investigated and classified (see Map 3), based on the following information:

- Landsat 7 multispectral satellite data from June 16 2002 (15 to 30 m ground resolution)
- Selected aerial pictures from summer 2002 and winter 2003
- Field work and ground pictures from June 2003
- Topographical maps (former Yugoslavia and Albania): 1970-1985 (1: 25.000 and 1: 50.000)

Additionally, old panchromatic satellite data and historic maps were used to analyse the habitat and land use development as well as to establish changes in the most important flooded areas and wetlands for selected parts of the project region:

- CORONA from January 20 1966 (2 m ground resolution)
- CORONA from May 26 1972 (5 m ground resolution)
- Topographical maps: 1900/1915 (1: 200.000 and 1: 75.000, Austrian monarchy)

The CORINE land use data set for Albania was used as a reference overview. Detailed land use data and geobotanic data, as well as other data sources describing the local land cover, could not be used, since what is available is mainly not in an appropriate format.

The satellite image was prepared for the classification and further GIS usage. Due to the excellent image quality and the use of only one, single scene, it was not necessary to apply atmospheric corrections and enhancements. It was not possible to perform an orthorectification because of lack of a digital elevation model for the area. On the other hand, the project area is located in the centre of the image and relief information was not basic to the analysis.

Habitats were classified in several iteration steps, based on unsupervised and supervised classifications (Maximum Likelihood method). Different class thresholds were used for the automatic classifications, but the best results were obtained using a supervised classification, with about 30 classes based on training areas. The final list of classes was set after the field calibration and analysis of the aerial picture. Based on this final classification the raster-based results were translated, partly automatically, into a vector GIS file (Shape) with a total sum of about 1,400 polygons with 39 habitat classes. Polygon correction and delineation in an overall plausibility check and cleaning the topology finalized the preparation.

As to other wetland classification approaches, the Ramsar and WetMed methodologies were utilized, and a summarizing and translating step to compare the results of the present classification with those from other systems should be an important next step.

4.3.2 Habitat classes

Table 2 shows the class code, habitat description, total count of polygons and the summed area in ha.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Count</th>
<th>Summed Area in Hectares (5 ha rounding)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Settlements</td>
<td>148</td>
<td>4,560</td>
</tr>
<tr>
<td>12</td>
<td>Coastal waters (Prodelta)</td>
<td>1</td>
<td>8,090</td>
</tr>
<tr>
<td>13</td>
<td>Lagoon, brackish waters</td>
<td>64</td>
<td>1,100</td>
</tr>
<tr>
<td>14</td>
<td>Sandy beach and shoreline</td>
<td>17</td>
<td>270</td>
</tr>
<tr>
<td>15</td>
<td>Dune with pioneer vegetation</td>
<td>55</td>
<td>760</td>
</tr>
<tr>
<td>16</td>
<td>Mud banks and shallow brackish waters</td>
<td>49</td>
<td>360</td>
</tr>
<tr>
<td>17</td>
<td>Beach swamps (<em>Carex, Juncus</em>)</td>
<td>48</td>
<td>385</td>
</tr>
</tbody>
</table>

Table 2: Habitat classification of the Delta and lagoon complex and the Bojana-Buna river corridor (compare Map 3)
Rapid Assessment of the ecological value of the Bojana-Buna Delta

Habitat classification

Map 3: Habitat classification

Legend
- International Roads
- Main Roads
- Local Roads
- Small roads
- Railway
- Major rivers
- Other rivers
- Permanent canals
- Small canals
- Embankments

Habitats
- Settlements
- Open Sea
- Coastal waters
- Lagoon, brackish water
- Sandy beach and shoreline
- Dune with pioneer vegetation
- Mud banks and shallow brackish waters
- Beach swamps (Carex, Juncus)
- Main rivers
- Main canals
- Lakes
- Filled gravel pits
- Macrophyte carpets
- River sand / gravel bars and islands
- Riverine pioneer succession
- Swampy pioneer vegetation
- Swamps (mostly Carex)
- Reed (Phragmites, Typha)
- Tamarix shrub
- Mostly softwood
- Mostly hardwood
- Montenegrine Oak-Hornbeam wood
- Mediterranean coastal wood
- Mediterranean shrub / Maccie and rocks
- Pine plantations, coniferous forest
- Agricultural fields
- Small scale agriculture
- Meadows and pastures (in MN with hedgerows)
- Extensive pastures
- Vineyards, olive plantations

Kilometers
Map Credit: Ulrich Schwarz, FLUVILIS 2004
1: 100,000
4.3.2.1 Description of selected habitats

This classification is focused on the wetland complexes along the Bojana-Buna River between Skadar lake and the Adriatic Sea.

4.3.2.2 Coastal habitats

The coastal zone comprises (a) the "coastal waters", defined as 2 kilometers (about 1 nautical mile) from the shore — no further investigations were done for the coastal waters — and (b) the lagoon complexes, with brackish waters, open mud banks with shallow brackish waters, beach swamps, the shoreline with the sandy beach as well as dunes with different pioneer plant species. The total area of the latter habitats is 2,875 ha, and the shallow, 5–25 meters deep coastal sea waters of the prodelta constitute an additional 8,090 ha.

4.3.2.3 River, lake and swamp habitats

These types of habitat used to cover huge areas before the melioration of the lowlands in Albania. The Bojana-Buna river develops characteristic gravel and sandy pioneer stands with small softwood floodplains on its “upper” reaches (downstream from Shkodra). Today, all potential hardwood stands are used as meadows and agricultural fields. The flow velocity of the river is high, the warm and cold waters from Skadar lake and the alpine Drin river mix together, and there are no large oxbows. Along the upper reaches between Oblika e Madhe and Muriqani, on the right and left sides of the Bojana-Buna near Gjo-Lulit and before the former breakthrough of the river through the karst chain, there are extensive wet meadows and pasture complexes.

4.3.2.4 Arable land

Arable lands can be divided into the following categories: (a) agricultural fields, (b) small-scale agriculture with small fields and scattered meadows, and (c) grasslands. The grasslands are split into meadows, in Montenegro typically bordered by hedgerows, and into huge pastures such as Gjo-Lulit. In Albania several areas are heavily overgrazed by cattle, horses and sheep.

Throughout the lowlands, the original Montenegrin Oak-Hornbeam forests have been reduced to small fragments, whereas larger areas of closed forests cover the foothills of the mountainous karst hinterlands. In particular, in the small-scale agricultural landscapes in Montenegro, fragments of this type of forest alternate with small meadows and fields.

4.3.2.5 Other habitats

All other habitat types, like Mediterranean forest, shrubland, rock vegetation, plantations and settlements, were not explicitly analyzed.

4.3.3 The barrier island of Velika Plaza

The former lagoon “Zoganjsko Jezero” in Montenegro is separated from the Adriatic Sea by an 11 km long barrier island. During the last century the greater part of the former lagoon was transformed into a salina (Solana Ulcinj). Although the flood regime of the area has been further impaired by the construction of an artificial dam along the Bojana River, the barrier islands of Velika Plaza are still regularly flooded (compare Map 2). "As a result of the complex effects of the

### Table 2

<table>
<thead>
<tr>
<th>Habitats</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 Main rivers</td>
<td>3,105</td>
</tr>
<tr>
<td>19 Main canals</td>
<td>10</td>
</tr>
<tr>
<td>20 Lakes</td>
<td>4,920</td>
</tr>
<tr>
<td>21 Filled gravel pits</td>
<td>10</td>
</tr>
<tr>
<td>22 Macrophyte carpets</td>
<td>10</td>
</tr>
<tr>
<td>23 River sand bars and islands</td>
<td>250</td>
</tr>
<tr>
<td>24 River pioneer succession</td>
<td>775</td>
</tr>
<tr>
<td>25 Swampy pioneer vegetation</td>
<td>70</td>
</tr>
<tr>
<td>26 Swamps (mostly Carex)</td>
<td>215</td>
</tr>
<tr>
<td>27 Reed (Phragmites, Thypha)</td>
<td>860</td>
</tr>
<tr>
<td>28 Tamarix shrub</td>
<td>470</td>
</tr>
<tr>
<td>29 Mostly Softwood</td>
<td>1,625</td>
</tr>
<tr>
<td>30 Mostly Hardwood</td>
<td>665</td>
</tr>
<tr>
<td>31 Montenegrin Oak-Hornbeam wood</td>
<td>6,330</td>
</tr>
<tr>
<td>32 Mediterranean coastal wood</td>
<td>15,525</td>
</tr>
<tr>
<td>33 Mediterranean shrub/Maccie and rock</td>
<td>4,135</td>
</tr>
<tr>
<td>34 Pine plantations, coniferous forest</td>
<td>945</td>
</tr>
<tr>
<td>35 Agricultural fields</td>
<td>800</td>
</tr>
<tr>
<td>36 Small scale agriculture</td>
<td>18,610</td>
</tr>
<tr>
<td>37 Meadows and pastures (in MN with hedgerows)</td>
<td>11,330</td>
</tr>
<tr>
<td>38 Extensive pastures</td>
<td>1,700</td>
</tr>
<tr>
<td>39 Vineyards, olive plantations</td>
<td>2,025</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>87,810</strong></td>
</tr>
</tbody>
</table>

Downstream from the breakthrough near Fraskanjel-Recei, the character of the 'lower Bojana-Buna' changes completely. The flow rate is reduced and the river has built a levee which blocks the tributaries, and is building Sasko Jezero as well as wet and swampy areas like the former river bed near Casi (Via Mortemese). The swamps are covered by extensive reed beds of Phragmites and Thypha, stands of sedges (often supported by over grazing). Above the alternatively dry and wet, partly alkaline soils, there are dense stands of Tamarix sp. interspersed with mosaics of softwood alluvial forests. Softwood forests consist mainly of *Populus alba* with intermixed stands of *Salix alba*. *Alnus glutinosa* grows along wet depressions, while small hardwood stands are dominated by *Quercus robur* ssp. *scutariensis*, *Ulmus* sp. and *Fraxinus angustifolia*. Brackish waters from the sea can reach the first Bojana-Buna meander (2.5 km from the delta front) during high tides and storms combined with low discharge of the river. The impact of seawater in Velipoja lagoon is visible, even up to 4 km behind the delta front.

Due to heavily fluctuating water levels and to water management for salt production, the Ulcinj salina hosts a special habitat complex, which is similar to shallow brackish water habitats. Similar conditions exist in some smaller natural areas along the coast on the eastern part of the delta.
river Bojana, the Adriatic Sea and the regime of winds in the Ulcinj area, a system of parallel sand dunes (barrier islands) was formed. The increase in the stability of the sand from the coast line towards the mainland and the decrease in salinity in the depressions between the dunes affected the zonal distribution of life communities with a special composition of avifauna” (Vasic 1979a). The author described 10 habitat zones for this geomorphologically highly characteristic part of the Bojana-Buna Delta (Figure 4).

In the Albanian part of the delta, a very similar zoning of habitat types exists parallel to the coastline. The new touristic complex of Velipoja was erected on a barrier island.
The Bojana-Buna delta in 1972. Velika plaza on the left, with the Ulcinj Salina above it, Ada Island in the middle (Montenegro), and Velipoja Lagoon on the right (Albania). Long stripes that run parallel to the delta front indicate large sand deposits as one of the main characteristics of the Bojana-Buna delta.