4.4 MACROPHYTES

4.4.1 Introduction

The objective of JDS concerning the collection and evaluation of Macrophytes was to gain comparable and reliable information by applying a uniform, standardised methodology. JDS provided a unique, first-time opportunity for the scientific community to get an overview of aquatic plant growth for the entire course of the Danube related to the defined JDS sampling points between Neu Ulm (Danube-km 2581) and the last three sampling points in the Danube Delta arms (Danube-km 12).

4.4.2 Sampling Sites

The official JDS sampling programme included altogether 98 sampling sites, 77 situated along the Danube itself and 21 along its main tributaries and side arms. Along the Danube itself, aquatic plants were collected on both banks (left/right). Although the tributaries were searched for macrophytes on both banks, their collection results were integrated into one single sample related to the smaller size of tributaries providing very consistent abiotic habitat conditions for the whole river transect. In addition, seven further sampling sites were later included in the JDS programme by the core team members since these points showed significance concerning evaluation. Four of the additional sampling points were locted in connected Danube oxbows, two in connected lakes and one within a natural meander of St. Gheorghe Danube Delta arm (Table MP-1). A total of 180 sampling points were investigated for aquatic plants.

Sampling site	Country	Location	river km
Starohájske rameno	SK	Oxbow at right Danube bank	1864
Asványráró (Old Danube)	H	Oxbow at right Danube bank	1812
Komarno/Komarom	H/SK	Oxbow at right Danube bank	1772
Tributary Vah	SK	Oxbow at left bank of tributary Vah	1766
Szob	H	Connected Lake at right Danube bank	1707
Upstream Novi Sad	YU	Connected Lake at left Danube bank	1262
St. Gheorghe arm	RO	Meander of St. Gheorghe Delta arm	6

TABLE MP-1: JDS additional sampling points for macrophytes.

4.4.3 Methodology

4.4.3.1 Sampling Procedure

The sampling procedure included the collection of aquatic plants and the recording of abiotic habitat parameters (Table MP-3) - crucial factors influencing the presence or absence of macrophytes. Additionally, at each sampling site, river-km, date, time, climatic condition and the length of the relevant river stretch was reported. Furthermore, each sampling site was documented by using digital photography for later reconstruction as part of any future survey.

A motorboat was used to access the individual stretches near the bank at each sampling point. At each site, 0.2 to 5 river-km were surveyed for macrophyte growth on both the right and the left bank.

Plant material was collected by hand or by using a rake. When necessary, especially within the lower Danube stretch marked by higher discharge rates, the plants were collected by snorkelling. Mosses were collected on hard substrates only (e.g. "rip-rap", boulders) and were either scraped or plucked. Simultaneously, the amount of plant mass (Kohler, 1978) was estimated on site using a five-scale system (Table MP-2).

Sampled mosses were put in paper bags to dry and were determined down to species level. Before the other plants were stored in 500-ml plastic bottles filled with 30% de-naturated ethanol, each macrophyte species was determined and entered in the appropriate sampling site protocol for later evaluations. Additionally, the plants were marked with differently coloured labels, each colour indicating the appropriate category of plant mass (see also Table MP-2).

After on-board plant determination and preservation, all sampling containers were recorded and stored in boxes. All preserved macrophyte samples were re-checked concerning determination in order to complete the species list. Both mosses and higher plants will be stored until October 2003.

Plant mass (abundance) level number	Plant mass (abundance) verbal classification	Label colour
1	very rare	white
2	rare	yellow
3	widely spread	blue
4	common	green
5	very common / plentiful	red

Table MP-2: Five-level scale including Plant Mass Estimates (Kohler 1978) used in JDS.

4.4.3.2 Quantification

The abundance of all aquatic plant species was quantified by Plant Mass Estimates (PMEs), following the method described by Kohler (1978). PMEs follow an exponential five-level scale (Janauer & Heindl 1998). PMEs can be used for further determination of dominance and distribution patterns, of rareness and of the degree of species endangerment.

The estimated plant masses served as a sound basis for the calculation of Relative Plant Mass (RPM: Pall & Janauer 1995) for the Total JDS Reach and for the nine geo-morphological reaches of the Danube.

4.4.3.3 Habitat Parameters

Habitat parameters (see Table MP-3) were assessed at each JDS sampling site regardless of the absence or presence of aquatic plants. Different sets of habitat parameters were considered in order to allow relations between macrophyte appearance and abiotic features to be integrated into evaluations.

TABLE MP-3: Abiotic habitat parameters recorded during JDS in addition to macrophyte collection.

Habitat parameter	Category
Bank structure	Large blocks, "rip-rap" Gravel Sand Fine substrate / flat (to medium) slope Fine substrate / (very) steep slope Concrete and other artificial material Floating mats ("Plaur")
Sediment type	Solid rock, "rip rap" Gravel Sand Fine material Detritus and other organic material
Connectivity type *(only types found during JDS)*	Main channel Tributary Small side arm Open end oxbow (lower end open) Oxbow, semi-separated (no permanent plant growth on the connecting zone, gravel) Big secondary channel Flood plain lake Reservoir/retainment
Flow class	No flow, stagnant Low flow, just visible – ca. 0,3 m/s Medium flow, 0,35 – 0,65 m/s High flow, > 0,7 m/s
Land use type (CORINE typology)	Artificial surfaces Agricultural areas Forest/semi-natural areas Wetlands Water bodies
Transparency	Transparency measured with Secchi Disk

4.4.4 Results

It must be pointed out that the evaluations were based on grab samples. At each site, a longitudinal stretch of the Danube between 0.2 to 5 km was sampled for macrophytes using a local scale approach. Therefore, the results do provide an overview of the distribution of macrophytes at this local scale for each sampling point, but they do not represent aquatic plant appearance along the entire length of the Danube River. Such results would have required a sampling method based on a finer and denser scale that was not possible in the case of JDS because of the time constraint. Besides, it would have failed the Survey's objective to achieve a representative overview.

As already mentioned, a total of 180 sampling points formed the data base for macrophyte evaluations (see Table MP-4).

TABLE MP-4: Composition of the number of JDS sampling points.

Sampling point location	Number of points
Main course	
Left bank	76
Right bank	76
Tributaries	21
Additional points	
Oxbows	4
Connected Lakes	2
Natural arm	1
TOTAL	**180**

The following results were evaluated a) for the Total JDS Reach and b) for the nine defined characteristic geo-morphological reaches (see Chapter 3).

4.4.4.1 Presence and Absence of Macrophytes at the Investigated Sampling Points

a) Total JDS Reach

Of the total of 180 sampling points investigated for aquatic life along the main course (left and right bank) and the tributaries and seven additional points (Table MP-4), 93 (52%) were inhabited by aquatic plants while the remaining 87 points (48%) had no plant growth.

b) Nine geo-morphological reaches

Figure MP-1 illustrates the distribution of JDS sampling points within each of the nine geo-morphological reaches (Chapter 3). The total number of sampling points and the number of sites are illustrated for each of the nine geo-morphological reaches regardless of whether or not they were inhabited by macrophytes. Calculating the percentual share concerning the absence/presence of macrophytes related to the number of sampling points, Figure MP-2 shows the highest percentage of sampling sites with macrophytes growth for Reach 6 (from Belgrade to Iron Gate Dam) covering totally 20 sampling points. Aquatic plants could be collected at 19 sites.

Furthermore, Reach 1 and Reach 2 show a high percentage of sampling points inhabited by macrophytes (75% and 82% respectively), followed by Reach 3 and Reach 9 (both 67%).

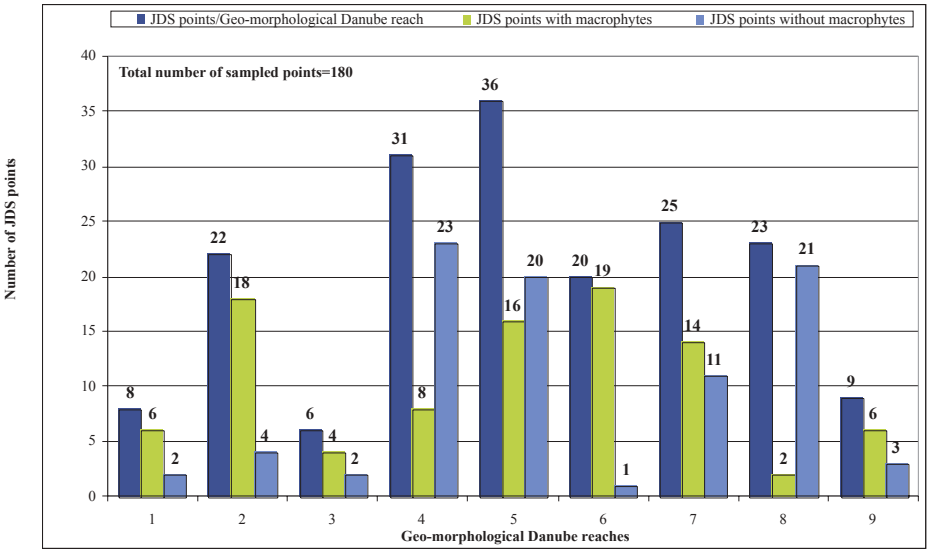


FIGURE MP-1: Number of sampling points for each of the nine geo-morphological reaches including the number of points concerning the presence or absence of aquatic plants.

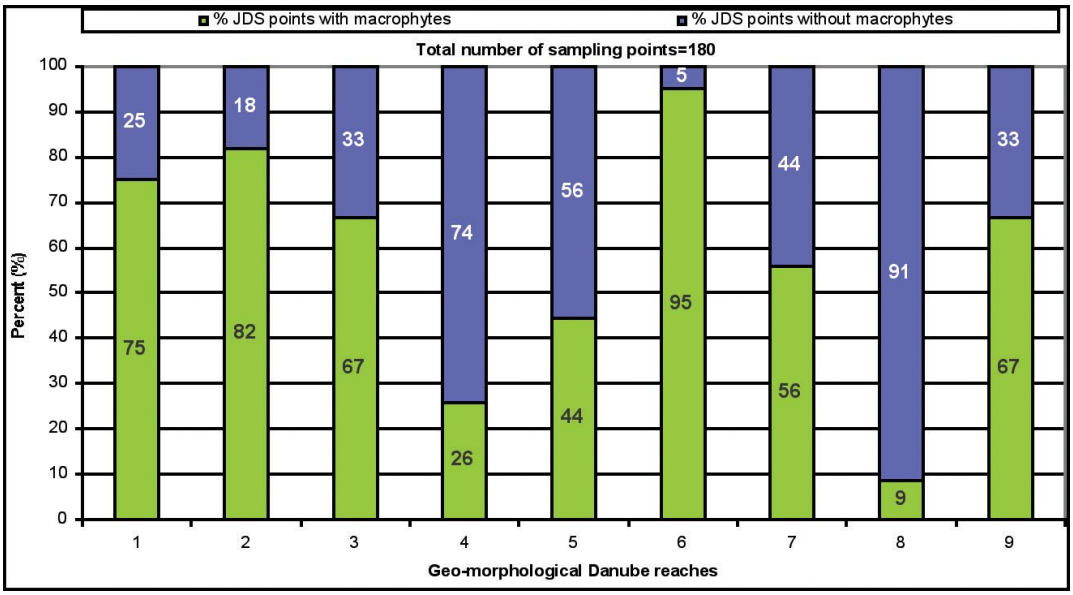


FIGURE MP-2: Presence and absence of aquatic plants in percentage (%) for each of the nine reaches related to the total of 180 sampling points.

Species distribution

Table MP-6 includes all macrophyte species that were collected at all JDS sampling points within the Total JDS Reach. Each found species is associated to the relevant species group (Table MP-5) and abbreviations used in the figures of this chapter are included. Additionally, this list shows whether an individual species was found within one of the nine defined geo-morphological reaches.

TABLE MP-5: Species groups of macrophytes taking taxonomic classes and different growth and life forms into consideration.

Grouping of macrophytes
Phycophyta
Bryophyta
Spermatophyta – submerged Rhizophytes
Spermatophyta – free-floating and floating leafed plants
Spermatophyta – amphibious plants
Spermatophyta – Helophytes

Table MP-7 demonstrates the distribution of each species on the left/right bank of the main course of the Danube, in the sampled tributaries, oxbows and connected lakes within the Total JDS Reach. Additionally, information on river kilometres for each sampling point, the country it was located in, geo-morphological reaches, species groups and the amount of plant mass is provided. Each column section were a species was collected is filled in black and shows a variation in height referring to the five-scale abundance system (Table MP-2). For the graphical illustration the five scaled system is transferred into three scales in order to provide a better optical overview. A very low bar indicates an abundance of a specific species of 1 or 2 (very rare or rare) whereas a high bar (e.g. completely filled) stands for the abundance estimate of 4 or 5 (common or very common, plentiful).

The Relative Plant Mass (RPM), weighted for the mass of each species or group of species and the stretches of species occurrence (Pall & Janauer 1995), indicates dominant and sub-dominant species within each Reach in relation to the overall plant mass in the relevant Reach.

TABLE MP-6: Species list of Total JDS Reach including species groups, appropriate species abbreviations and references concerning the occurrence of individual species within a geo-morphological reach

DANUBE TOTAL SURVEY	GEO-MORPHOLOGICAL REACHES									
Species-List	Abbreviation	1	2	3	4	5	6	7	8	9
PHYCOPHYTA										
Nitella gracilis (SMITH) AGARDH	Nit gra						x	x		
BRYOPHYTA										
Amblystegium varium (HEDW.) LINDB.	Amb var		x							
Brachythecium rivulare B.S.G.	Bra riv		x	x						
Bryum pallens SW.	Bry pal		x							
Cinclidotus riparius (BRID.) ARNOTT	Cin rip	x	x	x	x					
Cratoneuron filicinum (HEDW.) SPRUCE	Cra fil	x	x							
Didymodon tophaceus (BRID.) LISA	Did top		x							
Eurhynchium crassinervium (WILS.) SCHIMP.	Eur cra		x							
Fissidens rufulus B.S.G.	Fis ruf				x					
Fontinalis antipyretica HEDW.	Fon ant	x	x							
Hygrohypnum luridum (HEDW.) JENN.	Hyg lur		x							
Leptodictyum riparium (HEDW.) WARNST .	Lep rip	x								
Leskea polycarpa HEDW.	Les pol		x		x					
Rhynchostegium riparioides (HEDW.) CARD.	Pla rip		x							
Schistidium apocarpum (HEDW.) B.S.G.em. POELT	Sch apo		x							
SPERMATOPHYTA submerged Rhizophytes										
Elodea canadensis MICHX.	Elo can	x		x						
Elodea nuttallii (PLANCHON) ST. JOHN	Elo nut		x	x	x	x	x	x		x
Myriophyllum spicatum L.	Myr spi	x	x		x	x	x	x	x	x
Najas marina L.	Naj mar				x	x	x			
Potamogeton acutifolius LK.	Pot acu	x								
Potamogeton alpinus BALB.	Pot alp							x		
Potamogeton crispus L.	Pot cri	x		x	x	x	x	x		
Potamogeton gramineus L.	Pot gra					x	x			
Potamogeton lucens L.	Pot luc						x			
Potamogeton pectinatus L.	Pot pec	x	x	x	x	x	x	x		x
Potamogeton perfoliatus L.	Pot per	x	x	x	x	x	x	x		
Potamogeton praelongus WULF.	Pot pra					x				
Potamogeton pusillus L. sec. DANDY ET TAYLOR	Pot pus		x	x	x		x	x		
Potamogeton trichoides CHAMISSO et SCHLECHTENDAL	Pot tri	x								
Vallisneria spiralis L.	Val spi							x		
Zannichellia palustris L.	Zan pal	x		x	x		x	x		
SPERMATOPHYTA, free floating and floating leafed plants										
Ceratophyllum demersum L.	Cer dem	x		x	x	x	x	x	x	x

Hydrocharis morsus-ranae L.	Hyd mor					x	x		x	
Lemna minor L.	Lem min					x	x			x
Nymphaea alba L.	Nym alb	x								
Potamogeton natans L.	Pot nat					x	x			x
Potamogeton nodosus POIRET	Pot nod	x		x		x	x	x		x
Salvinia natans (L.) ALL.	Sal nat				x	x	x		x	x
Spirodela polyrhiza (L.) SCHLEIDEN	Spi pol					x	x			
Trapa natans L.	Tra nat					x	x			
SPERMATOPHYTA, amphibious plants										
Alisma gramineum LEJEUNE	Ali gra			x						
Limosella aquatica L.	Lim aqu				x					
Sagittaria sagittifolia L.	Sag sag							x		
Schoenoplectus triqueter (L.) PALLA	Scho tri				x					
Sparganium emersum REHMANN	Spa eme			x	x	x	x	x		
Sparganium sp. L.	Spa sp.			x						
SPERMATOPHYTA, Helophytes										
Cyperus fuscus L.	Cyp fus				x					
Typha angustifolia L.	Typ ang			x						
Typha latifolia L.	Typ lat			x						
NUMBER OF SPECIES	**49**	**15**	**17**	**16**	**17**	**17**	**20**	**14**	**4**	**8**

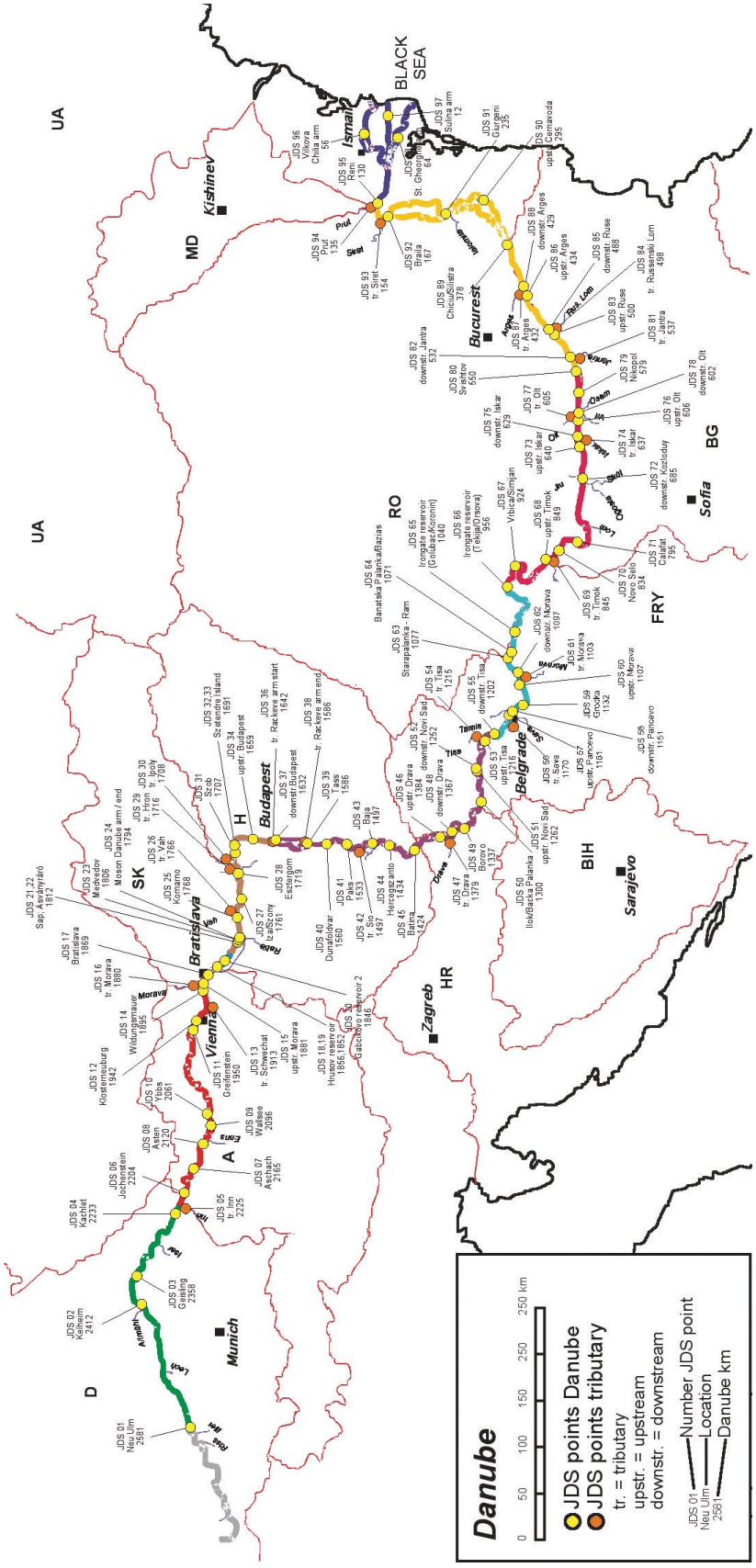


FIGURE MP-3: Survey map of Total JDS Reach including all JDS sampling sites, border lines of the Danube countries, indication of the major tributaries and major settlement. Geo-morphological Reaches are indicated by different colours of the Danube stretch.

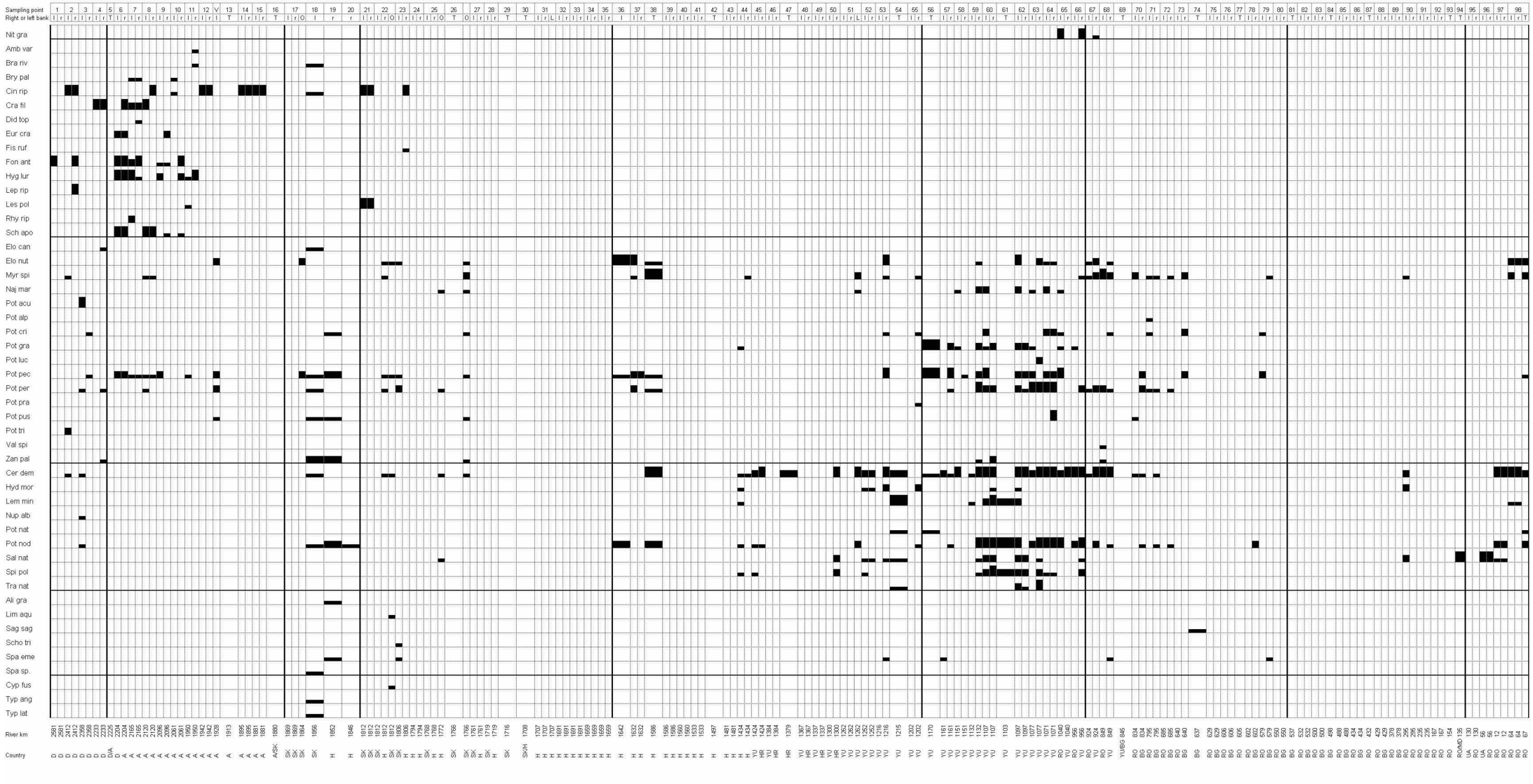


TABLE MP-7: Species distribution table including all JDS sampling points. River kilometres and JDS Danube countries are included. Bulk vertical lines define the extent of the nine designated geo-morphological reaches. Bulk horizontal lines illustrate the six species groups of aquatic plants. Estimated amount of plant mass is illustrated on the basis of a five-scale system. For the graphical illustration, the five-scale system is translated into a three-scale one for a better overview. A very low bar within column section indicates an abundance of a specific species of 1 or 2 (very rare or rare) whereas a high bar (e.g. completely filled) stands for the abundance estimate of 4 or 5 (common or very common, plentiful).
l – left bank, r – right bank, T – tributary, O – oxbow, L – connected lake.

a) Total JDS Reach

49 macrophyte species were collected within the Total JDS Reach.

Relative plant mass

Considering the Total JDS Reach, Figure MP-4 and Figure MP-5 show the calculated Relative Plant Mass (RPM) for both the six defined species groups and for the occurring aquatic plant species. Macrophytes were present at 93 out of 180 sampling points.

Figure MP-4 clearly illustrates the dominance in terms of Relative Plant Mass (RPM) of the Spermatophyta species group - free floating and floating leafed plants (40%), followed by Spermatophyta - submerged Rhizophytes (33%). Bryophyta (mosses) show a relative plant mass of 24 % while Phycophyta account for only 3%.

Concerning RPM of individual species within the Total JDS Reach, Figure MP- shows *Ceratophyllum demersum* as the dominant species, followed by *Potamogeton nodosus* and *Potamogeton pectinatus* although they are represented with a RPM lower than 10%.

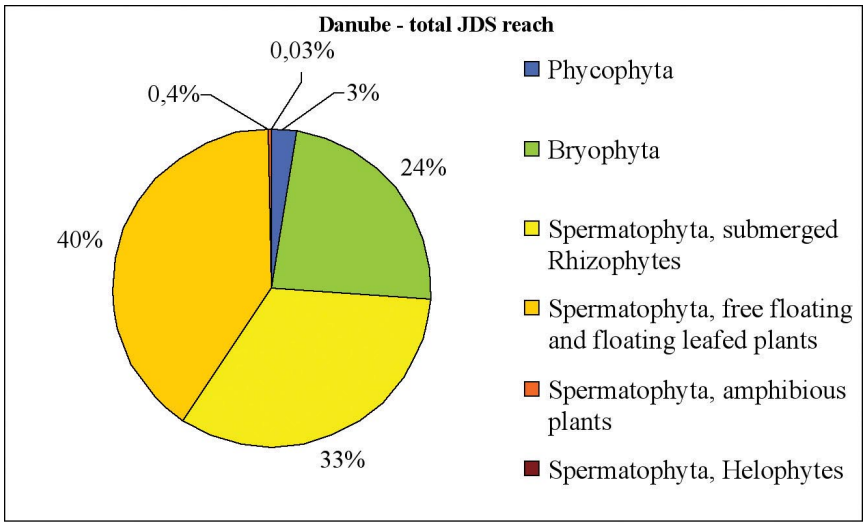


FIGURE MP-4: Relative Plant Mass (RPM) for designated species groups within the Total JDS Reach.

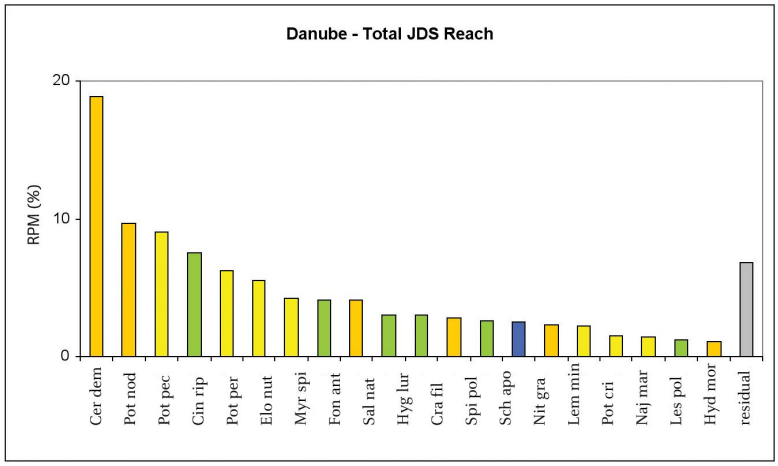


FIGURE MP-5: Relative Plant Mass for present macrophyte species within the Total JDS Reach.

Abiotic habitat parameters

Bank structure
The Total JDS Reach revealed a high dominance of sampling points with large stones, usually built into the rip-rap of the levees. However, in the lower reaches of the River other bank material becomes more dominant such as sand and fine material in the flat slopes. In several stretches, steep banks were formed of fine material usually shaped by floods. About one sixth of the points was characterised by a rather homogeneous mixture of sand and fine material.

Sediment structure of the littoral
Slightly more than 30% of the sampling points consisted of fine sediments in the littoral. Less than 30% were covered by sand mixed with fine material. About one sixth of the littoral areas consisted of gravel mixed with sand. Other areas contained pure gravel and gravel mixed with sand. No dominant layer of organic material was found in any of the littoral survey units.

Connectivity
Regarding connectivity, the Survey was predominantly carried out in the main river course. Mouth section of the tributaries, oxbows separated from the River or any other form of flood plain water bodies were investigated only rarely. Therefore, variety in terms of connectivity types is limited. However, on some occasions special habitats were sampled. 79% of the sampling areas were located along the main course of the River. Some oxbows were found and about 14% of the sites were found in reservoirs. As rare examples, two flood plain lake situations were also reported.

Flow characteristics
49% of the sampling sites were characterised by a flow faster than 70 cm/s. Both flow types 2 (= 5 – 30 cm/s) and 3 (35 – 65 cm/s) were found in about 24% of the sampling sites. Less than 3% of the sites showed negligible to practically no flow.

Transparency
Water transparency in the Danube River is largely influenced by a number of factors such as a suspended solid load carried by the tributaries from the alpine region, erosion in the lowlands, a succession of small to medium-sized hydroelectric-power plants in the upper reaches and the Iron Gate power regime. As a result, a wide variety of transparency readings could be expected. The measurements were carried out with a standardised Secchi disk. Water transparency varied, indeed, between 10 and 280 cm in different locations. The most frequent visibility depth was 55 cm (15% of the sampling sites). At most sites transparency ranged between 35 and 70 cm. Exceptionally high visibility values were found downstream of the Iron Gate reservoir probably as a result of higher flow velocities (up to 280 cm).

Land use
The distribution of land use types was largely determined by JDS sampling strategy. Therefore, a considerable deviation form a contiguous survey may be present in the data collected here. However, many points of most importance with respect to the general situation of the River were investigated and therefore an overview of the River is still of much interest. 51% of the sampling sites were located in areas where the river banks are forested with broadleaf trees. Due to the sampling strategy, about 28% of the sites were close to or within settled areas, and 18% were surrounded with industrial plants. Only a little more than 8% of the sites were located in agricultural areas of any kind. Slightly over 3% were situated in wetland areas. As pointed out above, these results mirror exactly the general JDS sampling strategy.

Concluding synopsis for Total JDS Reach

The Danube River boasts a broad diversity of abiotic habitat parameters such as different substrate types, flow types and transparency as a sound basis for the development of diverse macrophyte vegetation. In total, 49 different aquatic plant species were collected and determined within the Total JDS Reach. 14 moss species, 16 Spermatophyta - submerged rhizophyte species, 9 floating leafed and free-floating plants, 6 species representing Amphiphytes and 3 Helophyte species were identified. One of the collected species belongs to the species group of Characeae (Phycophyta).

Concerning plant mass, a clear dominance of higher plants (Spermatophyta) – free- floating and floating leafed plants was observed. Since these aquatic plants are usually found in waters marked by low transparency values, they base their photosynthetic activity on habitats on or very close to the water level. During JDS, these free-floating and floating leafed plant species were dominantly present in the stretches of the River characterised by such conditions.

One third of the collected and determined plants represent submerged, rooting species. These species differ from the above mentioned species groups as they tolerate higher flow velocities as habitat parameters. On the other hand, they depend on better transparency values.

Considering all collected and determined species, mosses (Bryophyta) account for a large share of the total plant mass. Mosses consume dissolved CO_2 from the water column and can therefore only populate habitats characterised by high flow velocities. In addition, mosses prefer hard substrates (e.g. boulders) which dominantly characterise the upper section of the Danube (Austria, Germany).

At the individual species level, *Ceratophyllum demersum* was clearly dominant throughout the Total JDS Reach. *Ceratophyllum demersum* is a free-floating, rootless species that can also occur attached to fine substrates developing rhizoids out of their leafs. In terms of plant mass, *Potamogeton nodosus* was found to be the second dominant species besides *Ceratophyllum demersum*. *Potamogeton nodosus* shows the morphology of an aquatic plant with floating leafs and can therefore also tolerate higher flow velocities. In terms of occurrence frequency, these two species are followed by *Potamogeton pectinatus*.

b) Geo-morphological reaches

GEO-MORPHOLOGICAL REACH 1

Neu Ulm (JDS1) – Confluence with the Inn River (JDS5), 356 Danube-km

Macrophytes were present at six out of eight sampling points.

15 species in total were collected in geo-morphological Reach 1. Bryphyta were represented with four species, Spermatophyta – submerged Rhizophytes with eight species and Spermatophyta – free-floating and floating leafed plants with three species.

Figure MP-6a and b illustrates the calculated Relative Plant Mass (RPM) for both the six defined species groups (Table MP-5) and for the occurring aquatic plant species in Reach 1. It shows Reach 1 to be clearly dominated by the species group Bryophyta (mosses – 71%) in terms of Relative Plant Mass (RPM). RPM for Spermatophyta - submerged Rhizophytes is calculated at 28%. Spermatophyta – free-floating and floating leafed plants – represent 1% of RPM.

Concerning Relative Plant Mass of these individual species, Figure MP-6b shows *Fontinalis antipyretica* to be the dominant moss species, followed by the mosses *Cinclidotus riparius* and *Leptodictyum riparium.*

a) b)

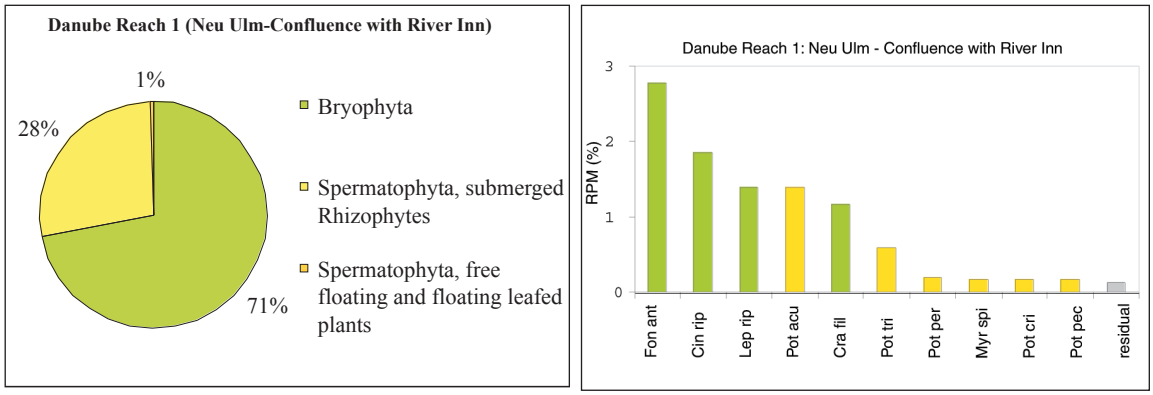


FIGURE MP-6: a) Relative Plant Mass (RPM) of defined species groups in Reach 1.
b) Relative Plant Mass of present macrophyte species in Reach 1.

Concerning river bank structure at the sampling sites, it is dominated by large blocks of the bank rip-rap. The sediment of the littoral consists predominantly of gravel. Sand was found in a few cases, or a mixture of gravel and sand. All sampling sites were located along the main course of the River (left and right bank). Both low and high flow velocities were reported. Medium water transparency values were measured (35 – 40 cm). Land along the riverbanks is predominately used for industrial purposes. Arable land was recorded at only one sampling site.

The dominance of Bryophyta (mosses) in Reach 1 is related to the present relative high flow velocities as well as to the bank structure dominated by big boulders ("rip-rap").

GEO-MORPHOLOGICAL REACH 2

The Inn River (JDS5) – the Morava River "Porta Hungarica" (JDS16), 345 Danube-km

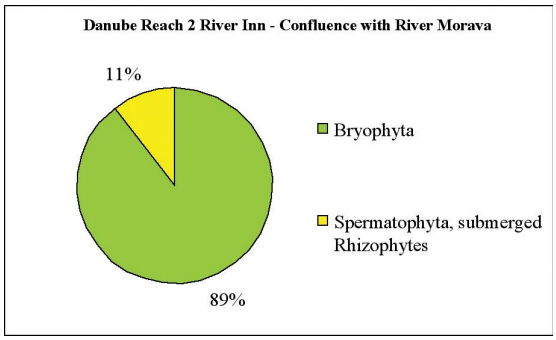
Macrophytes were present at 18 out of 22 sampling points.

A total of 17 macrophyte species were collected in Reach 2, out of which 12 belong to the species group Bryophyta and five can be assigned to the class Spermatophyta – submerged Rhizophytes.

Figure MP-7a illustrates Bryophyta (mosses) as dominant species group concerning RPM. RPM for Spermatophyta - submerged Rhizophytes - was calculated at 11%.

Concerning RPM of individual species in geo-morphological Reach 2, Figure MP-7b shows the prevailing *Cinclidotus riparius* being followed by the moss species *Hygrohypnum luridum* and *Fontinalis antipyretica.*

a)



b)

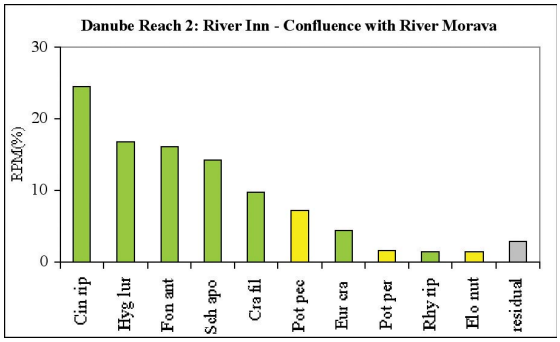


FIGURE MP-7: a) Relative Plant Mass (RPM) of defined species groups in Reach 2.
b) Plant Mass of present macrophyte species present in Reach 2.

The riverbanks consisted predominantly of large stones ("rip-rap"); gravel and gravel mixed with sand were occasionally recorded. The dominant sediment type in the littoral was sand mixed with fine material or gravel mixed with sand. Pure gravel and pure sand were rarely recorded. Almost all the sampling sites were located along the main river course, but three tributaries were sampled in addition. The flow was rather slow in about half the cases, but one third of the sites showed high current velocities. Intermediate flow was scarce. Visibility was slightly lower than in Reach 1, which may be due to the sedimentation of suspended solids in the numerous retainments of the existing hydroelectric power plants. About 60% of the sampling sites were located in or near urban areas or industrial facilities. However, along the rest of the sites broad- leafed deciduous forest lined the riverbanks.

Reach 2 has the characteristic features of running water within the Rhitral region. Nevertheless, it is impacted by hydroelectric power plants and their impoundments. Besides high flow velocities, the hard substrate (boulders at the stream's bank) provides ideal habitat conditions for mosses. *Fontinalis antipyretica* became dominant – in comparison to Reach 1 – and *Cinclidotus riparius* and *Hygrohypum luridum* became the key species.

As was mentioned earlier, Reach 2 is also shaped by the presence of hydro-electrical power plants that partly reduce flow velocities. This creates favourable habitat conditions for some higher plants.

GEO-MORPHOLOGICAL REACH 3

The Morava River "Porta Hungarica" (JDS16) – Gabcikovo Dam (JDS20), 64 Danube-km

Macrophytes were present at four out of six sampling points.

A total of 16 macrophyte species were collected in Reach 3; two species belong to the species group Bryophyta, seven can be associated to the class Spermatophyta – submerged Rhizophytes. Two species belong to the species group Spermatophyta – free-floating and floating leafed plants, while three species are associated with Spermatophyta – amphibious plants and two with Spermatophyta – Helophytes.

Figure MP-8a illustrates Spermatophyta - submerged Rhizophytes (74%) as dominant species

group in terms of RPM. Spermatophyta - free-floating and floating leafed plants represent 22% of RPM. The species group Spermatophyta – amphibious plants, Helophytes and Bryophyta account for 4% of RPM.

Concerning RPM of individual species, within the geo-morphological Danube Reach 3, Figure MP-8b shows *Potamogeton pectinatus* and *Zannichellia palustris* as dominant species followed by *Potamogeton nodosus*.

a) b)

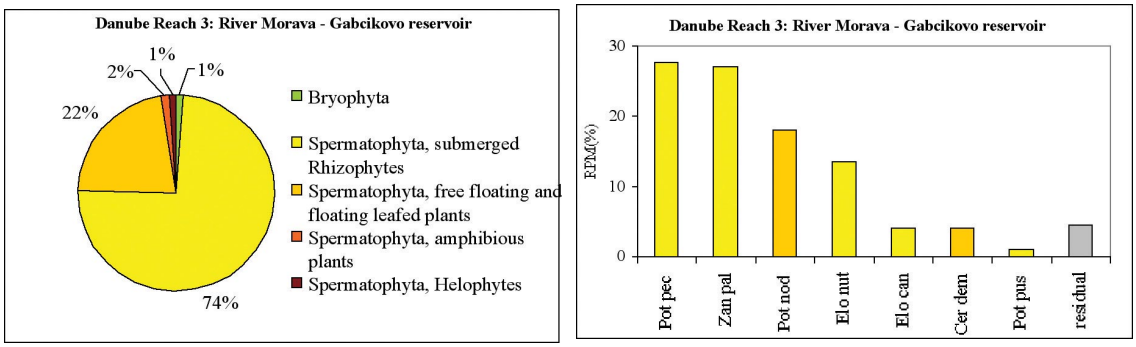


FIGURE MP-8: a) Relative Plant Mass (RPM) of defined species groups in Reach 3.
b) Relative Plant Mass of macrophyte species present in Reach 3.

The reservoir is lined with large stone blocks or concrete on its banks. Sometimes gravel or gravel mixed with sand were recorded. The littoral consisted mainly of sand or fine material, or mixtures of both sediment types. Regarding connectivity type, most sampling sites were located directly within the reservoir, but a few were placed along the main course of the River. Flow velocity ranged between intermediate (Bratislava area) and low. Due to sedimentation, increasing transparency values (50 cm) were measured with decreasing distance from the dam. Urban settlements, industrial facilities or riparian forests lined this reach of the River.

As explained earlier, Reach 3 is heavily impacted by the dam of a hydroelectrical power plant (Gabcikovo) influencing many abiotic river parameters. This impact was very well reflected on the appearance of the aquatic vegetation. Three quarters of the macrophytes were represented by the species group Spermatophytes – submerged Rhizophytes well adapted to habitat conditions marked by increasing water transparency values at sampling points closer to the dam. One quarter of the overall species were Spermatophyta – free-floating and floating leafed plants that prefer lower flow velocities as habitat conditions. Mosses were rare.

GEO-MORPHOLOGICAL REACH 4

Gabcikovo Dam (JDS20) – Budapest (JDS34), 157 Danube-km

Macrophytes were present at eight out of 31 sampling points.

A total of 17 macrophyte species were collected in reach 4. Three belong to the species group Bryophyta; eight can be associated with the class Spermatophyta – submerged Rhizophytes. Two species belong to the species group Spermatophyta – free-floating and floating leafed plants. Three species are associated with Spermatophyta – amphibious plants and one species

with Spermatophyta – Helophytes.

Figure MP-9a illustrates Bryophyta (67%) as the dominant species group concerning RPM. Spermatophyta – submerged Rhizophytes represent 27%, the species group Spermatophyta – free-floating and floating leafed plants, amphibious plants and Helophytes together represent 6%.

Concerning RPM of individual species in Reach 4, Figure MP-9b shows the mosses *Cinclidotus riparius* and *Leskea polycarpa* to be the dominant species, followed by the higher plant species *Myriophyllum spicatum*.

a) b)

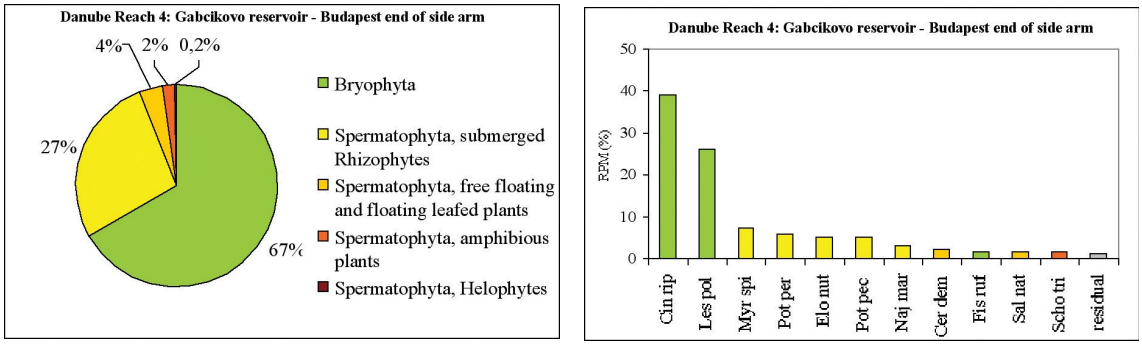


FIGURE MP-9: a) Relative Plant Mass (RPM) of defined species groups in Reach 4.
b) Plant Mass of macrophyte species present in Reach 4.

Almost all categories of bank structures were present in Reach 4 except for artificial material. The same is true of the littoral sediments, but here equal numbers of sampling sites with either gravel or fine material dominated over different mixtures of sediment types. About 80% of the sampling sites were located along the main course of the River. Regarding flow, all velocity values, ranging from stagnant to fast, were recorded. Medium transparency values were reported.

At most sampling sites in Reach 4, high flow velocities were measured which resulted in an increased occurrence of mosses.

GEO-MORPHOLOGICAL REACH 5

Budapest (JDS35) – Confluence with the Sava at Belgrade (JDS55), 457 Danube-km

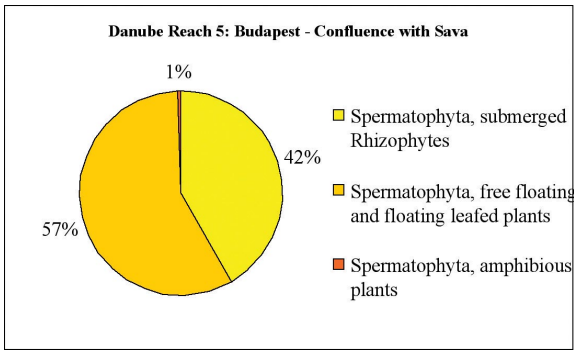
Macrophytes were present at 16 out of 36 sampling points.

A total of 17 macrophyte species were collected in Reach 5. Eight species can be associated with the species group Spermatophyta – submerged Rhizophytes. The species group Spermatophyta – free-floating and floating leafed plants are represented with another eight species; Spermatophyta – amphibious plants are represented by one species.

Figure MP-10a illustrates Spermatophyta – free-floating and floating leafed plants as the dominant species group in terms of RPM (57%). RPM for Spermatophyta - submerged Rhizophytes was 42%. Spermatophyta – amphibious plants represent 1%.

Concerning RPM of individual species in Reach 5, Figure MP-10b shows *Ceratophyllum demersum* to be the dominant species, followed by *Elodea nuttallii* and *Potamogeton pectinatus*.

a)



b)

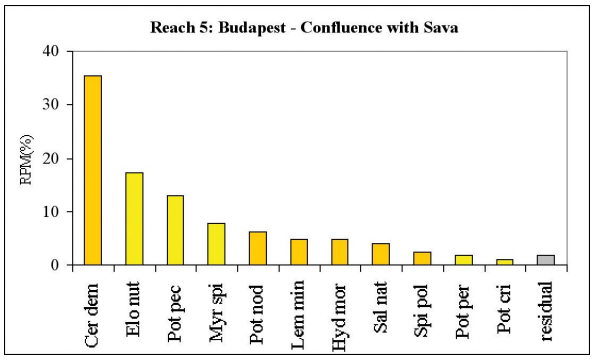


FIGURE MP-10: a) Relative Plant Mass (RPM) of defined species groups in Reach 5.
b) Relative Plant Mass of macrophyte species present in Reach 5.

This Reach was characterised by the presence of all bank types listed, but about one third of the sampling sites was lined with a mixture of sand and fine material. The littoral was dominated by the same mixture. The main course of the River was the most frequent connectivity type. High current velocities dominated the flow regime in the littoral zone. At most sites, reported transparency values were in the medium range (25 – 75 cm). The main land use type was broad-leafed forest.

The dominant occurrence of fine substrates in the Danube littoral is the probable reason for the absence of mosses. The influence by untreated wastewaters (Budapest area) increased, while the transparency values decreased. Therefore, the majority of the aquatic plant mass - free-floating and floating leafed species - was found on the water surface. The rest of the plant biomass was represented by submerged macrophytes and by a very small amount by amphibious plants.

GEO-MORPHOLOGICAL REACH 6

The Sava River at Belgrade (JDS55) – Iron Gate Dam (JDS66), 259 Danube-km

Macrophytes were present at 19 out of 20 sampling points.

A total of 20 macrophyte species were collected in Reach 6. The Species group Phycophyta was represented by one species (*Nitella gracilis*) while the class Spermatophyta – submerged Rhizophytes included 10 species. Eight species belong to the species group Spermatophyta – free-floating and floating leafed plants and one species can be assigned to amphibious Spernatophyta.

Figure MP-11a illustrates Spermatophyta – free-floating and floating leafed plants as the dominant species group concerning RPM (55%). RPM for Spermatophyta – submerged Rhizophytes amounts to 39%. Phycophyta represent 6% while Spermatophyta – amphibious plants account for <1% of RPM.

Concerning RPM of individual species in Reach 6, Figure MP-11b shows *Ceratophyllum demersum* as the dominant species, followed by *Potamogeton nodosus* and *Potamogeton perfoliatus*.

a) b)

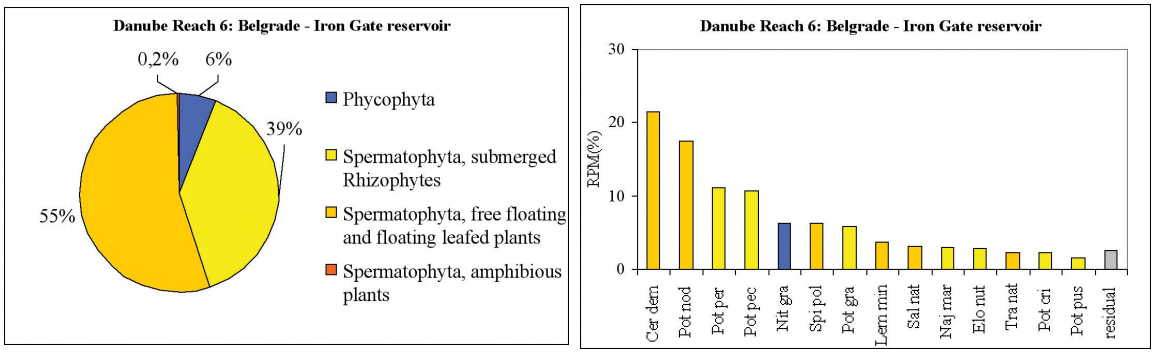


FIGURE MP-11: a) Relative Plant Mass (RPM) of defined species groups in Reach 6.
b) Relative Plant Mass of macrophyte species present in Reach 6.

The most dominant bank structure was fine material with gentle slopes, but in one case artificial material was also present. Fine sediment also characterised the littoral. Most sampling sites were located along the main course of the River in the main river channel of the reservoir. Velocities decreased with decreasing distance towards the Iron Gate Dam. Due to the great length of the retainment and the resulting decrease in carrying capacity for suspended solids, the Secchi depth increased dramatically; it ranged between 60 and 170 cm. 50% of the sites were lined by deciduous forest.

Danube Reach 6 was characterised by the impact of untreated wastewater (Belgrade area). Due do the impact of the Iron Gate Dam, flow velocities were drastically reduced which was clearly reflected on the occurring aquatic vegetation. Therefore, free-floating and floating leafed species were dominant, followed by submerged macrophytes. It has to be pointed out that the Phycophyta species *Nitella gracilis* was found at particular sampling sites marked by preferred habitat conditions (high transparency values and very low flow velocities).

GEO-MORPHOLOGICAL REACH 7

Iron Gate Dam (JDS66) – Confluence with the Jantra River (JDS 81), 406 Danube-km

Macrophytes were present at 14 out of 25 sampling points.

14 macrophyte species were collected in reach 7. One species represents the species group Phycophyta, nine species Spermatophyta – submerged Rhizophytes, while species group Spermatophyta – free-floating and floating leafed plants includes two species. Two amphibious plant species were collected.

Figure MP-12a illustrates Spermatophyta – submerged Rhizophytes (60%) as the dominant species group in Reach 7 in terms of RPM. Spermatophyta – free-floating and floating leafed plants represent 36%. The RPM for the species groups Phycophyta and Spermatophyta - amphibious plants totalled 2%.

Concerning RPM of individual species in Reach 7, Figure MP-12b shows *Ceratophyllum demersum* and *Myriophyllum spicatum* as the dominant species, followed by *Potamogeton perfoliatus*.

a) b)

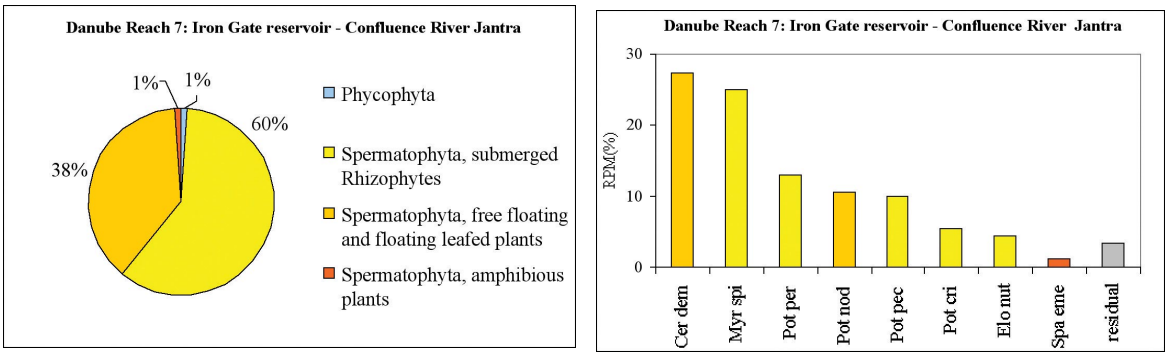


FIGURE MP-12: a) Relative Plant Mass (RPM) of defined species groups in Reach 7.
b) Relative Plant Mass of macrophyte species present in Reach 7.

Gravel was present at only a few sites as bank structure; the rest of the recorded sampling sites were lined with sand or finer material. Most littoral reaches consisted of sand or a mixture of sand and fine sediment fractions. All sampling sites were located along the main course, with the exception of the sampled tributaries. The dominant flow condition was of intermediate character; in a considerable number of cases high flow velocities were also recorded. Transparency ranged widely, from 20 to 280 cm.

In contrast to upstream Reach 6, this Danube stretch was characterised by higher flow velocities due to the fact that beyond the Iron Gate Dam no further impoundments break the river continuum of the Danube. Due to the fact that the transport of suspended solids from the backwaters of the Iron Gate Dam to the downstream river stretch is disconnected, high transparency values (130 cm to 280 cm) could be measured over a considerable length (about 280 km). Adapted very well to such habitat conditions, submerged, rooting macrophyte species occur dominantly. Free-floating and floating leafed plants are rarely present since these species prefer different habitat conditions. However, *Nitella gracilis* (Phycophyta) was found at a specific sampling site that provided adequate habitat conditions (high transparency values and very low flow velocities).

GEO-MORPHOLOGICAL REACH 8

The Jantra River (JDS81) – Reni (JDS95), 405 Danube-km

Macrophytes were present at two out of 23 sampling points..

Within Danube Reach 8, four species were collected. One species belongs to the species group Spermatophyta – submerged Rhizophytes while the other three species represents the class Spermatophyta – free-floating and floating leafed plants.

Figure MP-13a illustrates Spermatophyta – free-floating and floating leafed plants as the clearly dominant species group concerning RPM (95%). RPM for Spermatophyta - submerged Rhizophytes is calculated at 5%.

Concerning RPM of individual species within geo-morphological Reach 8, Figure MP-13b shows *Salvinia natans* as the dominant species, followed by *Ceratophyllum demersum* and *Hydrocharis morsus-ranae*.

a) b)

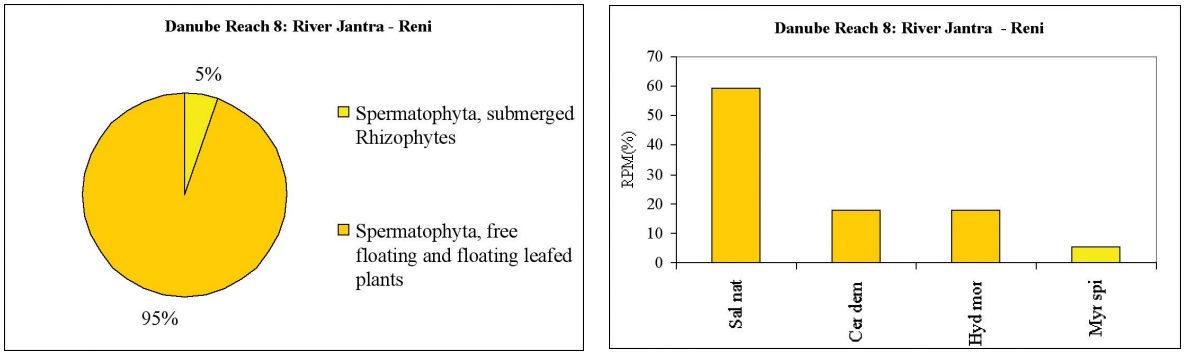


FIGURE MP-13: a) Relative Plant Mass (RPM) of defined species groups in Reach 8.
b) Relative Plant Mass of macrophyte species present in Reach 8.

Sand, fine material and a mixture of both were recorded as bank types. Sand and fine material also dominated the littoral. The main river channel and the tributaries were recorded as the dominant connectivity types within this Reach. High current velocities, stemming from the present flood influence, dominated the flow conditions. At most sampling sites low transparency values (10 – 30 cm) were measured. However, at some sites moderately high (50 – 65 cm) Secchi depth visibilities were recorded. Different types of agricultural area, broad-leafed forest and scrub were the characteristic land use types.

Due to the substrates in the stream's littoral and low transparency values, 95% of the plant mass was made up of free-floating and floating leafed plants. Only one species belonged to the submerged, rooting plants group.

While this Reach was sampled, the water level rose, which created an atypical on-site situation and caused fewer plants to be collected than would normally have been the case.

GEO-MORPHOLOGICAL REACH 9

Reni (JDS35) – Black Sea/Danube Delta arms (JDS96-98), 120 Danube-km

Macrophytes were present at six out of nine sampling points.

Eight macrophyte species were collected in Reach 9. Three species belong to the species group Spermatophyta – submerged Rhizophytes and five to Spermatophyta – free-floating and floating leafed plants.

Concerning this Reach it should be considered that due to a natural flood the water level was about 50 cm higher than usual, which influenced the sampling procedure. Furthermore, samples were collected exclusively within the main arms and one natural meander of the Danube Delta. The surrounding wetlands were not included in the official JDS programme. Sampling these ecosystems would have considerably increased the number of collected macrophyte species.

Figure MP-14a illustrates Spermatophyta – free-floating and floating leafed plants as the dominant species group concerning RPM (79%). Spermatophyta – submerged Rhizophytes plants are

represented with 21%.

Concerning RPM of individual species within Reach 9, Figure MP-14b shows *Ceratophyllum demersum* to be the dominant species, followed by sub-dominant species *Salvinia natans* and Elodea nuttallii.

a) b)

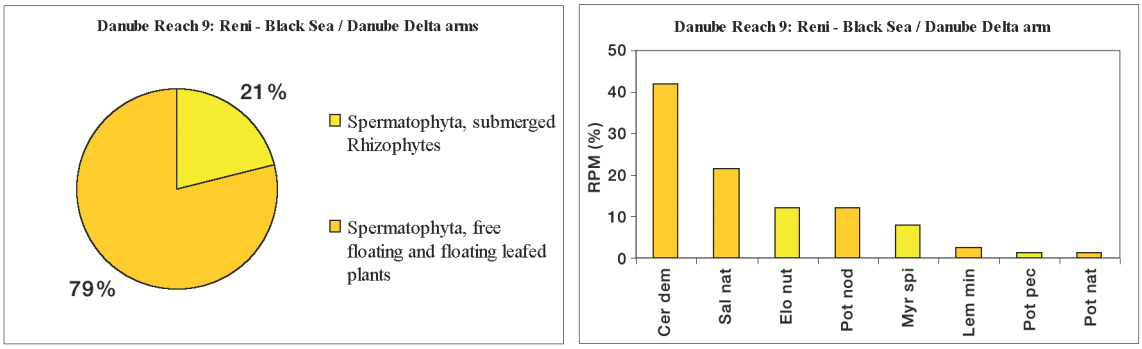


FIGURE MP-14: a) Relative Plant Mass (RPM) of defined species groups in Reach 9.
b) Relative Plant Mass of macrophyte species present in Reach 9.

In the Delta, fine material on both gentle and steep slopes of the river banks were recorded. Only pure fine material was present; no sand or gravel deposits were found at any sampling point. All sampling sites were located along the main course of the River. Visibility was rather poor (35 – 45 cm). The adjacent land mainly consisted of inland wetlands of the Delta, but also broad-leafed forest and some urban settlements.

Low flow velocities, fine sediments and very poor transparency resulted in a dominance of free-floating and floating leafed plants that prefer such habitat conditions. 21 % of the Relative Plant Mass was accounted for by submerged and rooting species.

Nine Geo-morphological Reaches - Summary

Figure MP-15 provides an overview on the Relative Plant Mass (RPM) for all species groups and for all geo-morphological reaches of the Danube. As shown in Figure MP-15, Reaches 1, 2 and 4 are clearly dominated by the species group Bryophyta (mosses). This dominance is related to high flow velocities as well as bank structures (big stone blocks) which combine to create preferable habitat conditions for mosses. The species group Spermatophyta - submerged Rhizophytes were collected in every geo-morphological reach. This species group is dominantly present within Reach 7 where its preferred habitat conditions consisting of both high transparency values and rather high flow velocities exist. Spermatophyta - submerged Rhizophytes also show a dominant share concerning RPM within Reach 3 where transparency values increase at sampling points closer to the dam of the Gabcikovo power plant. Spermatophyta – free-floating and floating leafed plants occur within all reaches except Reach 2. Dominant occurrence is recorded for Reaches 5, 6, 8 and 9 which are characterised by low water transparency and low to medium flow velocities. For the other three species, the Relative Plant Mass figures are lower.

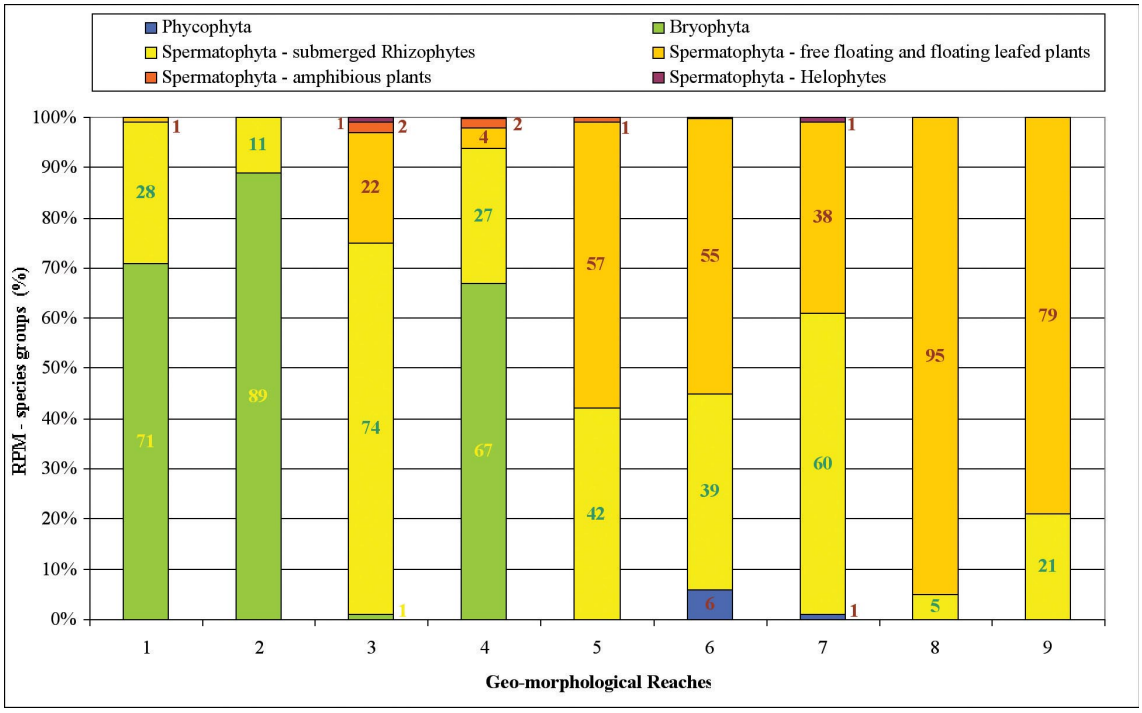


FIGURE MP-15: Relative Plant Mass for all species groups and all geo-morphological reaches.

4.4.5 Summary and Conclusions

This Survey was a unique opportunity to record the macrophyte vegetation of the second largest river in Europe and identify the many habitat parameters along its banks. Never before had it been possible to compare the different geo-morphhological reaches based on such a large body of information because previous surveys had not relied on a single methodology nor had they covered the entire length of the River.

93 (52%) of the total of 180 sampling points along the main course of the Danube (left and right bank), its tributaries and seven additional points (Table MP-4), were overgrown with aquatic plants while the remaining 87 points (48%) had no plant growth.

The appearance and distribution of macrophytes in running waters is determined by some significant criteria, such as:

- Flow conditions
- Substrate conditions and variation
- The availability of light (essential as an energy source for acquatic plants to perform photosynthesis)
- Physico-chemical conditions of the aquatic medium (e.g. nutrient content, trophic status)

All these criteria reflect on the overall distribution pattern of individual macrophyte species or groups. JDS macrophyte evaluations and results clearly reflect the impact of flow conditions. Three of the six species groups, Bryophyta, Spermatophyta-submerged Rhizophytes and Spermatophyta free-floating and floating leafed plants, serve as very good indicators of flow. Bryophyta (mosses) occurred as the key species in the rhithron section of the Danube (Danube Reaches 1,2 and 4) which is characterised by higher flow velocities and rough substrates on

both riverbanks. The other two species groups dominantly occurred in Reaches 3 and 5-9 marked by lower flow velocities and fine substrates.

In general, submerged macrophyte species prefer higher flow velocities than floating leafed or even free-floating species. The final dominance of these two species groups is decided upon the factor of light availability which in its turn is determined by the transparency of the river water. Submerged species prefer high transparency values as habitat conditions. A dominant occurrence of submerged Rhizophytes due to high transparency values was found in Reaches 3 and 7. If transparency values are low, macrophyte species, which grow on the water level or very close to it, become the dominant, key species. Reaches 8 and 9, where lower transparency values were recorded, were dominated by floating leafed and free-floating aquatic plant species.

Additionally, the occurrence and distribution of macrophyte species is crucially determined by nutrients. The majority of the plant species collected during JDS are indicators of eutrophic conditions. Some collected species such as *Ceratophyllum demersum*, *Potamogeton crispus* and *Zannichellia palustris* commonly serve as indicators of a significant nutrient load. Based on the broad distribution of these species within the longitudinal extent of the Danube River, a conclusion can be drawn about significant nutrient inputs and sources. The collected species group Characea (Phycophyta) usually serves as an indicator of oligotrophic (low in nutrients) habitats providing high transparency values. Such preferred conditions that allow the occurrence of this species obviously occur in some parts of the Iron Gate reservoir.

4.4.6 References

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