Joint Danube Survey 3

Chapter (long report) on: Macrophytes

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Igor Stanković, Karin Pall & Georg Janauer

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Contact
ICPDR Secretariat
Vienna International Centre / D0412
P.O. Box 500 / 1400 Vienna / Austria
T: +43 (1) 26060-5738 / F: +43 (1) 26060-5895
icpdr@unvienna.org / www.icpdr.org

Authors:

Igor Stanković, PhD

Hrvatske vode, Central Water Management Laboratory, Ulica grada Vukovara 220, Zagreb, Croatia, igorstankovic1@gmail.com

Karin Pall, PhD

SYSTEMA Bio- und Management Consulting GmbH, Bensasteig 8, 1140 Wien, Austria

Prof. Georg A. Janauer, PhD

University of Vienna, Department of Freshwater Ecology, Althanstrasse 14, 1090 Wien, Austria

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1 Introduction

1.1 Macrophytes

Macropyhtes are aquatic plants that live in the littoral zone of rivers and lakes (Haslam, 2006). Taxonomically, they are composed of non-vascular plants (bryophytes – mosses and liverworts), vascular plants (angiosperms) and macroalgae (charophytes, filamentous green algae, etc.). From a life-form point of view, macrophytes can be divided to emergent (helophytes) as well as free floating and submerged macrophytes (hydrophytes). Macrophyte surveillance does not stop in the river, but it goes up to the river banks because of water fluctuations. There we can find amphibious plants capable of living in and out of the water (amphiphytes), secondary water plants that prefer wet habitat or water related plants, and “chance” species originating from ruderal and nitrophilic habitats.

Littoral vegetation of rivers and lakes helps to reduce shoreline erosion by absorbing part of the wave energy and serves as habitat for all kind of animals (Kalff, 2001). Macrophytes trap particles and associated nutrients forming substrate for bacteria and periphyton. They are also feeding, breeding and hiding place for benthic invertebrates and littoral fish as well as a habitat for songbirds, amphibians, reptiles and mammals.

Through unbreakable connection with the aquatic habitat, macrophytes are a very important biological element for the assessment of ecological status of rivers and lakes. Therefore they are chosen as one of five biological elements for assessment of ecological status of water bodies in the Water Framework Directive (WFD, 2000). Macrophytes do not only deliver information about eutrophication, but also together with bank vegetation indicate the hydromorphological conditions of rivers and lakes and the naturalness of aquatic ecosystems.

1.2 The Danube macrophytes

The investigation on macrophytes has a long tradition in the Danube (Rath, 1995; Rath, 1997) and not only in the main course, but also in the tributaries, side arms and nearby lakes (Pall, 1996; Sârbu et al., 2011). As in other large rivers, the same is in the Danube where aquatic mosses dominate in the Upper Reach where they resist to high water current attached on the rocks. In the Middle Reach with still fast water current, but gravel as a substrate, less macrophytes occur, whereas the Lower Reach of large rivers like the Danube, is full with different forms and species of macrophytes. There their growth is eased by shallow water over a flat riverbed, by slow water current, muddy or sandy substrate and abundance of nutrients (Chambers et al., 1991; Dodds and Biggs, 2002).

Natural macrophyte distribution can be changed by anthropogenic influence, mainly by hydrological or morphological changes in the river (Gecheva, 2013). Structures like barriers of hydropower plants can slow down the water current in the impounded section just upstream of the dam and then this part of the Upper Reach of the river will adopt characteristics similar to the Lower Reach of the river (slow water current, muddy substrate). With changes in the environment, consequently changes in the water community will occur that refer to all groups of organisms, including macrophytes.

Many research activities were organised with the purpose to determine “health” of the Danube, lately called ecological status. One of that kind, certainly the biggest one, is the Joint Danube Survey, already conducted twice in the years 2001 and 2007 which collected valuable data about macrophytes in the Danube and in the tributaries, as well as for other aquatic organisms investigated (Janauer et al., 2002; Janauer et al., 2007).

2 Methods

2.1 Study area

Vegetation survey (macrophytes and other bank vegetation) was done in the Danube main channel and tributaries according to the Cruise manual (ICPDR, 2013) where study area is also described in details. Sampling sites were grouped according to the River Sections and as tributaries.

2.1.1 River Sections

Based on experiences in JDS 1 and a statistical analysis of macro-invertebrate distribution Moog et al. (2006) divided the Danube into 10 ecologically uniform reaches. The ICPDR used this classification as a basis for the assessment of water quality in JDS 2 and JDS3 with slight modifications (Table 1).

Table 1 Section Types of the Danube for JDS 3

River Section	Reach and sampling sites in the reach	River km
1	Upper Course of the Danube Breg- u. Brigach-confluence to Neu Ulm (JDS1)	2786 - 2581
2	Western Alpine Foothills Danube Neu Ulm to Passau – confluence with Inn River (JDS 2 - 5)	2581 - 2225
3	Eastern Alpine Foothills Danube Passau to Krems (JDS 6 - 8)	2225 - 2001
4	Lower Alpine Foothills Danube Krems to Gönyü / Kli.ská Nemá (JDS 9 - 14)	2001 - 1789.5
5	Hungarian Danube Bend Gönyü / Kli.ská Nemá to Baja (JDS 15 – 25)	1789.5 - 1497
6	Pannonian Plain Danube Baja to Bazias (JDS 26 – 42)	1497 - 1075
7	Iron Gate Danube Bazias to Turnu Severin (JDS 43 – 45)	1075 - 943
8	Western Pontic Danube Turnu Severin to Chiciu/Silistra (JDS 46 – 60)	943 – 375.5
9	Eastern Wallachian Danube Chiciu/Silistra to Isaccea (JDS 61 – 65)	375.5 - 100
10	Danube Delta (rkm 100: Isaccea;. rkm 20 on Chilia arm; rkm 19 on Sulina arm and rkm 7 on St. Gheorghe arm (JDS 66 – 68)	100 - 0

2.2 Vegetation survey

2.2.1 List of consumables and equipment

- *Writing paper A4*
- *Pencils*

- *Plastic bags 1 L with zipper*
- *Plastic bags 25 L*
- *Plastic bottle 500 mL*
- *Permanent markers, black*
- *Scotch tape, white*
- *Paper bags (appr. 13cm x 19cm)*
- *Absorbent paper tissues (kitchen roll)*
- *Petri dishes*
- *Pipettes*
- *Herbarium sheets*
- *Unbreakable bottles (wide neck) (0,5 L)*
- *Ethanol (96%)*
- *Field protocols*
- *Blotting pad*
- *Handheld GPS with replacement batteries (Garmin Montana 600)*
- *Camera (digital) with replacement batteries and battery charger (Pentax WP-3 with GPS)*
- *Waders*
- *Rubber boots*
- *Teva-sandals*
- *Rainwear*
- *Telescope rake with various top pieces*
- *Rake on a rope*
- *White dish for mosses*
- *Field magnifying glass (20x)*
- *Binocular*
- *Microscope*
- *Spray bottle*
- *Dissecting set*
- *Relevant and up-to-date taxonomical literature*
- *Herbarium press including auxiliary equipment*
- *Laptop*
- *DinoLite 5MP camera*
- *Hat*

- *Sun cream*
- *First aid kit*

2.2.2 Sampling procedure

Sampling of macrophytes and other bank vegetation was conducted from a small boat on six survey units of one kilometre length at each sampling site (Figure 1). Three survey units were sampled on the left and three on the right side of the river. For determining survey units a Garmin Montana 600 GPS device was used. Plants were collected by telescope rakes, by rakes on a rope or by hand when it was possible (Figure 2). Abundance of plants was estimated according to the Kohler 5-level scale (Kohler, 1978). This method is in full accordance with the European Standard (EN14184, 2003) (Table 2). Survey was documented with a Pentax WP-3 waterproof digital camera with GPS. Besides species list, additional parameters were recorded for each survey unit separately: presence of impoundment, incoming tributary or discharge, current velocity and diversity, estimated turbidity and Secchi depth, shading, type of bank fixation, proportion of submerged and emerged (bank) substrate as well as the slope and proportion of vegetation type on the banks. Species data and additional parameters were recorded in field protocols.

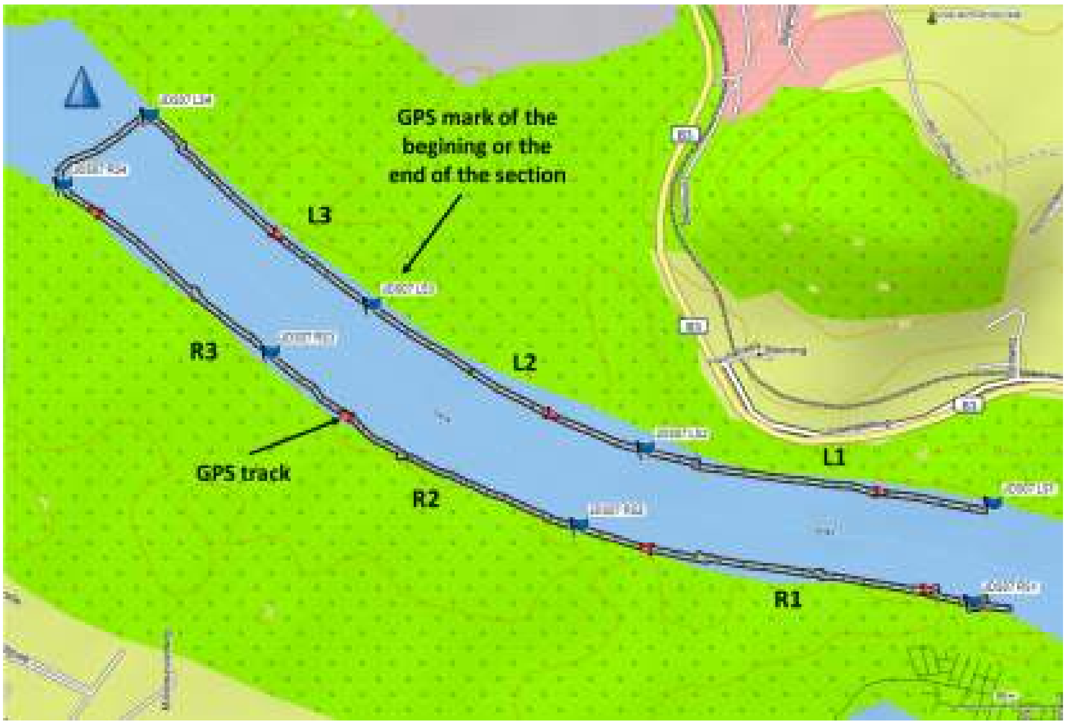


Figure 1 Example of sampling and survey units designation.

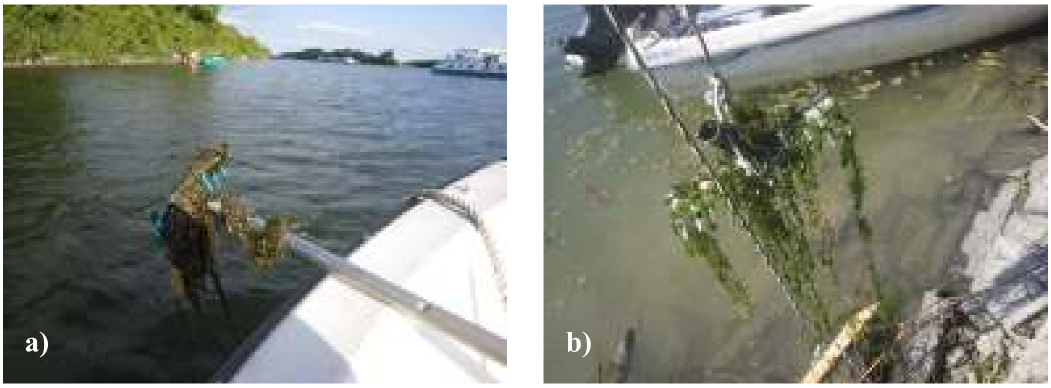


Figure 2 Sampling of macrophytes a) by telescope rakes and b) by rakes on a rope.

Table 2 Five-level estimaton scale (according to EN 14184:2003)

Level	Verbal descritpion	Explanation
1	Rare	Only single plants, up to 5 specimens
2	Occasional	Appr. 6 to 10 single plants, loosely scattered over survey section or up to 5 single plant stocks
3	Frequent	Cannot be overlooked, but not frequent; "to be found without having to search for it"
4	Abundant	Occurring frequently, but not in masses; incomplete cover exhibiting large gaps
5	Very abundant	Dominant, found more or less everywhere; cover markedly more than 50 %

2.3 Identification of the species

Plant species were identified in the field when possible while others were collected for later determination. Bryophytes were stored in paper bags, while vascular plants and charophytes were stored in 50% ethanol or in herbarium. Determination was carried out under Olympus SZ10 stereo-microscope with magnification 10-63 and Olympus BX51 microscope with magnification 100-400X. Species identification was followed by adequate literature (Atherton et al., 2010; Casper, 2008a; Casper, 2008b; Frey et al., 2006; Jäger et al., 2000; Krause, 2008; Martinčič et al., 2007; Smith, 1990; Smith, 2004; Van de Weyer et al., 2011a; Van de Weyer et al., 2011b). Species names were updated according to Hill et al. (2006) for mosses and The Plant List (2013) for liverworts, ferns and angiosperms.

2.4 Additional parameters

2.4.1 Secchi transparency

Secchi transparency was measured with Secchi plate hung on a rope with accuracy of 5 cm. It was measured on each sampling section, meaning six times on each sampling site.

2.4.2 Turbidity

Turbidity was estimated for each survey unit of one kilometre length and it was recorded in the field protocol according to Table 3.

Table 3 Turbidity classes

Code	Turbidity classes
0	None
1	Low
2	Medium
3	High

2.4.3 Shading

Shading of the surrounding trees was estimated for each survey unit of one kilometre length and it was recorded in the field protocol according to Table 4.

Table 4 Shading classes

Code	Shading classes
0	None
1	Low
2	Medium
3	High

2.4.4 Water flow velocity

Water flow velocity was estimated for each sampling section of one kilometre length and it was recorded in the field protocol according to Table 5.

Table 5 Water flow velocity classes

Code	Water flow velocity classes	Definition
0	None	0 cms-1
1	Low	≤ 30 cms-1
2	Medium	> 31 < 69 cms-1
3	High	≥ 70 cm cms-1

Diversity of water flow was estimated for each sampling section of one kilometre length and it was recorded in the field protocol according to Table 6.

Table 6 Classes of diversity of water flow velocity

Code	Diversity of water flow velocity classes
0	None
1	Low
2	Medium
3	High

2.4.5 Bank fixation

Bank fixation was recorded in field protocols as one of the most important parameters for bank vegetation. Percentage was recorded for each type of bank fixation or missing fixation, with an accuracy of 5% (Table 7).

Table 7 Bank fixation descriptors

Type of bank fixation	Description
None	% of natural bank, no fixation
Groynes	Number of groynes on the section
Old/abandoned rip rap	% of old rip rap on the section
Rip rap	% of rip rap on the section
Other	% of other type of bank fixation, usually conrete or metal

2.4.6 Submerged and emerged substrate

Type of submerged and emerged substrate was recorded in the field protocol according to EN16150 (2012)as listed in Table 8. Percentage of each type of submerged and emerged substrate was estimated with accuracy of 5% for each sampling section of one kilometre length.

Table 8 Substrate types according to EN 16150.

Substrate type	Description	Particle size
Technolithal	Solid material (usually stones) or geotextiles inserted into a river for the purposes of river engineering	>40 cm
Megalithal	Upper sizes of large cobbles, boulders, blocks and bedrock	>40 cm
Macrolithal	Coarse blocks, cobbles, gravel and sand	20 - 40 cm
Mesolithal	Fist to hand-sized cobbles with a variable percentage of gravel and sand	6,3 - 20 cm
Microlithal	Coarse gravel (size of a pigeon egg to a child's fist) with variable percentages of medium to fine gravel	2,0- 6,3 cm
Akal	Fine to medium-sized gravel	0,2 - 2,0 cm
Psammal	Sand	0,063 - 0,2 cm
Pelal	Fine particles, sludge, mud	< 0,063 cm

2.4.7 Bank vegetation forms

Bank vegetation forms were assessed in percentage with accuracy of 5% for each sampling unit of one kilometre length. The following categories were recorded in the field protocols: missing, grasses, tall forbs, reeds, shrubbery, riparian forest, broad-leaved forest, coniferous forest and mixed forest. Some of them are illustrated in the Figure 3.

Figure 3 Examples of bank vegetation forms: a) missing, b) grasses, c) tall forbs, d) riparian forest, e) reeds and f) broad-leaved forest.

2.5 Data analysis and organisation

2.5.1 Taxa clustering for analysis

Different life forms, different taxonomical groups and different microhabitats were sampled through the survey. Therefore, taxa clustering was necessary prior to data analysis with the goal of making specific conclusions. Identified taxa along the survey were clustered in the following way:

a) Taxonomically

BRYOPHYTES – traditional name used to refer to all embryophytes (land plants) that do not have true vascular tissue and are therefore called "non-vascular plants". Currently bryophytes are thought not to be a natural or monophyletic group; however the name is convenient and remains in use as a collective term for mosses, hornworts, and liverworts.

CHAROPHYTES – a member of macroalgae, commonly known as stoneworts. Stoneworts contain calcium carbonate deposits. Superficially resembling higher plants, stoneworts have rootlike and stemlike structures, as well as whorls of branches at regular intervals. They grow underwater, attached to the muddy bottoms of fresh or brackish rivers and lakes. Stoneworts are excluded here from other charophytes because they are considered as hydrophytes because of their large size and habitus similar to higher plnts.

PTERIDOPHYTES – in the broad interpretation of the term (sensu lato), are vascular plants (plants with xylem and phloem) that reproduce and disperse via spores. Because they produce neither flowers nor seeds, they are referred to as cryptogams. The group includes ferns, horsetails, clubmosses, spikemosses and quillworts. These do not form a monophyletic group, because ferns and horsetails are more closely related to seed plants than to lycophytes (clubmosses, spikemosses and quillworts). Therefore, pteridophytes are no longer considered to form a valid taxon, but the term is still used as an informal way to refer to ferns (monilophytes) and lycophytes.

ANGIOSPERMS –seed-producing plants like the gymnosperms and can be distinguished from the gymnosperms by characteristics including flowers, endosperm within the seeds, and the production of fruits that contain the seeds. Etymologically, angiosperm means a plant that produces seeds within an enclosure, in other words a fruiting plant.

MACROALGAE (excluding stoneworts) – large aquatic photosynthetic algae that can been seen without the aid of a microscope. The most familiar types can be generally divided into three groups: Green (Chlorophyta), Red (Rhodophyta), and Brown (Phaeophyta).

b) Life forms

HYDROPHYTES –Macrophyte species permanently living in the water – either completely or largely submerged – or swimming on the water either fully on the surface or with their leaves on the surface during the vegetation period. They also blossom or bear fruit on the water surface (“real” aquatic plants).

HELOPHYTES – Macrophyte species of which only the basal sections are submerged, while their leaves and florescences rise above the water level.

AMPHIPHYTES – Macrophyte species which can live either fully submerged in the water or temporarily ashore and out of water. This life-form group constitutes the transition from hydrophytes to helophytes.

WATER RELATED SPECIES – "other taxa related to aquatic environment" or "other taxa related to rivers and/or lakes". Taxa that are not macrophytes, but they can usually be found along the shoreline, taxa that like moist habitats and can be found elsewhere where is wet, but not specifically next to the river and/or lake.

CHANCE SPECIES – taxa that are related to the rural, open habitats or plants from the gardens. They do not belong to the river, but they say a lot about bank structure.

c) Bank and water species

With the respect to the substrate and habitat where plants were recorded, but with no influence of the taxonomical or life form approach whatsoever, taxa list was divided to two groups of the plants:

BANK SPECIES – Taxa that were recorded on the banks of the river, not submerged in to the water, with no matter to their taxonomical belonging or life form affiliation.

WATER SPECIES – Taxa that were recorded in the water, submerged and rooted in the substrate or found as floating taxa, with no matter to their taxonomical belonging or life form affiliation.

2.5.2 Relative Plant Mass (RPM)

The metric Relative Plant Mass (RPM) (Kohler and Janauer, 1995; Pall and Janauer, 1995) describes the quantitative relationship of individual plants and how they relate to each other with respect to dominance, as based on the total plant mass in a surveyed river reach. All species below 1 % RPM are combined in the „Residual“. The metric is weighted by the length of the survey units, in our case 10 times for 1 km (10 x 100 m = 1000 m = 1 km).

RPM is calculated following Pall and Janauer (1995):

$$RPM\ (\%) = \frac{\sum_{i=1}^{n}\left(M_i^3 L_i\right)100}{\sum_{j=1}^{k}\left(\sum_{i=1}^{n}\left(M_{ji}^3\ L_i\right)\right)}$$

RPM - Relative Plant Mass of a species

M_i - Plant Mass Estimate (PME) for the survey unit i of a species

L_i - Length in survey unit i

i, j, k - Running indices of different plant species

n - Total number of survey units in the surveyed river section

RPM concept was used to present the relationship of hydrophytes as shown on the Figure 4 and as value for basic species abundance data for other statistical calculations and the assessment of ecological status.

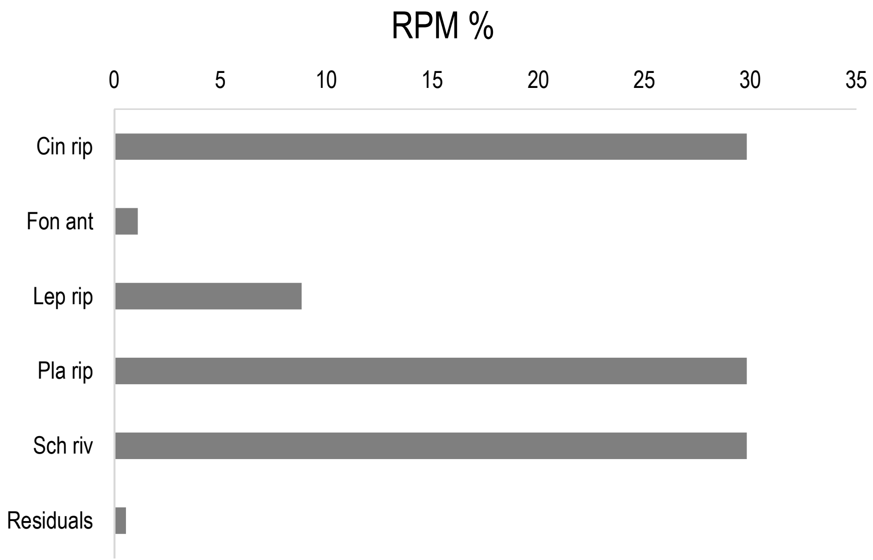


Figure 4 Example of an RPM diagram.

2.5.3 Distribution diagrams

Distribution Diagrams (Figure 5) performed in Microsoft Office Excel 2013 show the distribution of all species. Vertical lines mark survey unit borders. One survey unit length is proportional to the real length of 1 km. The height of the black bars indicates the abundance of each species in each survey unit according to the 5-level Kohler scale and is indicated for each bar size in the Figure 5. Sampling sites are indicated in the first line of the diagram. Survey units (or sampling sections) are indicated in the second line of the diagram where letters indicate side of the river (L = left, R = right) and numbers indicate the number of the survey unit (e.g. L1 – first survey unit (or sampling section) on the left side on the above indicated sampling site).

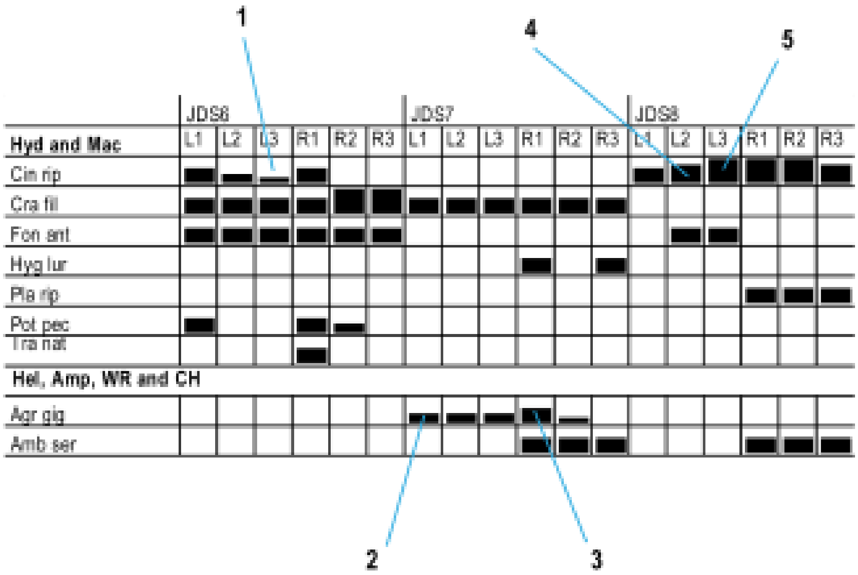


Figure 5 Example of the distribution diagram. Numbers explain meaning of the bar size according to the Kohler 5-level scale.

2.5.4 Statistical methods

Bray-Curtis similarity (Bray and Curtis, 1957) was calculated for River Sections based on the log transformed species data.

Non-metric Multidimensional Scaling ordinations (NMDS) were performed on resultant matrices with River Sections defined by Moog et al. (2006) and used as a grouping variable (Clarke, 1993). Additionally, NMDS was overlaid with cluster analysis for visualisation of River Section similarity.

Similarity Percentage Analyses (SIMPER) (Clarke, 1993) was also conducted with Bray-Curtis similarity measures on log transformed data to determine contributions of individual taxa to overall dissimilarity among River Sections. Bray-Curtis similarity, NMDS and SIMPER analysis were performed in Primer 6.1.6. (Clarke and Gorley, 2006) and Column Charts were performed in Microsoft Office Excel 2013.

A Canonical Correspondence Analysis (CCA) was employed, using the program CANOCO 4.5 (Smilauer and ter Braak, 2002). The analysis was based on the taxa relative plant mass (RPM) in relation to percentage of the representation of each submerged or emerged substrate. Data of RPM values were log transformed and centred while the substrate data were normalised prior to the analysis. The results are presented as a biplot where taxa and environmental variables (type of the substrate) are plotted together. For clearer visual information, original images were improved in Adobe Illustrator from the Adobe Master Collection CS6 package.

The One-Way ANOVA (with Tukey's post hoc test) was used to determine whether there are any significant differences between the groups of shading and emerged (bank) slope and their relationship with the bank vegetation. It was also used to determine whether there are any significant differences between the groups of current, current diversity, turbidity, shading and submerged slope and their relationship with the vegetation found in the water for this purpose divided to mosses, rooted plants, macroalgae (excluding stoneworts) and floating plants. The One-Way ANOVA was performed in Statistica 12 (StatSoft, 2011) and all data were log transformed prior the analysis.

3 Results

3.1 Completeness of the macrophyte survey

Most of the sampling sites were sampled according to standard procedure (360 km out of 412 km). Sampling sites JDS12, JDS23, JDS29 and JDS 56 were not sampled at all because of technical difficulties (e.g. low water level). On sampling sites JDS14 and JDS28 it was possible to sample only one side (due to danger of the landmines). On sampling sites JDS1, JDS37, JDS48, JDS51, JDS54 and JDS58 only one sampling section was sampled on the left and on the right side because survey out of small boat was obstructed due to low water level and it was carried out on foot. One additional sampling site was sampled because sampling site JDS3 was divided into JDS3 upstream and downstream of the dam.

3.2 Species composition in the Danube River and its main tributaries

3.2.1 Taxa list

During the whole survey, 182 taxa were identified to species level and 16 to genus level (198 taxa in total) (Table 9). Identified taxa belonged to the groups of bryophytes (35 taxa), ferns (4 taxa), angiosperms (150 taxa), charophytes (1 taxa) and other macroalgae (8 taxa).

Table 9 Taxa list with comparison of JDS1 and JDS2 findings. Life forms: Hyd – Hydrophytes, Hel – Helophytes, Amp – Amphiphytes, WR – water related species and CH – chance species. Bank or water species: B – taxa were recorded on the banks, W – taxa were recorded in the water.

Species code	Species name	Life form	Bank/ Water	JDS1	JDS 2
	Bryophytes				
Amb ser	*Amblystegium serpens* (Hedw.) Schimp.	CH	W		
Bar con var. com	*Barbula convoluta* var. *commutata* (Jur.) Husn.	CH	W		
Bra riv	*Brachythecium rivulare* Schimp.	Hyd	W	●	
Bra rut	*Brachythecium rutabulum* (Hedw.) Schimp.	Amp	W		
Bry pse	*Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb.	Amp	W		
Bry pse var. bim	*Bryum pseudotriquetrum* var. *bimum* (Schreb.) Lilj.	Amp	W		
Bry sp.	*Bryum* sp.		B		
Cin fon	*Cinclidotus fontinaloides* (Hedw.) P. Beauv.	Hyd	W		●
Cin rip	*Cinclidotus riparius* (Host ex Brid.) Arn.	Hyd	W	●	●
Con con	*Conocephalum conicum* (L.) Underw.	Amp	B		
Cra fil	*Cratoneuron filicinum* (Hedw.) Spruce	Hyd	W	●	●
Did rig	*Didymodon rigidulus* Hedw.	CH	B		
Fis cra	*Fissidens crassipes* Wilson ex Bruch & Schimp.	Hyd	W		
Fis cri	*Fissidens crispus* Mont.	SW	B		
Fis exi	*Fissidens exiguus* Sull.	Hyd	B		
Fis pus	*Fissidens pusillus* (Wilson) Milde	WR	B		
Fon ant	*Fontinalis antipyretica* Hedw.	Hyd	W	●	●
Hyg flu	*Hygroamblystegium fluviatile* (Hedw.) Loeske	Hyd	W		●
Hyg hum	*Hygroamblystegium humile* (P. Beauv.) Vanderpoorten, Hedenas & Goffinet	WR	W		
Hyg var	*Hygroamblystegium varium* (Hedw.) Mönk.	WR	B	●	
Hyg lur	*Hygrohypnum luridum* (Hedw.) Jenn.	Hyd	W	●	●
Lep rip	*Leptodictyum riparium* (Hedw.) Warnst.	Hyd	W	●	●

Species code	Species name	Life form	Bank/ Water	JDS1	JDS 2
Les pol	*Leskea polycarpa* Ehrh. ex Hedw.	Amp	W	●	●
Mar pol	*Marchantia polymorpha* L.	Amp	B		
Mni mar	*Mnium marginatum* (Dicks. ex With.) P. Beauv.	CH	W		
Pel sp.	*Pellia* sp.		B		
Phy pat	*Physcomitrella patens* (Hedw.) Bruch & Schimp.	WR	B		
Pla ell	*Plagiomnium ellipticum* (Brid.) T.J. Kop.	Amp	B		
Pla rip	*Platyhypnidium riparioides* (Hedw.) Dixon	Hyd	B	●	●
Poh mel	*Pohlia melanodon* (Brid.) A.J. Shaw	Amp	B		
Poh wah	*Pohlia wahlenbergii* (F. Weber & D. Mohr) A.L. Andrews	Amp	B		
Ric fro	*Riccia frostii* Aust.	WR	B		
Sch riv	*Schistidium rivulare* (Bridel) Podpera	Hyd	W		●
Sch sp.	*Schistidium* sp.		W		
Tor mur	*Tortula muralis* Hedw.	CH	B		
	Charophytes				
Nit obt	*Nitellopsis obtusa* (N.A.Desvaux) J.Groves	Hyd	W	●	●
	Pteridophytes				
Azo fil	*Azolla filiculoides* Lam.	Hyd	W		●
Equ arv	*Equisetum arvense* L.	CH	B		●
Equ flu	*Equisetum fluviatile* L.	Amp	W		
Sal nat	*Salvinia natans* (L.) All.	Hyd	W	●	●
	Angiosperms				
Abu the	*Abutilon theophrasti* Medik.	CH	B		●
Agr gig	*Agrostis gigantea* Roth	Amp	B		●
Agr sto	*Agrostis stolonifera* L.	Amp	B		
Ali pla	*Alisma plantago-aquatica* L.	Amp	W		●
Alo gen	*Alopecurus geniculatus* L.	Hel	B		●
Ama bli	*Amaranthus blitum* L.	WR	B		
Ama ret	*Amaranthus retroflexus* L.	CH	B		
Amb art	*Ambrosia artemisiifolia* L.	CH	B		
Ang syl	*Angelica sylvestris* L.	WR	B		
Art sp.	*Artemisia* sp.		B		●
Asc syr	*Asclepias syriaca* L.	WR	B		
Bid fro	*Bidens frondosa* L.	WR	B		●
Bid rad	*Bidens radiata* Thuill.	Hel	B		●
Bid tri	*Bidens tripartita* L.	Hel	B		●
Bol mar	*Bolboschoenus maritimus* (L.) Palla	Hel	W		●
Bra nig	*Brassica nigra* (L.) K.Koch	WR	B		
Bud dav	*Buddleja davidii* Franch.	CH	B		
But umb	*Butomus umbellatus* L. in the water	Hel	W	●	
But umb	*Butomus umbellatus* L. on the river bank	Hel	B	●	
Cal pal	*Caltha palustris* L.	Amp	W		
Car acu	*Carex acuta* L.	Hel	B		
Car ela	*Carex elata* All.	Hel	B		
Car hir	*Carex hirta* L.	WR	B		
Car rip	*Carex riparia* Curtis	Hel	B		
Car sp.	*Carex* sp.		B		
Cer dem	*Ceratophyllum demersum* L.	Hyd	W	●	●
Cha aur	*Chaerophyllum aureum* L.	WR	B		
Che alb	*Chenopodium album* L.	Ch	B		
Che fic	*Chenopodium ficifolium* Sm.	WR	B		
Che rub	*Chenopodium rubrum* L.	WR	B		
Cir ole	*Cirsium oleraceum* (L.) Scop.	WR	B		
Cle vit	*Clematis vitalba* L.	CH	B		
Cus cam	*Cuscuta campestris* Yunck.	CH	B		
Cyp fus	*Cyperus fuscus* L.	Hel	B	●	●
Cyp glo	*Cyperus glomeratus* L.	WR	B		●
Cyp lon	*Cyperus longus* L.	WR	B		●
Dat str	*Datura stramonium* L.	CH	B		
Dic mic	*Dichostylis micheliana* (L.) Nees	Hel	B		●
Dig cil	*Digitaria ciliaris* (Retz.) Koeler	CH	B		
Dys bot	Dysphania botrys (L.) Mosyakin & Clemants	CH	B		

Species code	Species name	Life form	Bank/ Water	JDS1	JDS 2
Ech cru	*Echinochloa crus-galli* (L.) P.Beauv.	CH	B		●
Ech lob	*Echinocistis lobata* (Michx.) Torr. & A. Gray	WR	B		
Ecl pro	*Eclipta prostrata* (L.) L.	WR	B		
Ele aci	*Eleocharis acicularis* (L.) Roem. & Schult.	Amp	W		
Ele ova	*Eleocharis ovata* (Roth) Roem. & Schult.	Hel	B		
Ele pal	*Eleocharis palustris* (L.) Roem. & Schult.	Amp	B		
Ele uni	*Eleocharis uniglumis* (Link) Schult.	Amp	B		
Elo nut	*Elodea nuttallii* (Planch.) H.St.John	Hyd	W	●	●
Epi hir	*Epilobium hirsutum* L.	Hel	B		
Era pil	*Eragrostis pilosa* (L.) P.Beauv.	CH	B		
Eri ann	*Erigeron annuus* (L.) Pers.	CH	B		
Eup can	*Eupatorium cannabinum* L.	WR	B		●
Eup luc	*Euphorbia lucida* Waldst. & Kit.	WR	B		
Fal jap	*Fallopia japonica* (Houtt.) Ronse Decr.	WR	B		
Fil ulm	*Filipendula ulmaria* (L.) Maxim.	WR	B		
Gly flu	*Glyceria fluitans* (L.) R.Br.	Amp	W		●
Gly max	*Glyceria maxima* (Hartm.) Holmb.	Hel	W		●
Gna uli	*Gnaphalium uliginosum* L.	WR	B		
Hel ann	*Helianthus annuus* L.	WR	B		
Hum lup	*Humulus lupulus* L.	WR	B		
Hyd mor	*Hydrocharis morsus-ranae* L.	Hyd	W	●	●
Hyp tet	*Hypericum tetrapterum* Fr.	WR	B		
Imp gla	*Impatiens glandulifera* Royle	WR	B		●
Imp par	*Impatiens parviflora* DC.	WR	B		
Inu bri	*Inula britannica* L.	WR	B		
Iri pse	*Iris pseudacorus* L.	Hel	W		●
Jun art	*Juncus articulatus* L.	Amp	B		
Jun com	*Juncus compressus* Jacq.	Hel	B		
Lem gib	*Lemna gibba* L.	Hyd	W		●
Lem min	*Lemna minor* L.	Hyd	W	●	●
Lem tur	*Lemna turionifera* Landolt	Hyd	W		●
Lin dub	*Lindernia dubia* (L.) Pennell	CH	W		
Lyc eur	*Lycopus europaeus* L.	Hel	B		●
Lys vul	*Lysimachia vulgaris* L.	WR	B		
Lyt sal	*Lythrum salicaria* L.	Hel	B		●
Men aqu	*Mentha aquatica* L.	Amp	B		●
Men lon	*Mentha longifolia* (L.) L.	WR	B		●
Men pul	*Mentha pulegium* L.	Amp	B		
Myo sco	*Myosotis scorpioides* L.	Amp	B		
Myr spi	*Myriophyllum spicatum* L.	Hyd	W	●	●
Naj mar	*Najas marina* L.	Hyd	W	●	●
Naj min	*Najas minor* All.	Hyd	W		●
Nup lut	*Nuphar lutea* (L.) Sm.	Hyd	W		●
Nym pel	*Nymphoides peltata* (S.G.Gmel.) Kuntze	Hyd	W		
Pan cap	*Panicum capillare* L.	CH	B		
Pas sp.	*Paspalum* sp.	Amp	B		
Per hyd	*Persicaria hydropiper* (L.) Delarbre	Amp	B		●
Per lap	*Persicaria lapathifolia* (L.) Delarbre	Hel	B		●
Per mac	*Persicaria maculosa* Gray	WR	B		
Per mit	*Persicaria mitis* (Schrank) Holub	Amp	B		●
Pet sp.	*Petasites* sp.	WR	B		●
Pha aru	*Phalaris arundinacea* L.	Hel	B		●
Phr aus	*Phragmites australis* (Cav.) Trin. ex Steud.	Hel	W		●
Pla lan	*Plantago lanceolata* L.	CH	B		●
Pla maj subsp. int	*Plantago major* subsp. *intermedia* (Gilib.) Lange	CH	B		
Pol avi	*Polygonum aviculare* L.	CH	B		
Por ole	*Portulaca oleracea* L.	CH	B		
Pot ber	*Potamogeton berchtoldii* Fieber	Hyd	W		
Pot cri	*Potamogeton crispus* L.	Hyd	W	●	●
Pot fri	*Potamogeton friesii* Rupr.	Hyd	W		●

Species code	Species name	Life form	Bank/ Water	JDS1	JDS 2
Pot gra	*Potamogeton gramineus* L.	Hyd	W	●	●
Pot luc	*Potamogeton lucens* L.	Hyd	W	●	●
Pot nat	*Potamogeton natans* L.	Hyd	W	●	●
Pot nod	*Potamogeton nodosus* Poir.	Hyd	W	●	●
Pot pec	*Potamogeton pectinatus* L.	Hyd	W	●	●
Pot per	*Potamogeton perfoliatus* L.	Hyd	W	●	●
Pot pus	*Potamogeton pusillus* L.	Hyd	W	●	●
Pot tri	*Potamogeton trichoides* Cham. & Schltdl.	Hyd	W	●	●
Ran flu	*Ranunculus fluitans* Lam.	Hyd	W		●
Ran rep	*Ranunculus repens* L.	Amp	B		
Ran sce	*Ranunculus sceleratus* L.	Amp	B		●
Ran sp	*Ranunculus* sp.		B		
Rap rap	*Raphanus raphanistrum* L.	CH	B		
Ror amp	*Rorippa amphibia* (L.) Besser	Amp	B		●
Ror syl	*Rorippa sylvestris* (L.) Besser	Amp	B		●
Rub sp.	*Rubus* sp.	CH	B		
Rud hir	*Rudbeckia hirta* L.	CH	B		
Rum aqu	*Rumex aquaticus* L.	Hel	B		
Rum hyd	*Rumex hydrolapathum* Huds.	Hel	B		●
Rum sp	*Rumex* sp.		B		●
Sag sag	*Sagittaria sagittifolia* L.	Amp	W	●	●
Sap off	*Saponaria officinalis* L.	CH	B		
Sch lac	*Schoenoplectus lacustris* (L.) Palla	Amp	W		●
Sch tri	*Schoenoplectus triqueter* (L.) Palla	Hel	W	●	●
Scu gal	*Scutellaria galericulata* L.	Hel	B		
Sen nem	*Senecio nemorensis* L.	WR	B		
Set pum	*Setaria pumila* (Poir.) Roem. & Schult.	CH	B		
Set vir	*Setaria viridis* (L.) P.Beauv.	CH	B		
Sol dul	*Solanum dulcamara* L.	WR	B		●
Sol nig	*Solanum nigrum* L.	CH	B		
Sol can	*Solidago canadensis* L.	WR	B		
Spa eme	*Sparganium emersum* Rehmann	Amp	W	●	●
Spa ere	*Sparganium erectum* L.	Hel	W		●
Spi pol	*Spirodela polyrhiza* (L.) Schleid.	Hyd	W	●	●
Sta pal	*Stachys palustris* L.	WR	B		●
Str alo	*Stratiotes aloides* L.	Hyd	W		●
Sym lan	*Symphyotrichum lanceolatum* (Willd.) G.L.Nesom	WR	B		●
Sym off	*Symphytum officinale* L.	WR	B		
Syr sp.	*Syringa* sp.		B		
Tra nat	*Trapa natans* L.	Hyd	W	●	●
Tus far	*Tussilago farfara* L.	CH	B		
Typ ang	*Typha angustifolia* L.	Hel	W	●	●
Typ lat	*Typha latifolia* L.	Hel	W	●	●
Typ sp.	*Typha* sp.	Hel	W		
Urt dio	*Urtica dioica* L.	CH	B		
Val spi	*Vallisneria spiralis* L.	Hyd	W	●	●
Ver ana	*Veronica anagalis-aquatica* L.	Amp	B		●
Xan spi	*Xanthium spinosum* L.	CH	B		
Xan str	*Xanthium strumarium* L.	CH	B		●
Zan pal	*Zannichellia palustris* L.	Hyd	W	●	●

Table 10 Macroalgae taxa list

Species code	Species name	Bank/Water	JDS1	JDS2
	Chlorophyta			
Cla glo	Cladophora glomerata (Linnaeus) Kützing	W		
Ent sp	Enteromorpha sp.	W		●
Hyd ret	Hydrodiction reticulatum (Linnaeus) Bory de Saint-Vincent	W		●
Oed spp	Oedogonium spp.	W		
	Rodophyta			
Tho his	Thorea hispida (Thore) Desvaux	W		

	Charophyta	
Spy spp	Spyrogira spp.	W
Zyg spp	Zygnema spp.	W
	Xanthophyta	
Bot gra	Botrydium granulatum (Linnaeus) Greville	B

3.2.2 Comparison with outcomes from JDS1 and JDS2

In comparison with previous Joint Danube Surveys, only the total number of identified species was compared because life-form categories were assigned differently and therefore a more detailed analysis was impossible. In comparison with JDS1 when 48 taxa were identified, 37 of them were equal taxa with JDS3 taxa list (77%). During JDS2 129 taxa were identified and 89 of them were the same species as identified in JDS3 (68%).

After accumulation of taxa in all three Joint Danube Surveys 249 taxa of macrophytes and other species related to river were identified. Final result of JDS3 was 80% identification of all three JDS taxa lists.

3.3 The Danube main course

3.3.1 Additional parameters

3.3.1.1 Secchi transparency

Secchi transparency was high in River Sections 1 and 2 (Figure 6) when it suddenly decreased in section 3 and stayed in a range between 45 and 150 cm until the end of River Section 7. A sudden increase of Secchi transparency in the beginning of River Section 8 was noted when the largest value was measured on the left side with 370 cm. Downstream a gentle decrease followed until the River Section 10, when last measured values were around 50 cm.

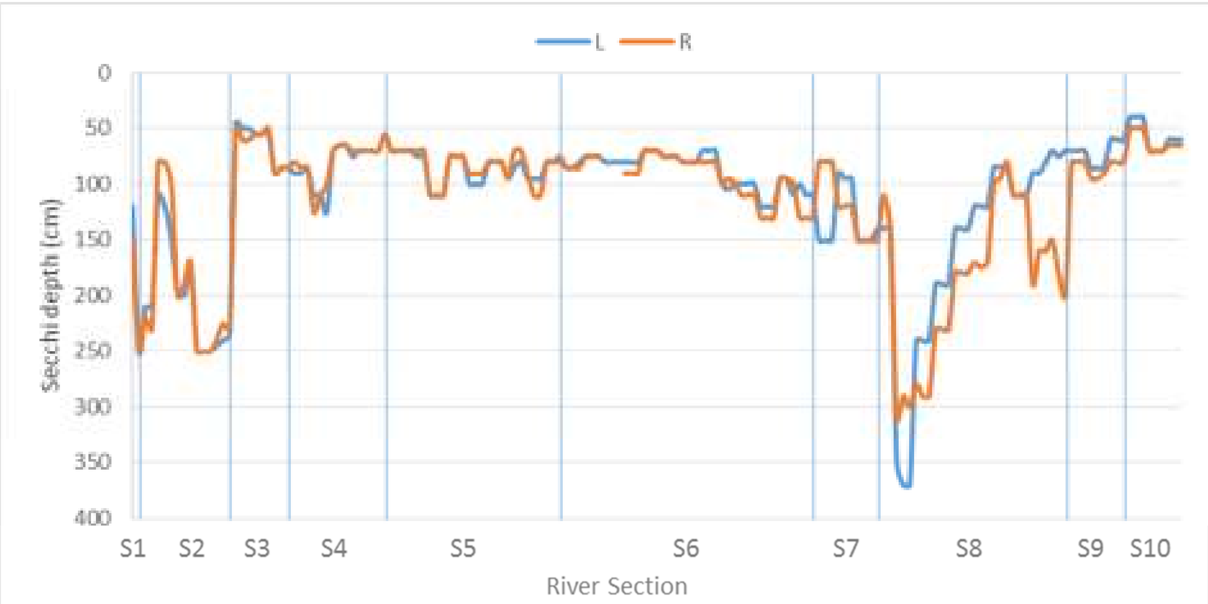


Figure 6 Secchi depth on the left and right side of Danube River

Box-Whiskers plot of Secchi transparency showed that a larger amplitude and the largest values were measured on the left side of the Danube, whereas the median was lower on the left side then on the right side of the Danube (Figure 7).

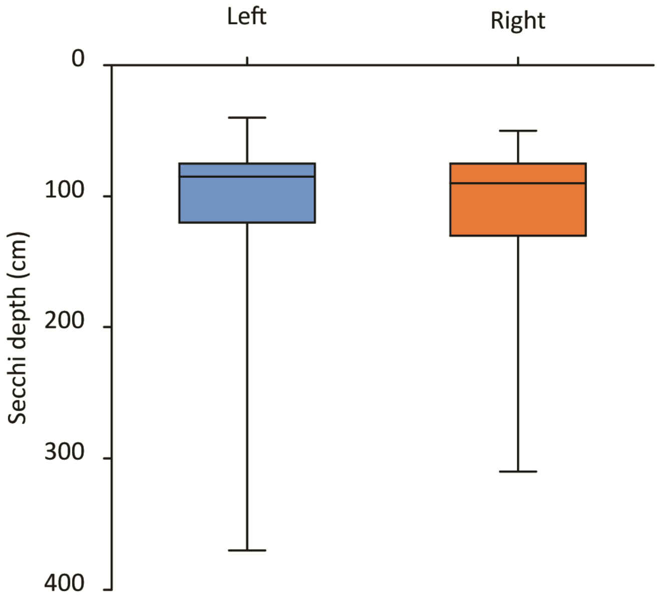
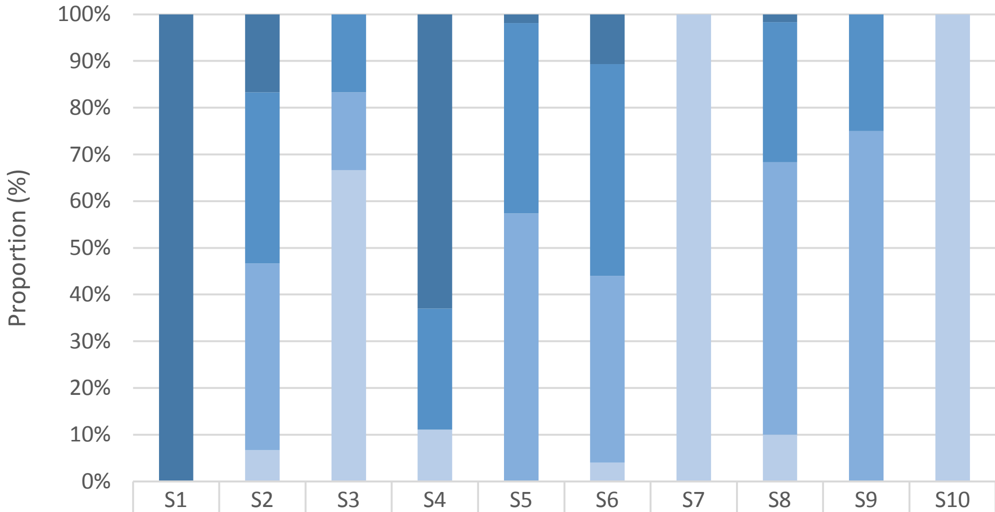


Figure 7 Box-Whiskers plot of Secchi depth

3.3.1.2 Water flow

Water flow classes showed a difference along the Danube (Figure 8). High velocity was dominant with a proportion of 100% and 63.0% in River Section 1 and 4. Opposite to high velocity, stagnant water was dominant in three River Sections, 3, 7 and 10. In River Sections 7 and 10 stagnant water was present with 100% on all sampling sites while it was covering 66.3% of Rivers Section 3. River Sections 2, 5 and 6 had an almost equal proportion of medium and low velocity classes with very low proportion of high and stagnant velocity classes. Low water velocity was dominant in River Sections 8 and 9 with up to 30.0% of medium water velocity.

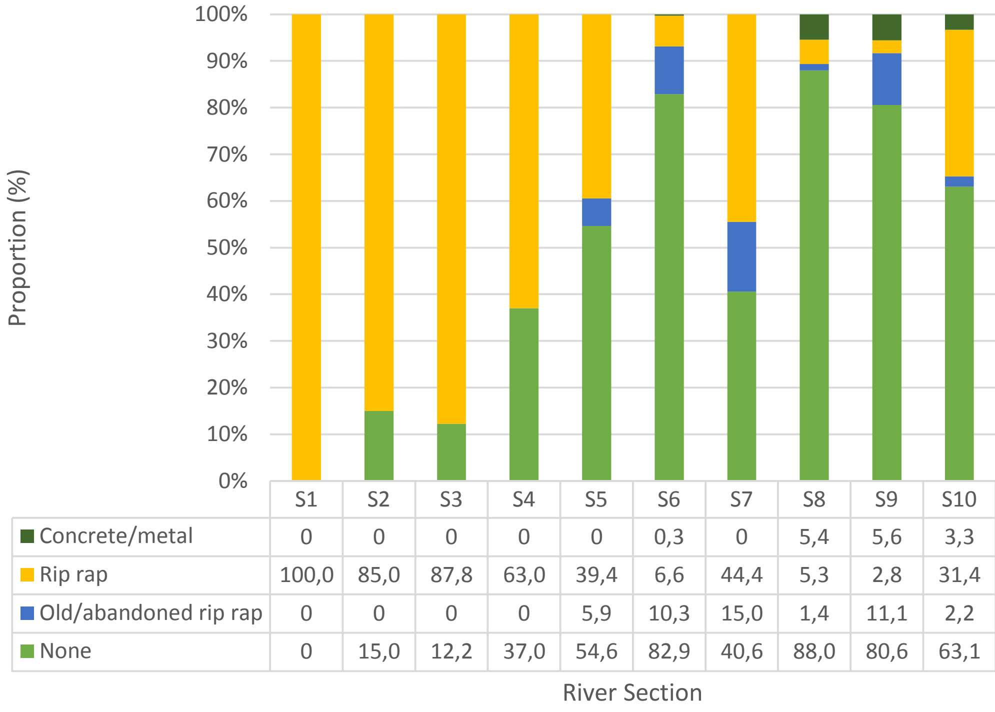


	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
High	100,0	16,7	0	63,0	1,9	10,7	0	1,7	0,0	0
Medium	0	36,7	16,7	25,9	40,7	45,3	0	30,0	25,0	0
Low	0	40,0	16,7	0,0	57,4	40,0	0	58,3	75,0	0
Stagnant	0	6,7	66,7	11,1	0	4,0	100,0	10,0	0	100,0

Figure 8 Proportion of water flow classes (stagnant, low, medium and high) in each section of Danube River.

3.3.1.3 Bank structure

The upper sections of the Danube had an opposite structure when compared with the lower sections (Figure 9). From River Section 1 where rip rap was represented with 100.0% of the bank structure, to River Section 4 with 63.0% of the rip rap, it was dominant bank structure. Natural banks with high proportion of no artificial structures were in River Sections 6, 8, 9 and 10. River Sections 5 and 7 had similar proportion of rip rap and natural bank structure. Old/abandoned rip rap was represented with small proportion on River Sections from 5 to 10, while other structures (concrete, metal) were represented, also with small proportion, in River Section 8, 9 and 10.

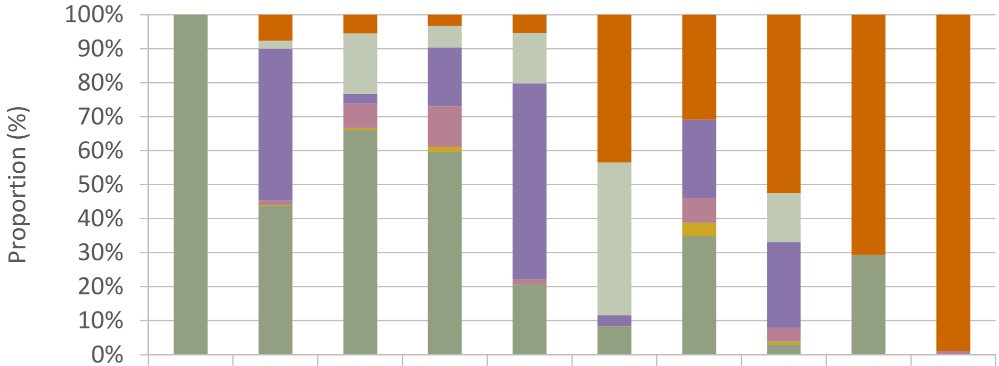


	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Concrete/metal	0	0	0	0	0	0,3	0	5,4	5,6	3,3
Rip rap	100,0	85,0	87,8	63,0	39,4	6,6	44,4	5,3	2,8	31,4
Old/abandoned rip rap	0	0	0	0	5,9	10,3	15,0	1,4	11,1	2,2
None	0	15,0	12,2	37,0	54,6	82,9	40,6	88,0	80,6	63,1

Figure 9 Proportion of bank structure fixation type (none, old/abandoned rip rap, rip rap and concrete/metal) in each section of Danube River.

3.3.1.4 Submerged substrate

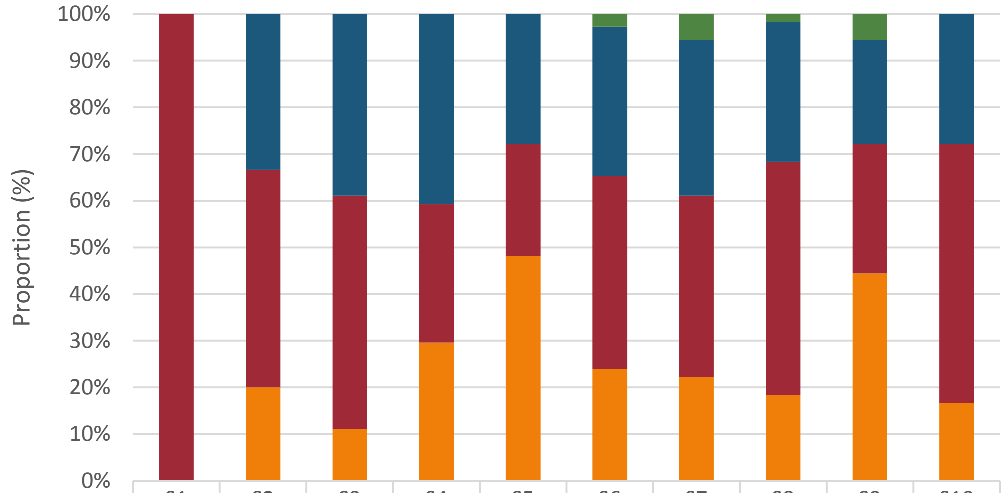
In the upper Sections of the Danube submerged artificial substrate (technolithal) was dominant (Figure 10). Technolithal was represented with 43.7 to 100.0% in River Sections from 1 to 4. On the other hand, pelal was dominating in lower River Sections, represented with 30.9 to 98.9% from sections 6 to 10. Third most represented type of the substrate was microlithal appearing in River Sections from 2 to 8 with proportion of 2.8 to 44.7%. Other types of the substrate were present with low proportion of only few %, while megalithal and akal were never recorded.



	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Pelal	0,0	7,7	5,6	3,3	5,5	43,4	30,9	52,5	70,6	98,9
Psammal	0,0	2,3	17,8	6,3	14,7	45,0	0,0	14,3	0,0	0,0
Akal	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Microlithal	0,0	44,7	2,8	17,4	57,7	3,1	23,0	25,3	0,0	0,0
Mesolithal	0,0	1,3	7,2	11,9	1,4	0,1	7,3	4,0	0,0	1,1
Macrolithal	0,0	0,3	0,6	1,5	0,0	0,0	3,9	0,8	0,0	0,0
Megalithal	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Technolital	100,0	43,7	66,1	59,6	20,7	8,4	34,8	3,0	29,4	0,0

Figure 10 Proportion types of submerged substrate (technolithal, megalithal, macrolithal, mesolithal, microlithal, akal, psammal and pelal) in each section of Danube River.

Slope of the submerged substrate was similar in most of the River Sections (Figure 11). Only in River Section 1 slope was 100.0% medium. In other River Sections there was similar proportion of steep, medium and flat slope of submerged substrate with slight variations. Vertical slope of submerged substrate was recorded only in sections from 6 to 9 with proportion of 1.7 to 5.6%.

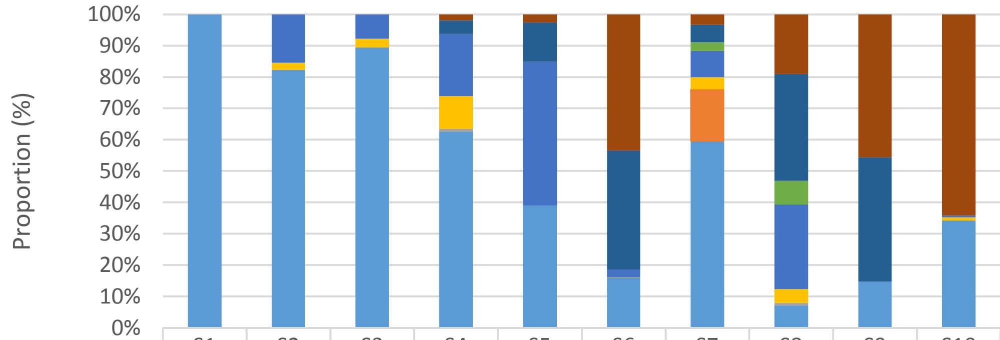


	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Vertical	0	0	0	0	0	2,7	5,6	1,7	5,6	0
Steep	0	33,3	38,9	40,7	27,8	32,0	33,3	30,0	22,2	27,8
Medium	100,0	46,7	50,0	29,6	24,1	41,3	38,9	50,0	27,8	55,6
Flat	0	20,0	11,1	29,6	48,1	24,0	22,2	18,3	44,4	16,7

Figure 11 Proportion of slope of submerged substrate (flat, medium, steep and vertical) on each section of Danube River.

3.3.1.5 Emerged substrate

In the upper sections of the Danube, in River Sections from 1 to 4, artificial techonlithal was dominant bank substrate with proportion of 39.0 to 100.0% (Figure 12). From section 5 to 10 more natural bank structure was recorded with microlithal, psammal and soil. Natural megalithal was present only in River Section 7 with proportion of 16.7% where also technolithal dominated with proportion of 59.0%.

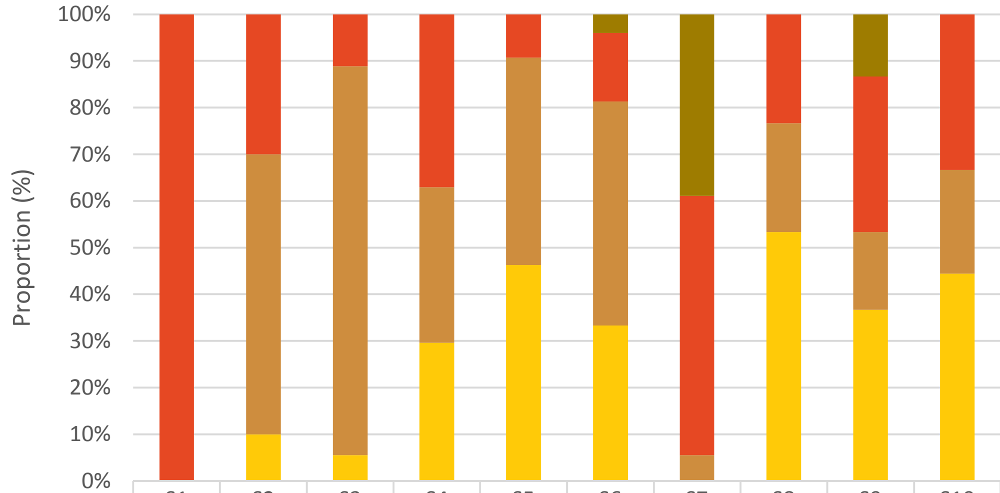


	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Soil	0	0	0	1,9	2,6	43,4	3,3	19,0	45,6	64,2
Psammal	0	0	0	4,4	12,6	38,0	5,6	34,2	39,7	0
Akal	0	0	0	0	0	0	2,8	7,5	0	
Microlithal	0	15,5	7,8	19,8	45,8	2,5	8,3	27,0	0	0,6
Mesolithal	0	2,2	2,8	10,4	0	0,1	3,9	4,3	0	1,1
Macrolithal	0	0	0	0,9	0	0	0	0,8	0	0
Megalithal	0	0	0	0	0	0	16,7	0	0	0
Technolital	100,0	82,3	89,4	62,6	39,0	15,9	59,4	7,2	14,7	34,2

River Section

Figure 12 Proportion types of emerged substrate (technolithal, megalithal, macrolithal, mesolithal, microlithal, akal, psammal and pelal) on each section of Danube River.

Bank slope or emerged substrate slope was steep in River Section 1 and mostly steep and vertical in River Section 7 (Figure 13). In River Sections 2 and 3 medium bank slope was dominant with 60.0 and 83.3%. Medium and flat bank slope was dominant in sections 4 to 6, while flat slope was dominant in lower sections from 8 to 10 in combination of medium bank slope with proportion from 23.3 to 33.3% and steep bank slope with proportion from 16.7 to 23.3%.



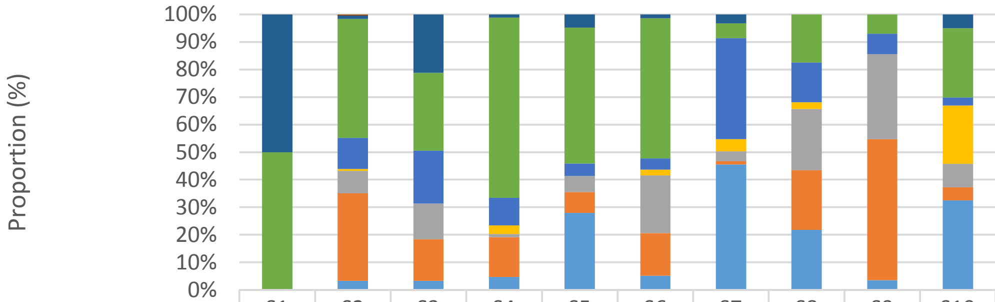
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Vertical	0	0	0	0	0	4,0	38,9	0	13,3	0
Steep	100,0	30,0	11,1	37,0	9,3	14,7	55,6	23,3	33,3	33,3
Medium	0	60,0	83,3	33,3	44,4	48,0	5,6	23,3	16,7	22,2
Flat	0	10,0	5,6	29,6	46,3	33,3	0	53,3	36,7	44,4

River Section

Figure 13 Proportion of emerged substrate slope (flat, medium, steep and vertical) on each section of Danube River.

3.3.1.6 Bank vegetation

Dominant bank vegetation form throughout long parts of the Danube, represented from section 1 to 6, was riparian forest with 28.3 to 65.4% (Figure 14). In River Section 1 its domination was shared with broad-leaved forest, both in proportion of 50.0%. Shrubbery and banks with missing vegetation dominated in River Section 7, while grasses and tall forbs were dominant in River Section 8 and 9. River Section 10 was mostly different from others because of 21.2% of reeds while most of other vegetation types were missing vegetation with 32.5%, and riparian forest with 25.1%.



	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Mixed forest	0	0	0	0	0	0	0	0	0	0
Coniferous forest	0	0,3	0	0	0	0	0	0	0	0
Broad-leaved forest	50,0	1,3	21,2	1,2	4,8	1,5	3,3	0	0	5,0
Riparian forest	50,0	43,2	28,3	65,4	49,4	50,7	5,3	17,5	7,1	25,1
Shrubbery	0	11,3	19,2	10,0	4,4	4,2	36,7	14,4	7,4	2,9
Reeds	0	0,7	0	3,1	0	2,1	4,4	2,4	0	21,2
Tall forbs	0	8,1	12,9	1,2	5,9	20,9	3,6	22,3	30,9	8,5
Grasses	0	31,8	15,1	14,5	7,5	15,4	1,1	21,6	51,2	4,8
Missing	0	3,3	3,3	4,7	28,0	5,2	45,6	21,8	3,5	32,5

River Section

Figure 14 Proportion bank vegetation forms (missing, grasses, tall forbs, reeds, shrubbery, riparian forest, broad-leaved forest, coniferous forest and mixed forest) on each section of Danube River.

3.3.2 Detailed species composition in the River Sections

3.3.2.1 River Section 1

The River Section 1 stretches in the Upper Reach of the Danube from Breg-Brigach confluence to Neu Ulm. Only one sampling site represented this Section (JDS1). Due to incapability of driving in a small boat, survey was done by foot and survey was done only on one kilometre of left and right side.

In this Section 24 taxa were identified and six of them were hydrophytes (Figure 15). More species were recorded on the left side of the Danube.

RPM diagram showed that bryophytes characterized hydrophytes in Section 1 (Figure 16). Taxa *C. riparius*, *P. riparoides* and *S. rivulare* were the dominant hydrophytes in Section 1, each with 29.8% of RPM. Other less abundant hydrophytes were *F. antipyretica*, *L. riparius* and *R. fluitans*.

Bank taxa that were most represented on the both river banks in the Section 1 were *Petasites* sp., *P. arundinacea*., *P. ellipticum* and *Rubus* sp.

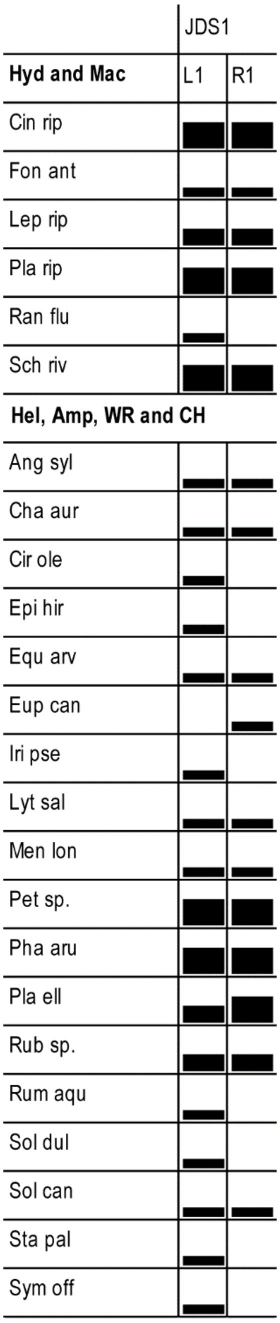


Figure 15 Distribution diagram for River Section 1

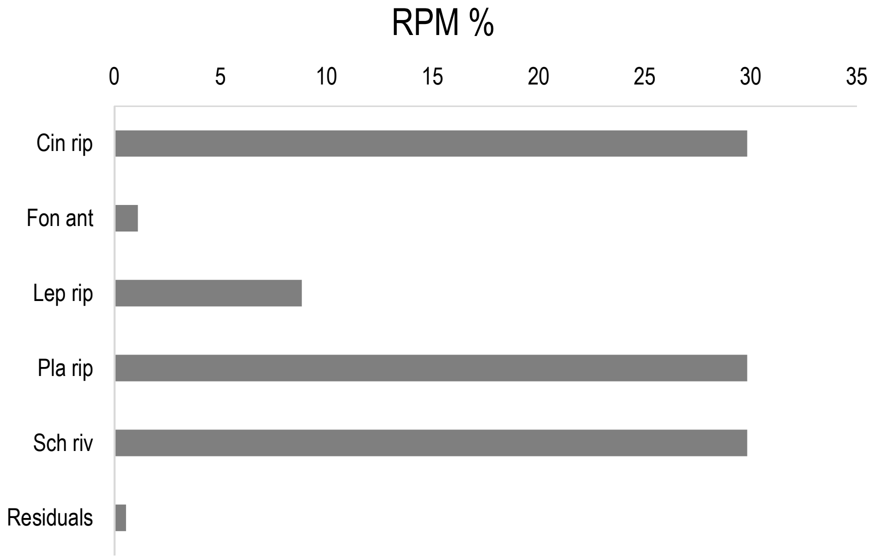


Figure 16 RPM diagram of Hydrophytes in River Section 1

3.3.2.2 River Section 2

The River Section 2 stretches along the Western Alpine Foothills from Neu Ulm to Passau at the confluence with the Inn River. This section was represented with five sampling sites (JDS 2-5).

In River Section 2, 56 taxa were identified (Figure 17). Among 19 hydrophytes, *C. riparius* was dominant taxon with 34.5% of RPM (Figure 18). *F. antipyretica* and *P. perfoliatus* contributed with 11.9% and 11.0% to the total RPM while all other hydrophytes contributed with <10% to the total RPM. Among aquatic species, aquatic bryophytes were dominant in the Section 2 except in the sampling site JDS3 upstream the dam where aquatic angiosperms dominated without any aquatic bryophytes identified. Dominant aquatic angiosperms on the sampling site JDS3 Upstream were *N. marina, N. lutea, P. bertcholdii, P. lucens, P. pectinatus, P. perfoliatus* and *P. pusillus*.

The most represented taxa among the bank vegetation community were *P. arundinacea* and *Rubus* sp. *L. salicaria* was not very abundant, but it was the taxon present at all sampling sites in Section 2. *A. stolonifera* was a frequent bank species at the sampling sites JDS2 and JDS5 while *A. sylvestris* was abundant or very abundant at sampling site JDS3 Upstream. *T. latifolia* was found frequent on the left side of the sampling site JDS3 Downstream.

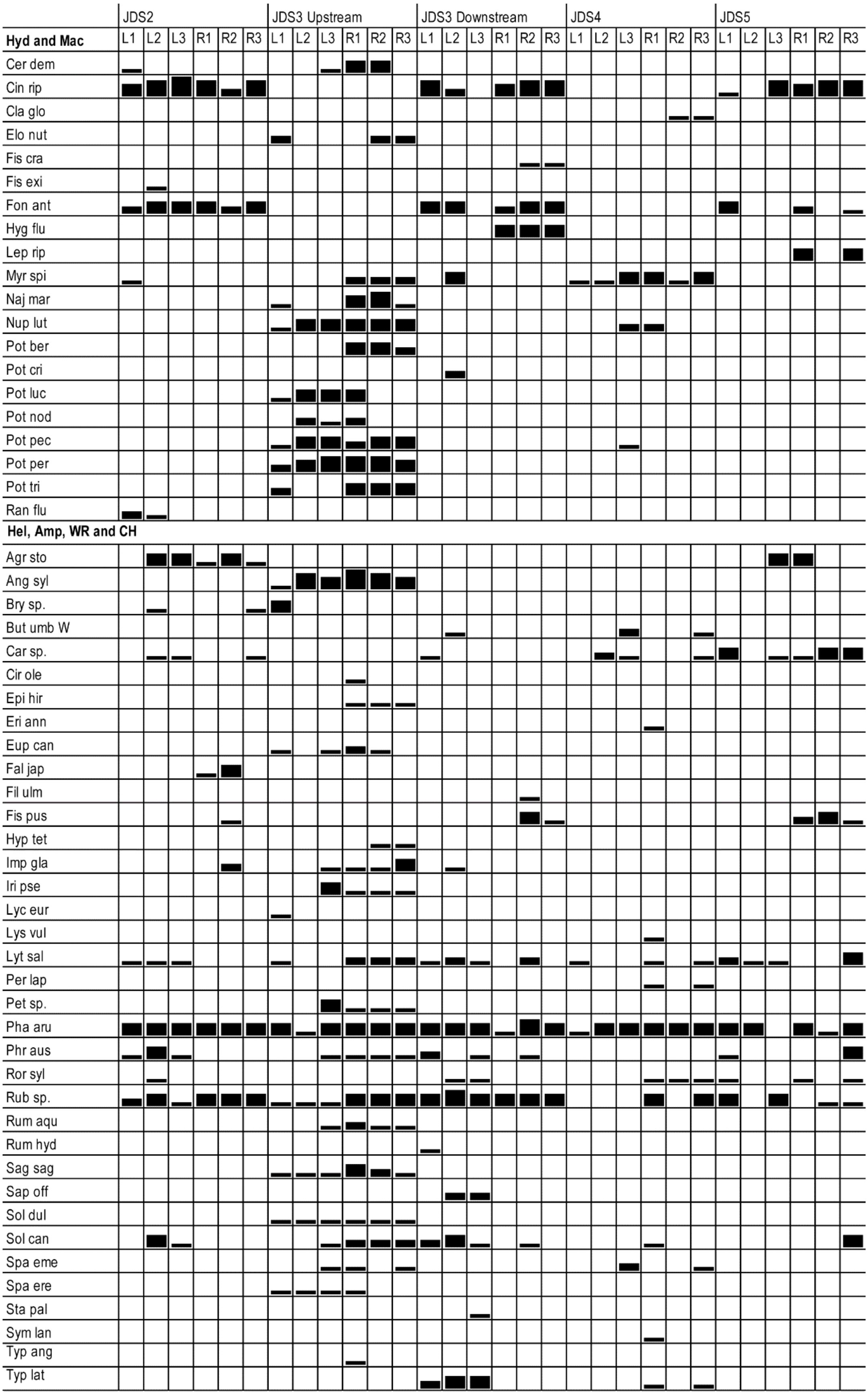


Figure 17 Distribution diagram for River Section 2

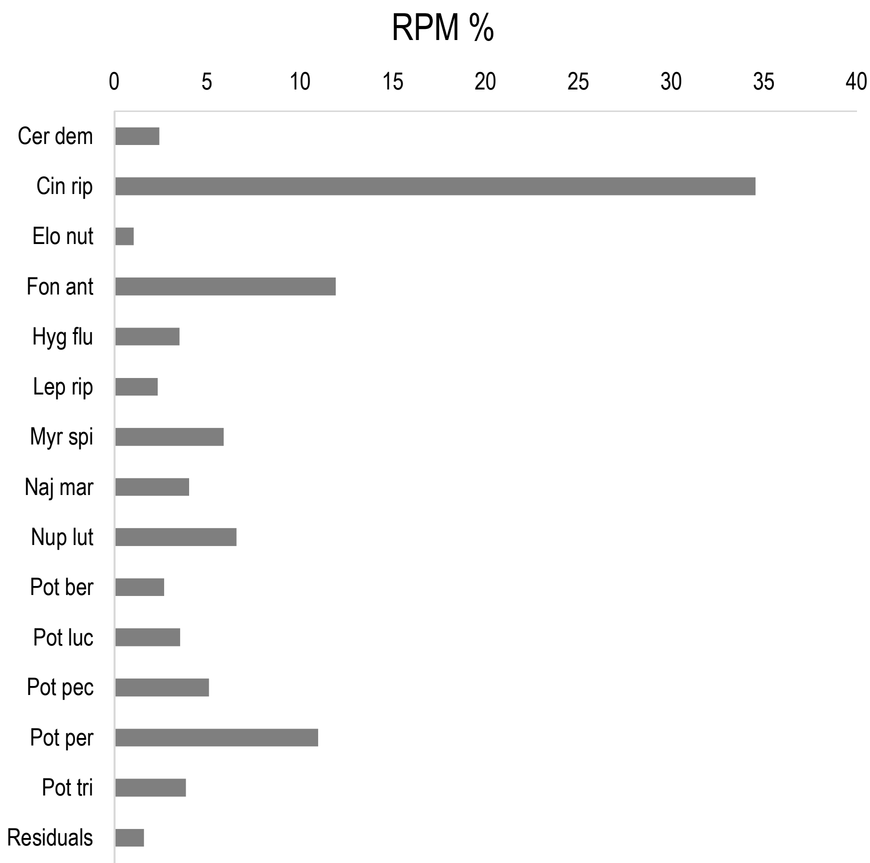


Figure 18 RPM diagram of Hydrophytes in River Section 2

3.3.2.3 River Section 3

River Section 3 stretches from Passau to Krems. This section was represented with three sampling sites (JDS 6-8).

Out of 63 identified taxa in the River Section 3, there were seven hydrophytes (Figure 19). Dominant hydrophyte taxa were the bryophytes *C. riparius* and *C filicinum* with 38.2% of RPM and 33.5% RPM (Figure 20). *F. antipyretica* was represented with 13.9% of the RPM while taxa *H. luridum, P. riparoides. P. pectinatus* and *T. natans* were each represented with <10% of the RPM.

With regard to the diversity, sampling site JDS8 was poorer in number of taxa then sampling sites JDS6 and JDS7. Next to hydrophytes, two more taxa, bryophytes *A. serpens* and *H. varium* had frequent abundance at the sampling site JDS8.

P. arundinacea was the only species present in most of the sampling sections at all three sampling sites, but with occasional abundance.

Bank species of the River Section 3, *A. sylvestris, D. rigidulus, E. cannabinum, M. longifolia, M. aquatica* and *S. canadensis* were found as occasional on both sampling sites JDS6 and JDS7, while *T. farfara* and *L. europaeus* were found only as occasional bank species at the sampling site JDS7.

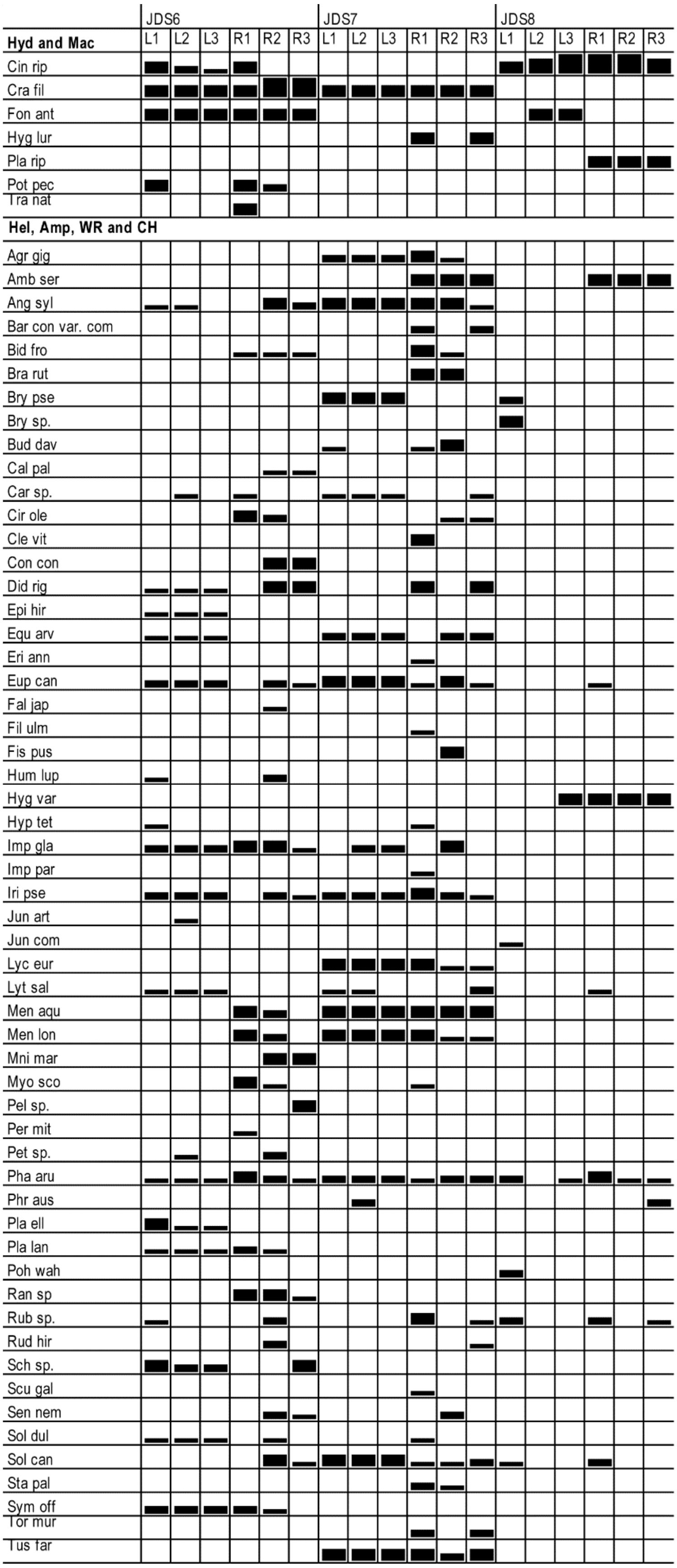


Figure 19 Distribution diagram for River Section 3

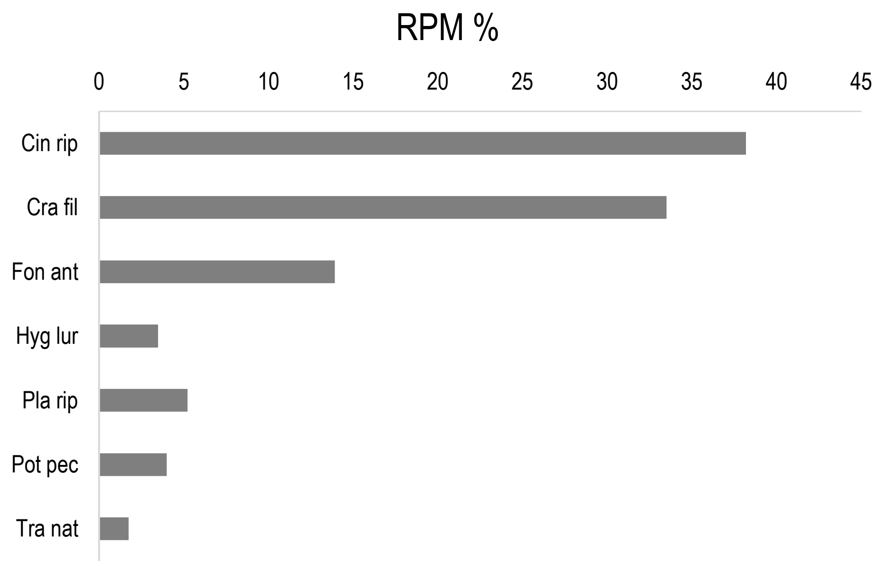


Figure 20 RPM diagram of Hydrophytes in River Section 3

3.3.2.4 River Section 4

River Section 4 stretches on Lower Alpine Foothills Danube from Krems to Gönyő / Kliská Nemá. This section was represented with five sampling sites (JDS 9-11 and 13-14).

In the River Section 4, 12 hydrophytes were identified among totally 53 taxa (Figure 21). Bryophyte *C. riparius* was dominant hydrophyte in this Section with 66.0% of the RPM (Figure 22). *P. riparoides* was the second species that had RPM >10% (14.6%) while all other species had RPM <10%.

Sampling site JDS14 showed highest diversity, both with hydrophytes as well as with other plants, while JDS11 showed higher diversity with banks species in comparison with other investigated sites.

Dominant, as well as most widely distributed bank taxa in Section 4 were *L. salicaria*, *P. arundinacea, Rubus* sp. and *S. canadensis*. This section was the first one where *X. strumarium* appeared and it was at the end of this Section, at sampling site JDS14.

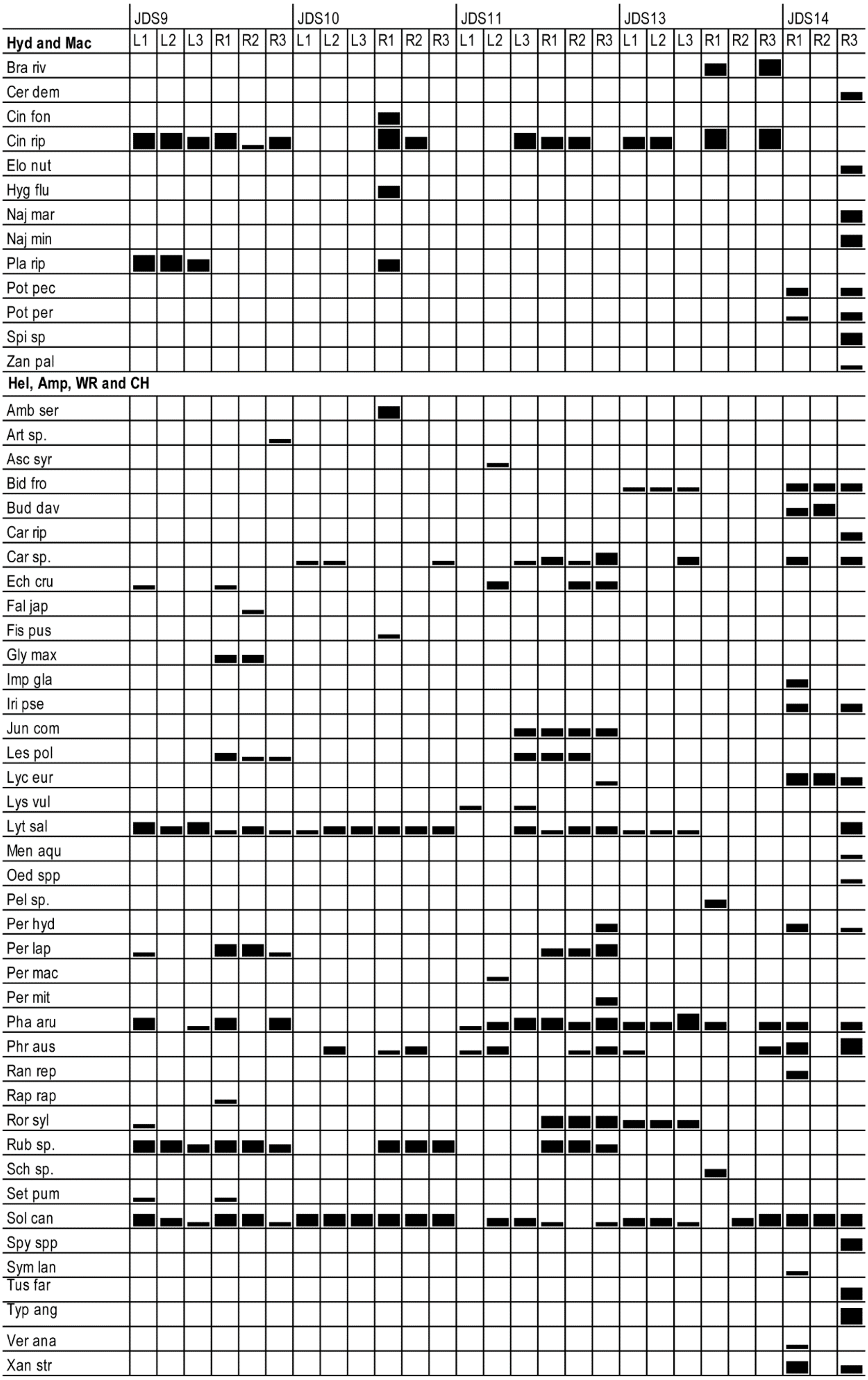


Figure 21 Distribution diagram for River Section 4

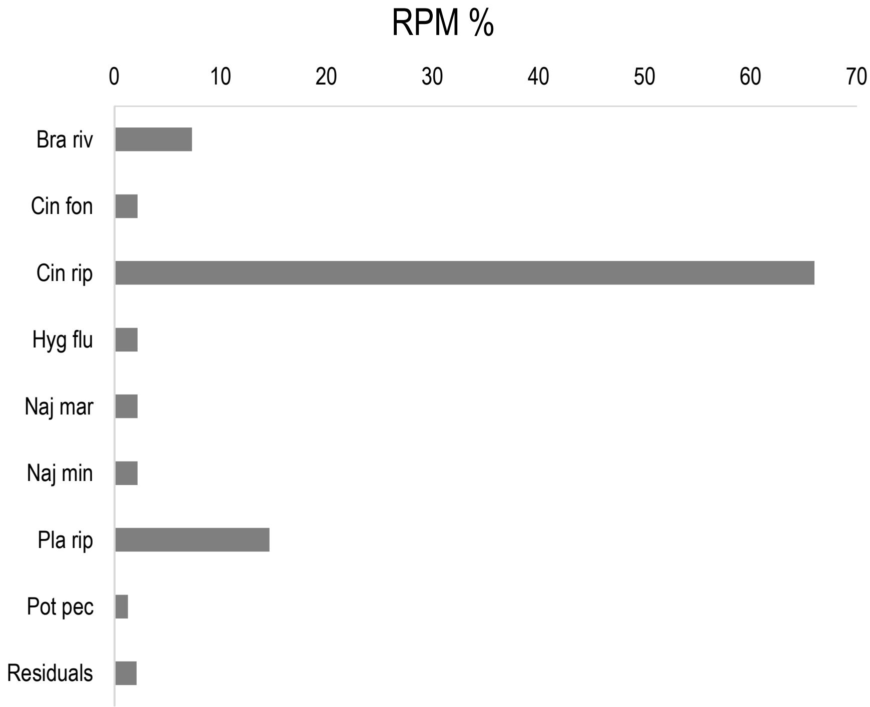


Figure 22 RPM diagram of Hydrophytes in River Section 4

3.3.2.5 River Section 5

River Section 5 stretches across the Hungarian Danube Bend from Gönyő/Kliská Nemá to Baja. This section was represented with nine sampling sites (JDS 15, 17-22 and 24-25).

In this Section, 9 hydrophytes were identified out of totally 44 taxa (Figure 23 and Figure 24). Dominant hydrophyte was *C. riparius* represented with 46.3% of the total RPM (Figure 25). Floating hydrophytes, *L. gibba*, *L. minor* and *S. natans* were represented with >10.0% of RPM while other taxa were represented with <10% of RPM.

Although dominant with RPM among hydrophytes, *C. riparius* was present only at three sampling sites (JDS15, JDS17 and JDS19). Other sampling sites had mostly floating hydrophytes, while at sampling site JDS25 no hydrophytes were found.

Sampling site JDS20 showed highest species diversity (hydrophytes excluded). Dominant bank taxa in Section 5 were *P. hydroppiper, P. lapathifolia, P. arundinacea* and *Carex* sp. Additionally, *R. sylvestris* and *B. frondosa* were highly represented at sampling sites from JDS21 to JDS25.

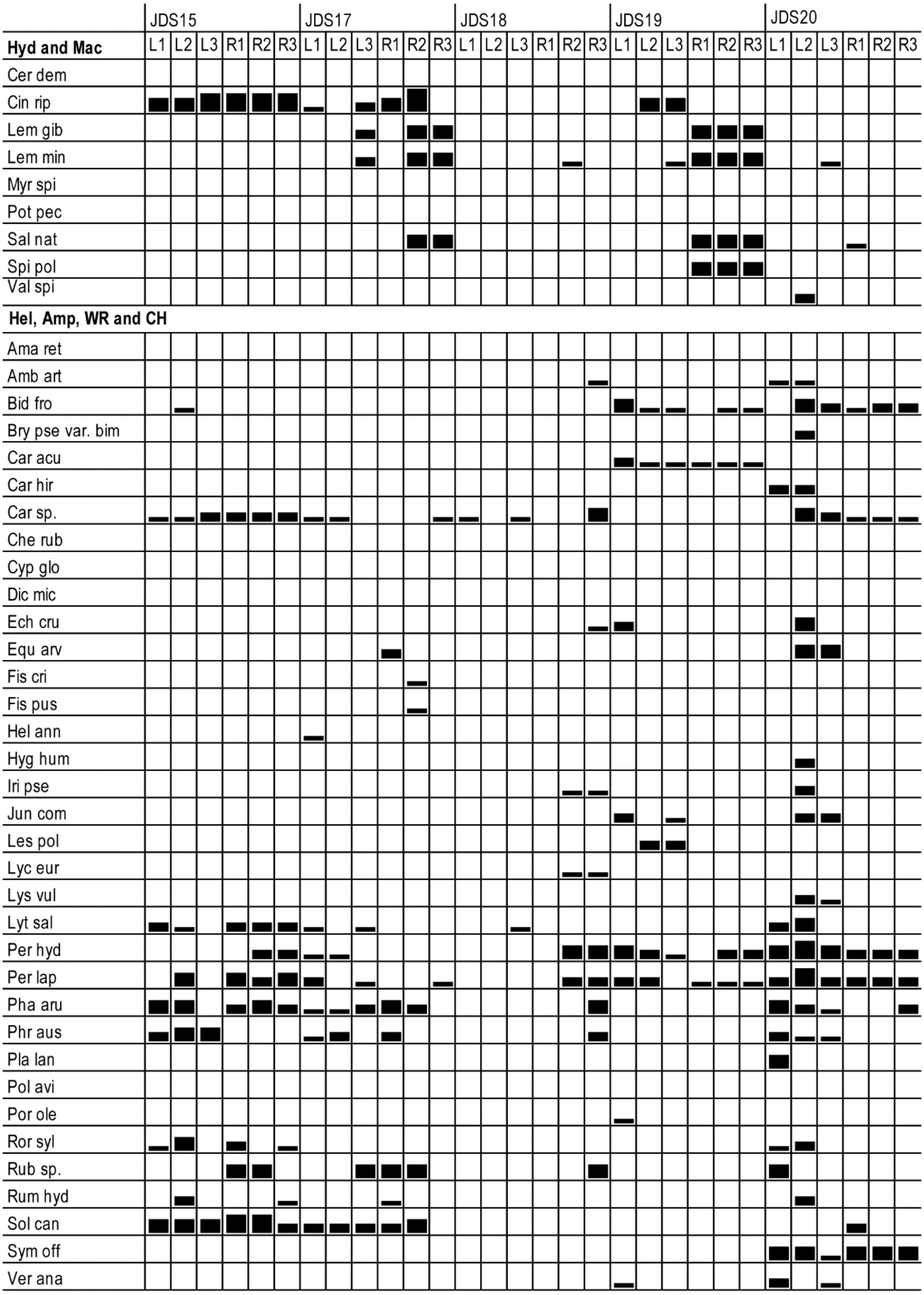


Figure 23 Distribution diagram for River Section 5 (JDS15 – 20)

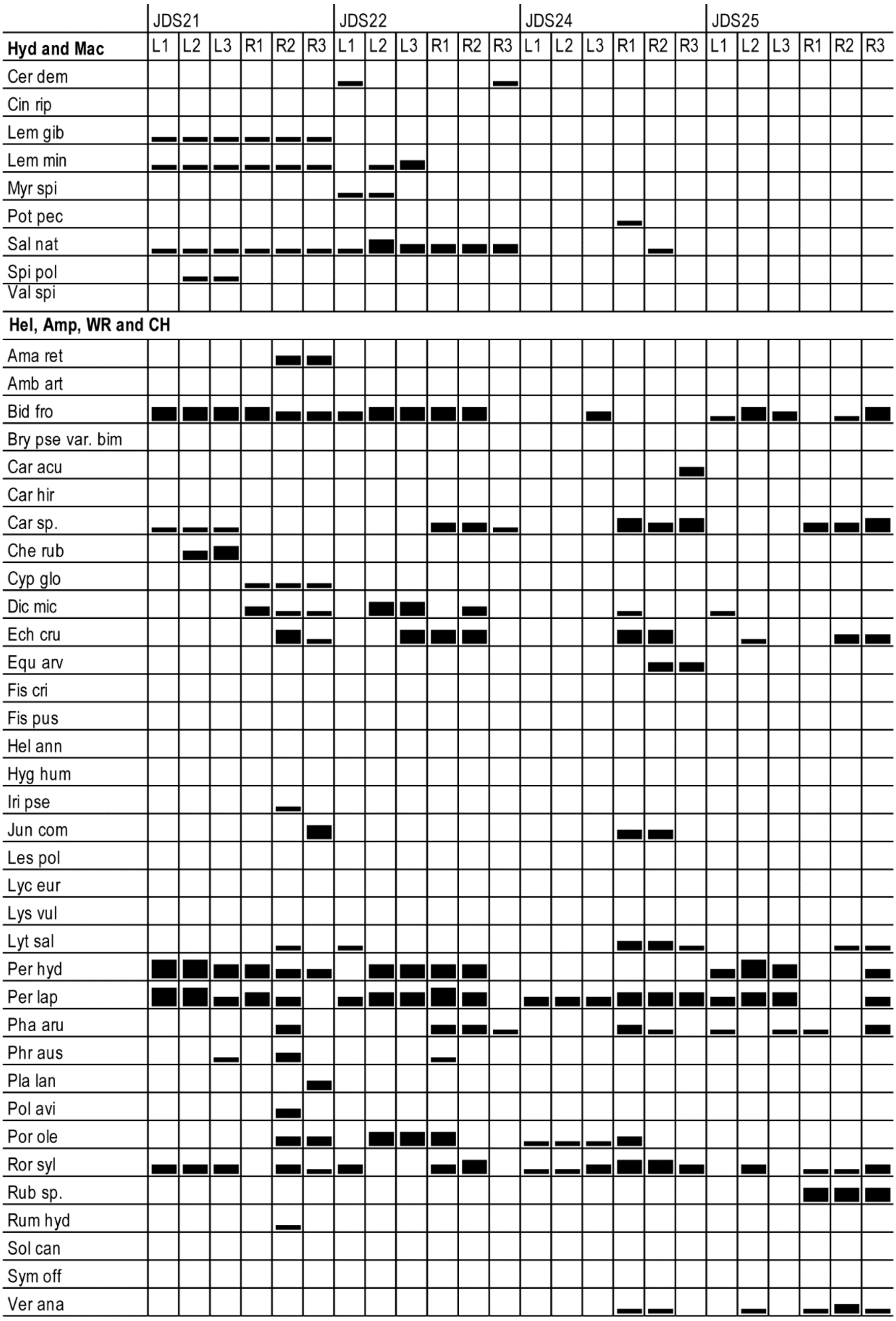


Figure 24 Distribution diagram for River Section 5 (JDS21 – 25)

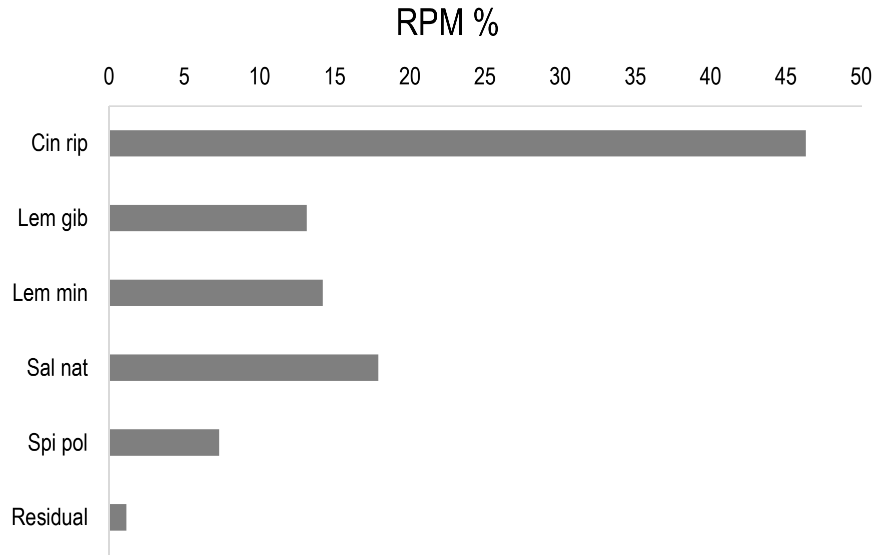


Figure 25 RPM diagram of Hydrophytes in River Section 5

3.3.2.6 River Section 6

River Section 6 stretches in the Pannonian Plain Danube from Baja to Bazias. This section was represented by 13 sampling sites (JDS 26-28, 30-34, 36, 38-40 and 42).

Out of 86 taxa identified in this Section, there were 19 taxa of hydrophytes (Figure 26 and Figure 27). *P. pectinatus* dominated in RPM with 22.8% (Figure 27). Floating hydrophytes, *L. gibba, L. minor, S. natans* and *S. polyrhiza* had 12.0% to 13.8% of RPM while other hydrophytes showed RPM <10%.

At sampling sites from JDS26 to JDS30 no hydrophytes were present with exception of rare occurrence of floating *S. natans* in the third sampling unit of the left side at sampling site JDS26. Hydrophytes started to appear in the third sampling unit on the right side of sampling site JDS31. From sampling site JDS33 to JDS42 hydrophytes were numerous and represented with high numbers, especially those species with higher percentage of RPM. Besides hydrophytes, the macroalga *C. glomerata* was abundant or very abundant at the sampling sites JDS36, JDS38, JDS40 and JDS 42 and this Section was the beginning of high abundance of *C. glomerata* along the Danube course.

Bank taxa *B. frondosa, E. crus-galli, C. fuscus, D. micheliana* and *P. lapathifolia* were present at all sampling sites in Section 6, often frequent or abundant. At the sampling sites JDS34 to JDS42, rare to frequent occurrence was recorded for *C. album* and *C. rubrum*.

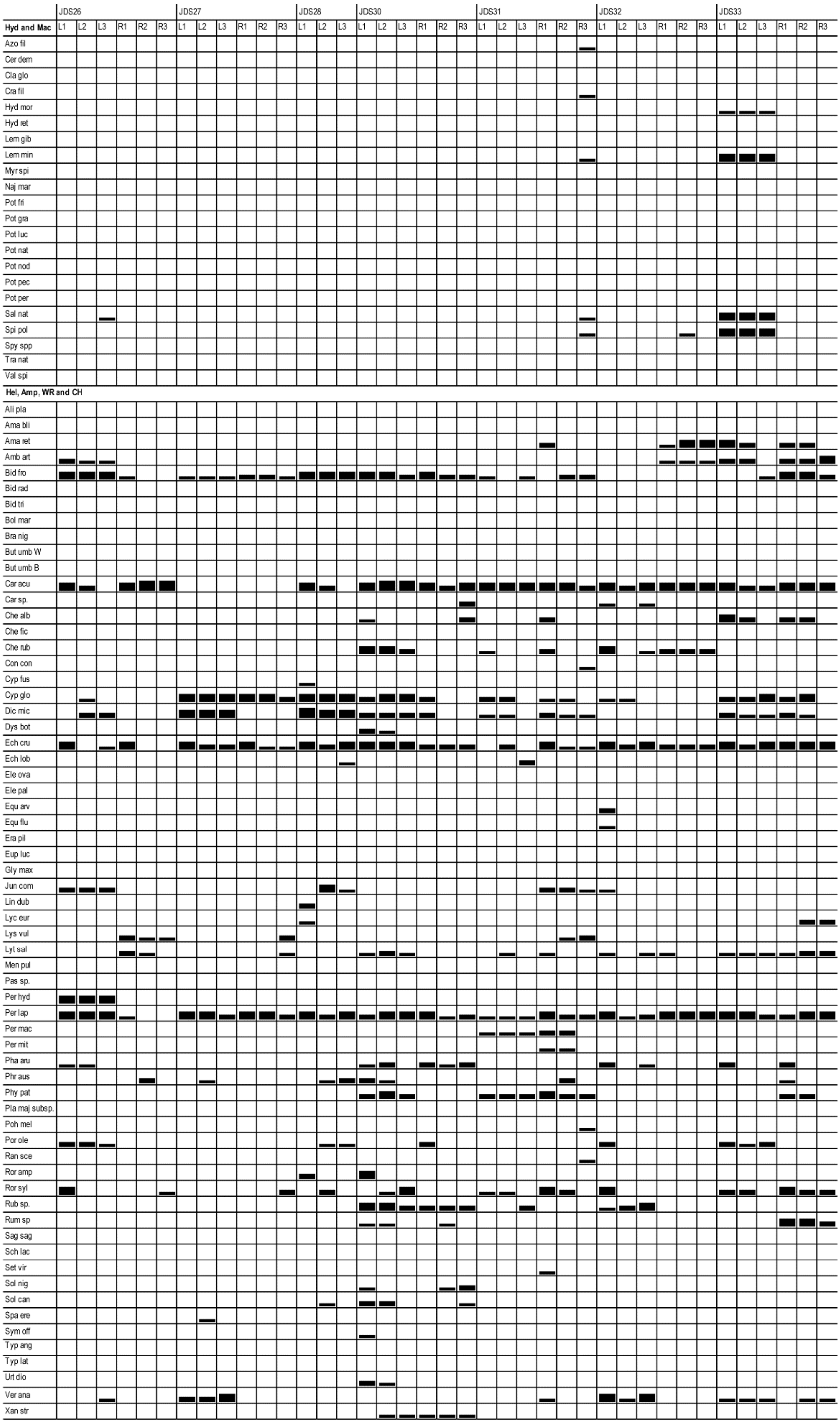


Figure 26 Distribution diagram for River Section 6 (JDS26 – 33)

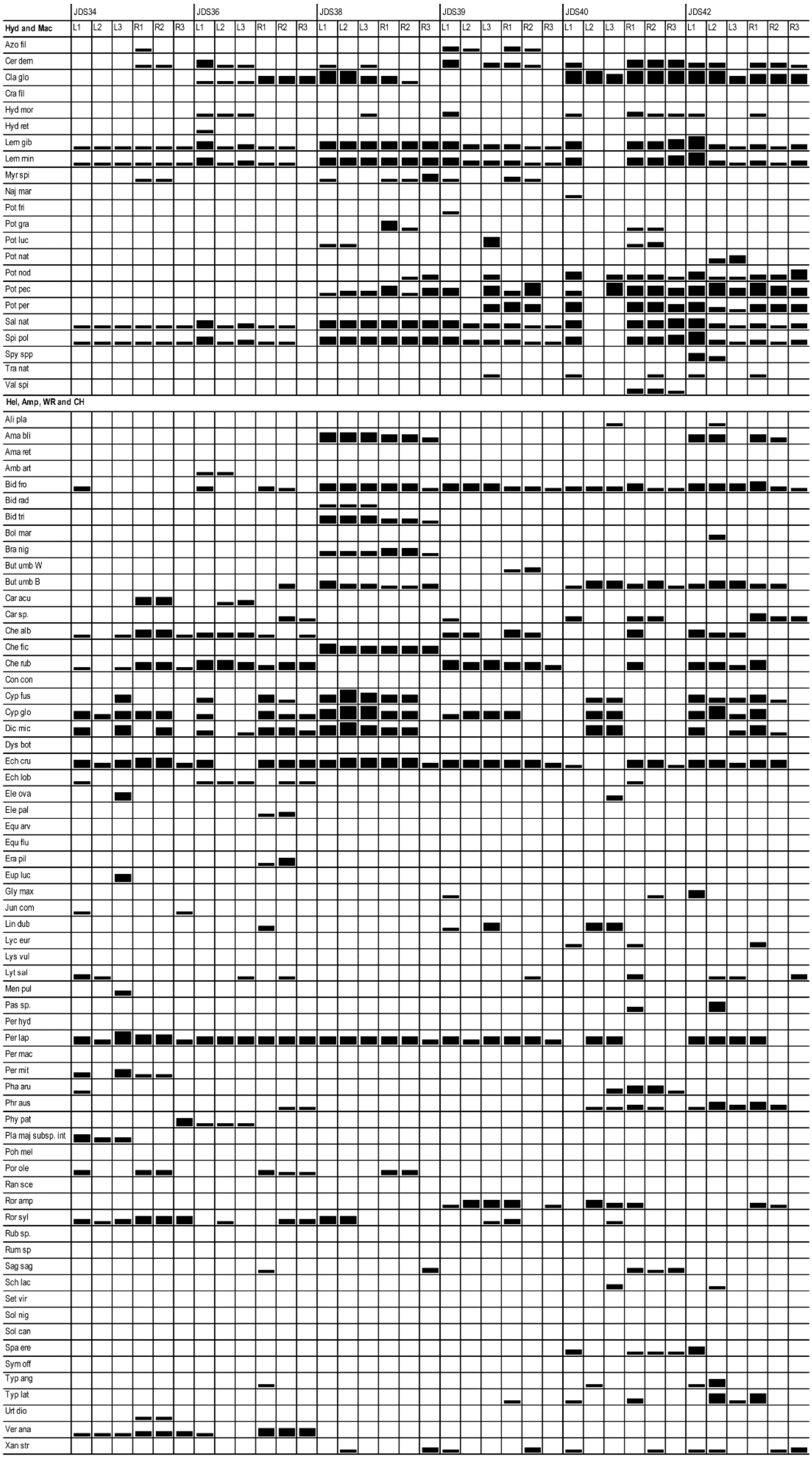


Figure 27 Distribution diagram for River Section 6 (JDS34 – 42)

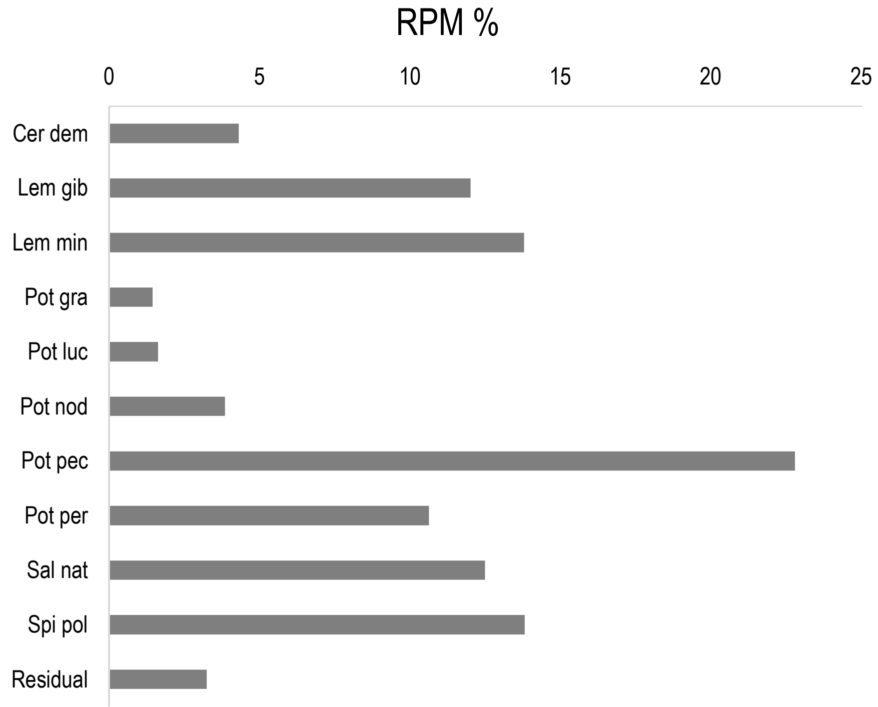


Figure 28 RPM diagram of Hydrophytes in River Section 6

3.3.2.7 River Section 7

River Section 7 represents Iron Gate Danube from Bazias to Turnu Severin. This section was represented with three sampling sites (JDS 43-45).

Among 49 identified taxa in this Section, 17 taxa of hydrophytes were identified (Figure 29). None of the hydrophytes was really dominant, but some taxa were more abundant than others (Figure 30). *P. pectinatus* had highest RPM (14.4%). The floating hydrophytes *L. minor* and *L. turionifera* had 11.5% of the RPM while *S. polyrhiza* had 11.31% of the RPM. *L. gibba* and *S. natans* were present with <10% of the RPM. *P. nodosus* also had RPM >10.0% (10.4%) while all other species had RPM <10%. Five taxa had RPM <1% and were counted as Residual, comprising *T. natans, V. spiralis, E. nuttallii, N. peltata* and *P. crispus*.

The macroalga *C. glomerata* was highly abundant and dominant at all three sampling sites, often covering the hydrophytes.

Compared to other vegetation life forms, hydrophytes were most abundant. Taxa of other life forms, also typical bank species, were highly diverse only at the sampling site JDS43 and not so much at the sampling sites JDS44 and JDS45. *P. lapathifolia* was the only bank taxon that was present at all three sampling sites with rare to frequent abundance. Besides that taxon, at the sampling site JDS43, *C. fuscus, C. glomeratus* and *D. micheliana* were frequent on the left bank, while *E. crus-galli* and *G. maxima* were recorded as frequent on the right bank.

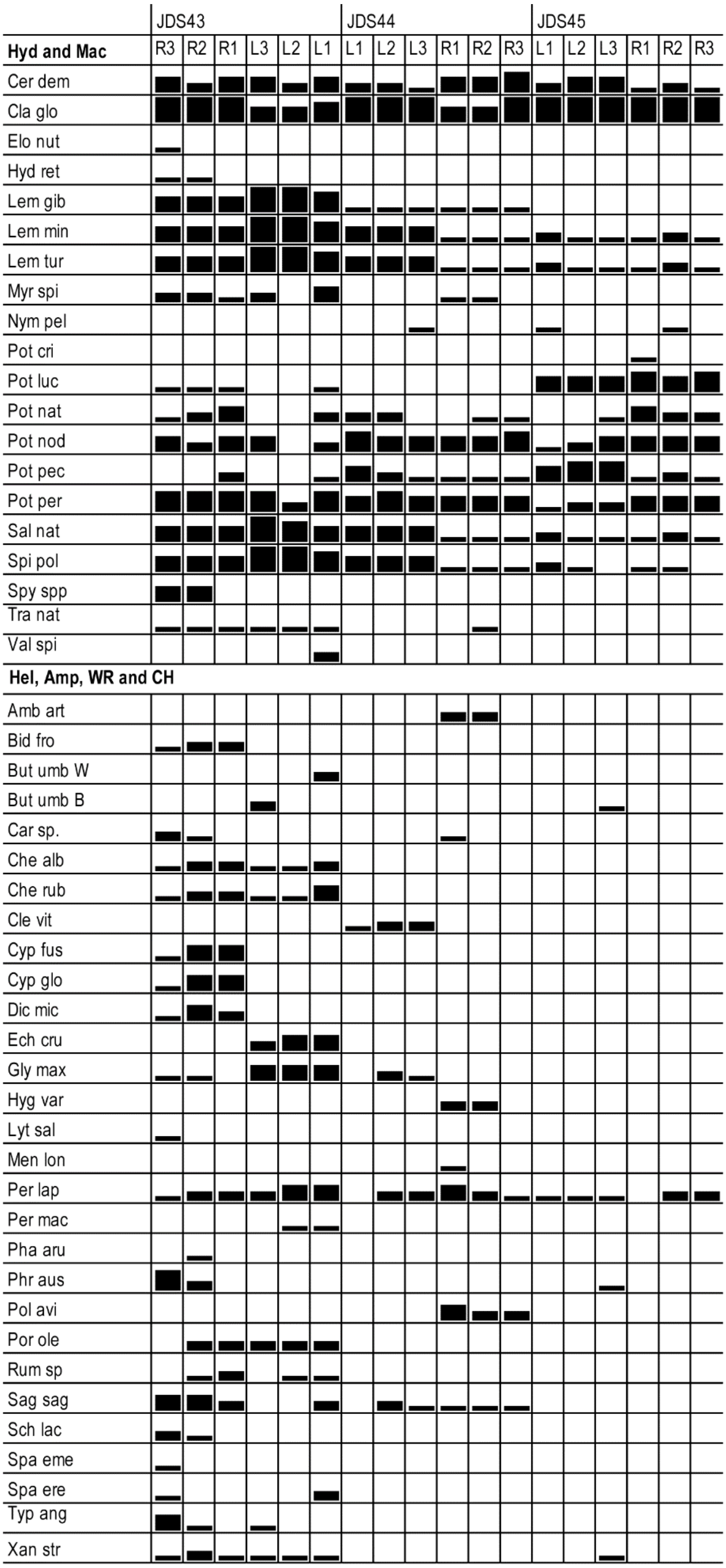


Figure 29 Distribution diagram for River Section 7

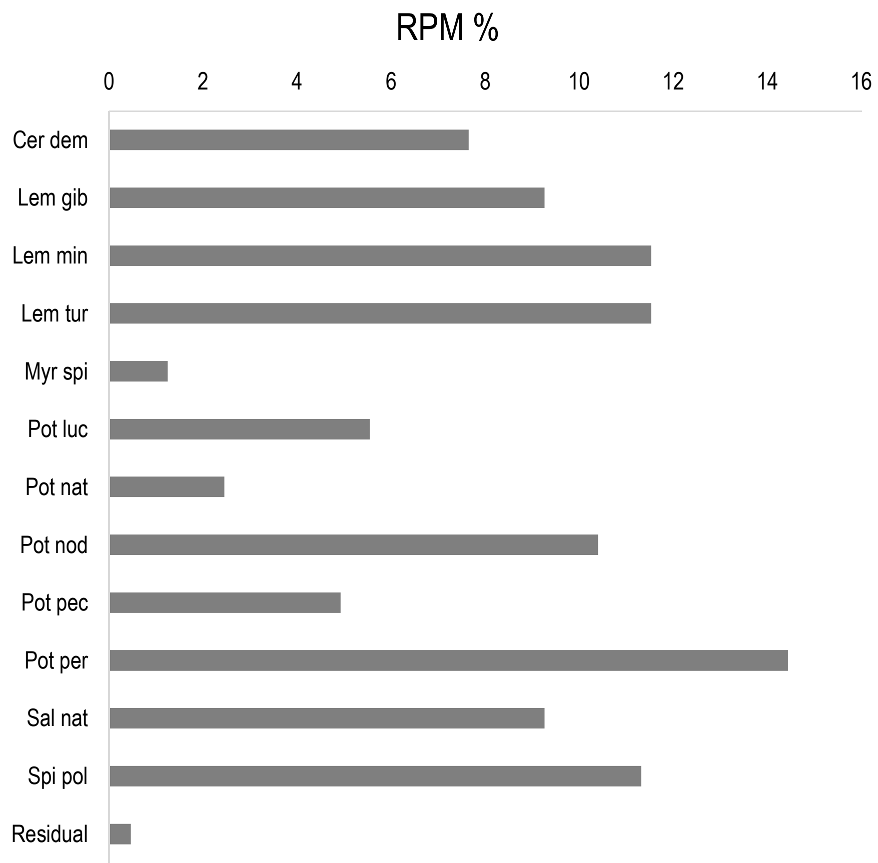


Figure 30 RPM diagram of Hydrophytes in River Section 7

3.3.2.8 River Section 8

River Section 8 stretches along the Western Pontic Danube from Turnu Severin to Chiciu/Silistra. This section was represented by 10 sampling sites (JDS 46-47, 49-50, 52-53, 55, 57 and 59-60).

In this Section, 24 hydrophytes were identified out of 75 taxa in total (Figure 31 and Figure 32). *P. perfoliatus* had highest RPM with 27.9% (Figure 33). Other hydrophytes with RPM >10.0% were *M. spicatum* with 16.8%, *P. crispus* with 12.4% and *V. spiralis* with 10.3%. Ten taxa were counted as Residual with RPM <1% (*N. obtusa, A. filiculoides, L gibba, L minor, L. turionifera, P. gramineus, P. lucens, P. natans, P. trichoides* and *S. polyrhiza*) while all others had RPM <10%.

Hydrophytes were diverse and abundant at sampling sites from JDS46 to JDS54 and they were not present, or only present with few individual species at sampling sites from JDS55 to JDS60. At the later sites, even macroalgae were not frequent or abundant, but there were more of them than hydrophyte taxa and they were represented by *C. glomerata, H. reticulatum* and *Spirogyra* spp.

According to the bank species, sampling site JDS46 was much poorer in species composition than other sampling sites in Section 8. *A. geniculatus, E. crus-galli, P. oleracea, P. lapathifolia* and *X. sturmarium* were frequent or abundant at all sampling sites except on JDS46. *B. umbellatus* was sporadically abundant throughout Section 8.

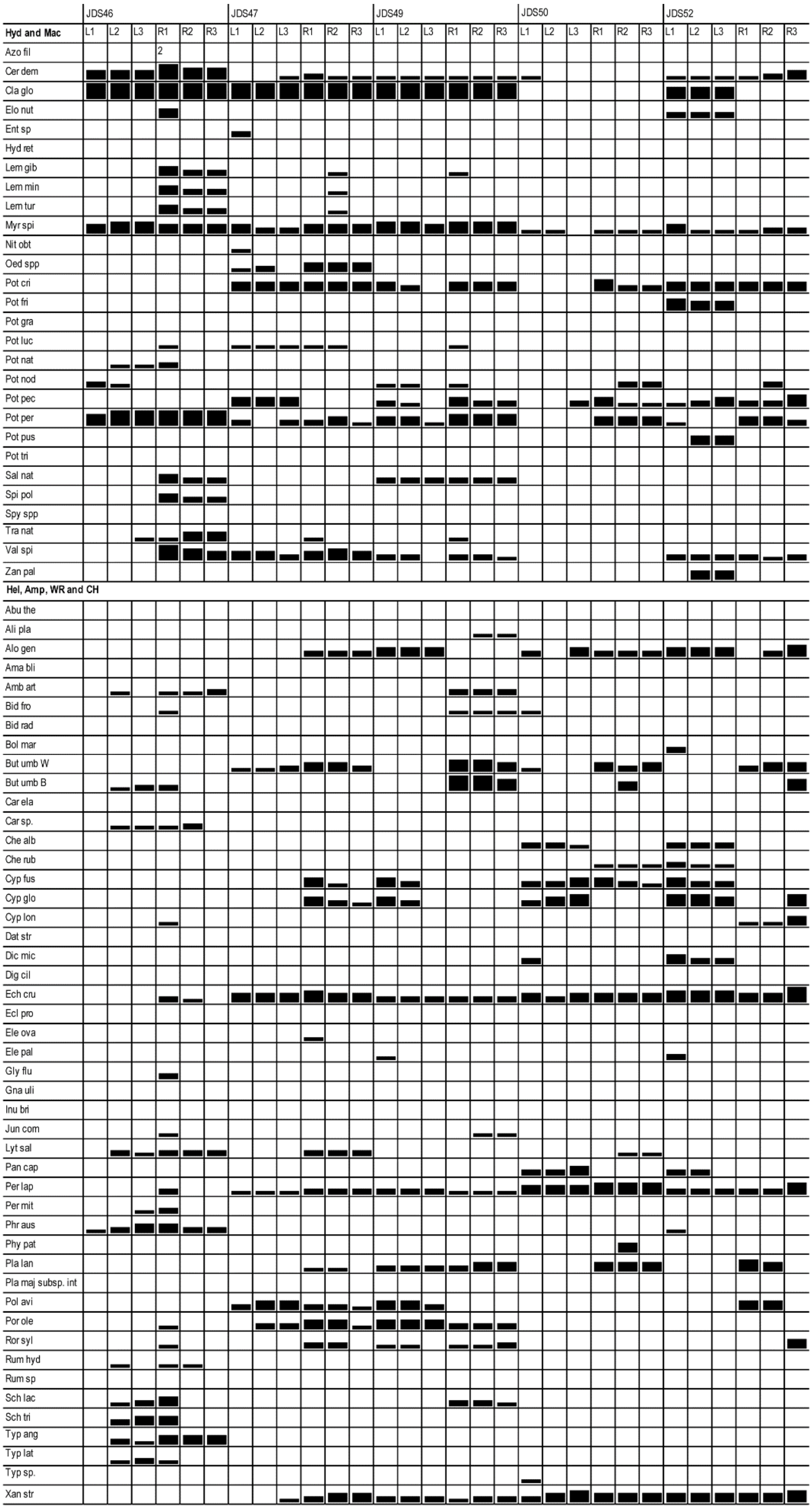


Figure 31 Distribution diagram for River Section 8 (JDS46 – 52)

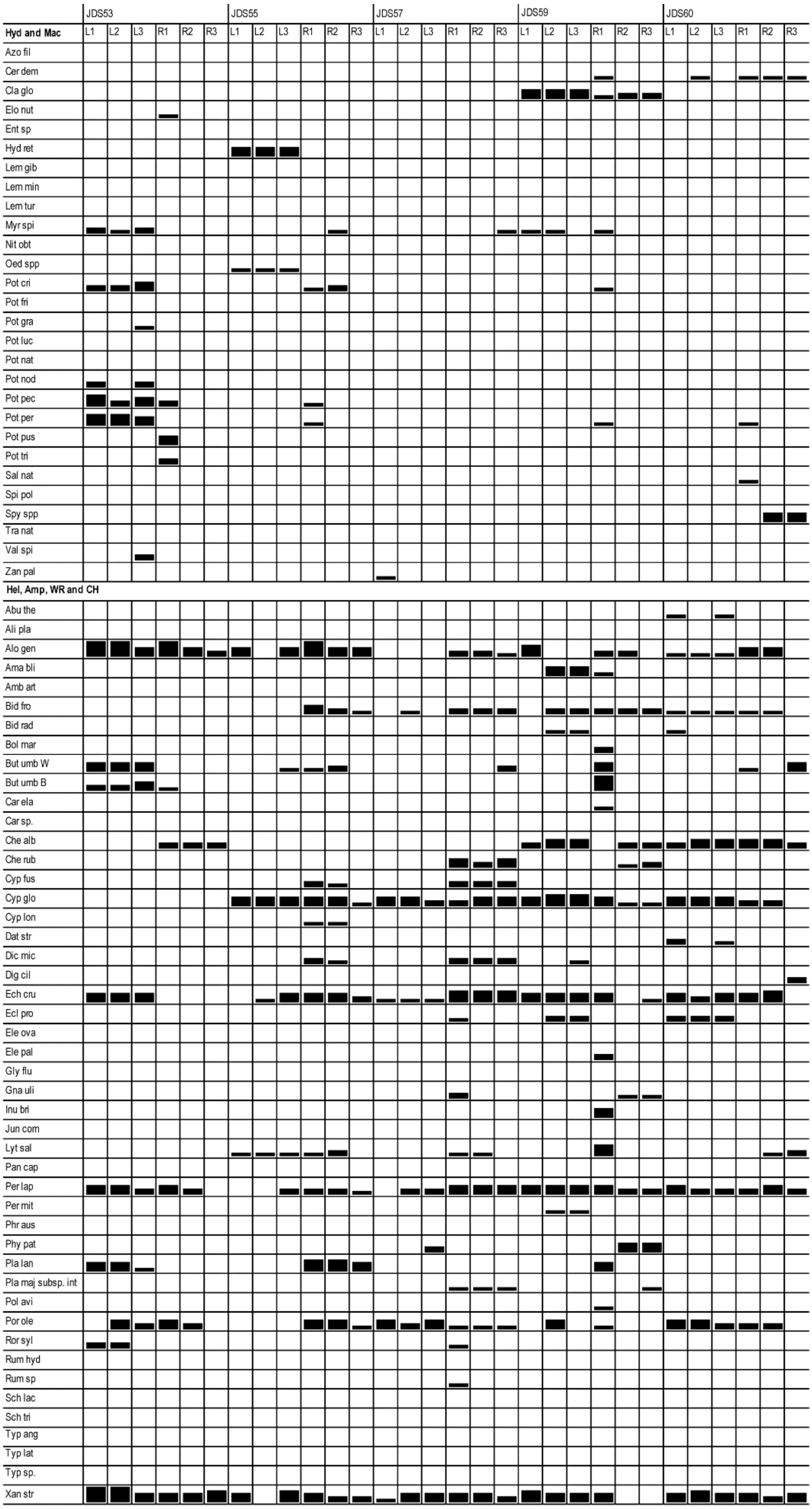


Figure 32 Distribution diagram for River Section 8 (JDS53 – 60)

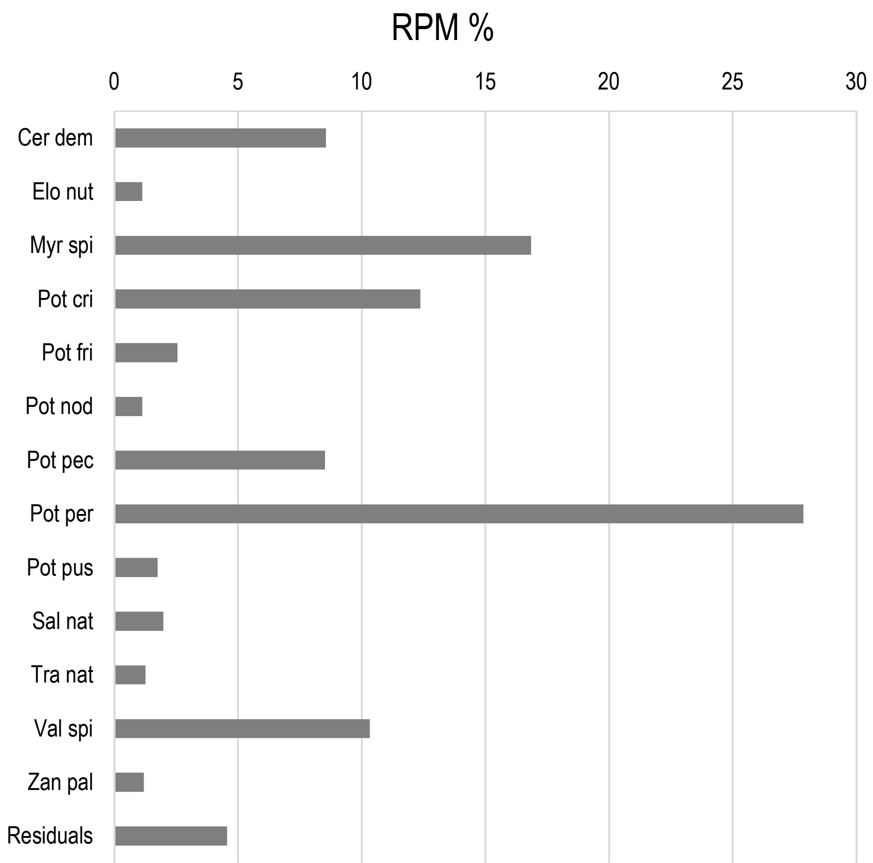


Figure 33 RPM diagram of Hydrophytes in River Section 8

3.3.2.9 River Section 9

River Section 9 represents the Eastern Wallachian Danube from Chiciu/Silistra to Isaccea. This section was represented by three sampling sites (JDS 61-62 and 65).

Among 39 identified taxa in Section 9, 9 of them were hydrophytes (Figure 34). *P. pectinatus* was the dominant hydrophyte represented with 74.5% of the RPM (Figure 35). *P. crispus* had 13.9% of the RPM while all other taxa had RPM <10%.

Sampling site JDS61 showed the highest diversity and abundance of hydrophytes, but only on the left side. High biomass and lower diversity of hydrophytes was also recorded only on the right side of the sampling site JDS62 with no macrophytes on the left side. At sampling site JDS65, no hydrophytes were detected on the left side of the river but they were bundant on the right side. Only *P. pectinatus* dominated there with single occurrence of *C. demersum* and *S. natans*. The macroalga *C. glomerata* was abundant on the right side of the sampling site JDS62 while *H. reticulatum* was frequent on the left side of the sampling site JDS61.

Taxa like *A. geniculatus, C. glomeratus*, *D. micheliana* and *X. strumarium* were abundant or very abundant and were the dominant bank taxa along the full length of Section 9.

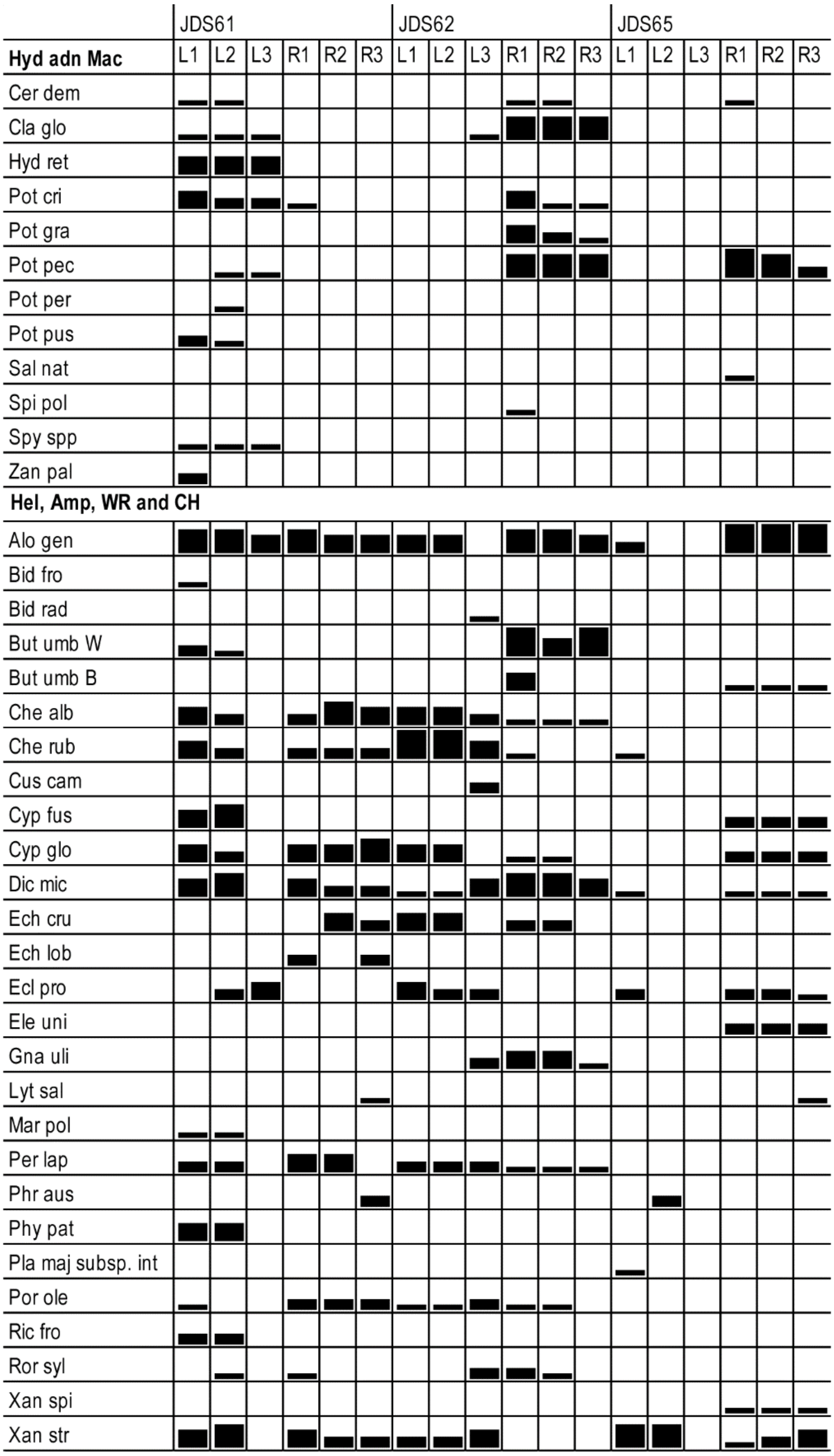


Figure 34 Distribution diagram for River Section 9

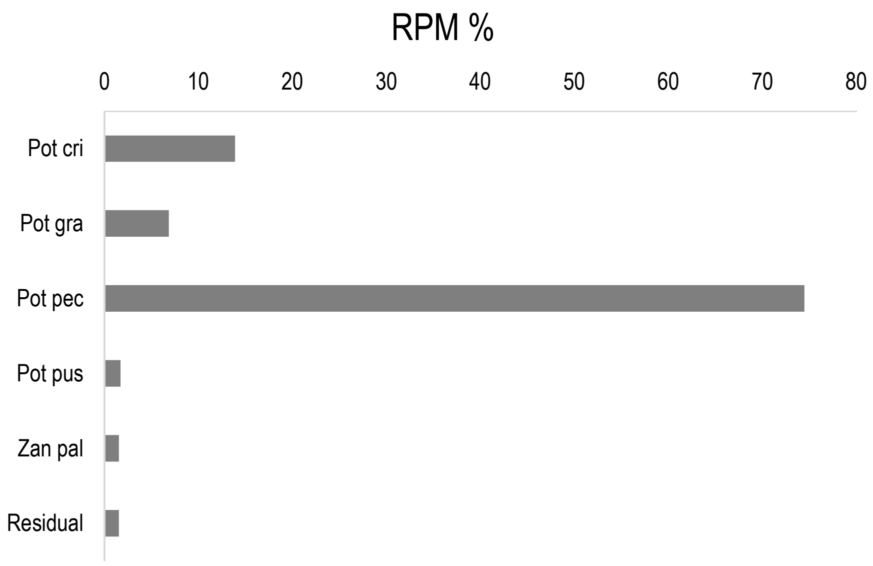


Figure 35 RPM diagram of Hydrophytes in River Section 9

3.3.2.10 River Section 10

River Section 10 represents the Danube Delta consisting of Chilia arm, Sulina arm and St. Gheorghe arm. This section was represented by three sampling sites (JDS 66-68).

In this Section, 10 taxa out of 45 were hydrophytes (Figure 36). *P. pectinatus* with 32.5% of the RPM and *P. perfoliatus* with 29.4% of the RPM were the dominant hydrophytes (Figure 37). *C. demersum, M. spicatum* and *S. natans* were represented with 10.5% of the RPM, while other taxa were represented with <10% of the RPM.

Highest diversity of the hydrophytes was recorded at the sampling site JDS66. Sampling site JDS67 was characterised by the very abundant macroalga *C. glomerata* on both sides of the river and with only sporadical records of *P. pectinatus*. The macroalga *C. glomerata* was also abundant on the left side of sampling site JDS68 while *P. pectinatus* was frequent on both sides.

The banks of the sampling site JDS66 were characterised by a high abundance of *P. australis* and abundant or frequent records of *T. angustifolia*. At the sampling site JDS67 bank vegetation was scarce and few taxa like *C. glomeratus, D. micheliana*, *G. uliginosum* and *X. strumarium* were recorded as rare or occasional. Sampling site JDS68 was the richest one regarding bank taxa diversity in the whole Section 10, where *X. strumarium, C. glomeratus, D. micheliana, G. uliginosum* and *C. rubrum* were abundant. Sampling site JDS68 was also very special because being the only sampling site where the macroalga *B. granulatum* was identified, together with the bryophyte *P. patens* and the pteridophyte *R. frostii*, which formed a special community in the shade of the willows.

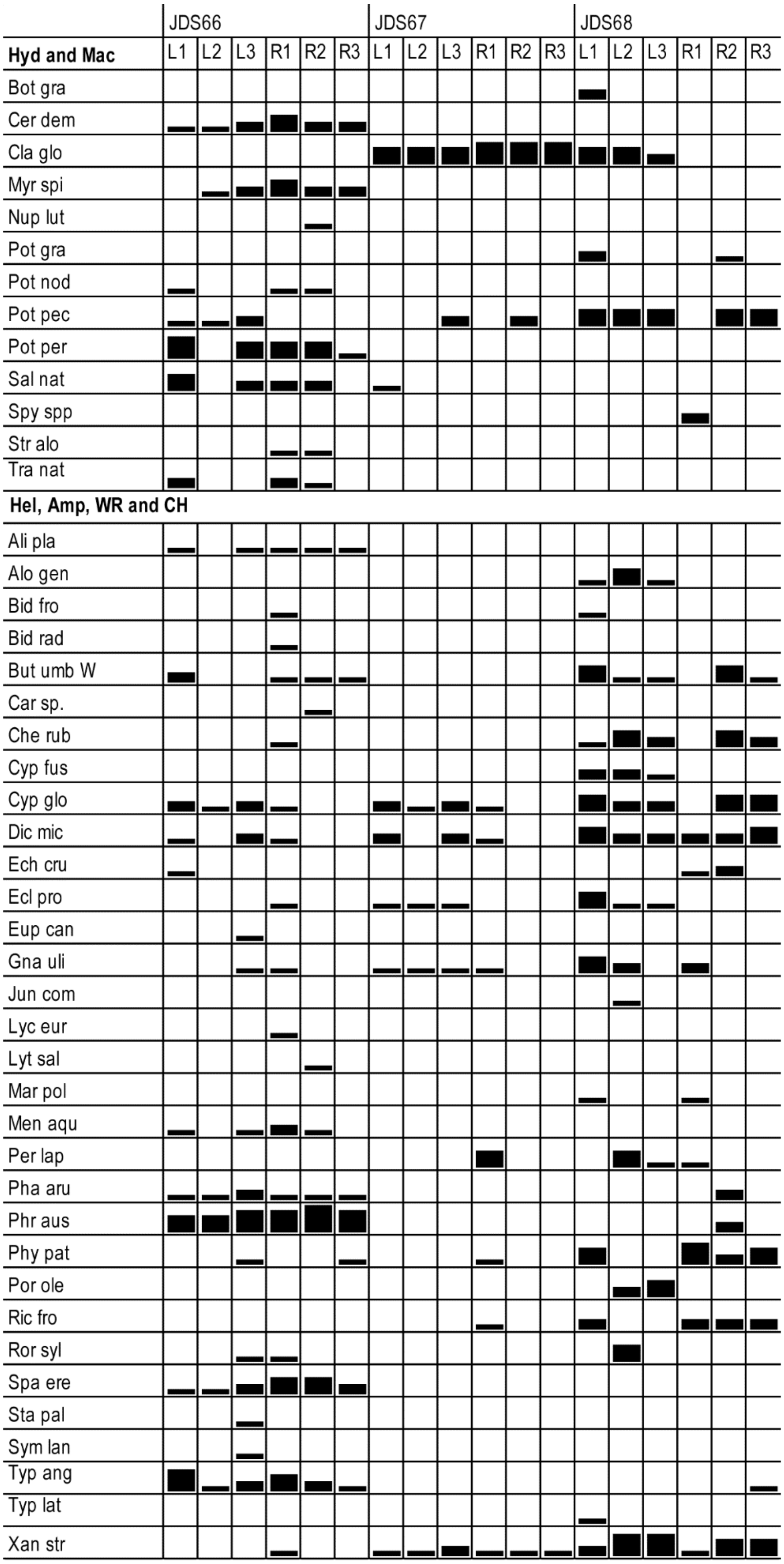


Figure 36 Distribution diagram for River Section 10

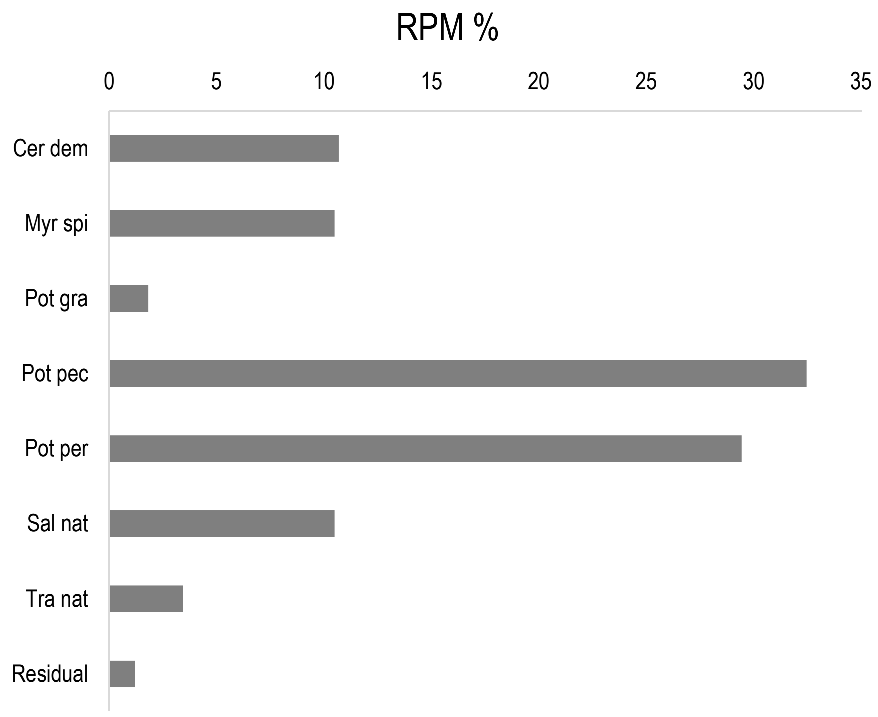


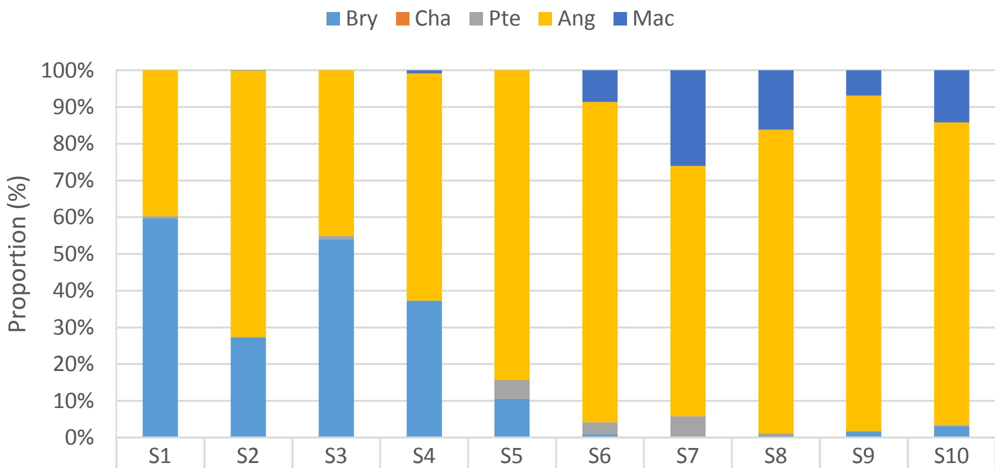
Figure 37 RPM diagram of Hydrophytes in River Section 10

3.3.3 Overview of taxonomical plant groups and life forms in the Danube

Angiosperms co-dominated with bryophytes in the first four River Sections and completely dominated in the rest of the Danube (Figure 38). Pteridophytes occurred in the Middle and Lower Danube, but with discernible relative plant mass only in Sections from 5 to 7 (3.3-5.5%) where the floating species *S. natans* was the dominant species in the group. A higher proportion of macroalgae occurred in the Sections from 5 to 10 (3.3-27.7%) with *C. glomerata* as the dominant species, while charophytes were identified only in River Section 8, represented by a single species, *N. obtusa*.

Macroalge (except stoneworts) and taxa identified to the genus level were not associated with life-forms. Therefore according to this concept 44 species belonged to hydrophytes, 28 species to helophytes, 34 species to amphiphytes, 40 species to the group of water related species and 35 taxa comprised the chance species.

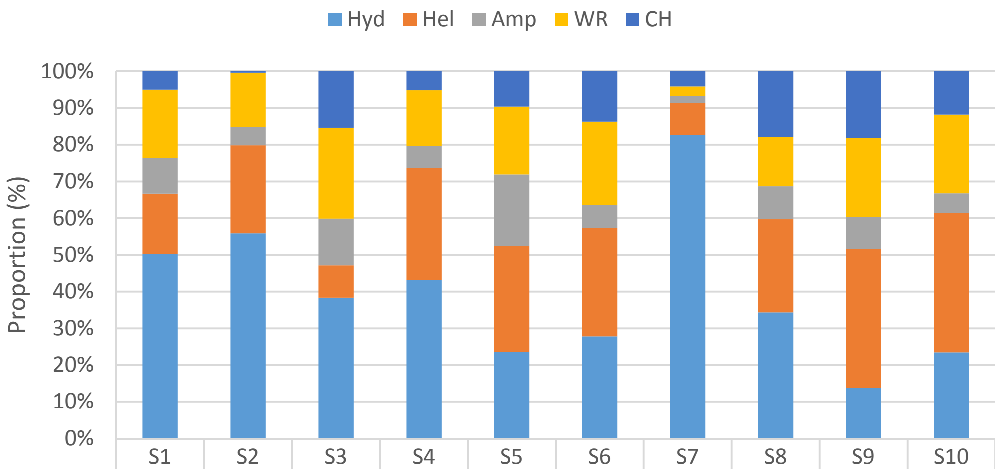
Hydrophytes and helophytes were the dominant groups throughout the whole river course (Figure 39). A complete dominance of hydrophytes was recorded in River Section 7 with 82.6%. Amphiphytes and chance species were represented with smallest percentage, while water related species showed an almost constant value close to 20% throughout the whole Danube.



	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Mac	0,0	0,0	0,0	0,8	0,0	8,6	26,0	16,2	6,8	14,2
Ang	39,7	72,6	45,0	61,9	84,2	87,3	68,1	82,7	91,4	82,3
Pte	0,6	0,0	1,0	0,0	5,3	3,3	5,6	0,6	0,0	0,4
Cha	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Bry	59,7	27,4	54,0	37,3	10,5	0,9	0,2	0,5	1,8	3,0

River Section

Figure 38 Proportion of plant groups in all River Section of Danube (Bry – Bryophytes, Cha – Charophytes, Pte – Pteridophytes, Ang – Angiosperms, Mac – Macroalgae)



	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
CH	5,0	0,4	15,4	5,2	9,7	13,7	4,2	35,3	18,2	11,8
WR	18,6	12,8	24,7	15,2	18,5	22,8	2,6	26,5	21,6	21,4
Amp	9,7	4,3	12,7	6,0	19,5	6,1	1,9	17,7	8,7	5,4
Hel	16,4	20,7	8,8	30,4	28,8	29,5	8,7	50,0	37,9	37,9
Hyd	50,3	48,4	38,3	43,3	23,5	27,8	82,6	67,7	13,7	23,4

River Section

Figure 39 Proportion of life forms in all River Section of Danube (Hyd – Hydrophytes, Hel – Helophytes, Amp – Amphiphytes, WR – water related plants, CH – chance species)

3.3.4 Characteristic species of River Sections

SIMPER analysis listed all species by their contribution to the Bray-Curtis similarity among samples within the River Sections, defining some species as characteristic for each Section. Detailed results of SIMPER analysis are given in Appendix 5 to Appendix 24.

3.3.4.1 Aquatic vegetation

Bryophytes defined the aquatic plant community in River Sections from 1 to 4 where *C. riparius*, *F. antipyretica*, *C. filicinum* and *A. serpens* contributed the highest share to the similarity between samples in one section. River Section 5 was characterized by the aquatic bryophyte *C. riparius* and floating taxa like *L. minor* and *S. natans*, while in River Section 6 only floating taxa like *L. minor*, *L. gibba*, *S. natans* and *S. polyrhiza* were characteristic for all samples within this section. From River Section 7 to 10, *C. glomerata* was the link between samples, while other taxa of macroalgae varied for different sections. In River Section 7 other characteristic taxa were *P. perfoliatus*, *P. nodosus* and *C. demersum*, while in River Section 8 other characteristic taxa were *M. spicatum*, *B. umbellatus*, *P. perfoliatus* and *P. crispus*. *P. pectinatus* and *P. crispus* characterised River Section 9, while River section 10 was characterised by *P. pectinatus* next to the macroalga *C. glomerata*.

3.3.4.2 Bank vegetation

In the River Sections from 1 to 4 only *P. arundinacea* was characteristic for all samples in these sections. Other bank taxa contributing to similarity between samples in each River Sections were for example *Petasites* sp. for River Section 1, *Rubus* sp. and *L. salicaria* for River Section 2, *E. cannabinum* for River Section 3 as well as *S. canadensis* and *L. salicaria* for River Section 4. *P. lapathifolia* and *P. hydropiper* were two taxa that considerably contributed to sample similarity in River Section 5. In River Section 6, *P. lapathifolia*, *E. crus-galli* and *B. frondosa* were characteristic taxa as well as *P. lapathifolia* in River Section 7. *X. strumarium* was the taxon with the highest contribution to similarity between samples in River Sections 8 to 10. Next to *X. strumarium*, *E. crus-galli*, *P. lapathifolia* and *A. geniculatus* were characteristic for River Section 8, *A. geniculatus*, *D. micheliana* and *C. glomeratus* for River Section 9 and *C. glomeratus* and *D. micheliana* for River Section 10.

3.3.5 Comparison of the Danube River Sections

3.3.5.1 Similarity of the Danube River Section based on the Non-metric Multi-Dimensional Scaling (NMDS)

The NMDS ordinations of the mean values of the River Sections overlaid with cluster analysis are reported in Figure 40 to Figure 42.

Figure 40 is a presentation of similarity of the River sections based on all determined taxa in the main course of the Danube River. It shows a clear distinction of two groups of Sections with different similarity pattern. The first group is characterised by Sections 1 to 5 and a joint similarity of 20%. Here also appeared a subgroup of Sections 4 and 5, with a greater similarity of 40%. The second group consisted of Sections 6 to 10, with a similarity of 40%. Inside that group, there also existed a subgroup with 60% similarity, which related to River Sections 9 and 10.

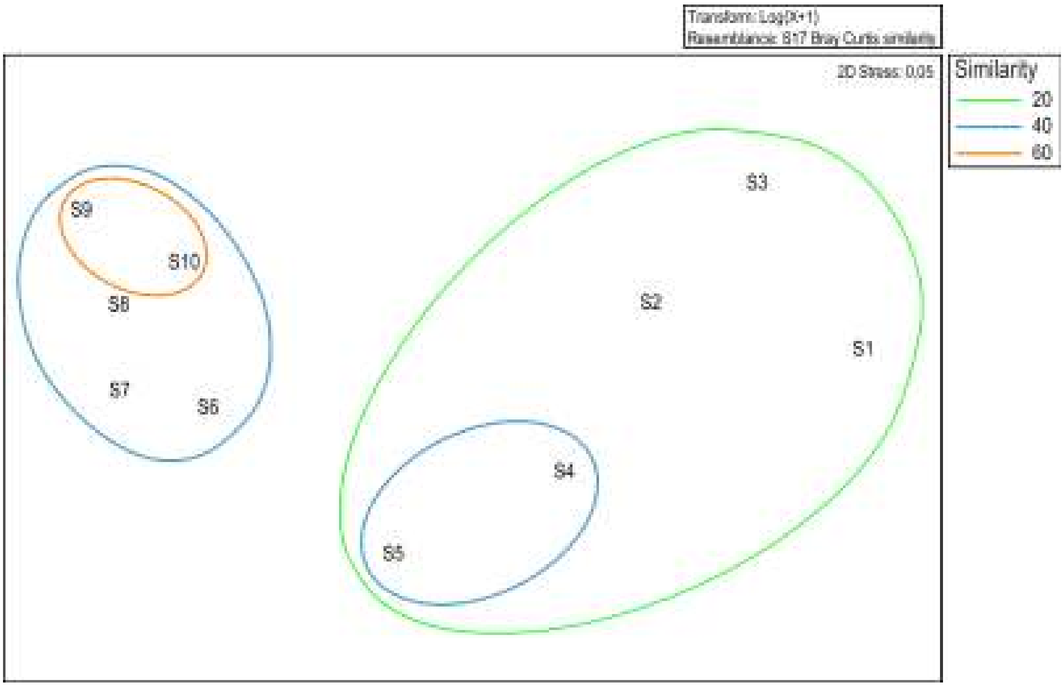


Figure 40 NMDS analysis of River Sections based on the river plant mass of all recorded taxa in the main course of the Danube.

In Figure 41 and Figure 42 taxa were divided due to those recorded in the water and those recorded on the banks.

Figure 41 shows two main groups of taxa recorded in the water. The first group consisted of River Sections 1 to 4 with a joint similarity of 20%. The second group consisted of River Sections 5 to 10 with a joint similarity of 20%, but with a clear distinction of two subgroups. One consisted of Sections 6, 7, 8 and 10 with similarity of 40%, and the second was located within the first subgroup with similarity of 60% for Sections 6 and 7.

Similarity of the River Sections based on the taxa recorded on banks is shown in Figure 42. There are two main groups dividing the Danube into two parts. The first group (20% similarity) consisted of River Sections 1 to 5, and the second one (similarity of 40%) consisted of River Sections 6 to 10. There are two subgroups with a similarity of 40% within the first group, one represented by River Sections 1 to 3, and the second subgroup characterising River Sections 4 and 5. Only one subgroup is present in the second group that consisted of River Sections 9 and 10 (similarity of 60%).

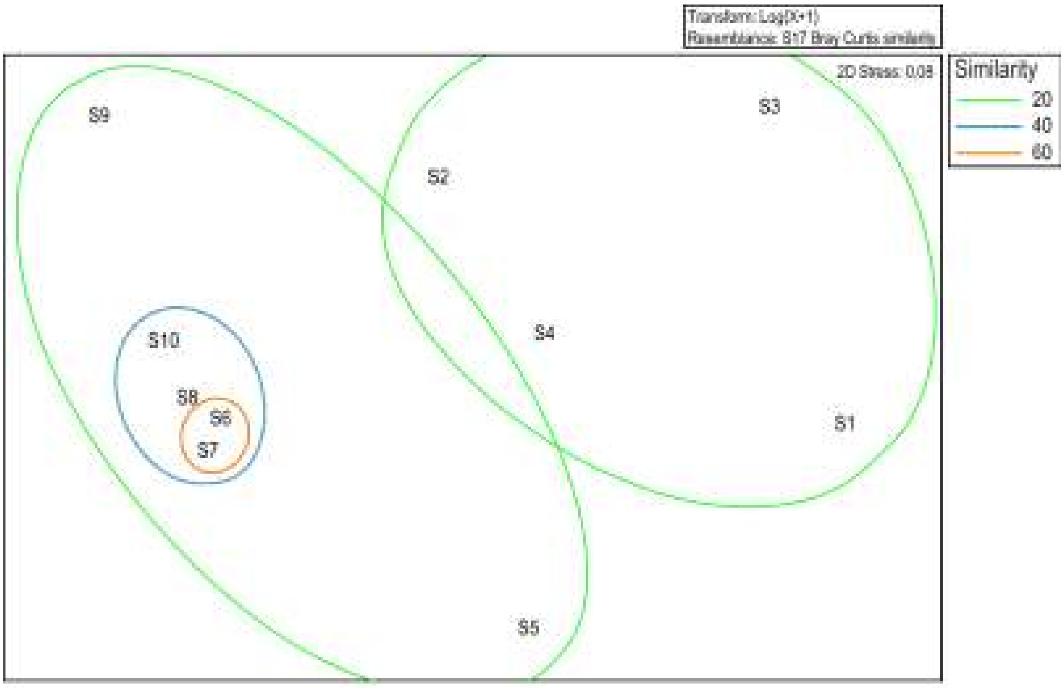


Figure 41 NMDS analysis of River Sections based on the river plant mass of taxa determined in the water of the main course of the Danube.

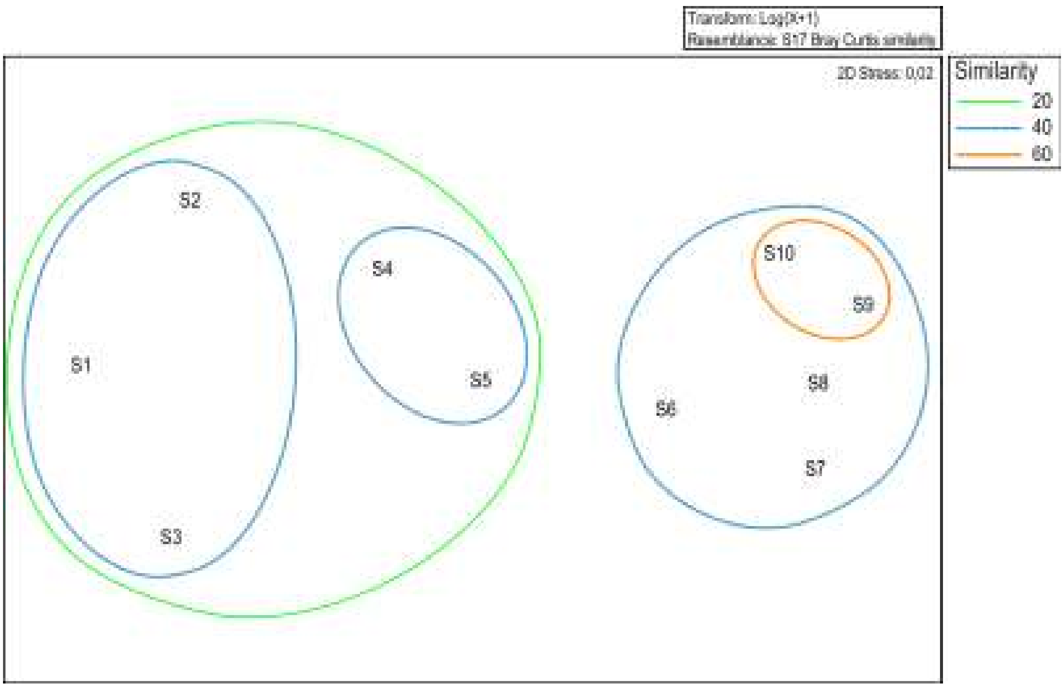


Figure 42 NMDS analysis of River Sections based on the river plant mass of taxa determined on the banks of the main course of the Danube.

Report of the NMDS ordinations of the relative plant mass (RPM) of all sampling sections (survey units) based on all recorded species in the main course of the Danube River is shown in Figure 43.

This graphic clearly demonstrates the change of the plant community following downstream the course of the Danube River, but in the overlay different River Sections can be observed, which are closer regarding their spatial distance.

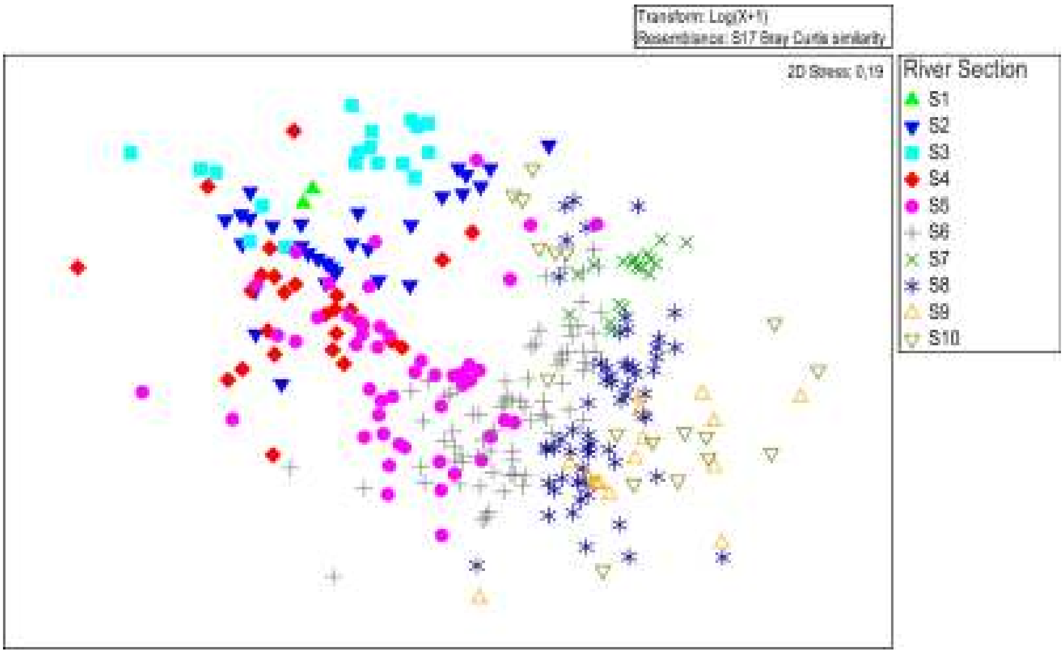


Figure 43 NMDS analysis of all sampling sections (survey units) based on the river plant mass of all taxa in the main course of the Danube.

3.3.5.2 Dissimilarity of River Sections based on SIMPER analysis

Dissimilarity of River Sections based on SIMPER analysis performed after Bray-Curtis similarity on relative plant mass of taxa showed that dissimilarity increased with distance between River Sections (Table 11). This analysis formed two groups of River Sections. One group covers River Sections from 1 to 4 with a dissimilarity between 70.67-82.28% and another group with River Sections from 6 to 10 with a dissimilarity between 70.88-86.54%. River Section 5 had the lowest dissimilarity range in comparison with other River sections (79.62-93.16), but still high enough not to group with upstream or downstream River sections.

Table 11 Dissimilarity (%) of River Sections based on SIMPER analysis performed after Bray-Curtis similarity on relative plant mass of all recorded taxa in the main course of the Danube.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1	-									
S2	70,67	-								
S3	71,25	79,96	-							
S4	75,28	74,15	82,28	-						
S5	89,44	85,68	90,95	80,85	-					
S6	96,27	93,44	96,51	89,91	79,62	-				
S7	99,54	93,82	98,48	96,56	88,24	76,94	-			
S8	98,78	94,74	98,30	93,71	87,96	75,83	76,71	-		
S9	99,54	97,53	99,17	96,34	92,54	80,59	86,54	70,88	-	
S10	97,72	92,81	96,45	94,77	93,16	83,44	80,27	78,53	76,53	-

Figure 44 shows dissimilarity of River Sections based on SIMPER analysis performed after Bray-Curtis similarity on a) relative plant mass of all taxa determined in the main course of the Danube, b) relative plant mass of taxa determined in the water of the main course of the Danube and c) relative plant mass of taxa determined on the banks of the main course of the Danube. It shows that dissimilarity increased with distance between River Sections just as shown in Table 11, but with a distinct difference between dissimilarity based on taxa identified in the water and on the banks. Dissimilarity between River Sections based on the relative plant mass of taxa recorded in the water of the main course of the Danube is higher than the one based on the relative plant mass of taxa recorded on the banks.

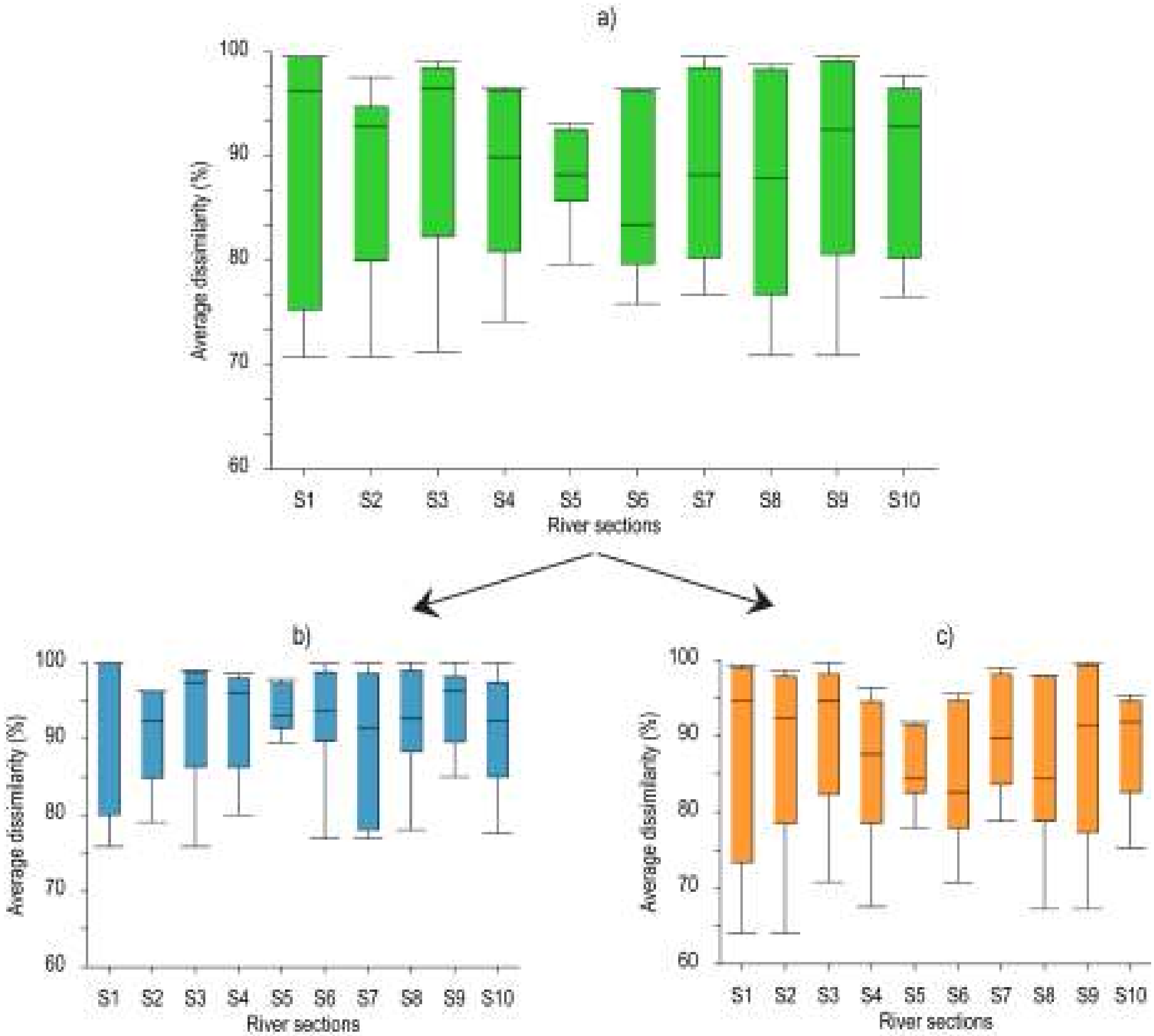


Figure 44 Average dissimilarity as a result of SIMPER analysis for: a) all taxa determined in the main course of the Danube, b) taxa determined in the water of the main course of the Danube and c) taxa determined on the banks of the main course of the Danube.

3.3.6 Ecological features of macrophytes in the Danube River

3.3.6.1 Light avialability

3.3.6.1.1 Secchi transparency

In the analysis of the correlation of Secchi transparency and relative plant mass of mosses, rooted plants, floating plants and macroalgae, Kendall's and Spearman Correlation Coefficients were calculated.

Kendall's Correlation Coefficient showed significantly negative correlation with Secchi transparency and mosses (τ=-0,091; $p \leq 0{,}05$), while both Correlation Coefficients (Kendall's and Spearmans) showed highly significant positive correlation between rooted plants (τ=0,179; ρ=0,257; $p \leq 0{,}01$) and macroalgae (τ=0,213; ρ=0,264; $p \leq 0{,}01$). There was no correlation between Secchi transparency and floating plants with both Kendall's and Spearman's Correlation Coefficients ($p > 0{,}05$).

3.3.6.1.2 Turbidity

One Way ANOVA was carried out for turbidity classes for relative plant mass of taxa recorded in the water of the main course of the Danube. Plants were separated into three categories (mosses, rooted plants and macroalgae, excluding stoneworts) and analysis was performed for each category separately:

- Differences between the relative plant mass of mosses and turbidity were not significant ($F = 1.307$, $p > 0.05$)
- Differences between the relative plant mass of rooted plants and turbidity were significant ($F = 12.826$, $p < 0.001$, $N = 320$, $df = 2$). High turbidity is different from other turbidity classes and it correlated with the lowest relative plant mass of rooted plants (Tukey HSD post hoc test, $p < 0.05$).
- Differences between the relative plant mass of macroalgae and turbidity were significant ($F = 4.407$, $p < 0.01$, $N = 320$, $df = 2$). High turbidity water is different from low turbidity water, while high turbidity can be considered as a transitional category. Low turbidity water related to the highest relative plant mass of macroalgae (Tukey HSD post hoc test, $p < 0.05$).

3.3.6.1.3 Shading

One Way ANOVA was done for shading classes separately for relative plant mass of taxa recorded in the water and on the banks of the main course of the Danube. When it was done for taxa recorded in the water, plants were separated into four categories (mosses, rooted plants, floating plants and macroalgae (excluding stoneworts)) and analysis was carried out for each category separately:

- Differences between the relative plant mass of mosses and shading were significant ($F = 9.039$, $p < 0.001$, $N = 320$, $df = 3$). No shading and high shading are different from low and medium shading. Low and medium shading have highest relative plant mass of mosses as compared to no shading and high shading (Tukey HSD post hoc test, $p < 0.05$).
- Differences between the relative plant mass of rooted plants and shading were significant ($F = 10.327$, $p < 0.001$, $N = 320$, $df = 3$). Medium shading is different from no shading, while low

and high shading can be considered as ‘transitional’ shading. No shading related to the highest relative plant mass of rooted plants (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of floating plants and shading were significant ($F = 9.716$, $p < 0.01$, $N = 320$, $df = 3$). Low and medium shading were different from no shading and high shading. No shading and high shading supported higher relative plant mass of floating plants (Fisher LSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of macroalgae and shading classes were significant ($F = 9.146$, $p < 0.001$, $N = 320$, $df = 3$). Medium and high shading are different from no and low shading, but low and high shading classes can be considered as transitional categories. No and low shading classes related with the highest relative plant mass of macroalgae (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of bank vegetation and shading were not significant ($F = 1.450$, $p > 0.05$).

3.3.6.2 Water current

3.3.6.2.1 Water current classes

One Way ANOVA was performed for water current classes for relative plant mass of taxa recorded in the water of the main course of the Danube. Plants were separated into four categories (mosses, rooted plants, floating plants and macroalgae (excluding stoneworts)) and analysis was done for each category separately:

- Differences between the relative plant mass of mosses and water current were significant ($F = 11.008$, $p < 0.001$, $N = 320$, $df = 3$). Low water current is different from high water current and standing water and high water current can be considered as transitional water currents. The lowest relative plant mass of mosses was found in sections with low water current and the highest relative plant mass related to sections with high water current (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of rooted plants and water current were significant ($F = 35.542$, $p < 0.001$, $N = 320$, $df = 3$). Medium and high water currents are different from standing water and low water current. Low water current can be considered as transitional water current. There is the highest relative plant mass of rooted plants on the sections with almost standing water and the lowest in the sections with medium or high water current (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of floating plants and water current were significant ($F = 10.592$, $p < 0.001$, $N = 320$, $df = 3$). Standing water is different from all the others, while high water current is different from standing water and low water current. High water current is a transitional category between low and medium water currents. There is the highest relative plant mass of floating plants in the sections with standing water and the lowest in the sections with medium and high water currents (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of macroalgae and water current were significant ($F = 18.562$, $p < 0.001$, $N = 320$, $df = 3$). Standing water is different from all the others as well as low water current, while medium and high water currents are different from standing water and from low water current. The highest relative plant mass of rooted plants was found in sections with standing water and the lowest in the sections with medium and high water currents (Tukey HSD post hoc test, $p < 0.05$).

3.3.6.2.2 Diversity of water current

One Way ANOVA was calculated for classes of water flow diversity for relative plant mass of taxa recorded in the water of the main course of the Danube. Plants were separated into four categories (mosses, rooted plants, floating plants and macroalgae (excluding stoneworts)) and analysis was done for each category separately:

- Differences between the relative plant mass of mosses and current diversity were significant ($F = 25.184$, $p < 0.001$, $N = 320$, $df = 3$). Low current diversity is different from other current diversity classes and it related to the highest relative plant mass of mosses (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of rooted plants and current diversity were significant ($F = 39.636$, $p < 0.001$, $N = 320$, $df = 3$). No current diversity is different from other current diversity classes and it supported the highest relative plant mass of rooted plants (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of floating plants and current diversity were significant ($F = 5.214$, $p < 0.001$, $N = 320$, $df = 3$). No current diversity is different from other current diversity classes and it exhibited the highest number of floating plants. High current diversity does not clearly differ from the rest as the post-hoc test has a problem distinguishing the differences when the standard deviation of the sample is bigger than the standard mean of the sample (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of macroalgae and current diversity were significant ($F = 32.021$, $p < 0.001$, $N = 320$, $df = 3$). No current diversity is different from other current diversity classes and it revealed the highest relative plant mass of macroalgae (Tukey HSD post hoc test, $p < 0.05$).

3.3.6.3 Substrate

3.3.6.3.1 Type of the substrate

Canonical Correspondence Analysis (CCA) was conducted to show how the type of substrate influences the community of macrophytes in the main course of the Danube. Two analysis were made separately, one for taxa recorded in the water of the main course of the Danube with submerged substrate, and the other one for the taxa recorded on the banks of the main course of the Danube and on emerged substrate.

Water taxa vs. submerged substrate

In the CCA analysis of the relative plant mass of taxa recorded in the water of the main course of the Danube and types of submerged substrate, 76 taxa and 6 types of the submerged substrate had been analysed (Figure 45). On F1xF2 ordination chart the first two unit values were 0.402 and 0.111, explaining 74.2% of the variance of the water taxa and submerged substrate. A Monte Carlo test showed that ordination was statistically significant (first axis: F-ratio=9.252, p=0.0040, p<0.05;

overall: trace=0.692, F-ratio=2.717, p=0.0040, p<0.05), indicating that the species were significantly related to the tested set of environmental variables.

The first axis highly correlated with technolithal (R=0.947) and the second axis highly correlated with microlithal (R=0.763) and pelal (R=-0.631). Taxa preferring hard substrate for growth, like technolithal, were among the group of bryophytes. Taxa preferring soft pelal as a substrate were rooted angiosperms with representatives like *Potamogeton* spp., *Najas* spp., *E. nuttallii* , while taxa like *M. spicatum, N. obtusa, V. spiralis* and *B. umbellatus* preferred microlithal as a growing substrate.

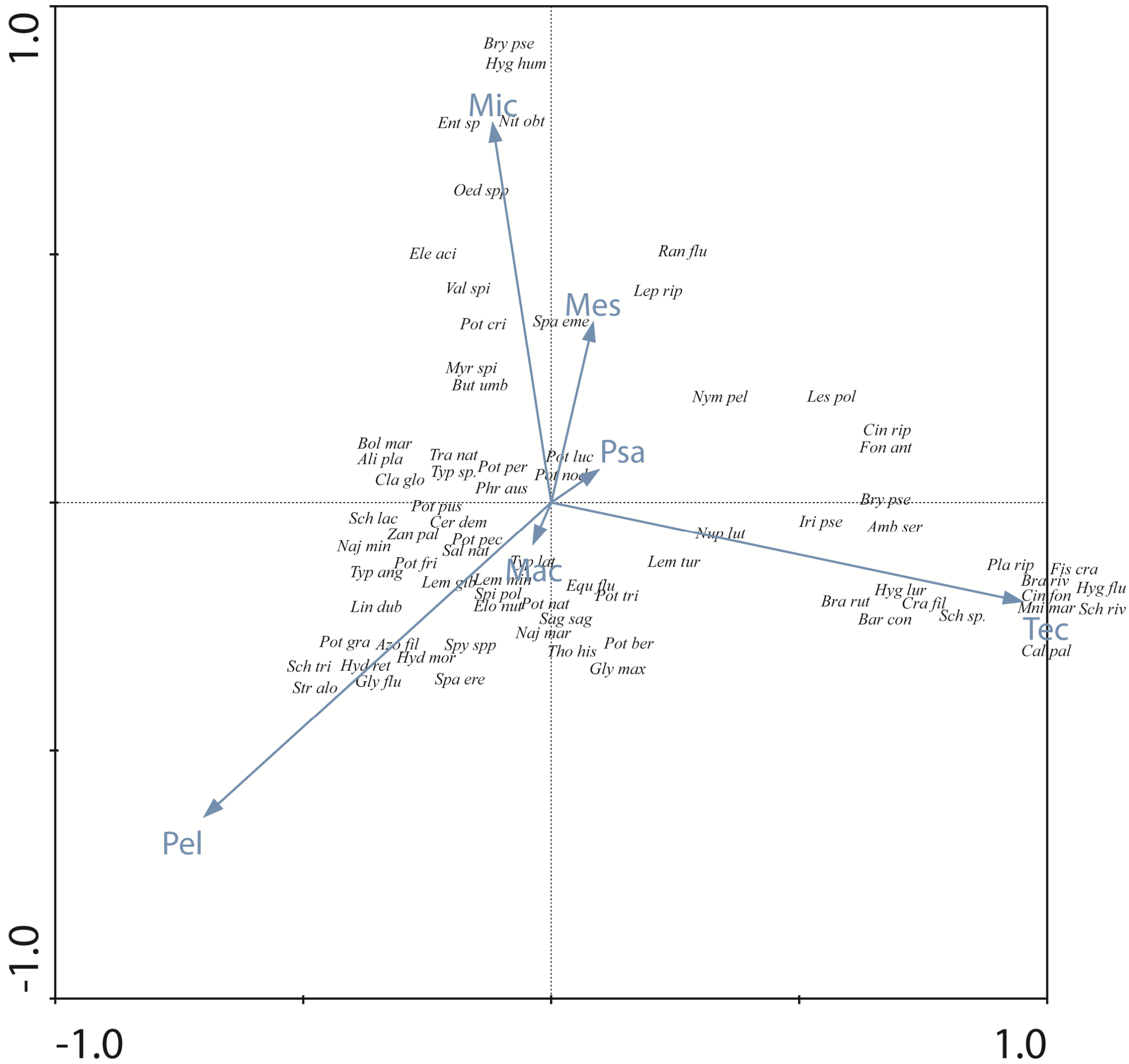


Figure 45 Canonical correspondence analysis (CCA) of taxa recorded in the water of the Danube and tributaries and type of submerged substrate. Codes for plant taxa are given in Table 6 and Table 7. Codes for the substrates: Tch – Technolithal, Mac – Macrolithal, Mes – Mesolithal, Mic – Microlithal, Psa – Psammal and Pel – Pelal.

Bank taxa vs. emerged substrate

In the CCA analysis of the relative plant mass of taxa recorded on the banks of the main course of the Danube and types of emerged substrate, 121 taxa and 8 types of the emerged substrate had been analysed (Figure 45). On F1xF2 ordination chart the first two unit values were 0.471 and 0.159 and they explained 69.5% of the variance of water taxa and submerged substrate. A Monte Carlo test showed that ordination was statistically significant (first axis: F-ratio= 13.095, p=0.0020, p<0.05; overall: trace= 0.906, F-ratio= 3.270, p=0.0020, p<0.05), indicating that the species were significantly related to the tested set of environmental variables.

The first axis highly correlated with technolithal (R= 0.952) and the second axis highly correlated with akal (R=0.597) and mesolithal (R=-0.445). Taxa preferring hard and artificial bank substrate (technolithal) were from the group of bryophytes and some other taxa like rural and water related angiosperms (e.g. *C. oleraceoum, A. gigantea, M. longifolia* and *Petasites* sp.). Although the emerged substrates akal and mesolithal had high correlation with the second axis, not so many taxa grouped around them. Some of the taxa preferring these substrates were *P. lanceolata, B. umbellatus, R. repens, C. elata*, etc. The emerged substrates pelal and soil did not highly correlated with first two axes, but a high number of taxa grouped around their vectors, meaning that they had high influence on the taxa composition. Characteristic taxa on those substrates were the bryophytes *P. patens* and *M. polymorpha*, the terrestrial macroalga B. *granulatum* and angiosperms like the rural *Xanthium* spp*., A. theophrasti, D. stramonium* and also tall forbs like *Bidens* spp., *Amaranthus* spp., *Persicaria* spp. and others.

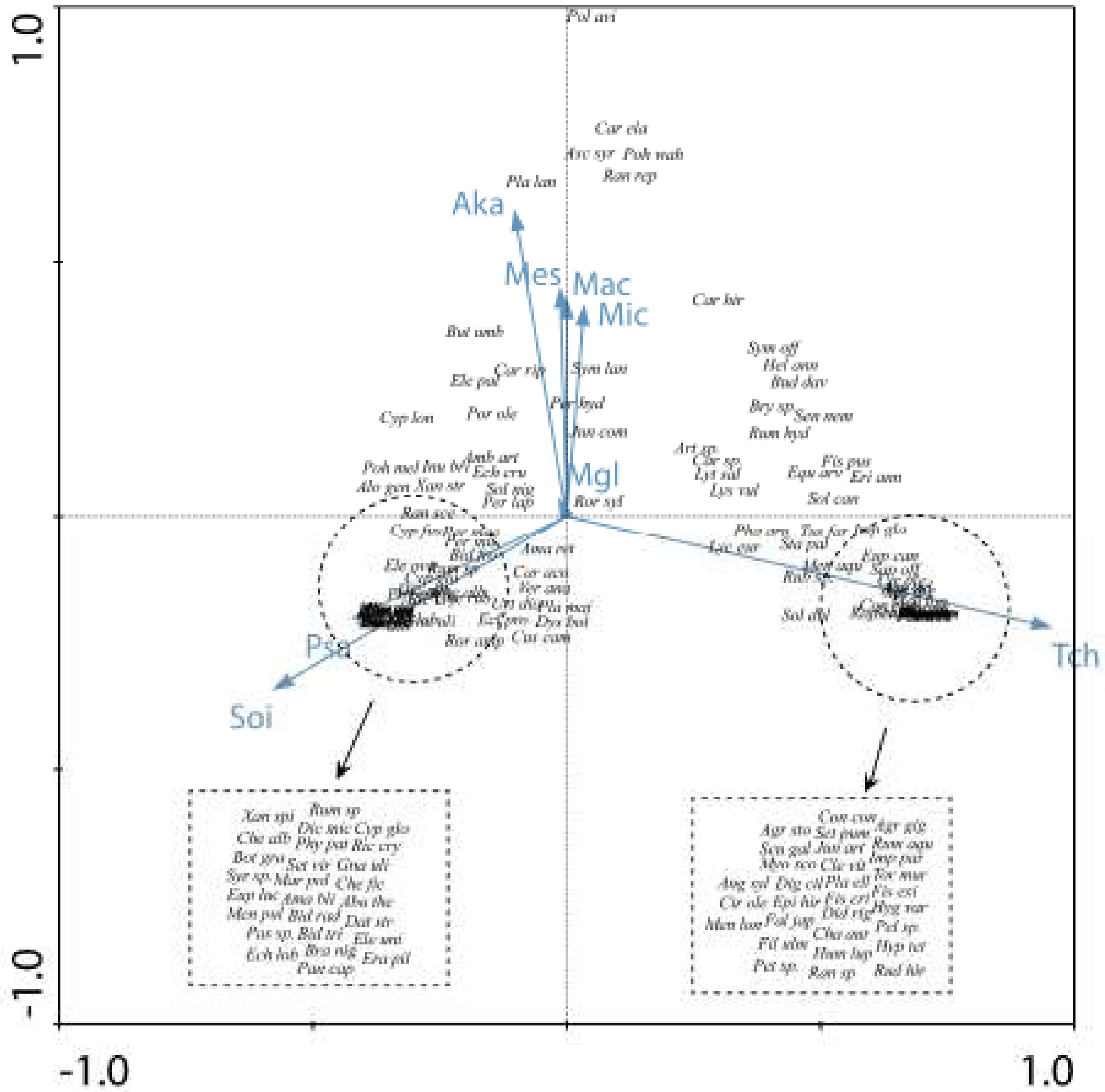


Figure 46 Canonical correspondence analysis (CCA) of taxa recorded on the banks of the Danube and tributaries and type of emerged substrate. Codes for plant taxa are given in Table 9 and Table 10. Codes for the substrates: Tch – Technolithal, Mgl – Megalithal, Mac – Macrolithal, Mes – Mesolithal, Mic – Microlithal, Aka – Akal, Psa – Psammal and Soi – Soil.

3.3.6.3.2 Slope of the substrate

One Way ANOVA was performed for classes of the substrate slope separately for relative plant mass of taxa recorded in the water and on the banks of the main course of the Danube. When it was done for taxa recorded in the water, plants were separated in four categories (mosses, rooted plants, floating plants and macroalgae, excluding stoneworts) and the analysis was done for each category separately:

- Differences between the relative plant mass of mosses and bank slope were not significant ($F = 1.823$, $p > 0.05$).

- Differences between the relative plant mass of rooted plants and bank slope were significant ($F = 12.771$, $p < 0.001$, $N = 320$, $df = 3$). Flat and medium bank slopes were different from steep and vertical bank slopes. On steep and vertical bank slopes relative plant mass of rooted plants was lower than on flat and medium bank slope (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of floating plants and bank slope were significant ($F = 3.138$, $p < 0.02$, $N = 320$, $df = 3$). Flat and medium bank slopes were different from steep and vertical bank slopes. On steep and vertical bank slopes relative plant mass of floating plants was lower than on flat and medium bank slopes. Vertical bank slope does not clearly differ from the rest as post-hoc test has a problem distinguishing the differences when the standard deviation of the sample is bigger than the standard mean of the sample (Tukey HSD post hoc test, $p < 0.05$).

- Differences between the relative plant mass of macroalgae and bank slope were not significant ($F = 2.148$, $p > 0.05$).

- Differences between the relative plant mass of bank vegetation and bank slope were significant ($F = 5.234$, $p < 0.001$, $N = 320$, $df = 3$). Vertical bank slope was different from other bank slope classes where steep bank slope is a transitional category. Relative plant mass of the bank vegetation is the lowest on vertical bank slope (Tukey HSD post hoc test, $p < 0.05$).

3.4 The main tributaries of the Danube River

3.4.1 Additional parameters

3.4.1.1 Secchi transparency

Secchi transparency in the main tributaries of the Danube was between 10 and 180 cm. Sava River had highest transparency when compared to other tributaries, reaching 180 cm. Conditional mean values of Secchi transparency were found in the tributaries Mosoni Danube, Tisa, Velika Morava, Timok and Iskar, and their values ranged between 50 and 100 cm. The lowest values of Secchi transparency were measured in the lower Danube tributaries, Jantra, Arges, Siret and Prut, ranging between 10 and 25 cm.

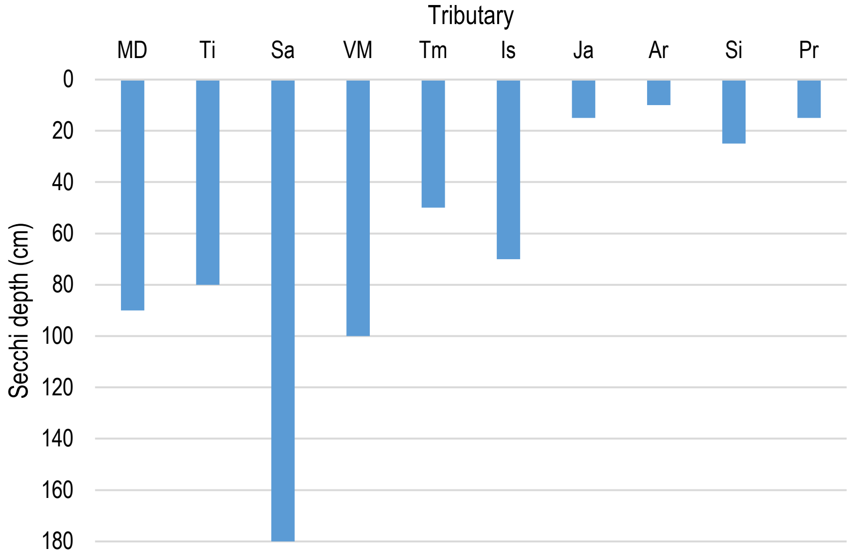
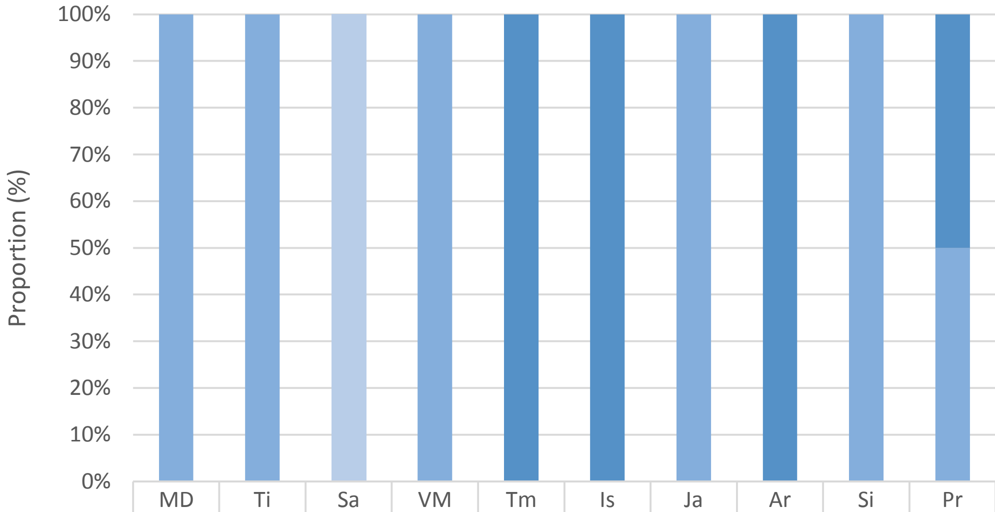


Figure 47 Secchi depth on the sampling sites of the Danube tributaries (MD – Moson Danube, Ti- Tisa, Sa – Sava, VM – Velika Morava, Tm – Timok, Is – Iskar, Ja – Jantra, Ar – Arges, Si – Siret, Pr – Prut).

3.4.1.2 Water flow

Water flow was low in most of the Danube tributaries (Moson Danube, Tisa, Velika Morava, Jantra and Siret) (Figure 48). Still water was observed only in the Sava River, while medium water flow was recorded in Timok, Iskar and Arges rivers. In the Prut River water flow classes were equally represented with medium and low current, while high water flow was never recorded in any tributary.



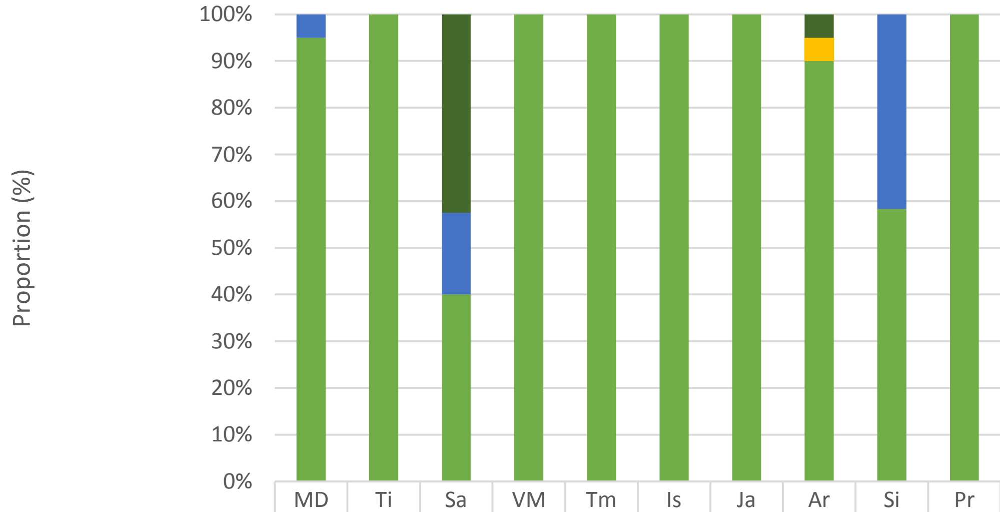
	MD	Ti	Sa	VM	Tm	Is	Ja	Ar	Si	Pr
High	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	100,0	100,0	0	100,0	0	50,0
Low	100,0	100,0	0	100,0	0	0	100,0	0	100,0	50,0
Stagnant	0	0	100,0	0	0	0	0	0	0	0

Tributary

Figure 48 Proportion of water flow classes (stagnant, low, medium and high) on the sampling sites of the Danube tributaries (MD – Moson Danube, Ti- Tisa, Sa – Sava, VM – Velika Morava, Tm – Timok, Is – Iskar, Ja – Jantra, Ar – Arges, Si – Siret, Pr – Prut).

3.4.1.3 Bank structure

Artificial bank structure was not present or rare on most of the sampling sites located in the Danube tributaries (Figure 49). Old/abandoned rip rap was recorded only in the Moson Danube River (5.0%), Sava River (17.5%) and Siret River (41.7%). Concrete or metal bank structure was recorded in the Sava and Arges rivers (42.5% and 5.0%) while rip rap was recorded only in the Arges River (5.0%).



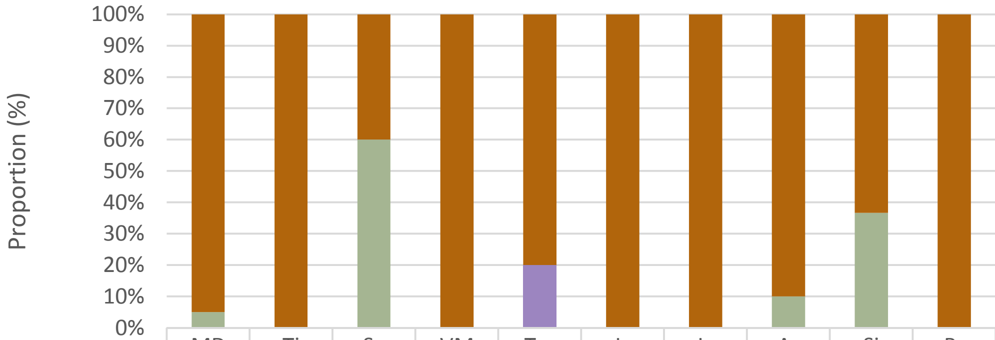
	MD	Ti	Sa	VM	Tm	Is	Ja	Ar	Si	Pr
Concrete/metal	0	0	42,5	0	0	0	0	5,0	0	0
Rip rap	0	0	0	0	0	0	0	5,0	0	0
Old/abandoned rip rap	5,0	0	17,5	0	0	0	0	0	41,7	0
None	95,0	100,0	40,0	100,0	100,0	100,0	100,0	90,0	58,3	100,0

Tributary

Figure 49 Proportion of bank structure fixation type (none, old/abandoned rip rap, rip rap and concrete/metal) on the sampling sites of the Danube tributaries (MD – Moson Danube, Ti-Tisa, Sa – Sava, VM – Velika Morava, Tm – Timok, Is – Iskar, Ja – Jantra, Ar – Arges, Si – Siret, Pr – Prut).

3.4.1.4 Submerged substrate

Pelal was the only submerged substrate in almost all sampling sites in the Danube tributaries (Figure 50). Exceptions were Sava River with 25.0% of technolithal, Timok River with 60.0% of microlithal and Ispra River with 20.0% of psammal.

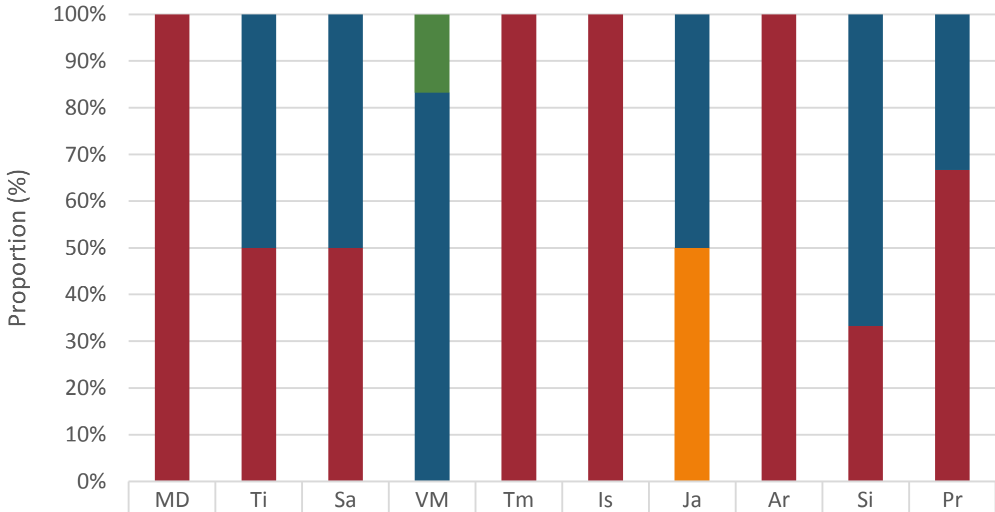


	MD	Ti	Sa	VM	Tm	Is	Ja	Ar	Si	Pr
Soil	95,0	100,0	40,0	100,0	80,0	100,0	100,0	90,0	63,3	100,0
Psammal	0	0	0	0	0	0	0	0	0	0
Akal	0	0	0	0	0	0	0	0	0	0
Microlithal	0	0	0	0	20,0	0	0	0	0	0
Mesolithal	0	0	0	0	0	0	0	0	0	0
Macrolithal	0	0	0	0	0	0	0	0	0	0
Megalithal	0	0	0	0	0	0	0	0	0	0
Technolithal	5,0	0	60,0	0	0	0	0	10,0	36,7	0

Tributary

Figure 50 Proportion types of submerged substrate (technolithal, megalithal, macrolithal, mesolithal, microlithal, akal, psammal and pelal) on the sampling sites of the Danube tributaries (MD – Moson Danube, Ti- Tisa, Sa – Sava, VM – Velika Morava, Tm – Timok, Is – Iskar, Ja – Jantra, Ar – Arges, Si – Siret, Pr – Prut).

The slope of the submerged substrate was medium in Moson Danube, Timok, Ispra and Arges rivers (Figure 51). An equal or almost equal proportion of medium and steep slope was recorded in Timok, Sava, Siret and Prut rivers. In the Velika Morava River the dominant slope was steep (83.3%) with some proportion of vertical slope (16.7%) of submerged substrate. Jantra River had an equal proportion of steep and flat slope of submerged substrate (50%:50%).



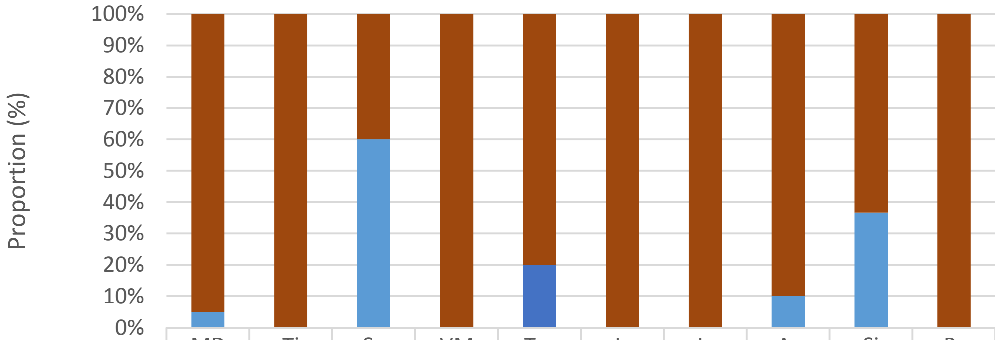
	MD	Ti	Sa	VM	Tm	Is	Ja	Ar	Si	Pr
Vertical	0	0	0	16,7	0	0	0	0	0	0
Steep	0	50,0	50,0	83,3	0	0	50,0	0	66,7	33,3
Medium	100,0	50,0	50,0	0	100,0	100,0	0	100,0	33,3	66,7
Flat	0	0	0	0	0	0	50,0	0	0	0

Tributary

Figure 51 Proportion of slope of submerged substrate (flat, medium, steep and vertical) on the sampling sites of the Danube tributaries (MD – Moson Danube, Ti- Tisa, Sa – Sava, VM – Velika Morava, Tm – Timok, Is – Iskar, Ja – Jantra, Ar – Arges, Si – Siret, Pr – Prut).

3.4.1.5 Emerged substrate

Soil was dominant or the only emerged substrate in the all Danube tributaries except in the Sava River where technolithal was represented with 60.0% and soil with only 40.0% (Figure 52). A small proportion of technolithal was recorded also in the rivers Moson Danube (5.0%), Arges (10.0%) and Siret (36.7%). In the Timok River next to soil, a small proportion of microlithal was recorded (20.0%).

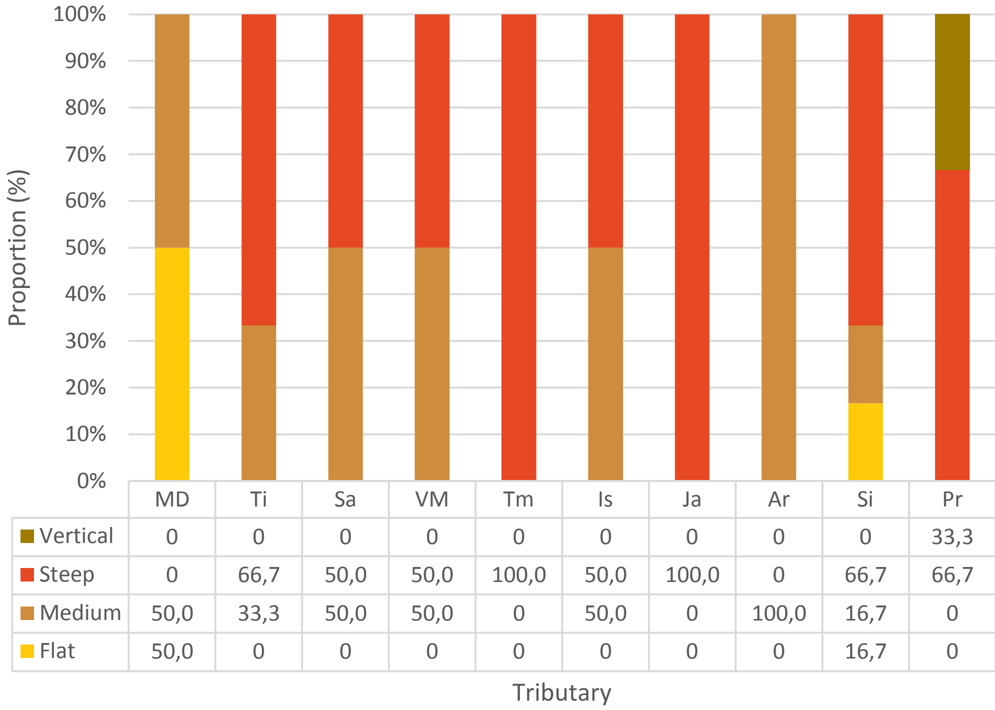


	MD	Ti	Sa	VM	Tm	Is	Ja	Ar	Si	Pr
Soil	95,0	100,0	40,0	100,0	80,0	100,0	100,0	90,0	63,3	100,0
Psammal	0	0	0	0	0	0	0	0	0	0
Akal	0	0	0	0	0	0	0	0	0	0
Microlithal	0	0	0	0	20,0	0	0	0	0	0
Mesolithal	0	0	0	0	0	0	0	0	0	0
Macrolithal	0	0	0	0	0	0	0	0	0	0
Megalithal	0	0	0	0	0	0	0	0	0	0
Technolithal	5,0	0	60,0	0	0	0	0	10,0	36,7	0

Tributary

Figure 52 Proportion types of emerged substrate (technolithal, megalithal, macrolithal, mesolithal, microlithal, akal, psammal and pelal) on the sampling sites of the Danube tributaries (MD – Moson Danube, Ti- Tisa, Sa – Sava, VM – Velika Morava, Tm – Timok, Is – Iskar, Ja – Jantra, Ar – Arges, Si – Siret, Pr – Prut).

Steep or medium slope of emerged substrate was recorded in most of the Danube tributaries (Figure 53). Both of them were equal or about equal in the Tisa, Sava, Velika Morava and Ispra rivers. Only steep slope was recorded in the Timok and Jantra rivers. Moson Danube River had an equal proportion of flat and steep emerged substrate slope, while in the Prut River steep slope was dominant with 33.3% of vertical slope. In the Siret River steep slope was dominant with 16.7% of medium and flat slope of the emerged substrate.

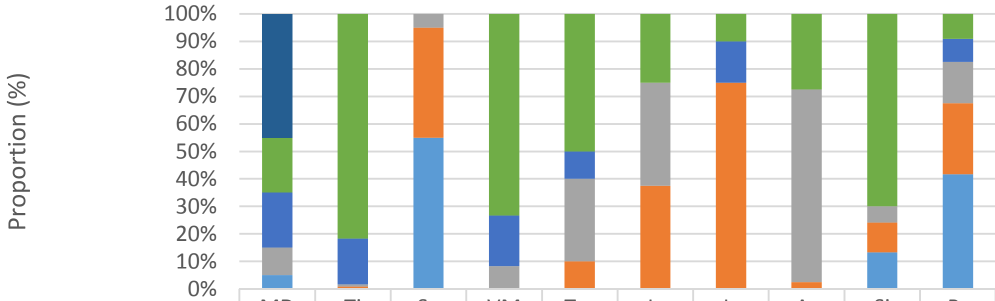


	MD	Ti	Sa	VM	Tm	Is	Ja	Ar	Si	Pr
Vertical	0	0	0	0	0	0	0	0	0	33,3
Steep	0	66,7	50,0	50,0	100,0	50,0	100,0	0	66,7	66,7
Medium	50,0	33,3	50,0	50,0	0	50,0	0	100,0	16,7	0
Flat	50,0	0	0	0	0	0	0	0	16,7	0

Figure 53 Proportion of emerged substrate slope (flat, medium, steep and vertical) on the sampling sites of the Danube tributaries (MD – Moson Danube, Ti – Tisa, Sa – Sava, VM – Velika Morava, Tm – Timok, Is – Iskar, Ja – Jantra, Ar – Arges, Si – Siret, Pr – Prut).

3.4.1.6 Bank vegetation

On the sampling sites in the Danube tributaries, four types of vegetation forms were dominant (Figure 54). Riparian forest was the dominant vegetation form in Tisa, Velika Morava, Timok and Siret rivers (50.0%-81.7%). Grasses were represented in a larger proportion in Sava, Ispra and Jantra rivers (37.5%-75.0%). In the Sava and Prut rivers, banks without vegetation (missing) were dominant (41.7%-55.0%). Tall forbs were dominant in the Arges River (70.0%), while only subdominant in Timok and Ispra rivers (30.0% and 37.5%). Broad-leaved forest was the dominant bank vegetation type in Moson Danube River (45.0%).



	MD	Ti	Sa	VM	Tm	Is	Ja	Ar	Si	Pr
Mixed forest	0	0	0	0	0	0	0	0	0	0
Coniferous forest	0	0	0	0	0	0	0	0	0	0
Broad-leaved forest	45,0	0	0	0	0	0	0	0	0	0
Riparian forest	20,0	81,7	0	73,3	50,0	25,0	10,0	27,5	70,0	9,2
Shrubbery	20,0	16,7	0	18,3	10,0	0	15,0	0,0	0	8,3
Reeds	0	0	0	0	0	0	0	0	0	0
Tall forbs	10,0	0,8	5,0	8,3	30,0	37,5	0	70,0	5,8	15,0
Grasses	0	0,8	40,0	0	10,0	37,5	75,0	2,5	10,8	25,8
Missing	5,0	0	55,0	0	0	0	0	0	13,3	41,7

Tributary

Figure 54 Proportion bank vegetation forms (missing, grasses, tall forbs, reeds, shrubbery, riparian forest, broad-leaved forest, coniferous forest and mixed forest) on the sampling sites of the Danube tributaries (MD – Moson Danube, Ti- Tisa, Sa – Sava, VM – Velika Morava, Tm – Timok, Is – Iskar, Ja – Jantra, Ar – Arges, Si – Siret, Pr – Prut).

3.4.2 Moson Danube River

In the Moson Danube River survey was done only for aquatic plants, and bank vegetation was not observed. At two sampling sections, four macrophyte taxa were recorded and they were all equally represented as frequent (Figure 55). *L. minor*, *L. gibba*, *S. natans* and *S. polyrhiza* contributed with 25.0% of RPM (Figure 56).

	JDS16	
Hyd and Mac	L1	R1
Lem gib	■	■
Lem min	■	■
Sal nat	■	■
Spi pol	■	■

Figure 55 Distribution diagram of all plants in Moson Danube River

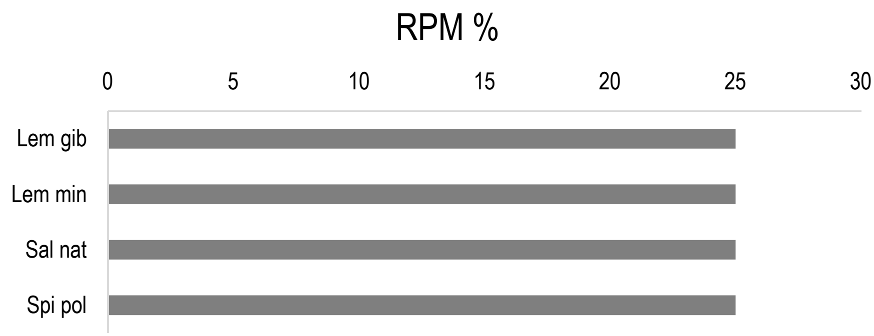


Figure 56 RPM diagram of Hydrophytes in Moson Danube River

Among the four recorded species, 75.0% belonged to the group of angiosperms and 25.0% to the group of pteridophytes, and all of them were floating hydrophytes (Figure 57).

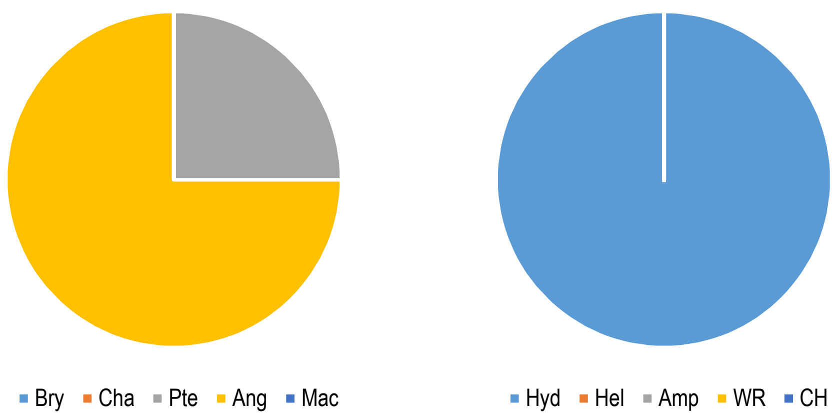


Figure 57 Proportion of plant groups and life forms in Moson Danube.

3.4.3 Tisa River

Tisa River was surveyed according to the standard methodology (three kilometres on the left and three kilometres on the right side) and 19 taxa were identified (Figure 58).

Four out of seven hydrophytes, the floating species *L. minor*, *L. gibba*, *S. natans* and *S. polyrrhiza*, each contributed with 20.8% to the RPM (Figure 59). They were followed by *C. demersum* with 10.5% of RPM and only 3.1% of RPM, each by *G. maxima* and *H. morsus-ranae*.

The dominant taxa for both banks were the angiosperm *P. lapathifolia* and the bryophyte *P. patens*. Characteristic taxa for the left bank were *A. artemisifolia*, *B. frondosa*, *C. rubrum* and *E. crus-gali* whereas *C. glomeratus* and *D. micheliana* were characteristic bank taxa of the right side.

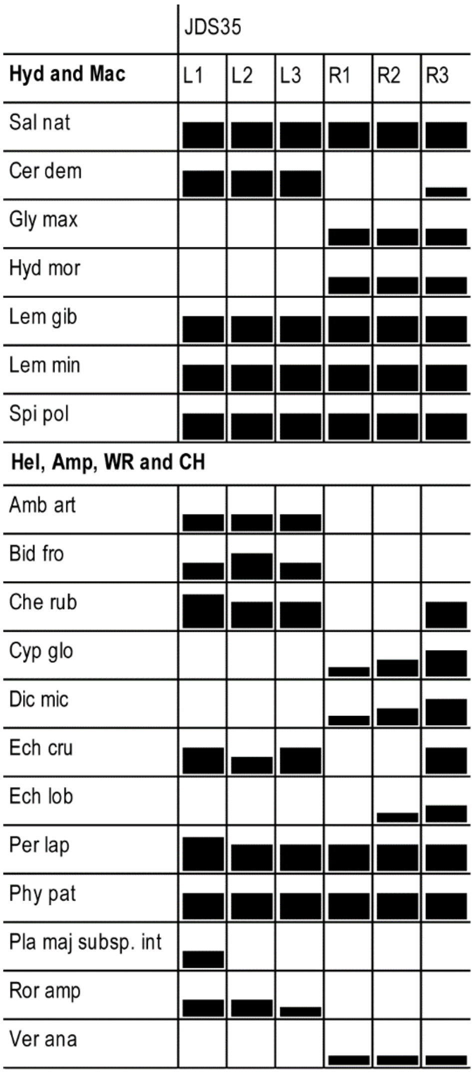


Figure 58 Distribution diagram of all plants in Tisa River

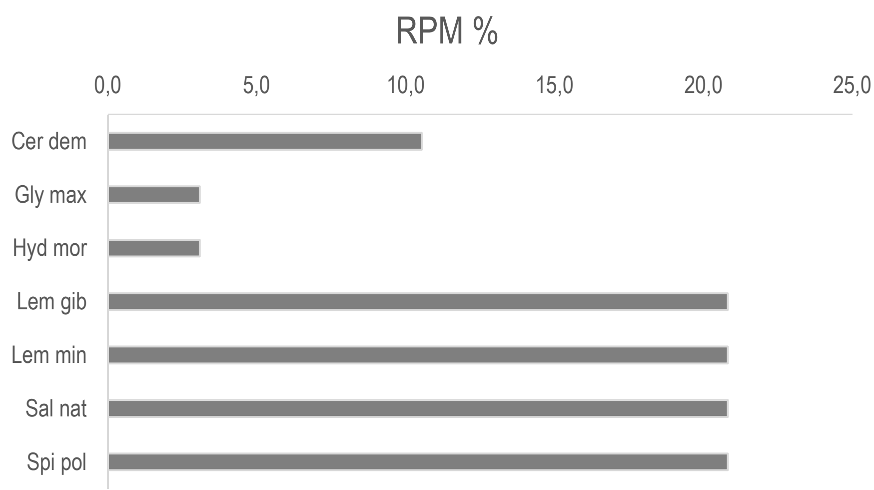


Figure 59 RPM diagram of Hydrophytes in Tisa River

The dominant plant group in the Tisa River was angiosperms with a proportion of 79.0% (Figure 60). Bryophytes and pteridophytes contributed with 10.5% each, while charophytes were not recorded.

Hydrophytes were the dominant plant life form in the Tisa River (48.9%) with co-domination of helophytes and water related species (16.8% and 25.6%).

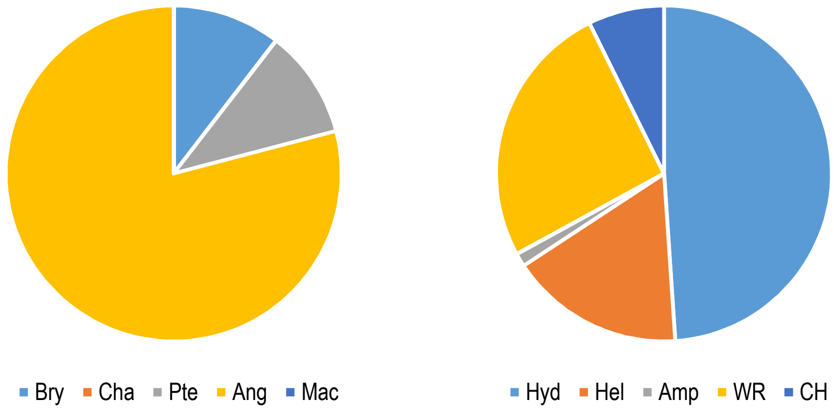


Figure 60 Proportion of plant groups and life forms in Tisa River

3.4.4 Sava River

In the Sava River 22 taxa were identified on two sampling sections, one on the left and one on the right side of the river (Figure 61). Nine taxa were hydrophytes.

C. demersum and *P. pectinatus* mostly contributed to the RPM with 56.8% and 28.4% (Figure 62). *C. demersum* and *L. riparium* were identified on both sides, while all other taxa were identified only on the right side of the Sava River. The macroalge *T. hispida* was identified only on the left side of the river attached to metal barrels that were floating partially submerged in the water.

Right side of the Sava River was richer with bank species as well (Figure 61).

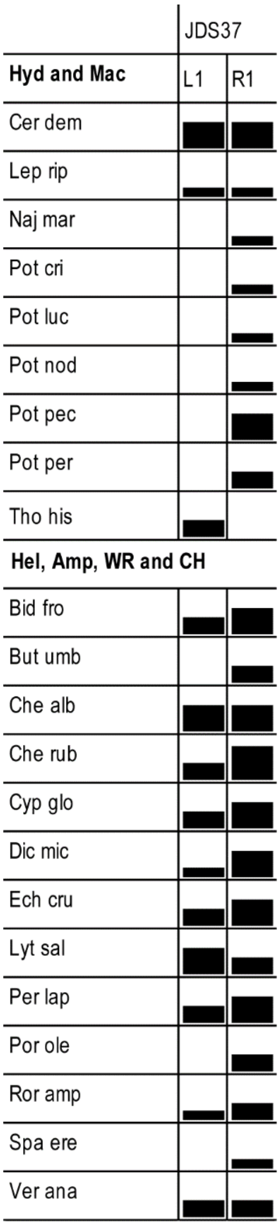


Figure 61 Distribution diagram of all plants in Sava River

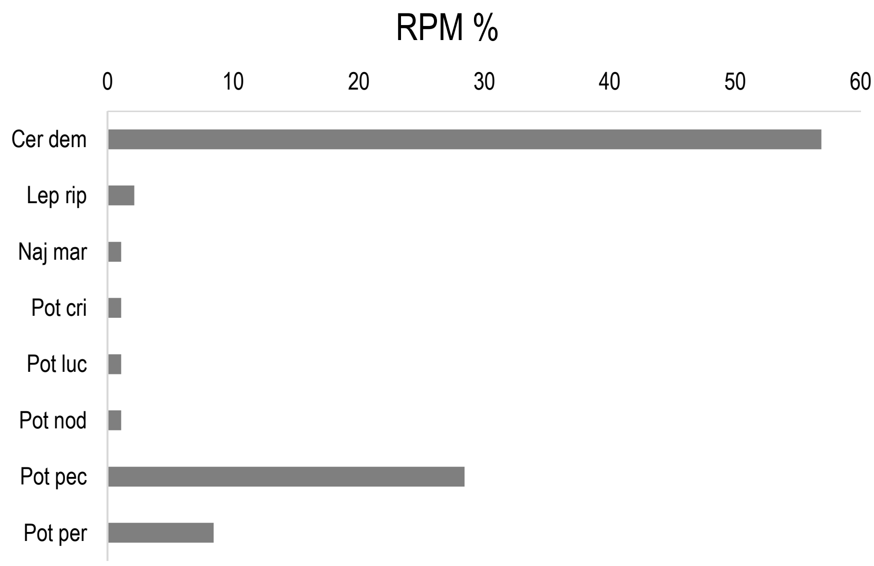


Figure 62 RPM diagram of Hydrophytes in Sava River

Angiosperms was dominant plant group in the Sava River (97.9%) with a small contribution of bryophytes and macroalgae (Figure 63). Among the life forms in the Sava River, amphiphytes were represented with the smallest proportion (5.3%) while other life forms (hydrophytes, helophytes, water related and chance species) were represented with a similar proportion (20.5-30.0%) (Figure 63).

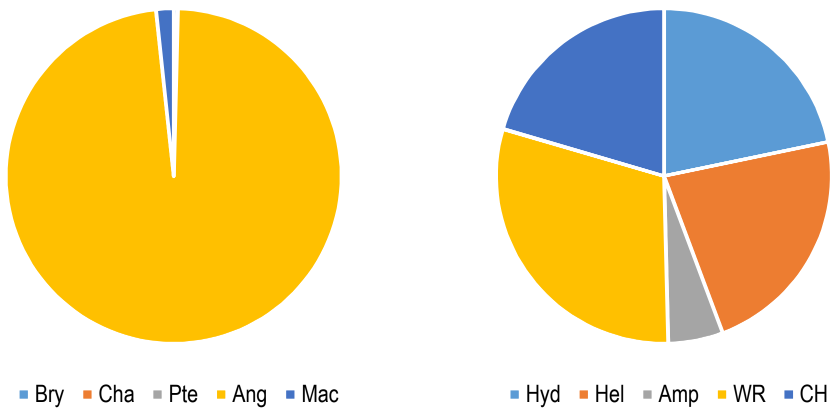


Figure 63 Proportion of plant groups and life forms on Sava River

3.4.5 Velika Morava River

In the Velika Morava River 20 taxa were identified (Figure 64). There was only one hydrophyte taxon, *C. demersum*, present at all six sampling sections (Figure 65). The macroalge *C. glomerata* dominated at all six sampling sections as abundant.

B. frondosa, C. rubrum, E. lobata and *P. arundinaceae* were the most common bank taxa in the Velika Morava River.

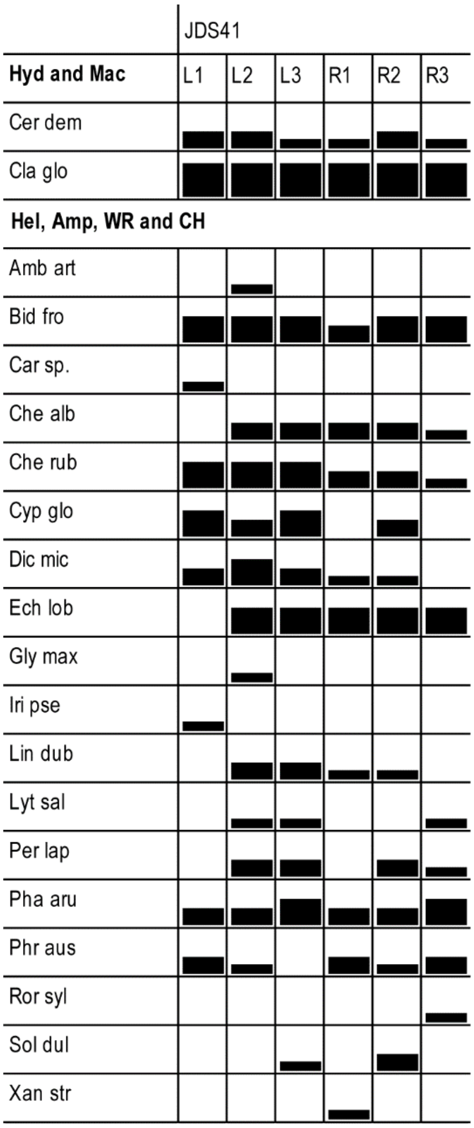


Figure 64 Distribution diagram of all plants in Velika Morava River

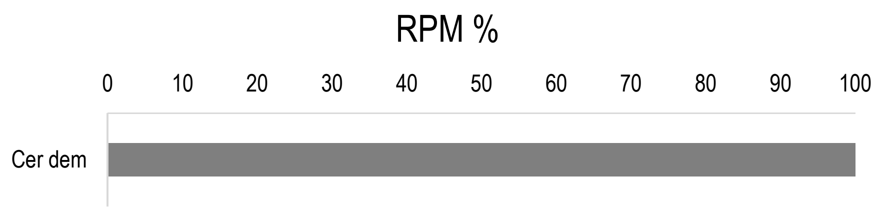


Figure 65 RPM diagram of Hydrophytes in Velika Morava River

In the Velika Morva River, only the plant groups of macroalgae (34.7%) and angiosperms were identified (65.3%) (Figure 66). The life forms hydrophytes (37.1%) and water related plants (41.1%) were co-dominant, while helophytes and chance species were represented with a smaller proportion (16.9% and 4.8%) (Figure 66). Amphiphytes were not present.

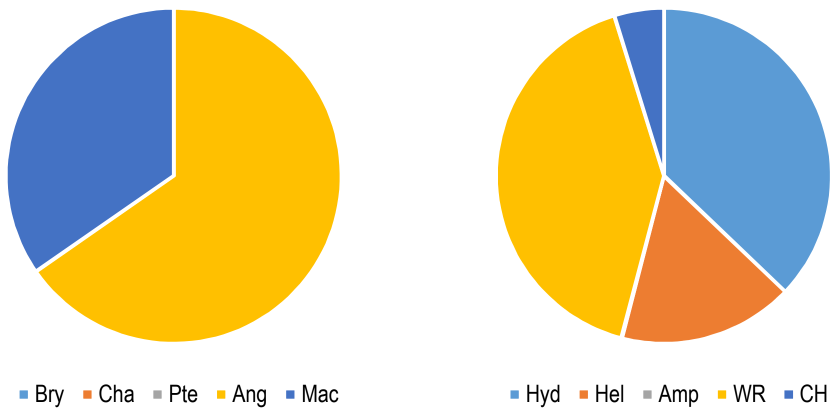


Figure 66 Proportion of plant groups and life forms in Sava River

3.4.6 Timok River

The Timok River is small and only one sampling section was surveyed, where 18 taxa were identified (Figure 67).Three of them were hydrophytes with *P. pectinatus, P. pusillus* and *P. trichoides*. All three species contributed equally to 33.3% to the RPM (Figure 68).

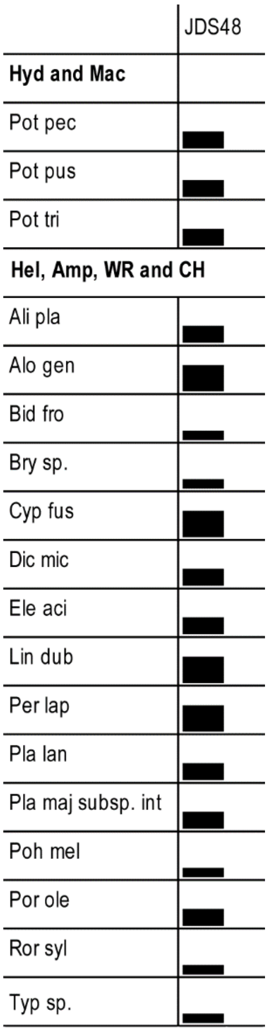


Figure 67 Distribution diagram of all plants in Timok River

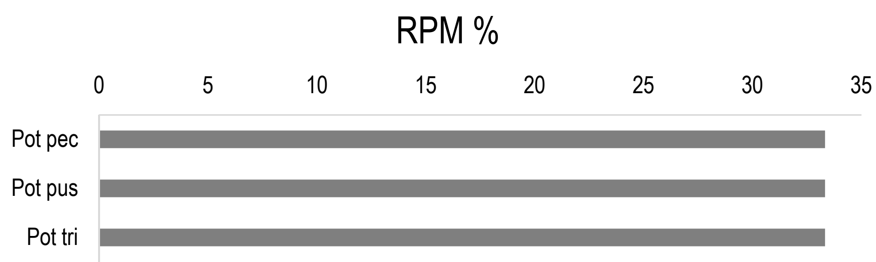


Figure 68 RPM diagram of Hydrophytes in Timok River

The dominant plant group in the Timok River was angiosperms (98.9%) (Figure 69). The second plant group was bryophytes (1.1%) while charophytes, pteridophytes and macroalgae were not detected. Helophytes were the dominant life form in the Timok River (48.6%) (Figure 69). Other life forms were represented in the following order: chance species (27.6%), hydrophytes (13.0%), amphiphytes (9.7%) and water related species (0.5%).

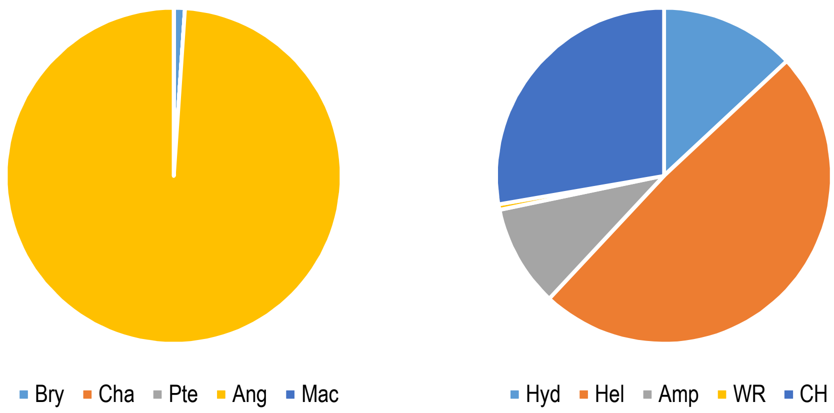


Figure 69 Proportion of plant groups and life forms in Timok River

3.4.7 Iskar River

The Iskar River was surveyed on two sampling sections, one on the left and one on the right side, with 10 taxa identified (Figure 70). Two hydrophytes were identified and *M. spicatum* was dominant with 77.8% of the RPM (Figure 71). *C. demersum* contributed to the 22.2% to the RPM of hydrophytes. *E. crus-galli, P. lapathifolia* and *X. strumarium* were the most abundant bank taxa in the Iskar River.

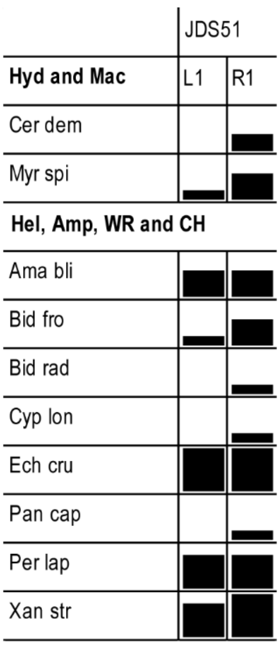


Figure 70 Distribution diagram of all plants in Iskar River

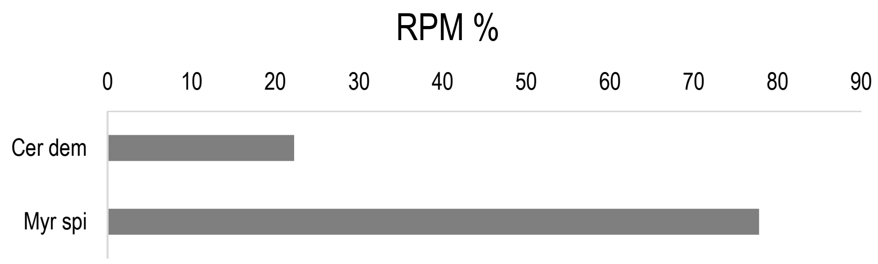


Figure 71 RPM diagram of Hydrophytes in Iskar River

In the Iskar River only angiosperms were present (Figure 72). Chance species were the dominant life form (66.0%) and amphiphytes were not recorded (Figure 72).

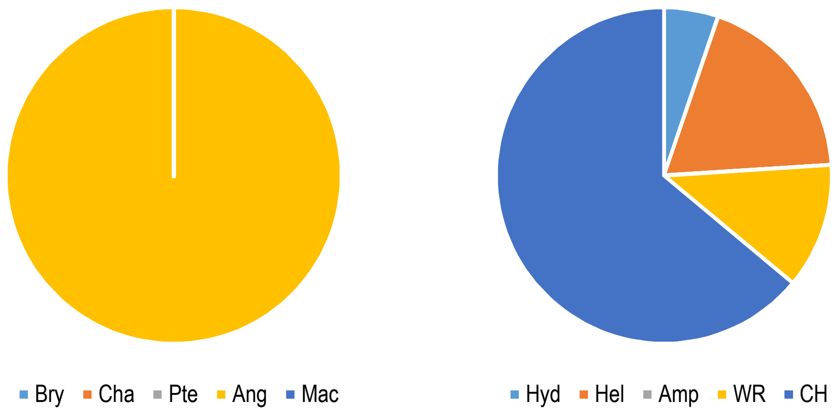


Figure 72 Proportion of plant groups and life forms in Iskar River

3.4.8 Jantra River

The Jantra River was surveyed on two sampling sections, one on the left and one on the right side. During the survey, 10 taxa were identified, two of them as hydrophytes (Figure 73). *C. demersum* and *N. marina* equally contributed to the RPM of hydrophytes with 50.0% (Figure 74) *C. demeresum* was recorded on the left side and *N. marina* on the right side. *E. crus-galli* and *X. strumarium* were the most abundant banks taxa on both sides of the river.

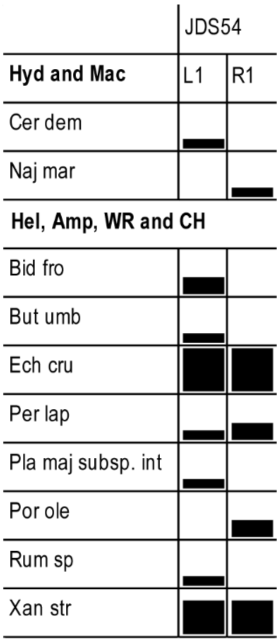


Figure 73 Distribution diagram of all plants in Jantra River

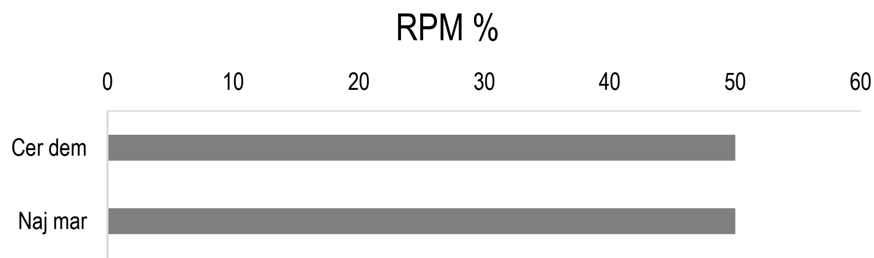


Figure 74 RPM diagram of Hydrophytes in Jantra River

Angiosperms were the only plant group recorded in the Jantra River, while chance species were dominant vegetation life form (94.9%) (Figure 75).

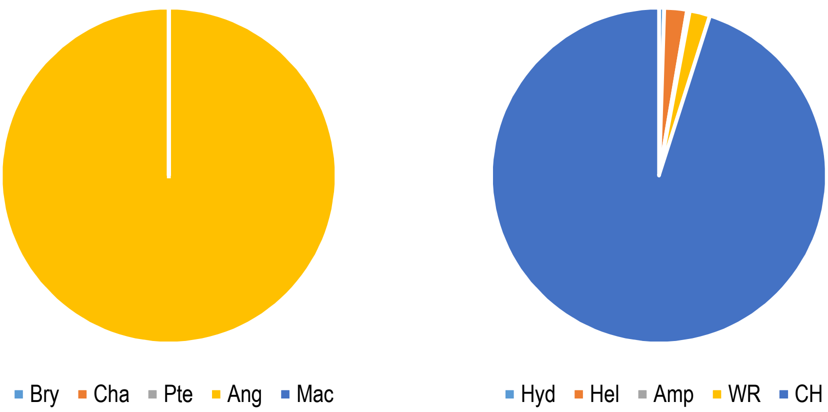


Figure 75 Proportion of plant groups and life forms in Jantra River

3.4.9 Arges River

The Arges River was surveyed on two sampling sections, one on the left and on one the right side. During the survey, 12 taxa were identified with only one hydrophyte taxon *C. demersum* (Figure 76, Figure 77). The right side of the Arges river was more rich in bank taxa and *A. blitum* was the most abundant one. *C. campestris* and *X. strumarium* were the most abundant taxa on the left bank of the Arges River.

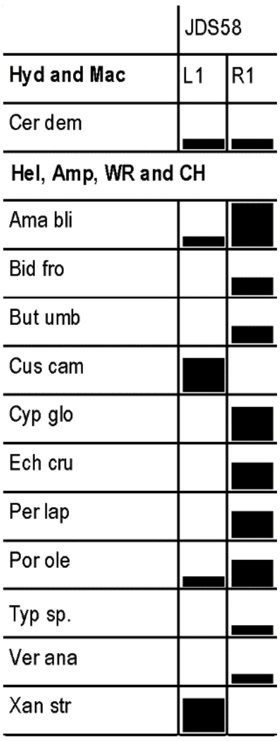


Figure 76 Distribution diagram of all plants in Arges River

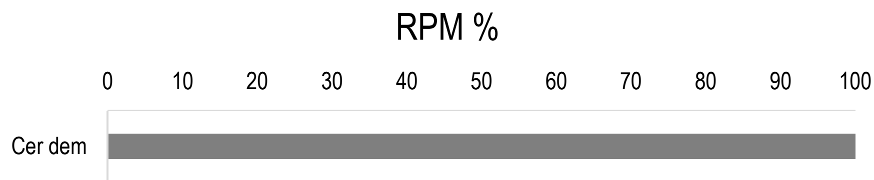


Figure 77 RPM diagram of Hydrophytes in Arges River

In the Arges River only angiosperms were recorded, while chance and water related species were co-dominant life forms (43.6% and 47.21%) (Figure 78).

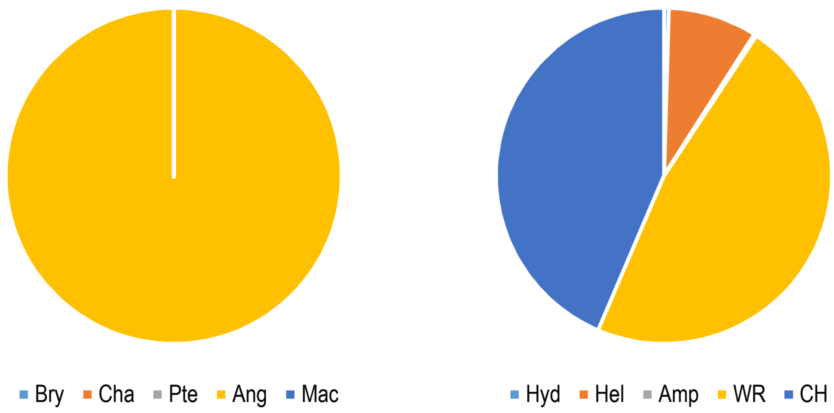


Figure 78 Proportion of plant groups and life forms in Arges River

3.4.10 Siret River

The Siret River was surveyed according to the standard procedure when six sampling sections were sampled, three on the left and three on the right side of the river. During the survey, 16 taxa were identified (Figure 79). Only one hydrophyte taxon was recorded with occasional appearance and that was the floating species *L. minor* (Figure 80).

The most abundant bank species were *C. campestris, E. crus-galli* and *X. strumarium*.

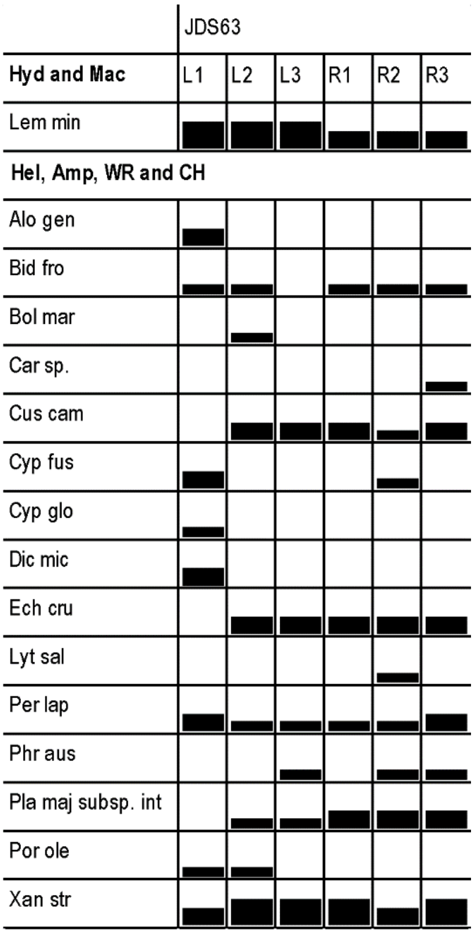


Figure 79 Distribution diagram of all plants in Siret River

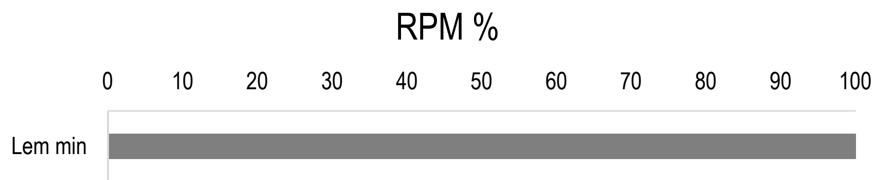


Figure 80 RPM diagram of Hydrophytes in Siret River

In the Siret River angiosperms was the only plant group recorded (Figure 81). Chance species were the plant life form most represented (58.3%), with hydrophytes (27.2%), helophytes (13.0%) and water related species (1.6%) following in decreasing importance.

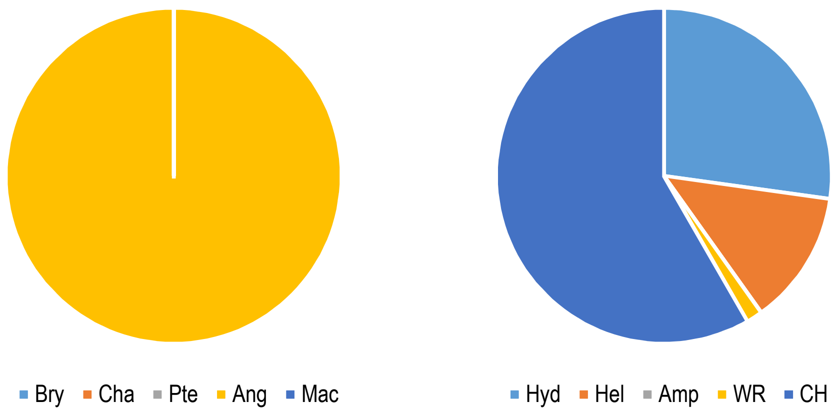


Figure 81 Proportion of plant groups and life forms in Siret River

3.4.11 Prut River

According to the standard procedure, survey was done on six sampling sections, three on the left and three on the right side of the river. During the survey, 21 taxa were identified and three of them were floating hydrophytes (Figure 82). *S. natans* showed highest RPM with 83.3% while other two hydrophyte taxa, *L. minor* and *S. polyrhiza* each contributed with 8.3% of the RPM to the total hydrophytes RPM (Figure 83).

On both sides of the Prut River *A. geniculatus* and *X. strumarium* were the most abundant taxa on the river banks. *A. aremisifolia* and *G. uliginosum* were characteristic taxa of the left bank, while *C. campestris, I. britanica* and *L. salicaria* were characteristic taxa of the right Prut River bank.

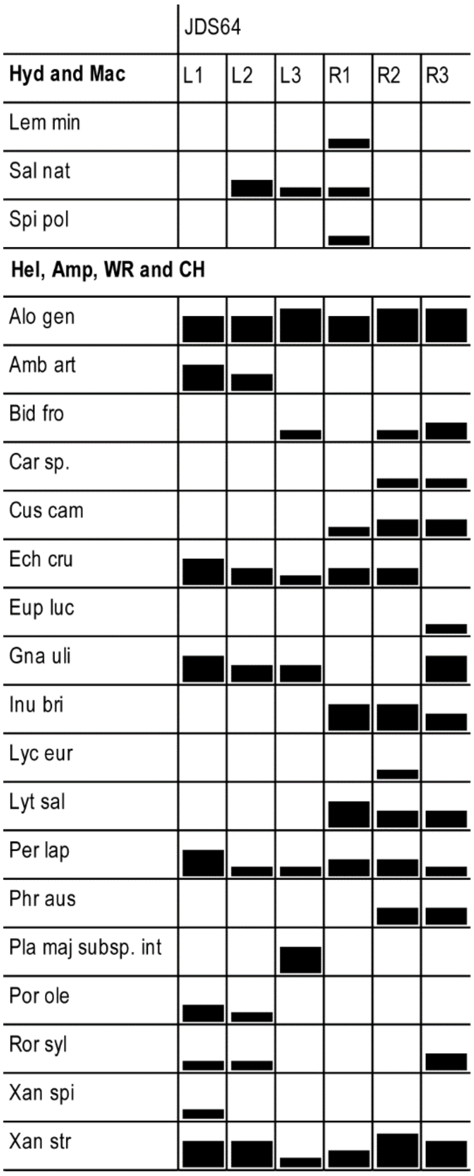


Figure 82 Distribution diagram of all plants in Prut River

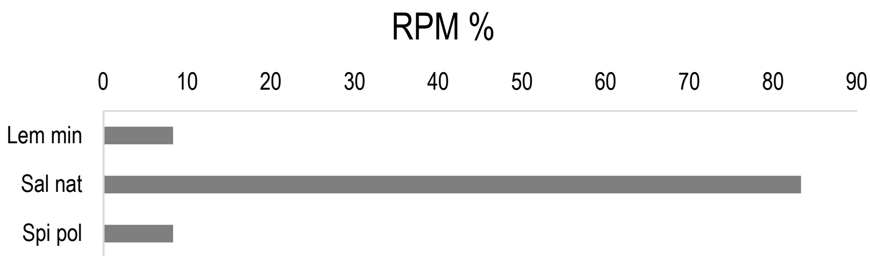


Figure 83 RPM diagram of Hydrophytes in Prut River

Angiosperms and a small proportion of pterydophytes were the dominant plant group in the Prut River (Figure 84). Helophytes and chance species were the life forms with the highest ratio (45.2% and 35.2%), water related species were less represented (17.0%), while hydrophytes and amphiphytes were represented each with less than 2.0%.

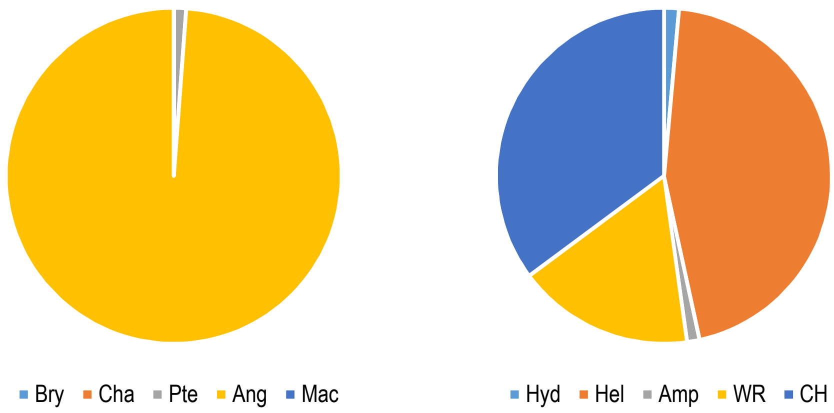


Figure 84 Proportion of plant groups and life forms in Prut River

4 Conclusions

General conclusions

- The JDS3 survey of macrophytes was completed successfully because all sampling sites on the main river were sampled according to standard procedure. Sampling sites sampled with shorter survey length or sites not sampled because of technical difficulties were those located in the tributaries.

- A total of 198 taxa were identified belonging to bryophytes (35 taxa), ferns (4 taxa), angiosperms (150 taxa), charophytes (1 taxon) and other macroalgae (8 taxa).

- In general, angiosperms were the dominant plant group in all River Sections. Bryophytes were the subdominant group in River Sections 1 to 4, and macroalgae were the subdominant group in River Sections 6 to 10.

- The cumulative number of identified taxa in all three Joint Danube Surveys was 249 taxa. 80% of all taxa was identified in JDS3, because of previous extended experience and because of the additional aim of identifying bank vegetation in detail with regard to the hydromorphological status.

Anthropogenic impact

- High Secchi transparency was observed in River Sections 1, 2 and 8. Hydropower plants had highest influence on the increase of Secchi transparency due to the retention of sediments upstream of the dam. Right side of the Danube had lower Secchi transparency than the right side.

- A higher proportion of very slow water velocity was observed in Sections 2, 3, 7 and 10. Natural very slow velocity was only recorded in Section 10 because it was in the Danube Delta, while in other Sections slow flow was a consequence of reservoirs.

- Anthropogenic impact on the Danube was also detected through bank structure and substrate composition, indicated by artificial materials. High anthropogenic impact was observed in Sections of the Upper Reach of the Danube, while it decreased downstream. A decreasing trend of artificial bank structure was observed along the Danube course. Upstream Sections (1-5) had a higher proportion of artificial bank structure (rip rap, concrete) than downstream Sections (6-10). Three types of submerged substrate were most represented: technolithal, pelal and microlithal. Technolithal was dominant in the upper River Sections (1-4) of the Danube, pelal was dominant in lower River Sections (6-10), while microlithal appeared in River Sections from 2 to 8.

- The significant proportion of the macroalga *C. glomerata* in Sections 6 to 10 indicates higher organic pressure in the lower parts of the Danube which can be natural or may be indicator of anthropogenic pressure.

Longitudinal change

- Natural longitudinal change of vegetation was observed from many aspects, but the main changes regarded taxonomic and life form composition. Bryophytes were the dominant aquatic taxa in River Sections 1 to 4, with *C. riparius* as the most representative taxon. River Section 5 was a transitional section where both *C. riparius* and floating taxa (*L. minor*, *S. natans*) were present, while River Section 6 was mainly characterized by floating taxa (*L. minor*, *L. gibba*, *Sa. natans*, *S. polyrhiza*). In River Sections 7 to 10 characteristic taxa were of the genus *Potamogeton*, as well as *C. demersum* and *B. umbellatus*.

- The longitudinal trend was confirmed by NMDS and SIMPER analysis based on species composition. NMDS analysis confirmed change of the plant community following the course of the Danube downstream, and separated the Danube vegetation into two main groups of River Sections with a clear division in Kliská Nemá. SIMPER analysis confirmed differences of the Sections along the Danube course with increasing longitudinal trend of intersection dissimilarity.

Ecological features of macrophytes

- Mosses preferred high turbidity water where light availability wasn't very important because they can grow in shaded habitat with low water transparency. They grew in high masses in parts of the Danube with high water velocity, while standing water wasn't their preferred habitat as suggested by the results of this study.

- Rooted water plants and macroalgae showed similar ecological preference of the habitat. Results suggest that light availability is very important for their growth. They preferred high transparency and low turbidity water and also, low shading effect of the riparian vegetation. Results also suggest that high water velocity acts stressful to rooted water plants and macroalgae because they preferred slow flowing and still water.

- Floating taxa were not affected by light availability (water transparency and shading effect) as indicated by results. Results suggests that they preferred still and slow flowing water although they were also present in Sections with high water velocity where they were drifted into the main river channel from side arms or upstream reservoirs.

- Results of this study suggest that type of the substrate is one of the most important habitat features for development of the plant community. As indicated by CCA analysis, bryophytes preferred hard substrate (technolithal, megalithal), while aquatic angiosperms and macroalgae preferred soft substrates (pelal, microlithal).

- When bank vegetation is considered, results suggest that bryophytes and rural plants preferred artificial substrate (technolithal) and natural large stones. Bryophytes grew on large pieces of hard material while rural plants were filling the gaps between the stones where soil with rich organic matter was deposited from the river.

- Results of this study also suggest that the shading effect had higher impact on bank vegetation than on water plants. It brings to the conclusion that water plants have wider space to spread away from the riparian vegetation while bank species have to adapt or disappear under the influence of the shading effect.

- As indicated with the results, macrophytes didn't prefer vertical or steep banks. It has to be taken into account when water quality is assessed with macrophytes because it will be impossible to use this biological element where it naturally doesn't grow or grows scarcely.

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7 Appendix

Appendix 1 Field protocol – Page 1

River:	Site ID:		Surveyor:		Date:	
JDS 3	Left Bank			Right Bank		
	Section 1	Section 2	Section 3	Section 1	Section 2	Section 3
GPS-WayPt. (from I to)	I	I	I	I	I	I
River-km (from I to)	I	I	I	I	I	I
Photo No. (from I to)	I	I	I	I	I	I
Direct impact						
impoundment [x]						
incoming tributary [x]						
incoming discharge [x]						
other [text]						
Current						
0 / 1 2 3 (none, low, medium, high)						
[m/s]						
Current diversity						
0 / 1 2 3 (none, low, medium, high)						
Turbidity						
0 / 1 2 3 (none, low, medium, high)						
Secchi transparency [5 cm]						
Shading						
0 / 1 2 3 (none, low, medium, high)						
Bank fixation						
none [%]						
groynes [number]						
old/abandoned rip rap [%]						
rip rap [%]						
other [text, %]						
Substrate submerged [%]						
Technolital						
Megalithal (>40 cm)						
Macrolithal (20 - 40 cm)						
Mesolithal (6,3 - 20 cm)						
Microlithal (2,0- 6,3 cm)						
Akal (0,2 - 2,0 cm)						
Psammal (0,063 - 0,2 cm)						
Pelal (< 0,063 cm)						
Bank slope, submerged						
1 2 3 / v (flat, med., steep, vertical)						
Substrate emerged [%]						
Technolital						
Megalithal (>40 cm)						
Macrolithal (20 - 40 cm)						
Mesolithal (6,3 - 20 cm)						
Microlithal (2,0- 6,3 cm)						
Akal (0,2 - 2,0 cm)						
Psammal (0,063 - 0,2 cm)						
Soil						
Bank slope emerged						
1 2 3 / v (flat, med., steep, vertical)						
Bank vegetation						
natural?/antropogenous? [n/a]						
missing [%]						
grasses [%]						
tall forbs [%]						
reeds [%]						
shrubbery [%]						
riparian forest [%]						
broad-leaved forest [%]						
coniferous forest [%]						
mixed forest [%]						
other [text, %]						
Surrounding landuse						
none [%]						
forest [%]						
agriculture [%]						
settlement area [%]						
industry [%]						
other [text, %]						
Remarks						
General:						

- Page 1-

Appendix 2 Field protocol – Page 2

River:		Site ID:		Surveyor:		Date:
JDS 3	Left Bank			Right Bank		
	Section 1	Section 2	Section 3	Section 1	Section 2	Section 3
GPS-WayPt. (from I to)	I	I	I	I	I	I
River-km (from I to)	I	I	I	I	I	I
Photo No. (from I to)	I	I	I	I	I	I
MACROPHYTES - HYDROPHYTES (Spermatophyta, Pteridophyta, Charophyta)						
SPECIES	PMI	PMI	PMI	PMI	PMI	PMI
MACROPHYTES - AMPHIPHYTES and HELOPHYTES (Spermatophyta, Pteridophyta)						
SPECIES	PMI	PMI	PMI	PMI	PMI	PMI
RIPARIAN VEGETATION (Spermatophyta, Pteridophyta), dominant Species						
SPECIES	PMI	PMI	PMI	PMI	PMI	PMI
Remarks						
General:						

Appendix 3 Field protocol – Page 3

River:								**Site ID:**		**Surveyor:**		**Date:**	
JDS 3								**Left Bank**			**Right Bank**		
								Section 1	Section 2	Section 3	Section 1	Section 2	Section 3
GPS-WayPt. (from I to)								I	I	I	I	I	I
River-km (from I to)								I	I	I	I	I	I
Photo No. (from I to)								I	I	I	I	I	I
MACROPHYTES - AQUATIC MOSSES													
SPECIES (ID)	Stone	Clay	Soil	Wood	Sub	WL	SPZ	PMI	PMI	PMI	PMI	PMI	PMI
Remarks													
General:													

Appendix 4 Longitude and latitude for the beginning and the end of each sampling section. JDSx LS1 – beginning of section 1, JDSx LS2 – beginning of section 2 and end of section 1, JDSx LS3 – beginning of section 4 and end of section 2, JDSx LS4 –end of section 3. LS – left side, RS – right side.

Name	Longitude	Latitude
JDS01 LS1	10° 1' 33,700" E	48° 25' 26,500" N
JDS01 LS2	10° 2' 9,000" E	48° 25' 43,400" N
JDS01 RS1	10° 1' 36,600" E	48° 25' 23,000" N
JDS01 RS2	10° 2' 10,200" E	48° 25' 41,000" N
JDS02 LS1	11° 54' 6,638" E	48° 54' 31,838" N
JDS02 LS2	11° 53' 17,884" E	48° 54' 31,349" N
JDS02 LS3	11° 52' 30,918" E	48° 54' 44,791" N
JDS02 LS4	11° 51' 44,957" E	48° 54' 58,464" N
JDS02 RS1	11° 54' 6,698" E	48° 54' 27,607" N
JDS02 RS2	11° 53' 17,332" E	48° 54' 28,371" N
JDS02 RS3	11° 52' 29,596" E	48° 54' 42,530" N
JDS02 RS4	11° 51' 44,821" E	48° 54' 55,045" N
JDS03 UPS LS1	12° 20' 5,491" E	48° 58' 44,353" N
JDS03 UPS LS2	12° 19' 47,973" E	48° 59' 1,786" N
JDS03 UPS LS3	12° 20' 31,282" E	48° 59' 19,218" N
JDS03 UPS LS4	12° 20' 49,974" E	48° 59' 49,962" N
JDS03 UPS RS1	12° 19' 59,459" E	48° 58' 33,906" N
JDS03 UPS RS2	12° 19' 33,891" E	48° 59' 1,561" N
JDS03 UPS RS3	12° 20' 15,835" E	48° 59' 22,186" N
JDS03 UPS RS4	12° 20' 33,140" E	48° 59' 49,765" N
JDS03 DOW LS1	12° 21' 18,491" E	48° 58' 34,839" N
JDS03 DOW LS2	12° 21' 58,925" E	48° 58' 22,119" N
JDS03 DOW LS3	12° 22' 34,279" E	48° 58' 23,130" N
JDS03 DOW LS4	12° 23' 3,202" E	48° 58' 49,767" N
JDS03 DOW RS1	12° 21' 14,468" E	48° 58' 30,353" N
JDS03 DOW RS2	12° 21' 53,093" E	48° 58' 19,618" N
JDS03 DOW RS3	12° 22' 35,731" E	48° 58' 19,924" N
JDS03 DOW RS4	12° 23' 4,236" E	48° 58' 47,194" N
JDS04 LS1	12° 57' 26,424" E	48° 49' 35,199" N
JDS04 LS2	12° 56' 41,600" E	48° 49' 48,396" N
JDS04 LS3	12° 56' 0,749" E	48° 50' 7,582" N
JDS04 LS4	12° 55' 19,221" E	48° 50' 24,194" N
JDS04 RS1	12° 57' 23,350" E	48° 49' 28,769" N
JDS04 RS2	12° 56' 38,468" E	48° 49' 42,676" N
JDS04 RS3	12° 55' 55,981" E	48° 50' 0,906" N
JDS04 RS4	12° 55' 12,878" E	48° 50' 19,446" N
JDS05 LS1	13° 6' 34,985" E	48° 41' 9,386" N
JDS05 LS2	13° 5' 44,480" E	48° 41' 2,767" N
JDS05 LS3	13° 5' 16,001" E	48° 41' 27,161" N
JDS05 LS4	13° 5' 36,783" E	48° 41' 44,198" N
JDS05 RS1	13° 6' 32,807" E	48° 41' 7,123" N
JDS05 RS2	13° 5' 46,000" E	48° 40' 59,941" N
JDS05 RS3	13° 5' 4,517" E	48° 41' 15,079" N
JDS05 RS4	13° 5' 31,477" E	48° 41' 47,526" N
JDS06 LS1	13° 41' 23,111" E	48° 31' 40,462" N
JDS06 LS2	13° 40' 36,628" E	48° 31' 53,260" N
JDS06 LS3	13° 39' 54,295" E	48° 32' 7,703" N
JDS06 LS4	13° 39' 32,051" E	48° 32' 36,672" N
JDS06 RS1	13° 41' 49,111" E	48° 31' 15,213" N
JDS06 RS2	13° 41' 11,285" E	48° 31' 33,183" N
JDS06 RS3	13° 40' 32,441" E	48° 31' 46,207" N
JDS06 RS4	13° 39' 48,591" E	48° 32' 2,091" N
JDS07 LS1	14° 24' 58,194" E	48° 15' 24,429" N
JDS07 LS2	14° 24' 14,684" E	48° 15' 30,110" N
JDS07 LS3	14° 23' 40,463" E	48° 15' 44,982" N
JDS07 LS4	14° 23' 12,707" E	48° 16' 4,318" N

Name	Longitude	Latitude
JDS07 RS1	14° 24' 55,735" E	48° 15' 14,350" N
JDS07 RS2	14° 24' 6,451" E	48° 15' 22,284" N
JDS07 RS3	14° 23' 27,852" E	48° 15' 40,025" N
JDS07 RS4	14° 23' 1,831" E	48° 15' 57,229" N
JDS08 LS1	15° 31' 31,767" E	48° 23' 12,966" N
JDS08 LS2	15° 31' 56,230" E	48° 23' 4,729" N
JDS08 LS3	15° 32' 59,780" E	48° 23' 20,238" N
JDS08 LS4	15° 33' 41,137" E	48° 23' 38,267" N
JDS08 RS1	15° 31' 40,433" E	48° 22' 57,691" N
JDS08 RS2	15° 32' 30,142" E	48° 23' 1,194" N
JDS08 RS3	15° 33' 17,997" E	48° 23' 15,173" N
JDS08 RS4	15° 33' 49,496" E	48° 23' 30,822" N
JDS09 LS1	16° 19' 50,480" E	48° 19' 52,414" N
JDS09 LS2	16° 20' 12,448" E	48° 19' 22,660" N
JDS09 LS3	16° 20' 32,896" E	48° 18' 52,193" N
JDS09 LS4	16° 20' 39,836" E	48° 18' 22,536" N
JDS09 RS1	16° 19' 39,490" E	48° 19' 49,372" N
JDS09 RS2	16° 19' 57,169" E	48° 19' 21,018" N
JDS09 RS3	16° 20' 15,580" E	48° 18' 52,164" N
JDS09 RS4	16° 20' 28,338" E	48° 18' 20,621" N
JDS11 LS1	16° 56' 15,223" E	48° 9' 0,673" N
JDS11 LS2	16° 56' 44,311" E	48° 9' 25,895" N
JDS11 LS3	16° 57' 5,479" E	48° 9' 54,479" N
JDS11 LS4	16° 57' 37,076" E	48° 10' 18,460" N
JDS11 RS1	16° 56' 15,047" E	48° 8' 52,105" N
JDS11 RS2	16° 56' 46,529" E	48° 9' 16,636" N
JDS11 RS3	16° 57' 13,936" E	48° 9' 49,104" N
JDS11 RS4	16° 57' 42,332" E	48° 10' 13,904" N
JDS13 LS1	17° 2' 36,060" E	48° 8' 29,749" N
JDS13 LS2	17° 3' 32,375" E	48° 8' 39,678" N
JDS13 LS3	17° 4' 20,572" E	48° 8' 37,104" N
JDS13 LS4	17° 5' 12,538" E	48° 8' 28,241" N
JDS13 RS1	17° 2' 38,772" E	48° 8' 25,032" N
JDS13 RS2	17° 3' 43,538" E	48° 8' 33,976" N
JDS13 RS3	17° 4' 17,846" E	48° 8' 29,612" N
JDS13 RS4	17° 5' 4,056" E	48° 8' 21,736" N
JDS14 RS1	17° 12' 14,285" E	48° 2' 34,098" N
JDS14 RS2	17° 11' 50,705" E	48° 2' 48,862" N
JDS14 RS3	17° 11' 27,985" E	48° 3' 2,160" N
JDS14 RS4	17° 10' 58,909" E	48° 3' 0,717" N
JDS15 LS1	17° 39' 13,870" E	47° 47' 36,796" N
JDS15 LS2	17° 39' 55,310" E	47° 47' 17,538" N
JDS15 LS3	17° 40' 27,707" E	47° 46' 55,448" N
JDS15 LS4	17° 41' 5,122" E	47° 46' 40,360" N
JDS15 RS1	17° 39' 6,764" E	47° 47' 29,386" N
JDS15 RS2	17° 39' 44,287" E	47° 47' 12,815" N
JDS15 RS3	17° 40' 19,304" E	47° 46' 53,684" N
JDS15 RS4	17° 40' 56,766" E	47° 46' 35,558" N
JDS16 LS1	17° 47' 20,657" E	47° 44' 18,758" N
JDS16 LS2	17° 46' 45,305" E	47° 44' 11,785" N
JDS16 RS1	17° 47' 24,669" E	47° 44' 16,179" N
JDS16 RS2	17° 46' 47,985" E	47° 44' 6,583" N
JDS17 LS1	17° 50' 12,890" E	47° 44' 32,082" N
JDS17 LS2	17° 51' 9,122" E	47° 44' 44,506" N
JDS17 LS3	17° 51' 36,230" E	47° 44' 48,800" N
JDS17 LS4	17° 52' 24,157" E	47° 44' 41,928" N
JDS17 RS2	17° 50' 51,036" E	47° 44' 30,282" N
JDS17 RS3	17° 51' 33,671" E	47° 44' 36,222" N
JDS17 RS4	17° 52' 19,470" E	47° 44' 35,142" N
JDS18 LS1	18° 8' 45,792" E	47° 45' 9,191" N
JDS18 LS2	18° 8' 35,117" E	47° 45' 40,597" N
JDS18 LS3	18° 8' 30,891" E	47° 46' 17,975" N

Name	Longitude	Latitude
JDS18 LS4	18° 8' 16,938" E	47° 46' 42,562" N
JDS18 RS1	18° 8' 36,829" E	47° 45' 14,543" N
JDS18 RS2	18° 8' 35,253" E	47° 45' 50,422" N
JDS18 RS3	18° 8' 28,198" E	47° 46' 18,066" N
JDS18 RS4	18° 8' 12,392" E	47° 46' 41,358" N
JDS19 LS1	18° 12' 29,128" E	47° 44' 41,140" N
JDS19 LS2	18° 13' 22,516" E	47° 44' 37,201" N
JDS19 LS3	18° 14' 8,642" E	47° 44' 31,805" N
JDS19 LS4	18° 14' 54,337" E	47° 44' 30,340" N
JDS19 RS1	18° 12' 38,585" E	47° 44' 26,819" N
JDS19 RS2	18° 13' 21,738" E	47° 44' 25,300" N
JDS19 RS3	18° 14' 9,200" E	47° 44' 18,089" N
JDS19 RS4	18° 14' 57,469" E	47° 44' 18,114" N
JDS20 LS1	18° 51' 48,837" E	47° 48' 53,885" N
JDS20 LS2	18° 52' 38,784" E	47° 48' 49,244" N
JDS20 LS3	18° 53' 24,342" E	47° 48' 39,614" N
JDS20 LS4	18° 54' 5,886" E	47° 48' 24,264" N
JDS20 RS1	18° 51' 43,682" E	47° 48' 38,250" N
JDS20 RS2	18° 52' 23,214" E	47° 48' 36,069" N
JDS20 RS3	18° 52' 56,298" E	47° 48' 29,394" N
JDS20 RS4	18° 53' 45,330" E	47° 48' 12,261" N
JDS21 LS1	19° 6' 6,898" E	47° 36' 49,479" N
JDS21 LS2	19° 6' 23,612" E	47° 37' 15,067" N
JDS21 LS3	19° 6' 35,957" E	47° 37' 46,542" N
JDS21 LS4	19° 6' 51,527" E	47° 38' 15,119" N
JDS21 RS1	19° 5' 50,226" E	47° 36' 48,607" N
JDS21 RS2	19° 6' 8,075" E	47° 37' 19,394" N
JDS21 RS3	19° 6' 21,953" E	47° 37' 49,598" N
JDS21 RS4	19° 6' 35,831" E	47° 38' 19,860" N
JDS22 LS1	19° 0' 45,738" E	47° 23' 13,902" N
JDS22 LS2	19° 0' 6,026" E	47° 23' 9,989" N
JDS22 LS3	18° 59' 22,103" E	47° 23' 2,652" N
JDS22 LS4	18° 58' 39,904" E	47° 22' 53,465" N
JDS22 RS1	19° 0' 30,402" E	47° 23' 23,813" N
JDS22 RS2	18° 59' 45,708" E	47° 23' 21,318" N
JDS22 RS3	18° 59' 11,522" E	47° 23' 14,237" N
JDS22 RS4	18° 58' 31,606" E	47° 23' 1,961" N
JDS24 LS1	18° 55' 47,122" E	46° 49' 0,307" N
JDS24 LS2	18° 55' 38,521" E	46° 49' 31,087" N
JDS24 LS3	18° 55' 39,025" E	46° 49' 59,840" N
JDS24 LS4	18° 55' 37,247" E	46° 50' 37,388" N
JDS24 RS1	18° 55' 24,251" E	46° 49' 7,349" N
JDS24 RS2	18° 55' 18,890" E	46° 49' 38,550" N
JDS24 RS3	18° 55' 20,583" E	46° 50' 9,766" N
JDS24 RS4	18° 55' 23,084" E	46° 50' 39,224" N
JDS25 LS1	18° 53' 17,041" E	46° 38' 3,951" N
JDS25 LS2	18° 52' 38,503" E	46° 37' 43,792" N
JDS25 LS3	18° 52' 12,212" E	46° 37' 17,836" N
JDS25 LS4	18° 51' 46,120" E	46° 36' 50,436" N
JDS25 RS1	18° 52' 52,957" E	46° 38' 18,014" N
JDS25 RS2	18° 52' 18,657" E	46° 37' 43,640" N
JDS25 RS3	18° 51' 51,487" E	46° 37' 17,998" N
JDS25 RS4	18° 51' 27,374" E	46° 36' 52,819" N
JDS26 LS1	18° 55' 21,335" E	46° 12' 16,639" N
JDS26 LS2	18° 54' 53,338" E	46° 12' 43,625" N
JDS26 LS3	18° 54' 34,830" E	46° 13' 17,630" N
JDS26 LS4	18° 54' 42,790" E	46° 13' 47,283" N
JDS26 RS1	18° 54' 58,352" E	46° 12' 13,629" N
JDS26 RS2	18° 54' 38,747" E	46° 12' 42,898" N
JDS26 RS3	18° 54' 19,195" E	46° 13' 24,297" N
JDS26 RS4	18° 54' 24,153" E	46° 13' 45,224" N
JDS27 LS1	18° 48' 53,737" E	45° 54' 37,015" N

Name	Longitude	Latitude
JDS27 LS2	18° 48' 21,114" E	45° 55' 1,862" N
JDS27 LS3	18° 47' 45,809" E	45° 55' 22,760" N
JDS27 LS4	18° 47' 9,287" E	45° 55' 42,967" N
JDS27 RS1	18° 48' 35,651" E	45° 54' 31,280" N
JDS27 RS2	18° 48' 3,128" E	45° 54' 53,003" N
JDS27 RS3	18° 47' 29,188" E	45° 55' 13,713" N
JDS27 RS4	18° 46' 57,191" E	45° 55' 34,871" N
JDS28 LS1	18° 54' 57,506" E	45° 33' 22,579" N
JDS28 LS2	18° 54' 14,432" E	45° 33' 30,510" N
JDS28 LS3	18° 53' 36,596" E	45° 33' 46,858" N
JDS28 LS4	18° 53' 25,692" E	45° 34' 19,178" N
JDS30 LS1	19° 4' 28,653" E	45° 31' 54,898" N
JDS30 LS2	19° 3' 46,825" E	45° 32' 2,958" N
JDS30 LS3	19° 3' 0,954" E	45° 32' 4,988" N
JDS30 LS4	19° 2' 21,721" E	45° 32' 6,227" N
JDS30 RS1	19° 4' 24,039" E	45° 31' 42,577" N
JDS30 RS2	19° 3' 44,082" E	45° 31' 47,255" N
JDS30 RS3	19° 3' 8,474" E	45° 31' 52,730" N
JDS30 RS4	19° 2' 25,865" E	45° 31' 55,366" N
JDS31 LS1	19° 22' 8,551" E	45° 13' 58,235" N
JDS31 LS2	19° 21' 30,107" E	45° 14' 3,491" N
JDS31 LS3	19° 20' 43,307" E	45° 14' 4,582" N
JDS31 LS4	19° 19' 59,797" E	45° 14' 5,863" N
JDS31 RS1	19° 22' 10,398" E	45° 13' 47,978" N
JDS31 RS2	19° 21' 25,117" E	45° 13' 47,172" N
JDS31 RS3	19° 20' 40,452" E	45° 13' 44,720" N
JDS31 RS4	19° 19' 58,483" E	45° 13' 50,499" N
JDS32 LS1	19° 48' 14,252" E	45° 13' 24,301" N
JDS32 LS2	19° 48' 57,978" E	45° 13' 24,740" N
JDS32 LS3	19° 49' 40,141" E	45° 13' 34,356" N
JDS32 LS4	19° 50' 20,101" E	45° 13' 50,919" N
JDS32 RS1	19° 48' 19,660" E	45° 13' 5,001" N
JDS32 RS2	19° 49' 5,945" E	45° 13' 11,903" N
JDS32 RS3	19° 49' 49,040" E	45° 13' 19,254" N
JDS32 RS4	19° 50' 28,263" E	45° 13' 39,623" N
JDS33 LS1	19° 53' 45,571" E	45° 15' 30,611" N
JDS33 LS2	19° 54' 28,048" E	45° 15' 15,289" N
JDS33 LS3	19° 55' 0,188" E	45° 14' 45,870" N
JDS33 LS4	19° 55' 12,245" E	45° 14' 16,015" N
JDS33 RS1	19° 53' 32,856" E	45° 15' 22,911" N
JDS33 RS2	19° 54' 8,334" E	45° 15' 3,330" N
JDS33 RS3	19° 54' 39,978" E	45° 14' 40,333" N
JDS33 RS4	19° 54' 56,426" E	45° 14' 10,849" N
JDS34 LS1	20° 15' 9,972" E	45° 9' 17,154" N
JDS34 LS2	20° 14' 34,253" E	45° 9' 40,799" N
JDS34 LS3	20° 13' 57,392" E	45° 10' 1,279" N
JDS34 LS4	20° 13' 30,133" E	45° 10' 10,776" N
JDS34 RS1	20° 15' 1,667" E	45° 9' 1,739" N
JDS34 RS2	20° 14' 27,633" E	45° 9' 27,479" N
JDS34 RS3	20° 13' 51,467" E	45° 9' 48,020" N
JDS34 RS4	20° 13' 24,157" E	45° 9' 58,720" N
JDS35 LS1	20° 16' 53,288" E	45° 8' 38,427" N
JDS35 LS2	20° 16' 57,868" E	45° 9' 13,196" N
JDS35 LS3	20° 16' 39,431" E	45° 9' 47,113" N
JDS35 LS4	20° 16' 48,728" E	45° 10' 20,148" N
JDS35 RS1	20° 16' 43,695" E	45° 8' 39,398" N
JDS35 RS2	20° 16' 47,208" E	45° 9' 12,387" N
JDS35 RS3	20° 16' 34,101" E	45° 9' 46,531" N
JDS35 RS4	20° 16' 37,319" E	45° 10' 24,579" N
JDS36 LS1	20° 22' 2,395" E	45° 1' 4,227" N
JDS36 LS2	20° 21' 36,342" E	45° 0' 26,115" N
JDS36 LS3	20° 20' 54,877" E	45° 0' 9,313" N

Name	Longitude	Latitude
JDS36 LS4	20° 20' 11,749" E	44° 59' 58,258" N
JDS36 RS1	20° 21' 44,859" E	45° 1' 4,948" N
JDS36 RS2	20° 21' 30,942" E	45° 0' 33,930" N
JDS36 RS3A	20° 20' 52,249" E	45° 0' 16,211" N
JDS36 RS3B	20° 20' 33,094" E	45° 0' 23,472" N
JDS36 RS4	20° 20' 7,436" E	45° 0' 7,837" N
JDS37 LS1	20° 23' 51,672" E	44° 47' 37,502" N
JDS37 LS2	20° 23' 8,976" E	44° 47' 25,860" N
JDS37 RS1	20° 23' 53,538" E	44° 47' 34,818" N
JDS37 RS2	20° 23' 10,910" E	44° 47' 23,633" N
JDS38 LS1	20° 34' 34,417" E	44° 51' 12,406" N
JDS38 LS2	20° 33' 53,248" E	44° 50' 57,678" N
JDS38 LS3	20° 33' 15,343" E	44° 50' 42,857" N
JDS38 LS4	20° 32' 41,449" E	44° 50' 24,871" N
JDS38 RS1	20° 34' 51,579" E	44° 50' 37,920" N
JDS38 RS2	20° 34' 8,695" E	44° 50' 40,211" N
JDS38 RS3	20° 33' 32,645" E	44° 50' 26,513" N
JDS38 RS4	20° 33' 2,264" E	44° 50' 5,161" N
JDS39 LS1	20° 38' 58,900" E	44° 49' 14,350" N
JDS39 LS2	20° 38' 42,022" E	44° 48' 44,690" N
JDS39 LS3	20° 38' 14,514" E	44° 48' 22,356" N
JDS39 LS4	20° 38' 6,309" E	44° 47' 52,976" N
JDS39 RS1	20° 38' 37,482" E	44° 49' 15,384" N
JDS39 RS2	20° 38' 19,856" E	44° 48' 49,957" N
JDS39 RS3	20° 38' 0,600" E	44° 48' 25,524" N
JDS39 RS4	20° 37' 42,744" E	44° 47' 57,354" N
JDS40 LS1	20° 59' 49,963" E	44° 43' 26,054" N
JDS40 LS2	20° 59' 7,264" E	44° 43' 6,730" N
JDS40 LS3	20° 58' 43,806" E	44° 42' 51,055" N
JDS40 LS4	20° 58' 10,607" E	44° 42' 29,099" N
JDS40 RS1	21° 0' 22,705" E	44° 42' 58,665" N
JDS40 RS2	20° 59' 42,299" E	44° 42' 48,074" N
JDS40 RS3	20° 59' 3,390" E	44° 42' 32,321" N
JDS40 RS4	20° 58' 29,665" E	44° 42' 12,762" N
JDS41 LS1	21° 2' 17,520" E	44° 42' 16,009" N
JDS41 LS2	21° 2' 8,488" E	44° 41' 47,800" N
JDS41 LS3	21° 2' 32,600" E	44° 41' 22,459" N
JDS41 LS4	21° 2' 48,991" E	44° 40' 58,922" N
JDS41 RS1	21° 2' 20,677" E	44° 42' 15,833" N
JDS41 RS2	21° 2' 11,220" E	44° 41' 47,954" N
JDS41 RS3	21° 2' 33,144" E	44° 41' 24,483" N
JDS41 RS4	21° 2' 52,238" E	44° 40' 58,019" N
JDS42 LS1	21° 7' 24,909" E	44° 44' 11,710" N
JDS42 LS2	21° 6' 44,298" E	44° 44' 1,849" N
JDS42 LS3	21° 6' 4,522" E	44° 43' 46,150" N
JDS42 LS4	21° 5' 25,904" E	44° 43' 32,952" N
JDS42 RS1	21° 7' 29,942" E	44° 43' 46,715" N
JDS42 RS2	21° 6' 57,150" E	44° 43' 44,177" N
JDS42 RS3	21° 6' 23,663" E	44° 43' 33,337" N
JDS42 RS4	21° 5' 43,505" E	44° 43' 19,499" N
JDS43 LS1	21° 23' 27,312" E	44° 48' 20,333" N
JDS43 LS2	21° 23' 36,805" E	44° 47' 58,200" N
JDS43 LS3	21° 23' 37,421" E	44° 47' 26,603" N
JDS43 LS4	21° 23' 50,878" E	44° 46' 56,655" N
JDS43 RS1	21° 22' 50,394" E	44° 48' 7,967" N
JDS43 RS2	21° 22' 59,369" E	44° 47' 37,072" N
JDS43 RS3	21° 23' 5,881" E	44° 47' 7,148" N
JDS43 RS4	21° 23' 30,991" E	44° 46' 41,416" N
JDS44 LS1	21° 41' 48,620" E	44° 39' 51,462" N
JDS44 LS2	21° 42' 26,395" E	44° 39' 35,899" N
JDS44 LS3	21° 43' 2,406" E	44° 39' 19,649" N
JDS44 LS4	21° 43' 52,360" E	44° 39' 18,198" N

Name	Longitude	Latitude
JDS44 RS1	21° 41' 49,283" E	44° 39' 41,083" N
JDS44 RS2	21° 42' 28,480" E	44° 39' 21,157" N
JDS44 RS3	21° 43' 8,991" E	44° 39' 8,276" N
JDS44 RS4	21° 43' 54,303" E	44° 39' 9,742" N
JDS45 LS1	22° 24' 8,205" E	44° 41' 43,559" N
JDS45 LS2	22° 23' 48,894" E	44° 41' 22,384" N
JDS45 LS3	22° 23' 17,218" E	44° 41' 2,112" N
JDS45 LS4	22° 22' 36,228" E	44° 40' 49,282" N
JDS45 RS1	22° 24' 36,666" E	44° 41' 12,664" N
JDS45 RS2	22° 24' 5,987" E	44° 40' 45,203" N
JDS45 RS3	22° 23' 24,957" E	44° 40' 29,384" N
JDS45 RS4	22° 22' 38,006" E	44° 40' 16,284" N
JDS46 LS1	22° 42' 45,446" E	44° 36' 18,490" N
JDS46 LS2	22° 43' 7,090" E	44° 35' 59,403" N
JDS46 LS3	22° 43' 37,841" E	44° 35' 32,878" N
JDS46 LS4	22° 44' 6,713" E	44° 35' 9,276" N
JDS46 RS1	22° 42' 21,478" E	44° 36' 3,409" N
JDS46 RS2	22° 42' 39,974" E	44° 35' 34,753" N
JDS46 RS3	22° 43' 11,932" E	44° 35' 14,662" N
JDS46 RS4	22° 43' 42,964" E	44° 34' 51,935" N
JDS47 LS1	22° 41' 22,543" E	44° 15' 38,348" N
JDS47 LS2	22° 41' 11,145" E	44° 16' 22,897" N
JDS47 LS3	22° 40' 51,506" E	44° 16' 50,427" N
JDS47 LS4	22° 40' 19,981" E	44° 17' 12,052" N
JDS47 RS1	22° 41' 0,510" E	44° 15' 32,559" N
JDS47 RS2	22° 40' 49,444" E	44° 16' 2,597" N
JDS47 RS3	22° 40' 34,140" E	44° 16' 33,373" N
JDS47 RS4	22° 40' 6,251" E	44° 16' 56,766" N
JDS48 LS1	22° 40' 22,210" E	44° 12' 55,456" N
JDS48 LS2	22° 40' 4,149" E	44° 12' 45,632" N
JDS48 RS1	22° 40' 25,895" E	44° 12' 52,802" N
JDS48 RS2	22° 40' 4,517" E	44° 12' 44,814" N
JDS49 LS1	22° 47' 13,956" E	44° 10' 24,053" N
JDS49 LS2	22° 47' 44,934" E	44° 10' 3,180" N
JDS49 LS3	22° 48' 21,560" E	44° 9' 44,712" N
JDS49 LS4	22° 48' 57,240" E	44° 9' 27,180" N
JDS49 RS1	22° 46' 50,639" E	44° 10' 6,064" N
JDS49 RS2	22° 47' 24,004" E	44° 9' 43,592" N
JDS49 RS3	22° 47' 59,881" E	44° 9' 22,378" N
JDS49 RS4	22° 48' 33,116" E	44° 9' 4,475" N
JDS50 LS1	23° 53' 50,901" E	43° 45' 4,165" N
JDS50 LS2	23° 54' 47,311" E	43° 44' 56,151" N
JDS50 LS3	23° 55' 31,620" E	43° 44' 52,440" N
JDS50 LS4	23° 56' 13,902" E	43° 44' 52,382" N
JDS50 RS1	23° 53' 59,878" E	43° 44' 45,010" N
JDS50 RS2	23° 54' 41,274" E	43° 44' 38,756" N
JDS50 RS3	23° 55' 29,050" E	43° 44' 34,771" N
JDS50 RS4	23° 56' 16,732" E	43° 44' 33,111" N
JDS51 LS1	24° 26' 26,771" E	43° 43' 54,773" N
JDS51 LS2	24° 26' 56,184" E	43° 43' 38,437" N
JDS51 RS1	24° 26' 29,214" E	43° 43' 55,654" N
JDS51 RS2	24° 26' 57,353" E	43° 43' 39,640" N
JDS52 LS1	24° 48' 23,450" E	43° 42' 46,656" N
JDS52 LS2	24° 49' 26,947" E	43° 42' 58,007" N
JDS52 LS3	24° 50' 7,958" E	43° 43' 0,894" N
JDS52 LS4	24° 50' 43,166" E	43° 42' 53,744" N
JDS52 RS1	24° 48' 30,867" E	43° 42' 30,521" N
JDS52 RS2	24° 49' 11,680" E	43° 42' 38,408" N
JDS52 RS3	24° 49' 40,973" E	43° 42' 38,826" N
JDS52 RS4	24° 50' 19,860" E	43° 42' 25,873" N
JDS53 LS1	25° 23' 51,158" E	43° 37' 23,898" N
JDS53 LS2	25° 24' 37,800" E	43° 37' 23,358" N

Name	Longitude	Latitude
JDS53 LS3	25° 25' 10,816" E	43° 37' 30,537" N
JDS53 LS4	25° 25' 52,734" E	43° 37' 43,759" N
JDS53 RS1	25° 24' 1,562" E	43° 37' 0,541" N
JDS53 RS2	25° 24' 42,844" E	43° 37' 8,292" N
JDS53 RS3	25° 25' 24,341" E	43° 37' 14,729" N
JDS53 RS4	25° 26' 7,073" E	43° 37' 22,559" N
JDS54 LS1	25° 34' 10,978" E	43° 38' 21,435" N
JDS54 LS2	25° 34' 2,639" E	43° 37' 51,816" N
JDS54 RS1	25° 34' 13,063" E	43° 38' 21,650" N
JDS54 RS2	25° 34' 4,775" E	43° 37' 51,417" N
JDS55 LS1	25° 37' 42,330" E	43° 40' 39,835" N
JDS55 LS2	25° 37' 0,131" E	43° 40' 24,348" N
JDS55 LS3	25° 36' 13,734" E	43° 40' 7,583" N
JDS55 LS4	25° 35' 37,684" E	43° 39' 48,085" N
JDS55 RS1	25° 37' 53,904" E	43° 40' 13,893" N
JDS55 RS2	25° 37' 13,544" E	43° 40' 2,701" N
JDS55 RS3	25° 36' 36,288" E	43° 39' 46,156" N
JDS55 RS4	25° 36' 0,983" E	43° 39' 26,838" N
JDS57 LS1	26° 0' 27,780" E	43° 53' 28,836" N
JDS57 LS2	26° 1' 22,152" E	43° 53' 48,024" N
JDS57 LS3	26° 2' 3,441" E	43° 54' 7,089" N
JDS57 LS4	26° 2' 39,169" E	43° 54' 22,936" N
JDS57 RS1	26° 0' 58,414" E	43° 53' 13,553" N
JDS57 RS2	26° 1' 42,218" E	43° 53' 28,025" N
JDS57 RS3	26° 2' 24,702" E	43° 53' 41,964" N
JDS57 RS4	26° 3' 4,910" E	43° 53' 57,919" N
JDS58 LS1	26° 37' 5,822" E	44° 3' 35,336" N
JDS58 LS2	26° 37' 16,502" E	44° 3' 51,587" N
JDS58 RS1	26° 36' 53,465" E	44° 3' 32,878" N
JDS58 RS2	26° 37' 12,415" E	44° 3' 52,476" N
JDS59 LS1	26° 39' 16,448" E	44° 3' 58,036" N
JDS59 LS2	26° 39' 55,991" E	44° 4' 13,994" N
JDS59 LS3	26° 40' 37,114" E	44° 4' 28,985" N
JDS59 LS4	26° 41' 20,508" E	44° 4' 41,606" N
JDS59 RS1	26° 39' 23,638" E	44° 3' 25,816" N
JDS59 RS2A	26° 40' 23,415" E	44° 4' 2,014" N
JDS59 RS2B	26° 40' 9,692" E	44° 3' 26,010" N
JDS59 RS3	26° 41' 4,315" E	44° 4' 13,634" N
JDS59 RS4	26° 41' 47,893" E	44° 4' 15,362" N
JDS60 LS1	27° 14' 13,016" E	44° 7' 10,499" N
JDS60 LS2	27° 13' 27,134" E	44° 7' 9,854" N
JDS60 LS3	27° 12' 42,779" E	44° 7' 11,881" N
JDS60 LS4	27° 11' 58,085" E	44° 7' 14,001" N
JDS60 RS1	27° 14' 14,143" E	44° 6' 47,412" N
JDS60 RS2	27° 13' 20,669" E	44° 6' 47,218" N
JDS60 RS3	27° 12' 39,096" E	44° 6' 50,116" N
JDS60 RS4	27° 11' 57,318" E	44° 6' 58,496" N
JDS61 LS1	27° 51' 48,427" E	44° 46' 29,075" N
JDS61 LS2	27° 51' 3,045" E	44° 46' 32,063" N
JDS61 LS3	27° 50' 18,561" E	44° 46' 34,072" N
JDS61 LS4	27° 49' 35,915" E	44° 46' 45,944" N
JDS61 RS1	27° 51' 54,468" E	44° 46' 39,907" N
JDS61 RS2	27° 51' 14,339" E	44° 46' 38,424" N
JDS61 RS3	27° 50' 32,615" E	44° 46' 46,614" N
JDS61 RS4	27° 49' 44,947" E	44° 46' 55,513" N
JDS62 LS1	27° 59' 40,582" E	45° 17' 59,175" N
JDS62 LS2	27° 59' 46,529" E	45° 18' 39,002" N
JDS62 LS3	28° 0' 3,741" E	45° 19' 11,572" N
JDS62 LS4	28° 0' 18,371" E	45° 19' 42,568" N
JDS62 RS1	28° 0' 3,805" E	45° 18' 4,831" N
JDS62 RS2	28° 0' 17,064" E	45° 18' 33,725" N
JDS62 RS3	28° 0' 39,417" E	45° 19' 3,465" N

Name	Longitude	Latitude
JDS62 RS4	28° 1' 2,514" E	45° 19' 36,073" N
JDS63 LS1	28° 0' 43,985" E	45° 24' 0,957" N
JDS63 LS2	28° 0' 6,610" E	45° 23' 49,657" N
JDS63 LS3	27° 59' 29,443" E	45° 23' 59,309" N
JDS63 LS4	27° 59' 10,417" E	45° 23' 29,789" N
JDS63 RS1	28° 0' 41,270" E	45° 23' 58,297" N
JDS63 RS2	28° 0' 9,385" E	45° 23' 45,042" N
JDS63 RS3	27° 59' 31,776" E	45° 23' 54,964" N
JDS63 RS4	27° 59' 11,116" E	45° 23' 28,727" N
JDS64 LS1	28° 11' 48,858" E	45° 28' 18,037" N
JDS64 LS2	28° 11' 9,078" E	45° 28' 29,341" N
JDS64 LS3	28° 10' 53,497" E	45° 28' 58,534" N
JDS64 LS4	28° 10' 39,454" E	45° 29' 30,055" N
JDS64 RS1	28° 11' 48,590" E	45° 28' 17,599" N
JDS64 RS2	28° 11' 8,214" E	45° 28' 29,015" N
JDS64 RS3	28° 10' 53,201" E	45° 28' 57,754" N
JDS64 RS4	28° 10' 38,701" E	45° 29' 29,904" N
JDS65 LS1	28° 16' 0,898" E	45° 27' 22,601" N
JDS65 LS2	28° 16' 40,246" E	45° 27' 1,894" N
JDS65 LS3	28° 17' 7,102" E	45° 26' 31,509" N
JDS65 LS4	28° 17' 17,254" E	45° 26' 0,161" N
JDS65 RS1	28° 15' 38,419" E	45° 27' 10,822" N
JDS65 RS2	28° 16' 16,395" E	45° 26' 51,407" N
JDS65 RS3	28° 16' 41,624" E	45° 26' 24,734" N
JDS65 RS4	28° 16' 59,009" E	45° 25' 55,654" N
JDS66 LS1	29° 35' 12,379" E	45° 23' 42,619" N
JDS66 LS2	29° 35' 52,544" E	45° 23' 31,117" N
JDS66 LS3	29° 36' 2,995" E	45° 23' 3,473" N
JDS66 LS4	29° 36' 28,105" E	45° 22' 37,967" N
JDS66 RS1	29° 34' 31,246" E	45° 23' 33,785" N
JDS66 RS2	29° 35' 7,451" E	45° 23' 13,618" N
JDS66 RS3	29° 35' 42,396" E	45° 22' 52,842" N
JDS66 RS4	29° 36' 15,015" E	45° 22' 30,947" N
JDS67 LS1	28° 57' 45.1" E	45° 11' 41.4" N
JDS67 LS2	28° 58' 27.4" E	45° 11' 33.3" N
JDS67 LS3	28° 59' 01.1" E	45° 11' 13.4" N
JDS67 LS4	28° 59' 33.1" E	45° 10' 49.8" N
JDS67 RS1	28° 57' 46.0" E	45° 11' 36.6" N
JDS67 RS2	28° 58' 24.1" E	45° 11' 28.7" N
JDS67 RS3	28° 58' 59.1" E	45° 11' 09.1" N
JDS67 RS4	28° 59' 29.4" E	45° 10' 45.3" N
JDS68 LS1	28° 54' 35,262" E	45° 9' 30,971" N
JDS68 LS2	28° 54' 54,662" E	45° 9' 13,295" N
JDS68 LS3	28° 55' 39,270" E	45° 9' 17,798" N
JDS68 LS4	28° 56' 25,098" E	45° 9' 9,947" N
JDS68 RS1	28° 54' 18,608" E	45° 9' 34,632" N
JDS68 RS2	28° 54' 37,242" E	45° 9' 10,429" N
JDS68 RS3	28° 55' 33,791" E	45° 9' 5,303" N
JDS68 RS4	28° 56' 16,447" E	45° 8' 53,783" N

Appendix 5 Contributions of individual aquatic taxa to the similarity between the samples in the River Section 1 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Cin rip	23.74	23.74
Pla rip	23.74	47.48
Sch riv	23.74	71.22
Lep rip	18.62	89.84
Fon ant	10.16	100.00

Appendix 6 Contributions of individual bank taxa to the similarity between the samples in the River Section 1 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Pet sp.	16.29	16.29
Pha aru	16.29	32.59
Pla ell	12.78	45.37
Rub sp.	12.78	58.15
Equ arv	6.97	65.13
Ang syl	6.97	72.10
Cha aur	6.97	79.08
Lyt sal	6.97	86.05
Men lon	6.97	93.03

Appendix 7 Contributions of individual water taxa to the similarity between the samples in the River Section 2 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Cin rip	42.10	42.10
Fon ant	25.16	67.26
Myr spi	10.43	77.70
Phr aus	6.83	84.52
Nup lut	3.30	87.82
Typ lat	1.91	89.74
Pot pec	1.81	91.55

Appendix 8 Contributions of individual bank taxa to the similarity between the samples in the River Section 2 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Pha aru	49.74	49.74
Rub sp.	25.24	74.98
Lyt sal	8.88	83.86
Car sp.	4.75	88.61
Sol can	3.31	91.92

Appendix 9 Contributions of individual water taxa to the similarity between the samples in the River Section 3 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Cra fil	29.65	29.65
Cin rip	23.04	52.69
Iri pse	16.66	69.35
Fon ant	13.18	82.53
Amb ser	7.20	89.73
Bry pse	3.76	93.49

Appendix 10 Contributions of individual bank taxa to the similarity between the samples in the River Section 3 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Pha aru	24.72	24.72
Eup can	10.01	34.73
Hyg var	7.06	41.79
Ang syl	6.58	48.36
Imp gla	6.56	54.93
Sol can	6.45	61.37
Men aqu	5.40	66.78
Men lon	3.94	70.71
Equ arv	3.90	74.62
Rub sp.	3.62	78.24
Did rig	2.99	81.22
Tus far	2.88	84.10
Lyt sal	2.74	86.84
Lyc eur	2.02	88.86
Sym off	1.82	90.68

Appendix 11 Contributions of individual water taxa to the similarity between the samples in the River Section 4 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Cin rip	65.07	65.07
Phr aus	24.46	89.53
Les pol	6.05	95.58

Appendix 12 Contributions of individual bank taxa to the similarity between the samples in the River Section 4 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Sol can	41.67	41.67
Lyt sal	20.85	62.53
Pha aru	17.32	79.85
Rub sp.	10.12	89.97
Car sp.	3.21	93.18

Appendix 13 Contributions of individual water taxa to the similarity between the samples in the River Section 5 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Sal nat	32.02	32.02
Cin rip	20.19	52.21
Lem min	19.15	71.36
Phr aus	17.68	89.04
Lem gib	8.37	97.41

Appendix 14 Contributions of individual bank taxa to the similarity between the samples in the River Section 5 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Per lap	29.60	29.60
Per hyd	17.40	46.99
Car sp.	11.73	58.72
Bid fro	11.72	70.44
Pha aru	7.93	78.37
Ror syl	7.03	85.39
Sol can	3.20	88.59
Lyt sal	2.86	91.45

Appendix 15 Contributions of individual water taxa to the similarity between the samples in the River Section 6 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Spi pol	18.95	18.95
Sal nat	18.95	37.90
Lem min	17.32	55.22
Lem gib	12.41	67.63
Phr aus	9.56	77.19
Cla glo	7.69	84.89
Pot pec	4.96	89.85
Cer dem	3.20	93.05

Appendix 16 Contributions of individual bank taxa to the similarity between the samples in the River Section 6 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Per lap	22.27	22.27
Ech cru	20.32	42.59
Bid fro	12.20	54.79
Cyp glo	10.58	65.37
Car acu	7.01	72.38
Dic mic	5.99	78.36
Che rub	4.31	82.68
Ror syl	2.97	85.65
Che alb	2.04	87.68
Lyt sal	1.81	89.50
Ver ana	1.55	91.05

Appendix 17 Contributions of individual water taxa to the similarity between the samples in the River Section 7 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Cla glo	16.51	16.51
Pot per	12.53	29.04
Pot nod	11.06	40.10
Cer dem	10.22	50.32
Lem min	8.31	58.63
Lem tur	8.31	66.94
Sal nat	8.28	75.22
Spi pol	6.51	81.73
Pot pec	4.89	86.62
Pot nat	3.38	90.00
Lem gib	2.99	92.99

Appendix 18 Contributions of individual bank taxa to the similarity between the samples in the River Section 7 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Per lap	74.84	74.84
Xan str	4.38	79.21
Cle vit	3.28	82.49
Por ole	3.04	85.53
Che alb	2.96	88.49
Che rub	2.96	91.45

Appendix 19 Contributions of individual water taxa to the similarity between the samples in the River Section 8 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Myr spi	18.44	18.44
Cla glo	16.93	35.37
Pot per	13.29	48.66
But umb	12.85	61.51
Pot cri	11.57	73.08
Cer dem	8.07	81.14
Pot pec	8.05	89.19
Val spi	5.08	94.27

Appendix 20 Contributions of individual bank taxa to the similarity between the samples in the River Section 8 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Xan str	19.83	19.83
Ech cru	19.41	39.24
Per lap	17.79	57.03
Alo gen	10.44	67.47
Cyp glo	9.12	76.59
Por ole	6.75	83.34
Che alb	2.95	86.29
Pla lan	2.68	88.97
Lyt sal	2.41	91.37

Appendix 21 Contributions of individual water taxa to the similarity between the samples in the River Section 9 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Pot pec	41.33	41.33
Pot cri	16.13	57.46
Cla glo	15.80	73.26
But umb	7.98	81.24
Phr aus	5.71	86.95
Cer dem	5.30	92.25

Appendix 22 Contributions of individual bank taxa to the similarity between the samples in the River Section 9 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Alo gen	25.87	25.87
Xan str	14.58	40.45
Dic mic	13.77	54.23
Cyp glo	9.54	63.77
Che alb	7.00	70.77
Ecl pro	6.53	77.30
Che rub	5.85	83.15
Per lap	5.32	88.47
Por ole	3.40	91.87

Appendix 23 Contributions of individual water taxa to the similarity between the samples in the River Section 10 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Cla glo	43.49	43.49
Pot pec	23.04	66.53
But umb	8.36	74.89
Phr aus	7.23	82.13
Typ ang	4.05	86.17
Spa ere	2.74	88.91
Cer dem	2.69	91.60

Appendix 24 Contributions of individual bank taxa to the similarity between the samples in the River Section 10 based on the SIMPER analysis.

Species	Contribution (%)	Cumulative (%)
Xan str	23.85	23.85
Cyp glo	23.63	47.49
Dic mic	17.41	64.90
Pha aru	7.95	72.85
Gna uli	7.76	80.61
Phy pat	5.15	85.75
Ecl pro	4.15	89.90
Che rub	2.74	92.64