DIPLOMARBEIT

Titel der Diplomarbeit

River floodplain habitats and their aquatic macrophyte vegetation: biodiversity and conservation status defined by connectivity

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1. Abstract

Using the example of the *Rosskopfarm* oxbow system in the left-hand floodplain of the Danube River east of Vienna (Austria) the change of the macrophytic assemblages in a timeframe of 22 years is shown. Surveys of 5 different dates (1987, 1993, 1994, 1994 Students Survey and 2009) are compared. Statistical methods (Indicator Species Analysis, Species Length correlation, Multi-Response Permutation Procedure, Simpson-Index of Diversity, Berger-Parker Index of Dominance) and other survey methods (Distribution-Diagram, Plant Mass, and Habitat Types) are used to ascertain the time depending differences. Furthermore, the change in connectivity due to river bed incision processes affecting the flora and fauna in this system is also addressed. The alterations of habitat types related to the Flora Fauna Habitat Directive are discussed.

The difficulty of applying the rules two different Directives of the EU-Commission (Flora Fauna Habitat Directive and Water Frame Directive) is addressed for the *Rosskopfarm* oxbow system, also.

Am Beispiel des Rosskopfarmes, eine Auenlandschaft auf der linken Donauuferseite östlich von Wien, wird die Veränderung der Makrophytenvegetation innerhalb von 22 Jahren gezeigt. Zum Vergleich dienen 5 zu unterschiedlichen Zeitpunkten durchgeführte Vegetationserhebungen (1987, 1993, 1994, ISS 1994 und 2009). Statistische Analysen ((Indicator Species Analysis, Species Length correlation, Multi-Response Permutation Procedure, Simpson-Index of Diversity und Berger-Parker Index of Dominance) und andere Methoden (Distribution-Diagramme, Plant Mass und Habitat Types) werden angewandt um die zeitabhängigen Unterschiede festzustellen. Weiters wird die Änderung der Anbindungsdauer an den Hauptstrom, ein Resultat der Eintiefung der Donau, und die daraus resultierende Veränderung der Flora und Fauna angesprochen. Folgen für die ausgewiesenen Habitate der Flora Fauna Habitat Richtlinie werden besprochen.

Am Beispiel der Rosskopfarmes wird auch auf die Problematik der Anwendung zweier EU-Richtlinien (Wasser Rahmenrichtlinie und Flora Fauna Habitat Richtlinie) eingegangen.

2. Introduction

Floodplains are a dynamic habitat which is highly affected by flood events and the connectivity with the main river channel. The connectivity may change in this dynamic system over time because of natural or human related causes. Natural causes can be river channel deepening processes because of erosion and transportation. Human related causes can be construction measures like dykes for mitigating flood damages or channel straightening measures improving navigation conditions. Hence, a change of the connectivity of the lateral water bodies may be the result which has also an effect on the biodiversity especially for these water bodies (Schönborn 1992).

The connectivity and the flow conditions are important abiotic factors for fauna and flora in floodplain habitats. Theses abiotic factors create habitats providing certain living conditions. All species have habitat preferences to which they are bound to. Hence, species can be used as indicators (Haslam 1978) to draw conclusions concerning the connectivity of habitats with the main stream.

Amoros et al. (1987) stated a framework of functional units to connect biotopes and biocoenoses to river landforms. The crucial role of connectivity as important factor for species occurrence has been a field of study for a long time. The effects of lateral connectivity with the main current on macrozoobenthos stated by e.g. Waringer et al. (2005), Chovanec et al. (2005) or Reckendorfer et al. (2006). The linkage between channel connectivity and macrophytes was worked out by e.g. Sarbu et al (2010) and Strausz et al. (2009). The relationship of the deviation of connectivity and α-Diversity was described by Amoros et Bornette (2002).

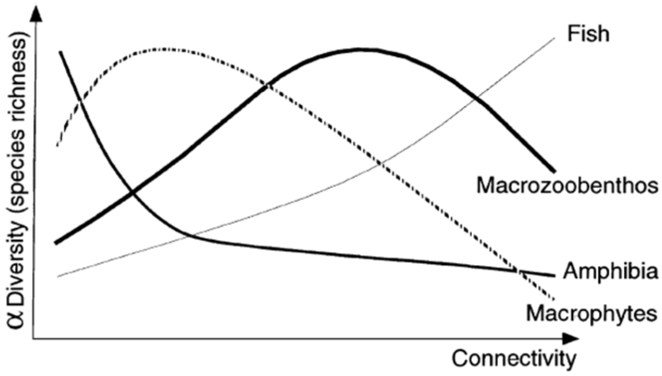

Figure 2-1: Idealized α-diversity patterns of different biota in relation to river connectivity in a Danube floodplain, Austria (modified from Tockner et .al. (1998) in: C. Amoros and G. Bornette, 2010.

As part of the Multifunctional Integrated Study Danube Corridor and Catchment (MIDCC) the abiotic parameter ‘connectivity type’ was assessed and defined by a number-based code. (www.biogis.net)

Biodiversity has a certain value for mankind. A degradation of diversity can be perceived as a risk from the human point of view. For example a loss of lentic aquatic habitats as consequence of an aggradation process, or of throughflow impacts as a consequence of insufficient river restoration measures, would not meet sustainability goals (Strausz et al. 2009). Preventing the loss of biodiversity is also important in terms of other ecosystem services, for example for cultural values or for leisure activities.

3. Material and Methods

3.1. Study area

The Rosskopfarm Oxbow System (ROS) is a relict branch of the Danube in the left-hand floodplain to the East of Vienna, close to the village of *Stopfenreuth*. The lower end of the system is an open connection with the main river channel.

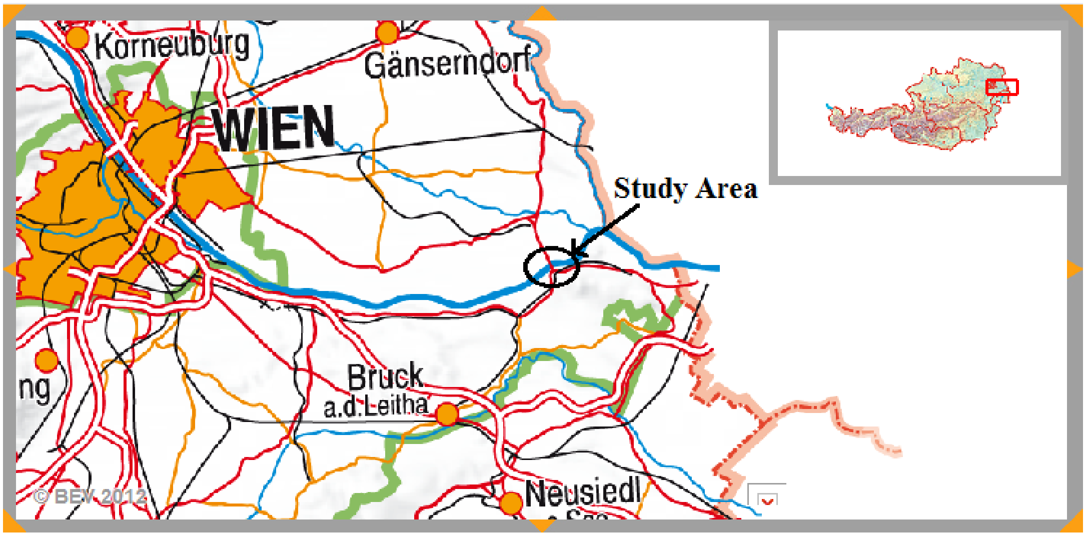

Figure 3-1: Overview map (BEV MAPS 2012, access 29.9.2012), the black circle marks the study area.

The oxbow system is subdivided into five parts by small barrages (Figure 3-2). A small opening in each of the dams enables some through-flow, but prevents the individual water bodies to fall dry completely. The barrages had to be constructed after the regulation of the main Danube channel and the separation of the oxbows, as without these physical provisions the water bodies would have fallen dry instantly, as the gradient of the regulated main river channel is approx. 0.4‰. In the West of the floodplain the *Marchfeld* Flood Protection Levee confines the system at the up-river end of the Rosskopfarm II-part.

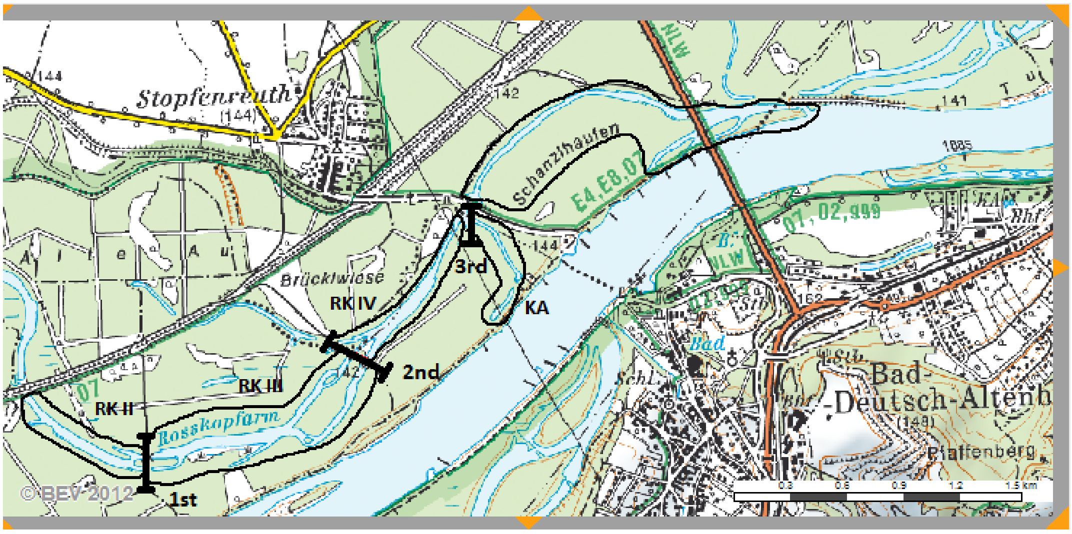

Figure 3-2: Map of the Rosskopfarm Oxbow System with 3 indication bars counted from left to right. (BEV MAPS 2012, access 29.9.2012)

The ROS is situated on the left side of the Danube, its upstream end is located at river kilometre 1890.3 and its downstream end, the mouth of *Schanzelhaufen* (SH), merges with the Danube at river kilometre 1885.7. The ROS consists of *Rosskopfarm II, Rosskopfarm III, Rosskopfarm IV, Schanzelhaufen and Karpfenarm.*

In accordance with earlier studies the following abbreviations are used in this thesis:

Rosskopfarm II…………RK II

Rosskopfarm III………... RK III

Rosskopfarm IV………... RK IV

Schanzelhaufen………… SH

Karpfenarm……………...KA

The ROS waterbody is confined by the "*Marchfeldschutzdamm"* dyke and interrupted by several barrages. The first barrage (*Wunderl Traverse,* 1st bar in Figure 3-2*)* seperates RK II from RK III. The 2nd and the 3rd barrage (*Nördliche und Südliche Entenhaufen Traverse)* seperate RK III from RK IV. It is parallel to the 2nd bar in Figure 3-2.

The KA merges with the RK IV near the barrage "*Uferhausstraße"* and is separated from RK IV by the 3rd indication bar (Figure 3-2; VIADONAU 2006).

The groynes and culverts are also representing elevation steps:

Wunderl Traverse…………………...141.50 m

Nördliche Entenhaufen Traverse……142.10 m

Südliche Entenhaufen Traverse…… .142.20 m

Durchlass Uferhausstraße…………...142.00 m

The western sections RK II-RK IV are directly connected with the main river channel during flood events. The KA features 3 small channels, which connect it with the main river channel up to 8 days per year. During the remaining periods connection is provided by groundwater. The SH is also connected with the main channel at 3 locations, providing inflow of river water up to 18 days per year. At the mouth of the SH direct river connection exists for 255 days per year (VIADONAU 2006).

3.2. Records

Five different records of macrophyte surveys were used for this thesis, covering the period between 1987 and 2009:

1987 Prof. Dr. P. Englmaier (upon request by Prof. G.A. Janauer)

1993 C. Hüpfel, G. Kum (Project Leader: Prof. G.A. Janauer)

1994 C. Hüpfel, G. Kum (Project Leader: Prof. G.A. Janauer)

1994 Student Field Course (Supervising teacher: Prof. G.A. Janauer), this Introductory Students Survey is abbreviated as "ISS".

2009 Macrophyte Survey of the whole Danube river channel and the floodplain water bodies between Vienna and the Slovak and Hungarian border. This study was part of the 'Integrated River Engineering Project on the Danube to the East of Vienna' (*Flussbauliches Gesamtprojekt Donau östlich von Wien*). This project is conducted by 'viadonau', as part of the Trans-European-Network-V, and supported by the European Union (VIADONAU, 2010).

The sections of the survey of 1987 were not explicitly present in map style. The arrangement of the individual sections was set up by using the written descriptions, the total length of each section and the known location of the barrages.

The survey units for the "Student field course 1994" were not exactly placed, only the survey unit length was present. The starting point of this record was determined at the beginning of RK II. . By using a map base and the given length of the survey units, the sections of the Rosskopfarm-System could be arranged properly. KA was not surveyed in the Student Field Course.

In 1993 and 1994 the records were taken by the project personnel, starting at from RK II to SH in the direction of flow. Drawings of the water bodies were available.
For this thesis the data of the 2009 survey - Integrated River Engineering Project on the Danube to the East of Vienna – were arranged from the western end of RK II towards the merging of the system with the Danube River. The KA (*Karpfenarm*) was free of macrophytic vegetation in that year, resulting in no macrophyte record.

For the record in 2009 the data provided by "*Flussbauliches Gesamtprojekt Donau östlich von Wien*" were again arranged from RK II in the direction of flow towards the Danube. The Karpfenarm had no macrophytic vegetation in that year, so no record was conducted. In this year 2 species (*Circaea lutetiana* and *Polygunum aviculare*) were recorded. These are no typical water plants so they weren´t considered for the assessment.

3.3. Determination of macrophyte abundance

Macrophyte abundance data were recorded using the "Kohler" Method. This method estimates the abundance of a species in a defined survey unit in 5 levels (Kohler et al. 1971).

1 = very rare; 2 = rare; 3 = frequent; 4 = abundant; 5 = very abundant.

Based on this approach the online-tool KOHLER ON THE WEB 2012 provided by www.biogis.net (2012) was used to generate the images of the Distribution Diagram, T-O-Ratio (MMT/MMO), relative abundance and Mean Mass Indices

The PME is the 5-scale level of Kohler et al. (1971) and serves as the numerical basis for calculating the other metrics.

The Distribution-Diagram shows the plant abundance of each species in each survey unit and the survey unit lengths in their true relationship. The diagram is well suited for overview purposes and first-glance interpretation.

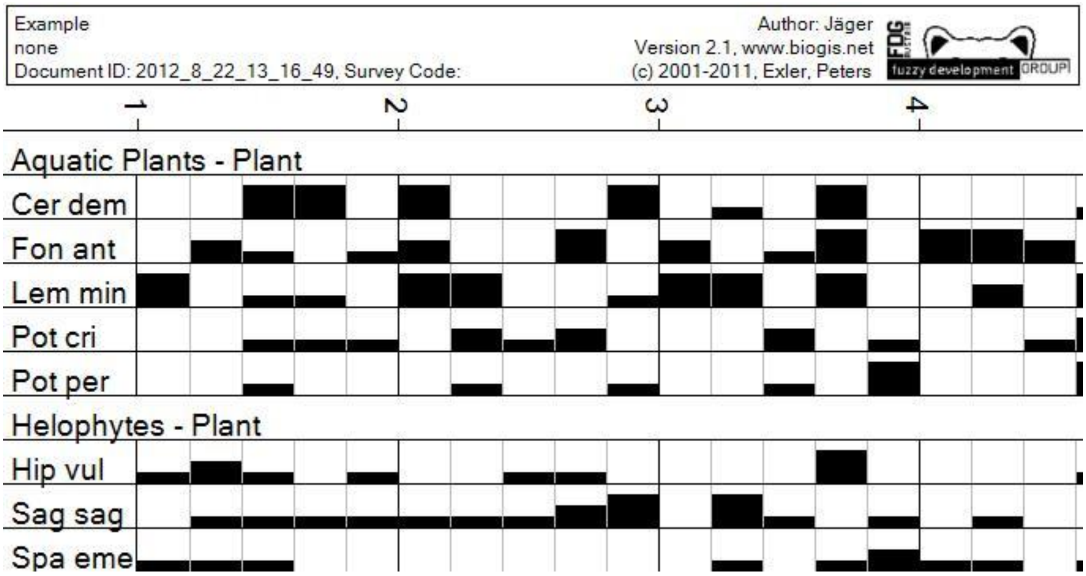

Figure 3-3: Example of a Distribution-Diagram

The relative abundance diagram sorts species by abundance weighted by the survey unit length.

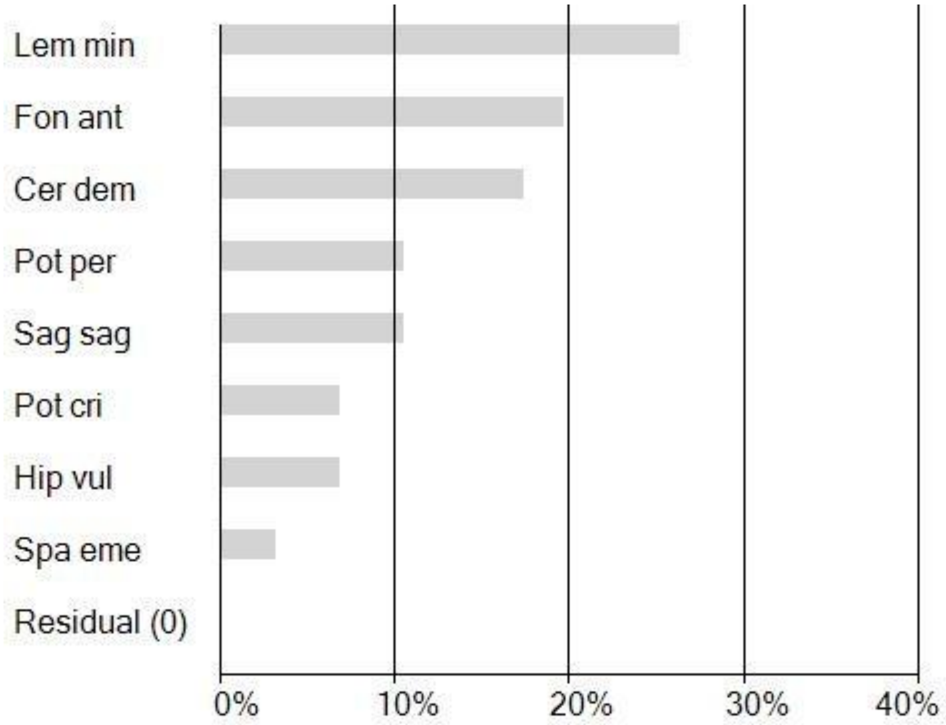

Figure 3-4: Example for a relative abundance diagram

Residuals are all species which fall below a certain value. This value can be modified and is set to 1%.

The Mean Mass Index (MMT/O) and the T-O-Ratio enables a comparison of species abundance in survey units of occurrence and in relation to total survey length (Janauer et Schmidt 2004).

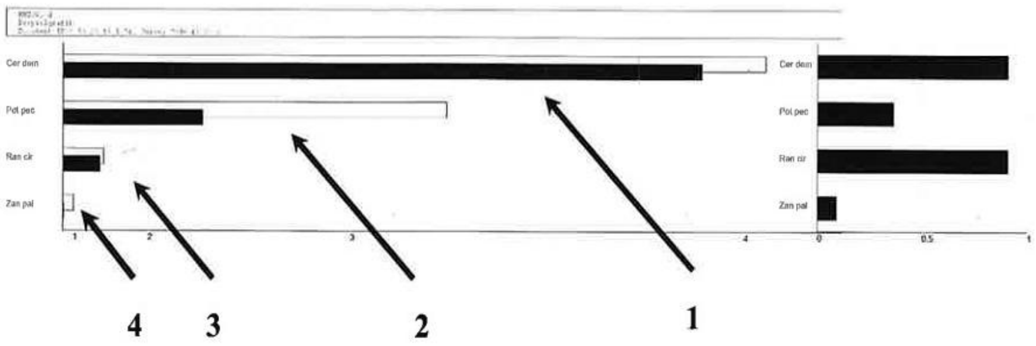

Figure 3-5: Example of MMO/T Types and T-O-Ratio (Janauer et Schmidt, 2004)

Figure 3-5 displays the 4 types of MMT/O. The black bar is the 'Mean Mass' (mean abundance) of a species regarding all survey units (Mean Mass Total). The white bar displays the mean abundance of a species in survey units of its occurrence. (Mean Mass Occurrence). The ratio amongst MMO and MMT is called T-O-Ratio and provides a metric for the establishment of a species. The higher the ratio, the better is this species established in a surveyed river course.

Type 1: High result for MMO as well as MMT, hence the T-O Ratio is more than 0.5. This species is well established in this river.

Type 2: MMO is much higher than MMT thus the T-O-Ratio is below 0.5. This species is well established in survey units of its occurrence, but less present regarding all survey units.

Type 3: Low values of MMO as well as MMT. The T-O-Ratio is higher than 0.5.This species has a low but constant distribution.

Type 4: Low MMO but even lower MMT, with the T-O-Ratio below 0.5. This species is really rare and extremely low in distribution.

The Cumulative Kohler Index (CKI) calculates the total plant mass by summing up the cubed Kohler values and by calculating the cube root of it (Kohler et al 1971, Kohler et Janauer 1995, Janauer et Heindl 1998, Pall et Janauer, 1998, 1995).

The results are related to following classes:

1-1.5: ………………1

1.5-2.5: …………….2

2.5-3.5: …………….3

3.5-4.5: …………….4

More than 4.5: ……..5

It is a proxy index for the abundance of all species occurring in a survey unit.

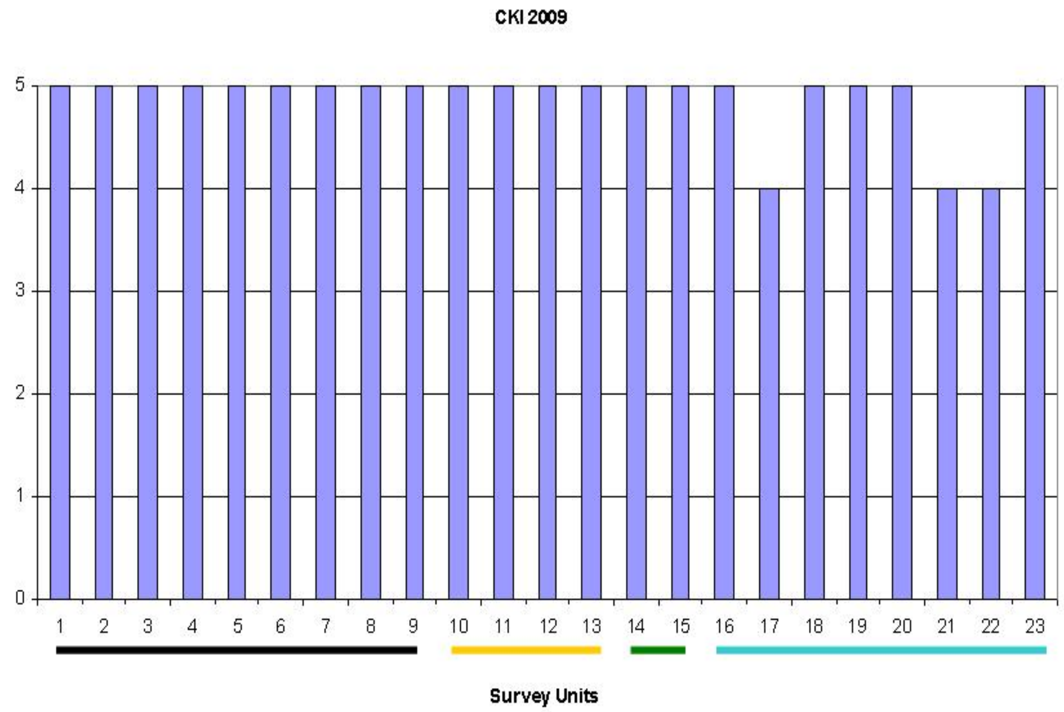

Figure 3-6: from left to right: RK II, RK III, RK IV, and SH, indicated by the horizontal lines below the survey unit numbers.

Figure 3-6 gives an example for the CKI in 2009. It is quite clear that for water bodies with many species and high abundances of some species – which can be characteristic for oxbow lakes and other small and shallow still water bodies – the highest class is reached very soon and does not differentiate individual survey units very well.

Figure 3-7 shows the same survey but based just on the accumulated abundance proxies (KI^3), and excluding the cube root procedure. It is called “KI^3 “and it is used for this thesis.

This method is more exact, as it enables to display and compare higher sums of plant mass which accumulate when many species have high PMEs; the CKI would reduce all these cases to a general value of „5“. This becomes apparent by comparing Figure 3-6 and Figure 3-7, both addressing the same survey.

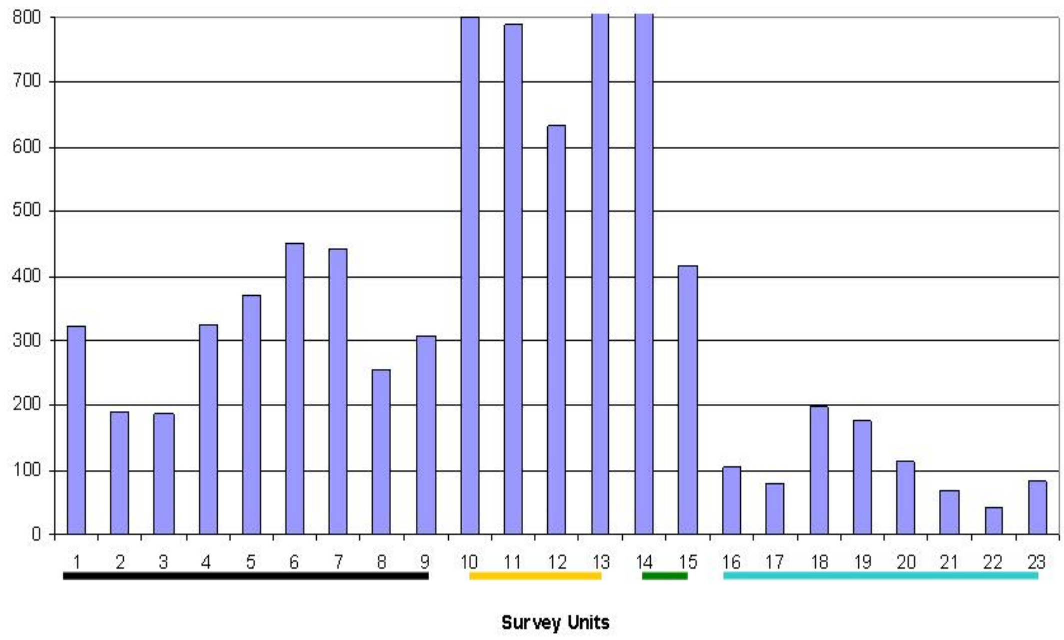

Figure 3-7: KI^3 from left to right: RK II, RK III, RK IV, and SH.

Figure 3-7 shows the same record when applying the KI^3, which provides the correct relationship between the accumulated plant masses and does not limit "5"like the CKI of Pall et Janauer (1998).

3.4. Habitat types related to the FFH-Directive

The Council Directive 97/62 (EC 1997) was created to adapt the Directive 92/43 EEC (European Council 1992). It extends the Annex 1 of the FFH-Directive about the Natura-2000 codes. These codes are in use to classify the specific Flora-Fauna-Habitat-Types (FFHT).

The classification of the Flora-Fauna-Habitat types follows the guidelines in "*Handbuch der FFH-Lebensraumtypen Österreichs*" ('Handbook of Austria FFH Habitat-Types' (Ellmauer, Traxler 2000).

For this study habitat types related to the FFH-Directive use the abbreviation "FFHT".

Three different FFHT´s occur in the study area:

- Natura 2000-Code 3140: Oligotrophic to mesotrophic base-rich pools and ponds of all altitudinal belts, the ground is covered with layers of Characean algae poor in species. These clean waters are clear and blue to greenish in colour.

Plant species in the Rosskopfarm-Oxbow System: *Chara spp.* and *Nitella spp.*

- Natura 2000-Code 3150: Water bodies rich in nutrients and of slightly basic reaction, natural standing water bodies. The floating and submerged vegetation is poor in species. The water is of greyish to blue-greenish colour.

Plant species in the Rosskopfarm-system: *Ceratophyllum demersum, Hydrocharis morsus-ranae (dominant), Lemna spp., Myriophyllum spicatum, Myriophyllum verticillatum, Najas marina, Potamageton sp. (dominant), Spirodela polyrhiza, Stratoites aloides (dominant), Ranunculus circinatus,*

- Natura 2000-Code 3260: natural or near to natural waters from planar- to montane-level, flowing vegetation.

3.5. Habitat types related to connectivity

Aggregations of potamon river landforms are defined by Amoros et al. (1987) as functional units. This typology was developed for field operations.

In this thesis Habitat Types are differentiated according to the concept of the Floodplain Index-approach and the concept of hydrological connectivity with the main channel. The Habitat-Types correlating with hydrological connectivity were determined by Reckendorfer et al. (2006) as:

HT 1: C^d > 330days

HT 2: C^d < 330 days

HT 3: C^d< 120days

HT 4: C^d < 5days

HT 5: C^d: temporary waters

Habitat-Types which concern this approach use the abbreviation “HT”. The abbreviation C^d is defined as the number of days of average annual connection with the main channel.

These five Habitat-Types can also be represented by the Floodplain Index (FI) (Chovanec et al., 2005). The Floodplain Index is based on a species specific habitat value which is related to the species preferences. The hydrologic connectivity influences the species composition, so a water body in a study site can be characterized by its floodplain index.

Habitats which are related to the Floodplain-Index use the abbreviation "H".

The connectivity is following the functional sets of Amoros et al. (1987). This approach reaches from H1 (Eu-Parapotamon, dynamic, large running waters) to H5 (Paleopotamon, permanent/standing waters with no permanent and direct connection). A description of FI-related Habitats is given below:

H1: Eupotamal permanent water body, high lateral hydrologic connectivity, no macrophytes

H2: Litoral standing and permanent backwaters, reduced connectivity and dynamics, few macrophytes

H3: Open water areas, permanent standing waters, significantly reduced connectivity and dynamics

H4: Litoral permanent standing waters, high sedimentation, significantly reduced connectivity and dynamics

H5: Temporary pools, significantly reduced connectivity and dynamics, dried-up periods, high sedimentation

Figure 3-8 gives an overview of the H-types in the study area.

The sections RKII, RK III and RK VI are classified H 4 (yellow), KA and SH belong to H 3 (green). For clearer section boundaries compare to Figure 3-2. The different shape of the beginning of the RK II section can be explained by flood dynamics.

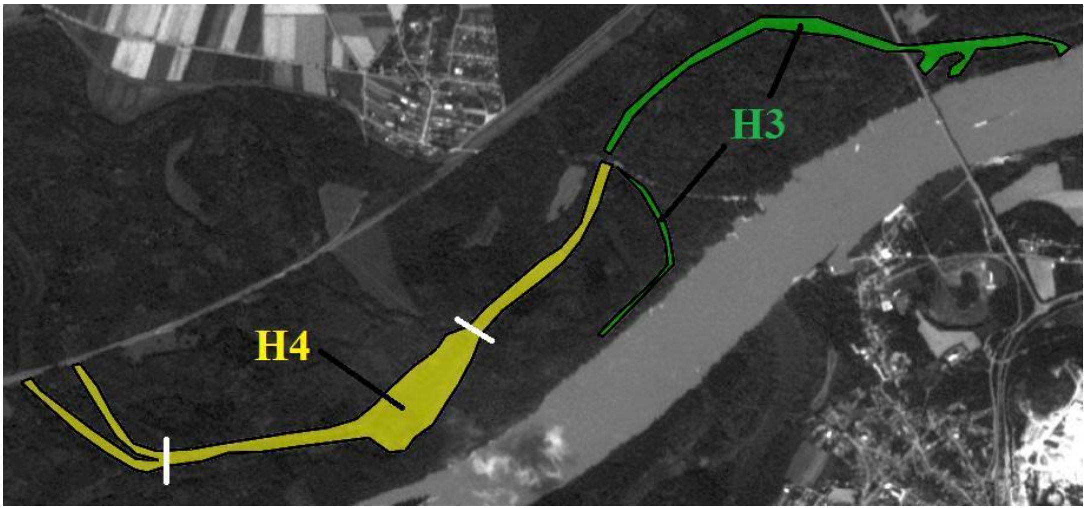

Figure 3-8: Habitats related to C[d] of the Rosskopfarm-System**,** Reckendorfer personal communication 2012; Satellite image: Includes material © (2010) RapidEye AG, Germany. All rights reserved

3.6. *Statistical Methods*

Multi-Response Permutation Procedure (MRPP)

To figure out statistical differences among the sections RK II, RK III, RK IV, KA and SH, a Multi-Response Permutation Procedure (Peck 2010) was used. It delivers the p-Value for group differences. Results below 0.05 indicate significant differences. The p-Value was calculated for the RK-Sections based on the values of KI^3 and the habitat parameters in every record.

Indicator Species Analysis (ISA)

For the Indicator Species Analysis the method of Dufréne et Legendre (1997) was used. The first column lists the abbreviations of the plant species, the MaxGroup column displays in which group an individual species had the highest value and the final column displays the statistical significance. A p-Value below 0.05 indicates a statistically significant difference.

For every record the ISA was conducted (a) for the FI-related habitats (“H”-parameter) and (b) the RK-Sections, so 2 datasets are available for each survey.

Berger-Parker Dominance and Simpson-Diversity

The PAST-Programme was used to assess the diversity and dominance of species (HAMMER et al 2001). The Simpson-Diversity (Simpson 1949) serves as indicator for the biodiversity, the Berger-Parker-Index (Magurren 2004) shows the dominance of species in an investigation area. The results are demonstrated as Box plots by using the statistical programme STATGRAPH 5.0 (StatPoint Technologies, Inc. 2009).

Abbreviations in use for this thesis:

Simpson-Diversity-Index… SDI

Berger-Parker-Dominance… BPD

Correlation of Survey Length and Species Number amongst the ROS-sections

A simple table indicates if a correlation of survey length and species number exists in the study area.

4. Results

4.1. Presence-Absence-Analysis

Table 4-1: Presence-Absence Diagram for Hydrophytes**,** species in bold marked as "value enhancing" species.

Hydrophyten	1987	1993	1994	ISS 1994	2009
Ber ere					■
Cal sp		■	■		■
Cer dem	■	■	■	■	■
Cha fra					■
Cin rip					■
Ele sp.		■	■		■
Elo can		■	■		■
Ent int			■		
Fon ant	■			■	■
Fon hyp					■
Hyd mor	■	■	■	■	
Lem min	■	■	■		■
Lim aqu			■		
Myr spi	■	■	■	■	■
Myr ver	■	■	■	■	■
Naj mar	■	■	■	■	■
Nie obt		■	■	■	■
Nup lut	■	■	■	■	■
Nym alb	■	■	■	■	■
Pol hyd		■	■		■
Pot cri	■	■	■	■	■
Pot luc	■	■	■	■	■
Pot pec	■	■	■	■	■
Pot per	■	■	■	■	■
Pot sp.			■		
Ran cir	■	■	■	■	■
Spi pol	■	■	■		■
Str alo	■				
Utr vul	■		■		

Ver ana					■
Ver sp.		■			
Zan pal		■			

Following hydrophytes are occurring every year: *Ceratophyllum demersum, Myriophyllum spicatum, Myriophyllum verticillatum, Najas marina, Nuphar lutea, Nymphaee alba, Potamageton crispus, Potamageton lucens, Potamageton pectinatus, Potamageton perfoliatus* and *Ranunculus circinatus.*

Table 4-1 displays a singular record of following species: *Alisma anagallis-aquatica, Berula erecta, Chara fragilis, Cinclidotus riparius, Enteromorpha intestinalis, Fontinalis hypnoides, Limosella aquatica, Zannichellia palustris* and species of *Veronica* and *Potamageton.*

For both tables 3-7 and 3-8 are species in bold marked as "value enhancing" species. (Directly translated, based on ELLMAUER 2005)

Table 4-2: Presence-Absence Diagram for Helophytes, species in bold marked as "value enhancing" species.

Helophytes	1987	1993	1994	ISS1994	2009
Agr sto					■
Ali lan		■	■		■
Ali pla				■	
Cal lob	■				
Car ela				■	■
Car gra					■
Car rip					■
Cha sp.		■	■		
Ele aci	■				
Ele pal			■		
Elo nut			■		
Equ pal					■
Gal apa					■
Gal pal		■			■
Gly max					■
Hip vul	■	■	■	■	■
Iri pse		■	■	■	■
Lem gib			■		
Lem tri	■		■		

Lys num					
Men aqu					
Myo pal					
Myo sco					
Oen aqu					
Pha aru					
Phr aus					
Poa pal					
Ran sce					
Ric flu					
Ror amp					
Ror pal					
Ror sp.					
Rum hyd					
Rum pal					
Sag sag					
Sch lac					
Spa eme					
Spa ere					
Spa sp.					
Typ lat					

Table 4-2 shows, that *Hippuris vulgaris, Sagittaria sagittifolia* and *Sparganium emersum* are present in all records.

Furthermore it displays singular records of the following species: *Agrostis stolonifera, Alisma plantago-aquatica, Callitriche obtusangula, Carex gracilis, Carex riparia, Eleocharis acicularis, Eleocharis palustris, Galium aparine, Glyceria maxima, Lemna gibba, Mentha aquatica, Myosotis scorpioides, Poa palustris, Ranunculus scleratus, Riccia fluitans, Rorippa palustris, Rumex hydrolapathum, Rumex palustris, Schoenoplectus lacustris and Sparganium sp.*

4.2. Species Abundance and Distribution

4.2.1. Survey Results of 1987

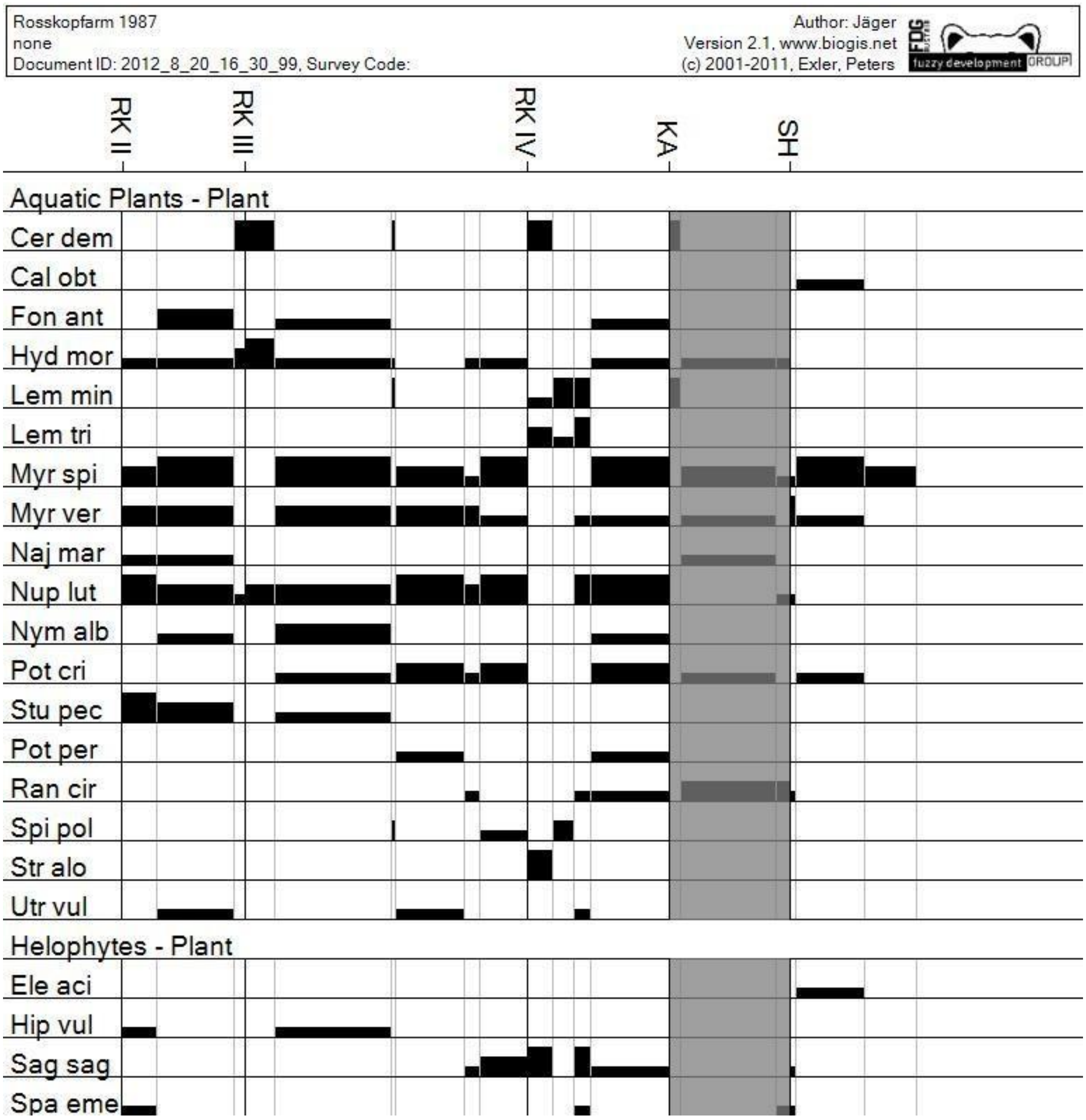

Figure 4-1: Distribution-Diagram for Rosskopfarm Oxbow System (ROS) 1987. From left to right: RK II, RK III, RK IV, KA (grey shade) and SH. Length of survey units in the diagram relates directly to their true length in the field.

The two *Myriophyllum* species, as well as floating leaf *N. lutea* are quite abundant in RK II – IV, whereas the submersed *S. pectinata* and *P. crispus* do not dominate the water bodies. KA is somewhat similar to the RK sections, but SH is rather bare of aquatic macrophyte and helophyte species.

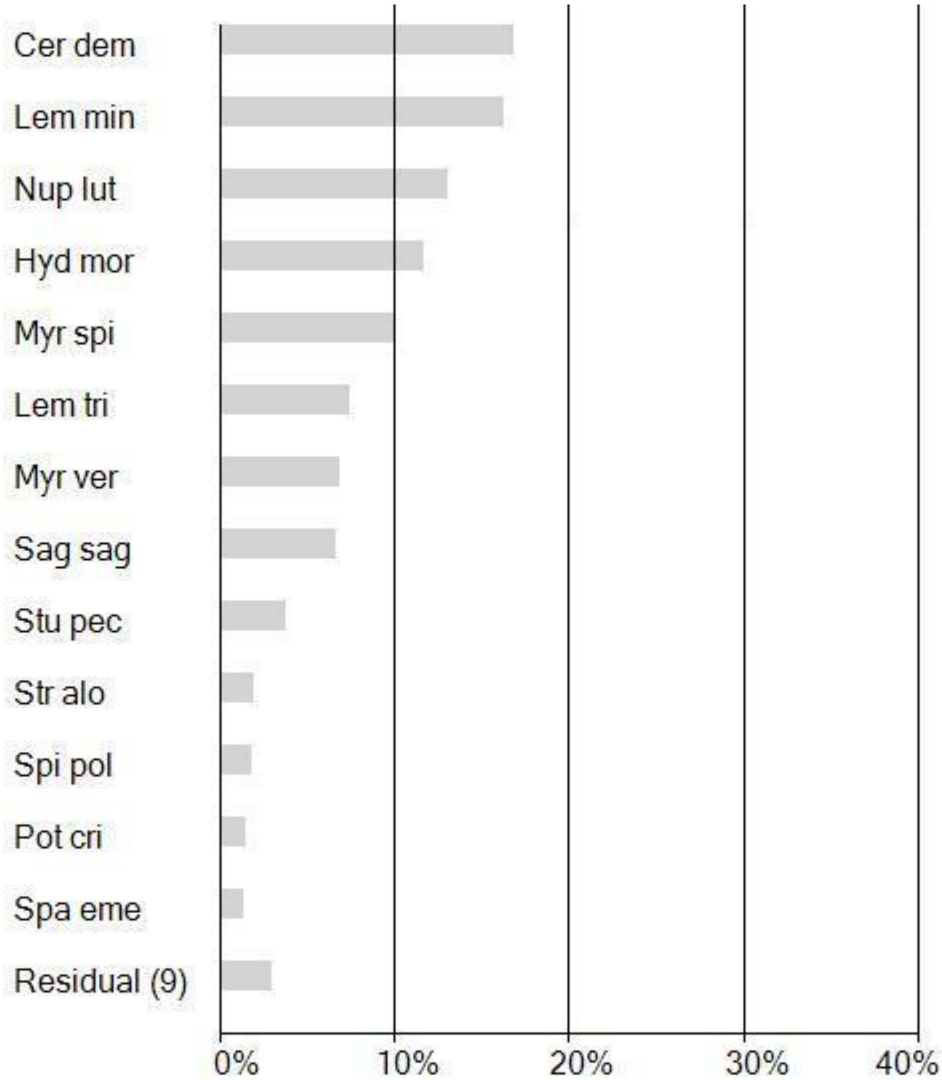

Figure 4-2: relative abundance in 1987

Myriophyllum spicatum, *Nuphar lutea*, *Ceratophyllum demersum* and *Lemna minor* provided the highest contribution to the relative abundance of all species.
9 species contribute less than 1%.

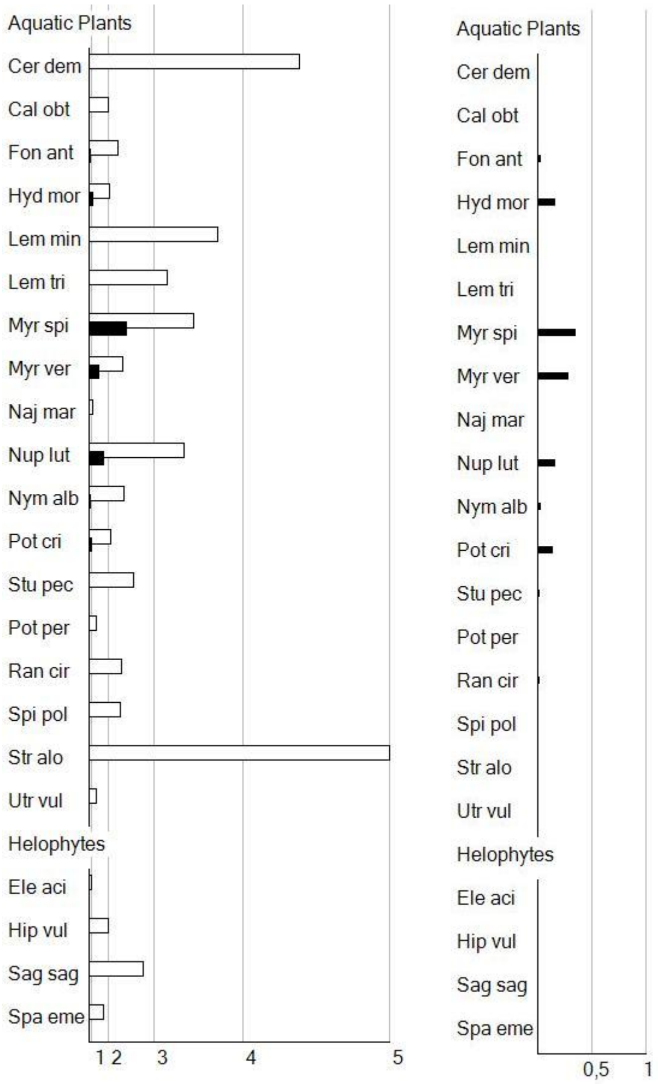

Figure 4-3: MMT/O and T/O-Ratio in ROS 1987

No species has a distribution ratio more than 0.5. Even though *Ceratophyllum demersum* and *Lemna minor* have no distribution ratio over 0.5, they add important rates of plant mass. *Stratiotes aloides* and *Ceratophyllum demersum* have a low distribution but high PME, hence a low T-O-Ratio is the result.

4.2.2. Survey Results of 1993

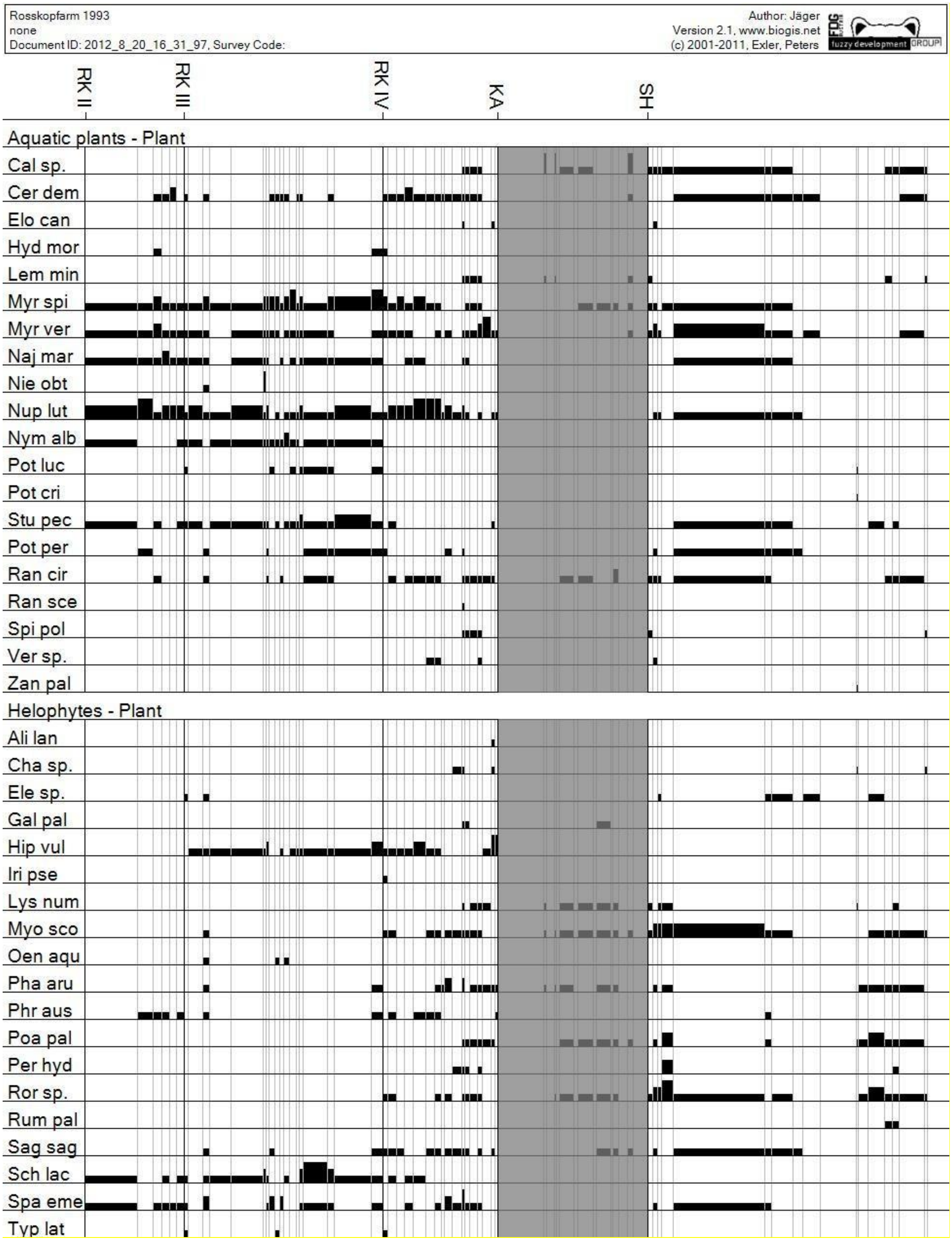

Figure 4-4: Distribution-Diagram for ROS 1993. From left to right: RK II, RK III, RK IV, and SH.

Nuphar lutea and *Myriophyllum spicatum* dominated RK II-VI, *Myriophyllum verticillatum* and *Myosotis scorpioides* dominated the SH. The broad “gap” in the middle of Figure 4-4 is the first survey unit of Karpfenarm. This unit lacked any plant growth. Considering the helophytes of section RK II and RK III they are rare in occurrence and many survey units are without helophytic vegetation.

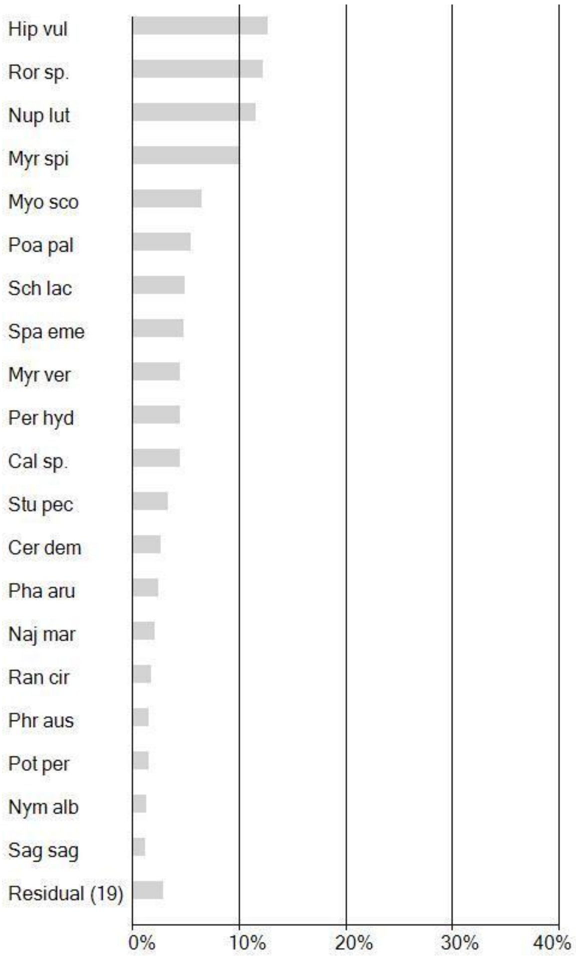

Figure 4-5: relative abundance in ROS 1993

According to the relative abundance *Hippuris vulgaris* is dominant.

19 species contributed less than 1%.

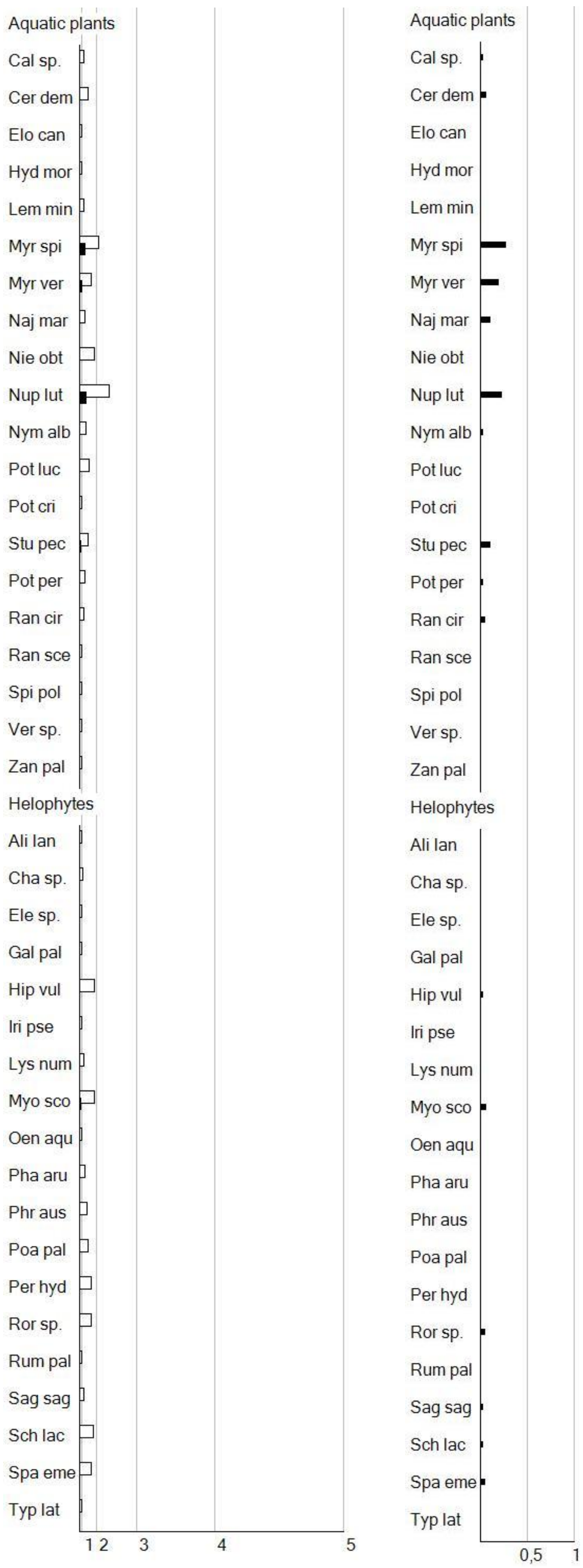

Figure 4-6: MMT/O and T/O-Ratio 1993

This figure displays that all species are vulnerable in Rosskopfarm-River in 1993. Only *Myriophyllum spicatum, Myriophyllum verticillatum, Najas marina and Nuphar lutea* are constant in abundance.

The T-O-Ratio of the value enhancing *Ranunculus cirrcinatus* increased compared to 1987 but *Lemna trisulca* was not recorded. *Hydrochorus morsus-ranae* decreased the ratio clearly. *Nitellopsis obtusa* is occurring in RK III in low amount.

The number of residuals amounts to 19 species (Figure 4-5), this is higher than the record of 1987 (Figure 4-2).

4.2.3. Survey Results of 1994

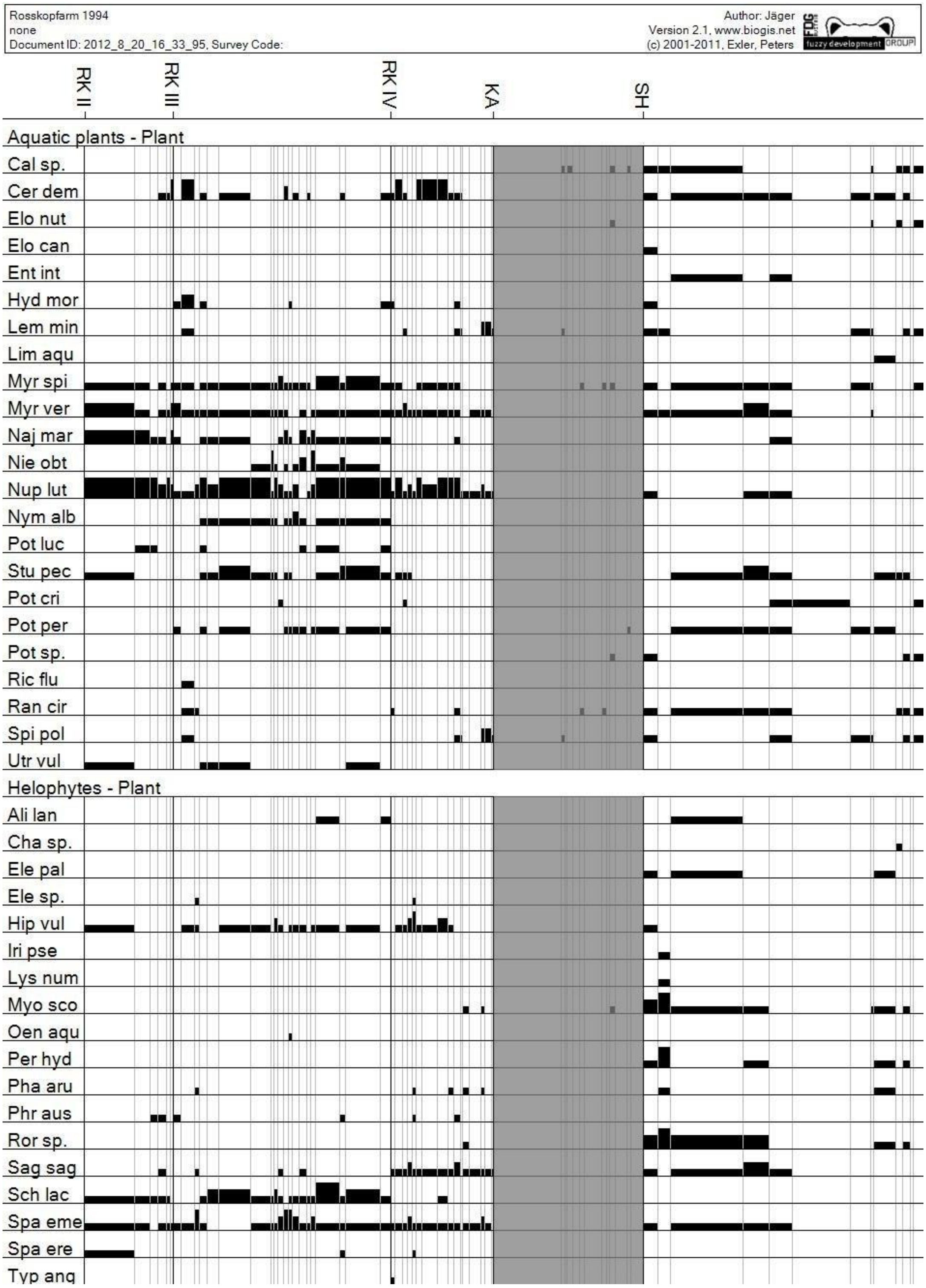

Figure 4-7: Distribution of macrophytes in ROS 1994. From left to right: RK II, RK III, RK IV, and SH.

Remarkable in 1994 are the high abundance of *Nuphar lutea* in the sections RK II-RK IV and the subsequent decrease of this species distribution in KA and SH.

(Figure 4-7) The first section of Karpfenarm is visible as a broad gap in the middle of Figure 4-7. No macrophytes were detected in this section. Considering *Myriophyllum spicatum*, which contributed much to relative abundance in the preceding records, its abundance and relative abundance is much lower in 1994.
A clear difference in plant abundance can be ascertained between the helophytes and hydrophytes. Hydrophytes are less occurring in RK II, RK III and, especially so, in KA. Only one plant species, *Myosotis scorpioides*, occurs in KA and no other helophytes could be detected.

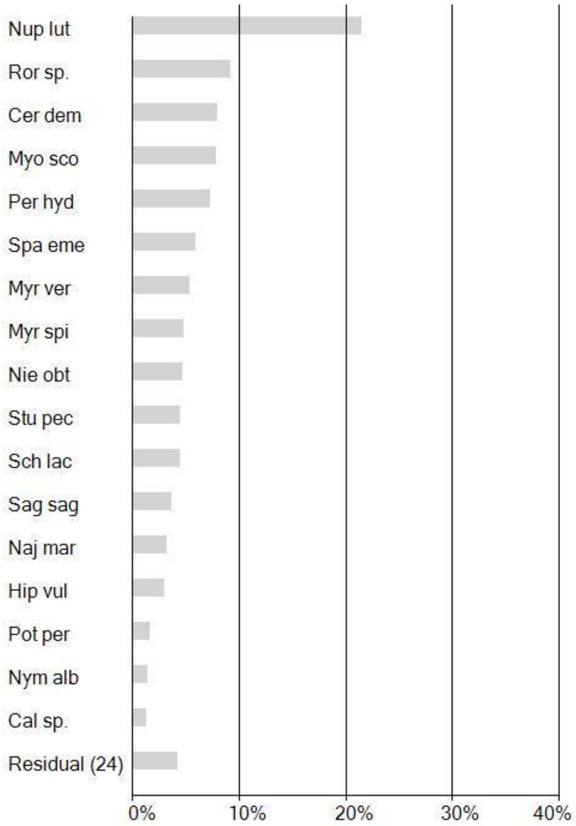

Figure 4-8: relative abundance in ROS 1994.

Nuphar lutea dominates the relative amount of macrophytes. In this record 24 species provide a relative abundance less than 1%.

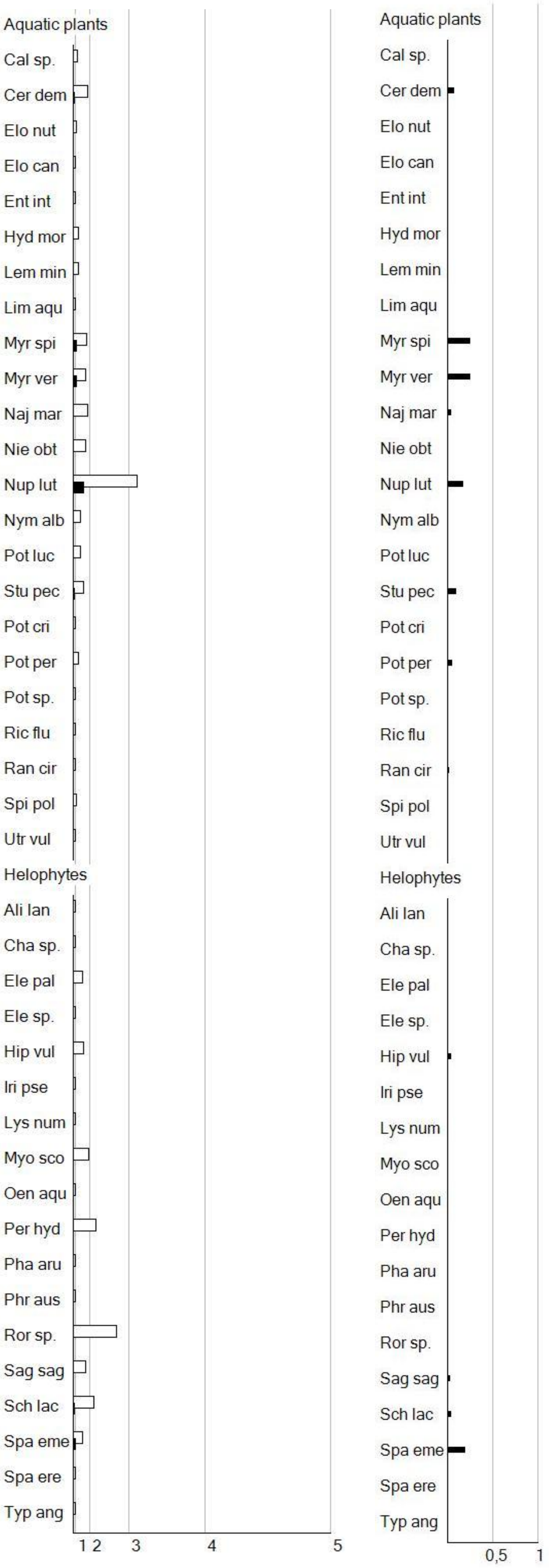

Figure 4-9: MMT/O and T/O-Ratio 1994

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Figure 4-9 shows low results for MMT and MMO. The T-O-Ratio indicates that only *Nuphar lutea*, *Myriophyllum spicatum*, *Myriophyllum verticillatum* and *Sparganium emersum* were quite constant with respect to their occurrence and abundance.

4.2.4. Survey Results of Introductory Students Survey 1994

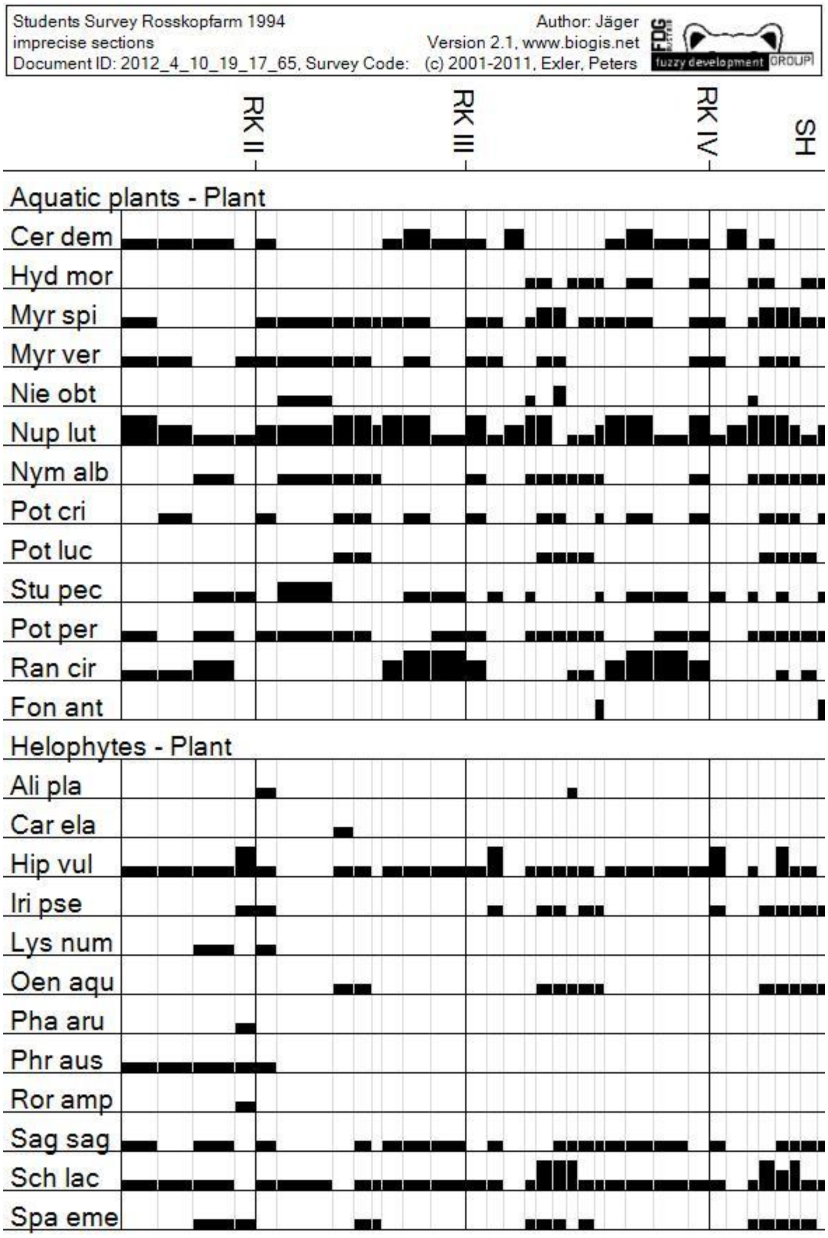


Figure 4-10: Distribution Diagram for the „Introductory Students Survey 1994“. From left to right: RK II, RK III, RK IV, and SH. No record was conducted on KA.

Schoenoplectus lacustris and *Nuphar lutea* were established in all sections. *Ranunculus cirrcinatus* had 3 “peaks” in this record.

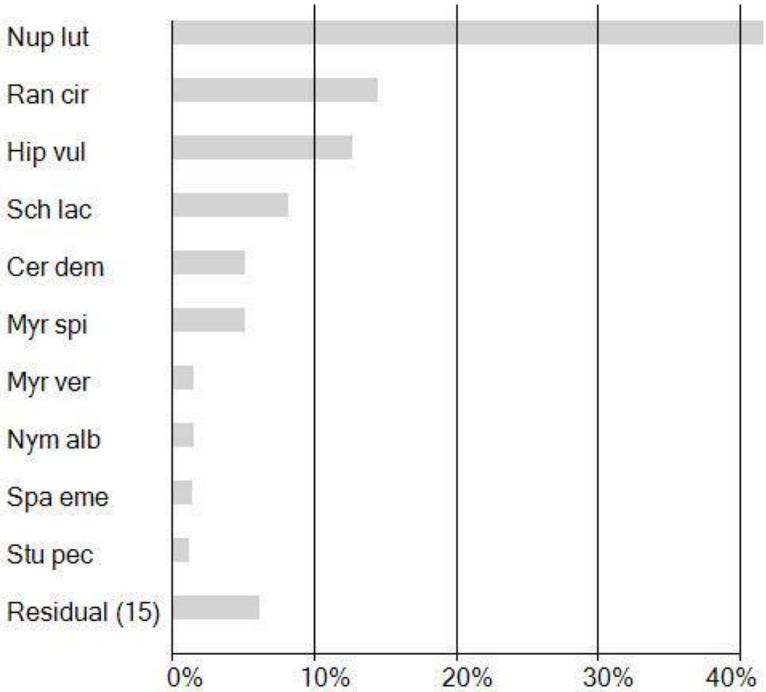


Figure 4-11: relative abundance for “Introductory Students Survey 1994”

Nuphar lutea contributed most to the relative abundance in this record. *Hippuris vulgaris and Ranunculus cirrcinatus* contributed each more than 10%. Fifteen species are occurring as residuals.

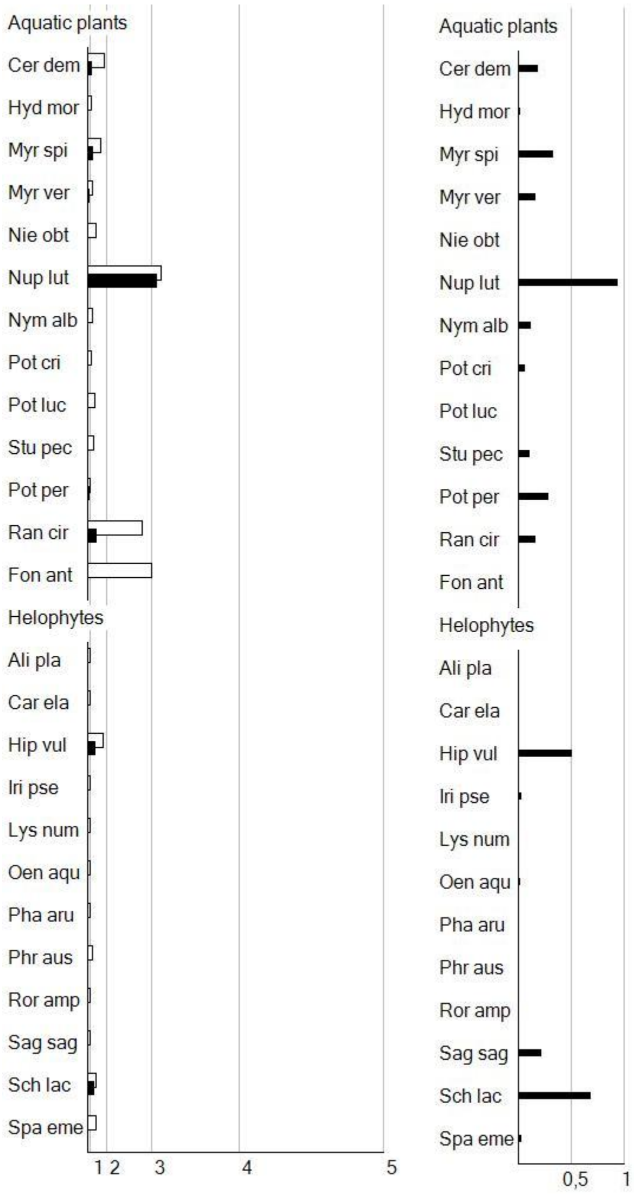


Figure 4-12: MMT/O and T/O-Ratio "Introductory Students Survey"

Figure 4-12 displays the predominant distribution of *Nuphar lutea* which is well established in this year as well as *Rannunculus circinatus*. The majority of the macrophytes were low in abundance regarding the total water body ensemble, but occurred in almost all survey units, so a T-O-Ratio of more than 0.5 is reached by many species.

4.2.5. Survey Results of 2009

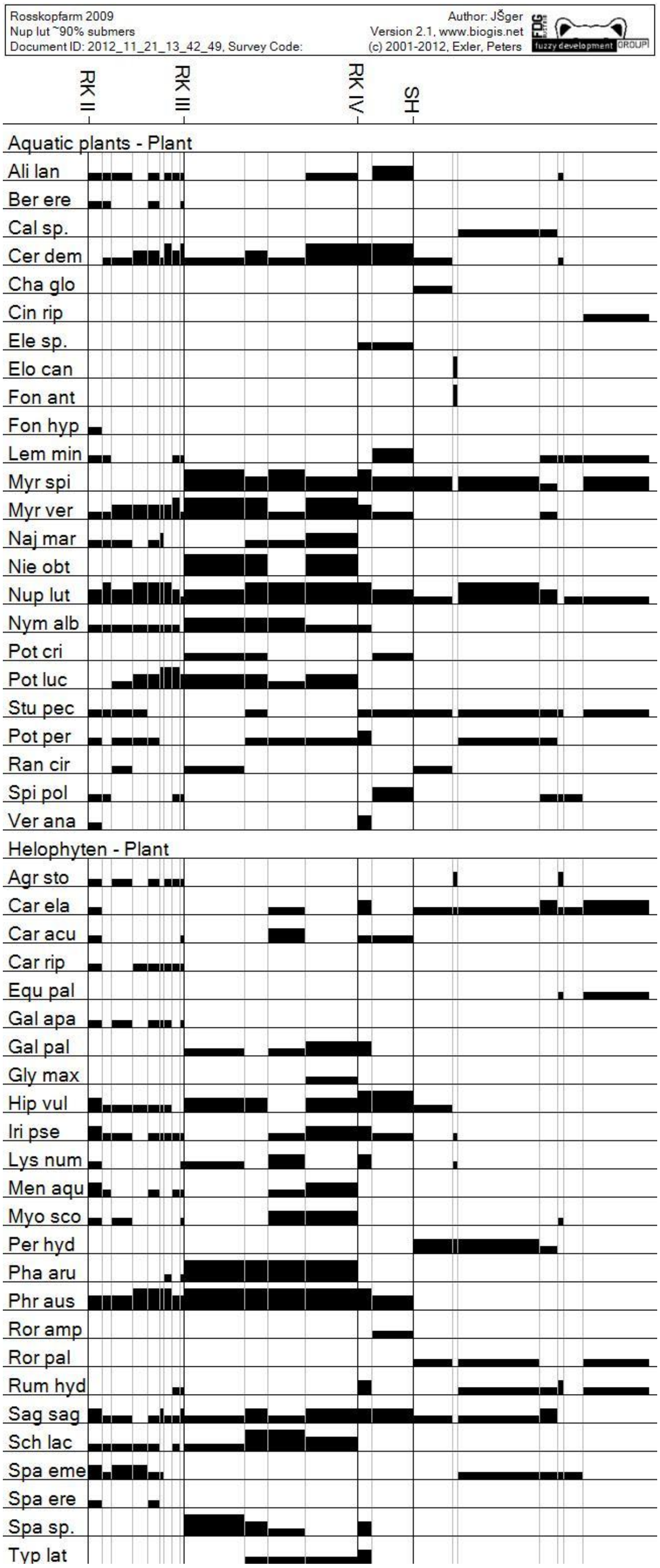


Figure 4-13: Plant Distribution in ROS 2009. From left to right: RK II, RK III, RK IV, and SH. No record was conducted on *Karpfenarm.*

Figure 4-13 shows the dominance of some submersed aquatic species like *Ceratophyllum demersum, Nitellopsis obtusa, Nuphar lutea* and *Myriophyllum spicatum, Myriophyllum verticillatum* and *Potamageton lucens. Myriophyllum spicatum* did not occur in RK II but had high PME in the following sections. The highest PMEs occurred in RK IV, whereas in section SH rather low PMEs were detected.

Concerning the helophytes (*Phalaris arundinacea* and *Phragmites australis* had local peaks with high PME but were confined to RK II and RK III.

It is necessary to mention, that a long part of RK IV could not be recorded by boat due to the dry situation in that year, hence no vegetation was recorded for a long part of RK IV. That is also the explanation, why the total length of RK IV is much shorter compared to other surveys.

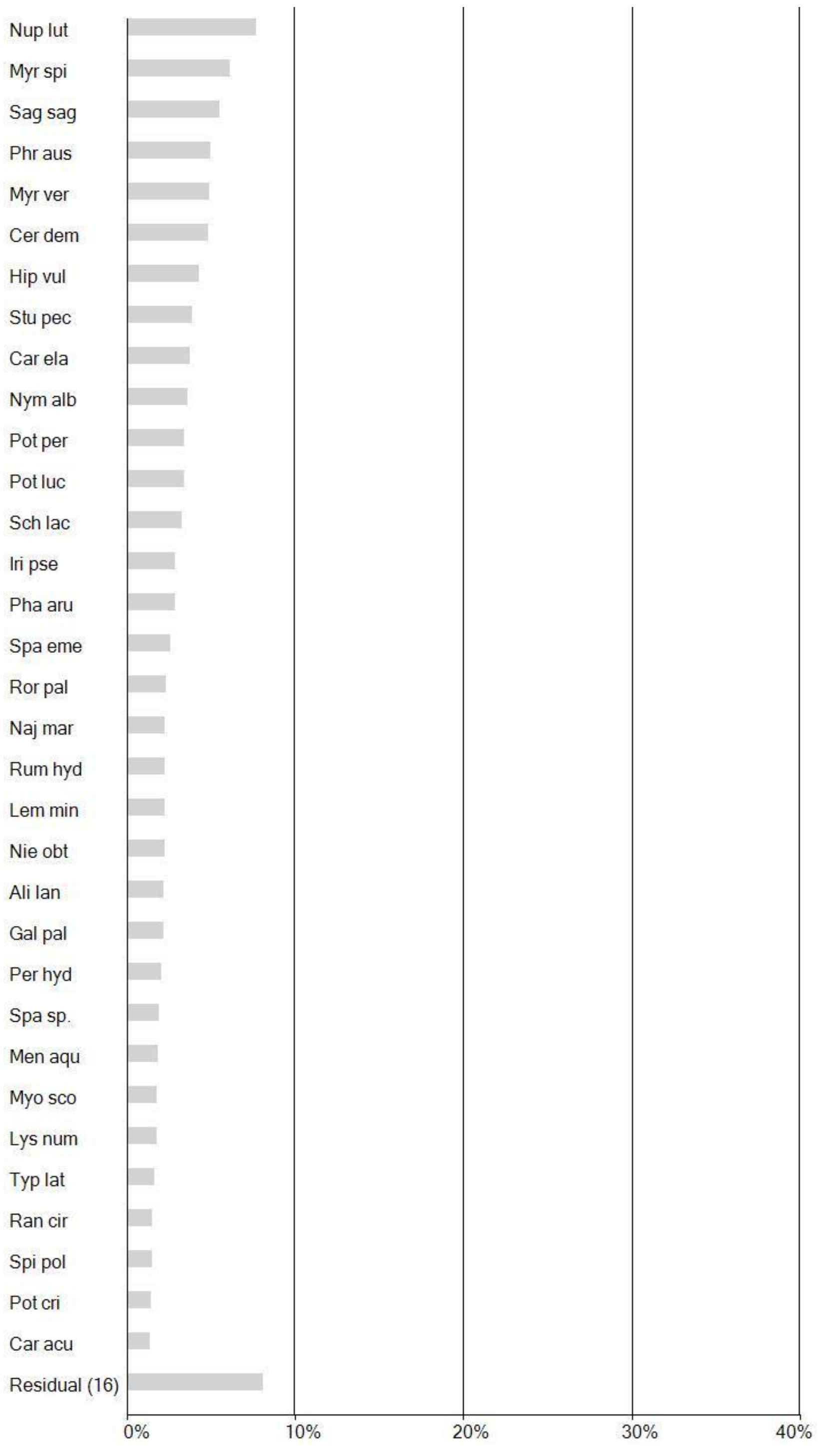
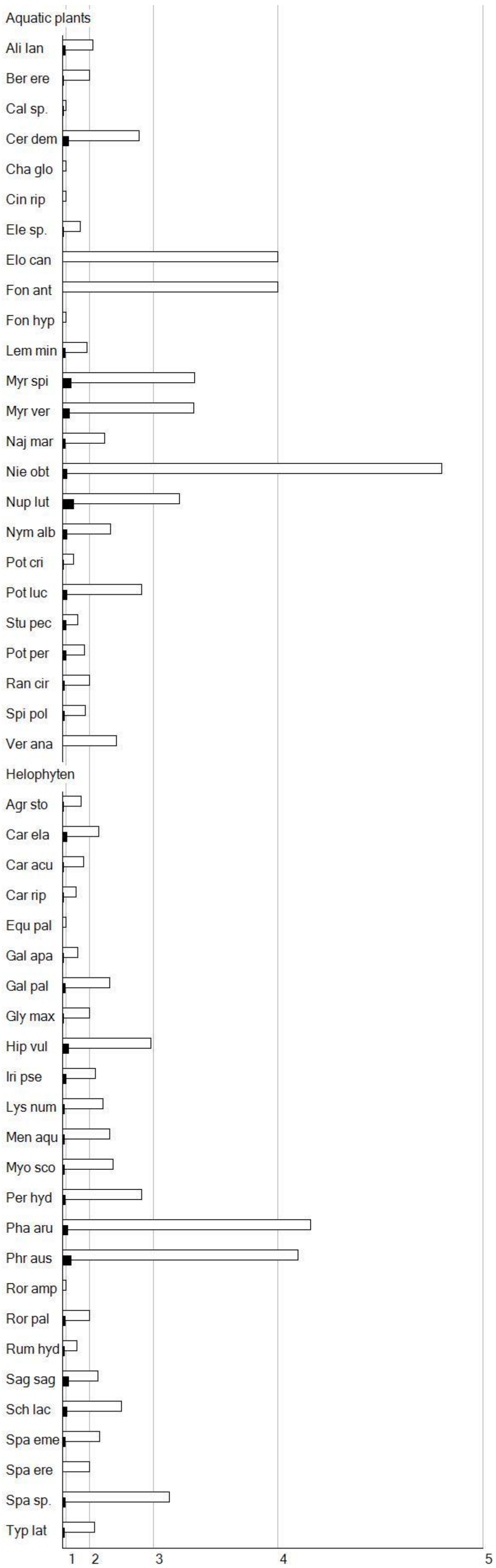


Figure 4-14: relative abundance in ROS 2009.

Concerning the relative abundnace, *Nuphar lutea* and *Phragmites australis* are dominating. The high result for *Phragmites australis* is unique for this record and does not occur in the other survey. Noticeably is the high T-O-Ratio of *Nuphar lutea*, it reaches nearly 1. In that record (Figure 4-14) a high number of residuals (16) were ascertained.



Aquatic plants
Ali lan
Ber ere
Cal sp.
Cer dem
Cha glo
Cin rip
Ele sp.
Elo can
Fon ant
Fon hyp
Lem min
Myr spi
Myr ver
Naj mar
Nie obt
Nup lut
Nym alb
Pot cri
Pot luc
Stu pec
Pot per
Ran cir
Spi pol
Ver ana
Helophyten
Agr sto
Car ela
Car acu
Car rip
Equ pal
Gal apa
Gal pal
Gly max
Hip vul
Iri pse
Lys num
Men aqu
Myo sco
Per hyd
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Aquatic plants
Ali lan
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Car rip
Equ pal
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Gal pal
Gly max
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Iri pse
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Men aqu
Myo sco
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1

Figure 4-15: MMT/O and T/O-Ratio 2009

Only two plant species reach a T/O-Ratio more than 0, 5: *Nuphar lutea and Sagittaria sagittifolia.*

4.3. Comparison of KI³ results among all years

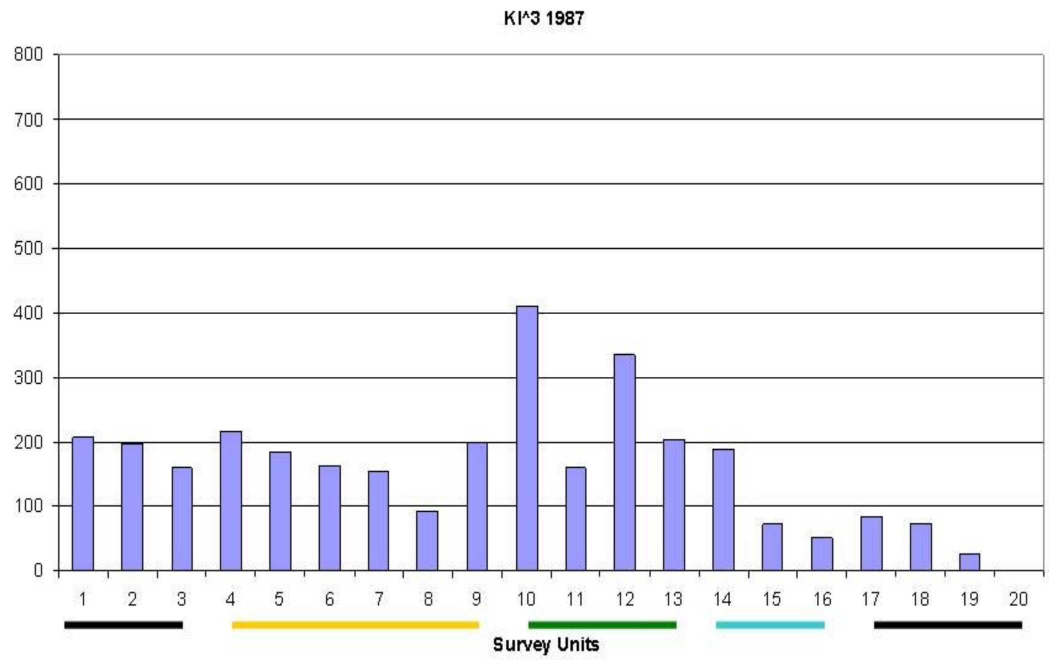

Figure 4-16: Sum of KI³ for all Survey Units (SU) of Rosskopf oxbow ensemble 1987. Survey units1-3: RK II; Survey Units 4-9: RK III; Survey Units 10-13: RK IV; Survey Units: 14-16: *Karpfenarm*; Survey Units 17-20: *Schanzelhaufen*

The KI³ of 1987 is about the same for most survey units, but except for survey unit 8, 10 and 12, the two latter values in RK IV. A lower value for the overall abundance was detected in the sections of *Karpfenarm* and *Schanzelhaufen*.

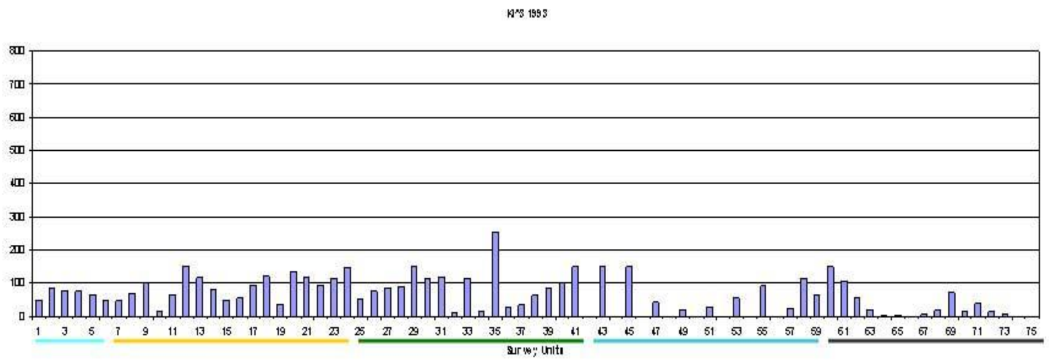

Figure 4-17: Sum of KI^3 for all Survey Units (SU) of Rosskopf oxbow ensemble 1993. Survey units 1-6: RK II; Survey Units 7-24: RK III; Survey Units 25-41: RK IV; Survey Units: 42-56: *Karpfenarm*; Survey Units 57-74: *Schanzelhaufen*

The result of the KI^3 in 1993 shows fluctuations between all sections of the ROS. The highest accumulated abundance occurred in RK IV. The KA and SH showed lower KI^3 and several Survey Units were without any aquatic plant growth.

The record of 1993 (Figure 4-17) shows a decrease of plant mass for the crossing from RK III to RK IV.

The KI^3 peaks are between 200 and 250 each year but the sections RK III and RK IV reach in 2009 values up to 800 (Figure 4-20). This is almost double of the highest result of 1987 (Figure 4-16). The sections KA and SH, which are related to another connectivity type, show lower values.

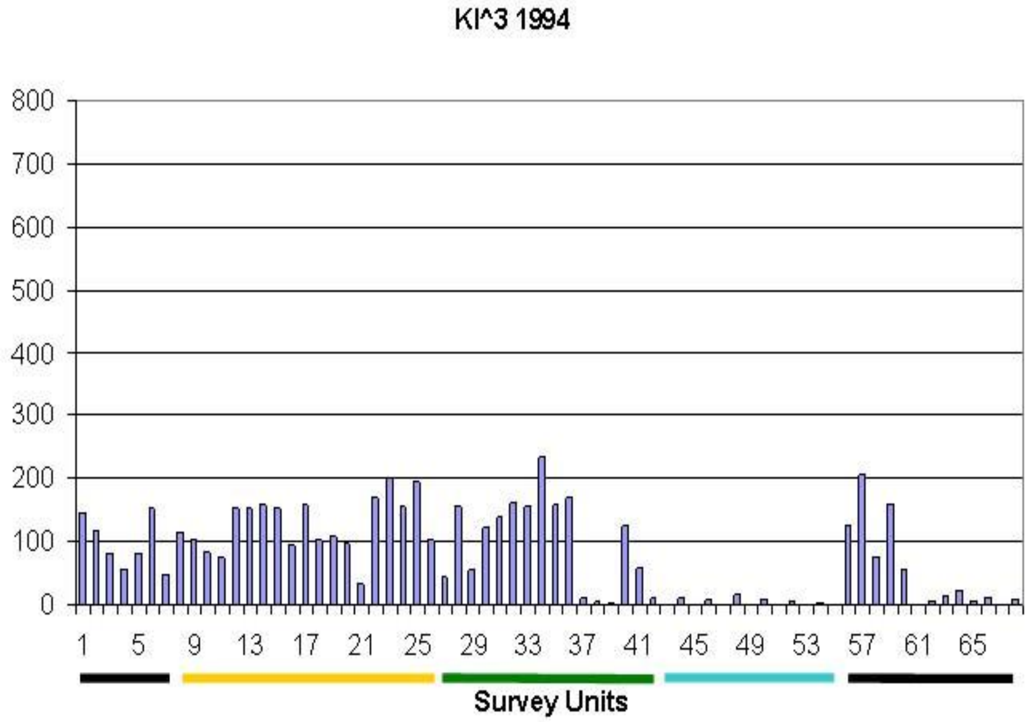

Figure 4-18: Sum of KI^3 for all Survey Units (SU) of Rosskopf oxbow ensemble 1994. Survey units 1-7: RK II; Survey Units 8-26: RK III; Survey Units 27-42: RK IV; Survey Units: 43-55: *Karpfenarm*; Survey Units 56-68: *Schanzelhaufen*

Figure 4-18 displays that in 1994 the KI^3 varied across all survey units s of RK II, RK III and RK IV, with the latter characterised by the peak of this survey. The KA contained survey units without macrophyte vegetation or rather low KI^3. SH was characterised by high KI^3 at the upper end of the section, and by low values at the lower end, where it merges with the Danube.

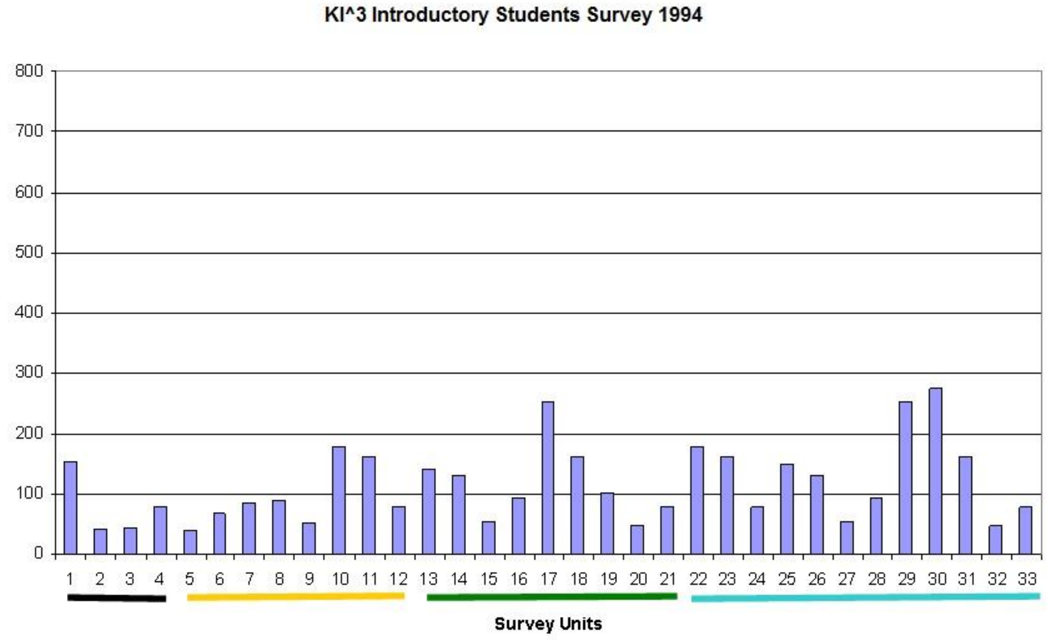

Figure 4-19: Sum of KI^3 for all Survey Units (SU) of Rosskopf oxbow ensemble Introductory Students Survey 1994. Survey units 1-4: RK II; Survey Units 5-12: RK III; Survey Units 13-21: RK IV; Survey Units: 22-33: *Schanzelhaufen,*

For the Introductory Students Survey (ISS) of 1994 the results varied considerably, with high values occurring in RK IV and SH. This latter value is quite different from the results of the other years.

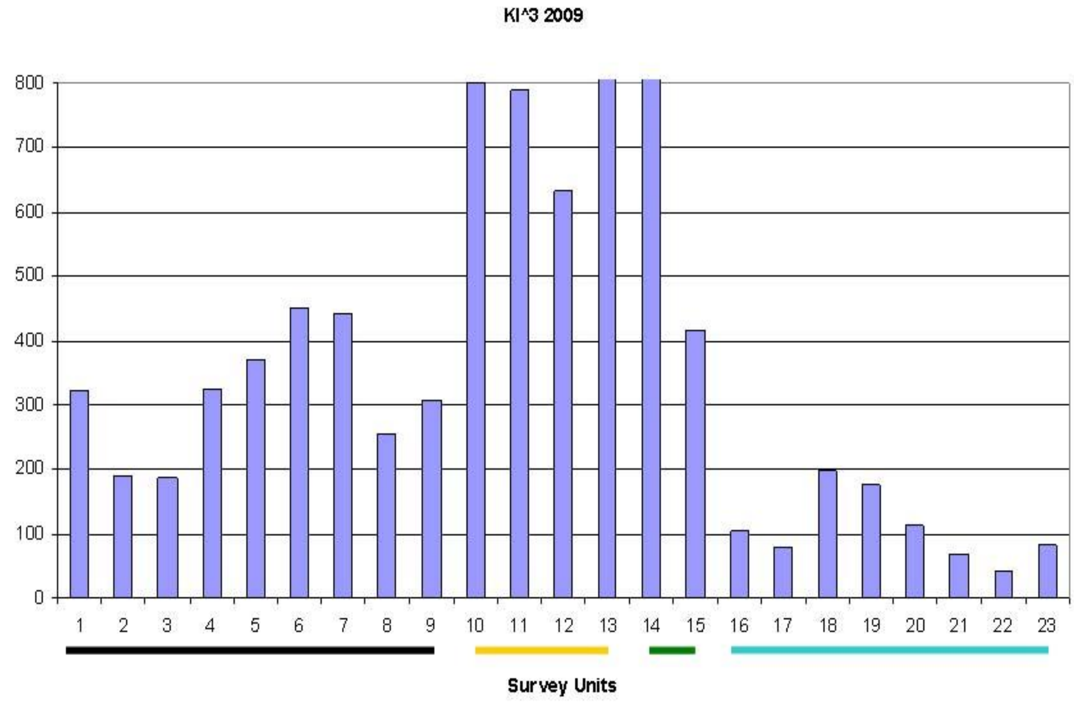

Figure 4-20: Sum of KI^3 for all Survey Units (SU) of Rosskopf oxbow ensemble 2009. Survey units 1-4: RK II; Survey Units 5-12: RK III; Survey Units 13-21: RK IV; Survey Units: 22-33: *Schanzelhaufen*

The survey of 2009 shows very high values for KI^3 in particular for RK III and RK IV.

4.4. Statistical Analysis

4.4.1. Simpson Index and Berger-Parker Dominance

The results of the PAST-Programme were graphically arranged as box plots. (n=3-40). Boxes show the median value as a central horizontal line, the upper and lower quartiles are indicated as the limits of the boxes. The ranges of the values are displayed as horizontal bars delimiting the vertical lines. The area of significance is indicated as a notched area at the box's side.

The Floodplain Index related habitats (H) belong to another category hence they are separated from the other ROS sections by a line.

Following sections of the ROS belong to H 4: RK II

RK III

RK IV

Following sections of the ROS belong to H 3: KA

SH

Abbreviations in use for this method:

Simpson-Diversity-Index… SD

Berger-Parker-Dominance… BPD

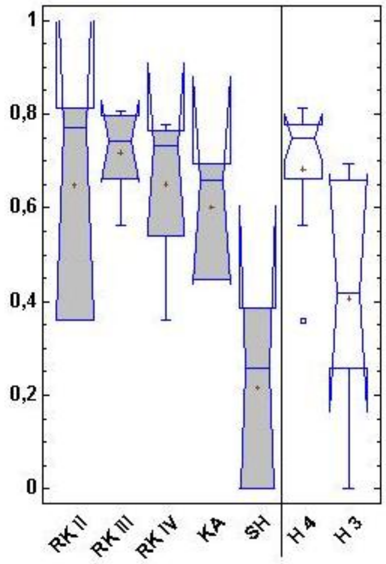

Figure 4-21: Simpson Diversity 1987

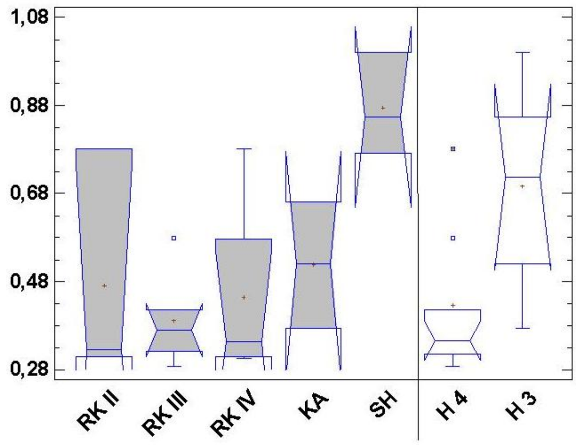

Figure 4-22: Berger-Parker-Dominance 1987

The Simpson Diversity (SD) shows lower results for the SH than for the other sections. The dominance is high for SH and significantly different from all other ROS-sections.

Among the sections of RK II and the KA no significant difference could be shown regarding diversity or dominance.

Grouping the ROS in accordance with the Floodplain Index displays significant differences in dominance and diversity for H3 and H4, in the survey of 1987.

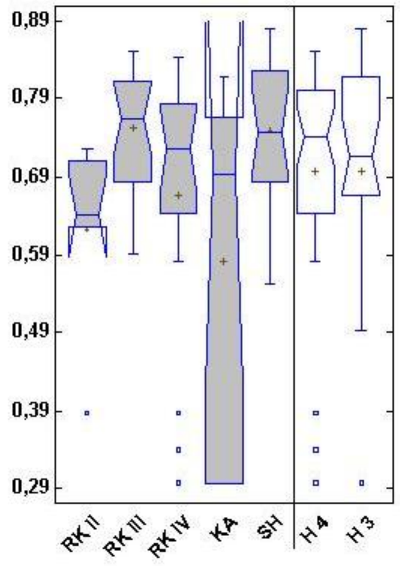

Figure 4-23: Simpson Diversity 1993

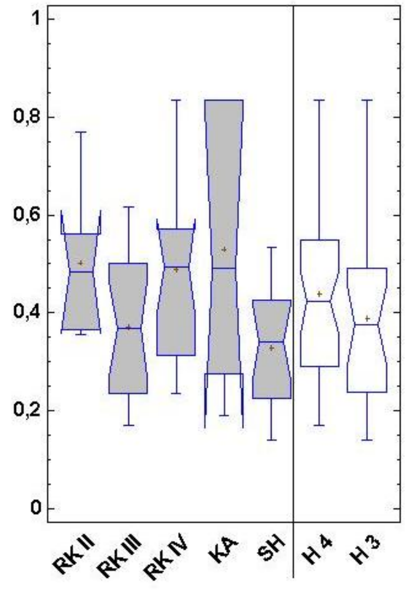

Figure 4-24: Berger-Parker-Dominance 1993

Concerning the Simpson-Diversity the mean value is the highest for RK III and lowest for RK II. For the record of 1993 the dominance shows little differences of range. The section KA possesses a wide statistical spread in dominance from 0.25-0.85. Comparing H3 and H4 no significant difference was detected. It should be noticed that some lower values are marked as outliers.

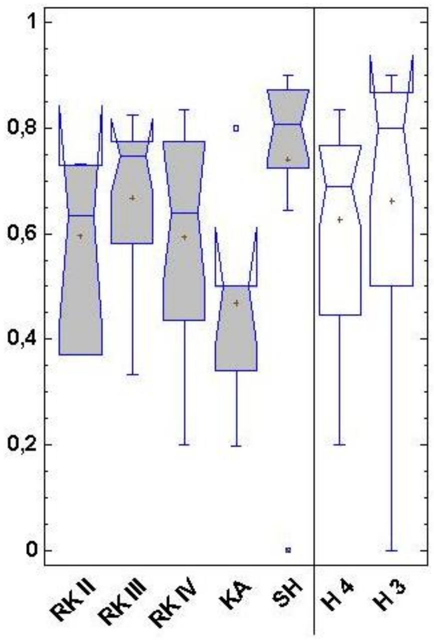

Figure 4-25: Simpson Diversity 1994

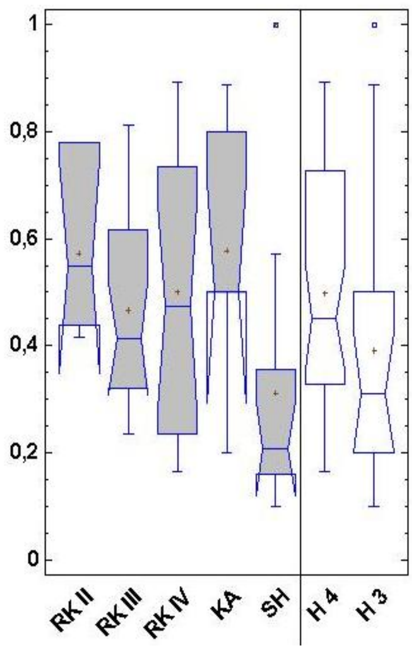

Figure 4-26: Berger-Parker-Dominance 1994

The SD is highest for SH, which is significantly different to the KA section. No differences are indicated among the other sections of the ROS.

Related to BPD the SH is significantly different from RK II, RK III and KA, the highest median can be observed for RK II.

The SI has a clear outlier in H3.

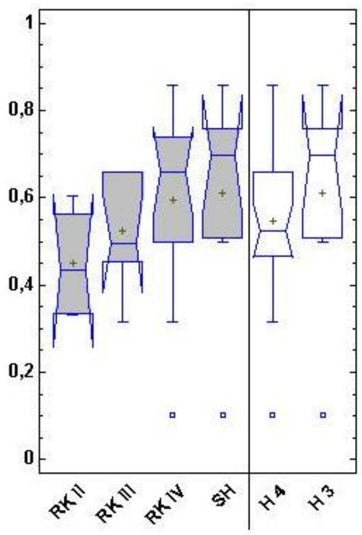

Figure 4-27: Simpson Diversity ISS

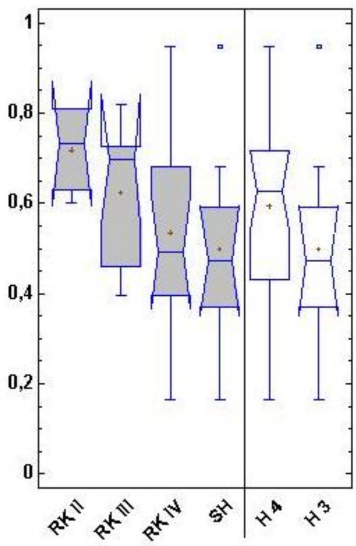

Figure 4-28: Berger-Parker-Dominance Students Survey 1994

ROS section SH has the highest value of diversity in this record. KA was not surveyed this year. The result for the BPD indicates a significant difference among SH and RK II.

The median dominance for H4 is higher than for H3. It is vice versa for SD.

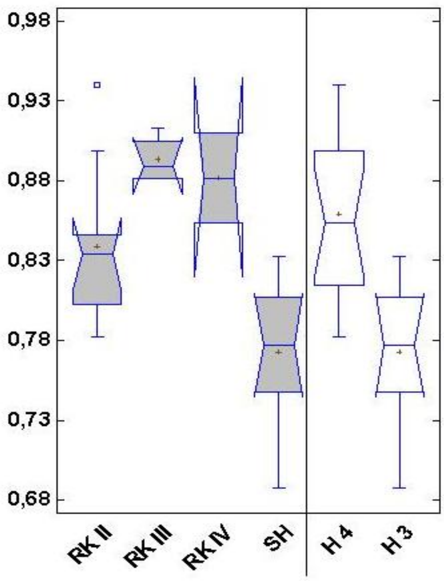

Figure 4-29: Simpson Diversity 2009

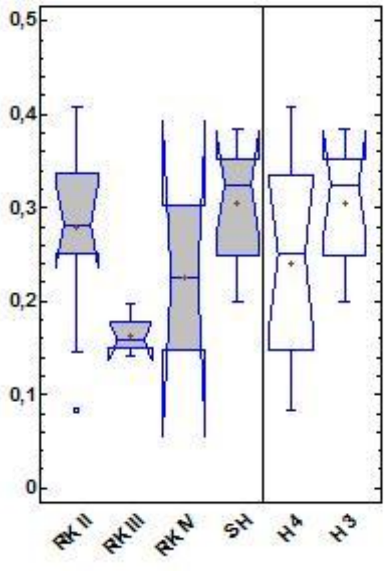

Figure 4-30: Berger-Parker-Dominance 2009

For this record only 2 survey units were investigated for the section RK IV, so this section has a poor statistical importance. It is apparent that RK II, RK IV and SH indicate significant differences. For the SH the diversity is clearly lesser as compared to the other sections.

According to the FI approach, H3 and H4 are clearly different regarding the diversity, but they are not different concerning the dominance. In KA no macrophyte vegetation was found in that year, so no box plot could be prepared.

4.4.2. Indicator Species Analysis

Table 4-3: Indicator Species of the Rosskopfarm Oxbow System

	Rosskopfarm 2	Rosskopfarm 3	Rosskopfarm 4	Karpfenarm	Schanzelhaufen
1987		*Potamogeton pectinatus*	*Lemna trisulca* *Sagittaria sagitifolia*		
1993	*Nuphar lutea* *Nymphaea alba*	*Myriophyllum spicatum* *Potamogeton pectinatus* *Ptomogeton lucens* *Schoenoplectus lacustris* *Rorippa sp.*	*Hippuris vulgaris* *Sagittaria sagittifolia*	*Callitriche sp.* *Lemna minor* *Lysimachia nummularia* *Myosotis palustre*	*Eleodea sp.* *Rorippa sp.*
1994	*Myriophyllum verticillatum* *Najas marina* *Nuphar lutea*	*Nitellopsis obtusa* *Nymphaea alba*	*Sagittaria sagittifolia*	*Callitriche sp.*	*Eleocharis palustris* *Myosotis palustre* *Polygonum hydropiper*

		Schoenoplectus lacustris *Sparganium emersum*			*Rorippa sp.*
ISS 1994	*Phragmites australis*				
2009	Carex riparia Galium aparine	*Myriophyllum verticillatum* *Nitellopsis obtusangula* *Nymphaea alba* *Sparganium sp.*	*Eleocharis sp.* *Hippuris vulgaris*		*Polygonum hydropiper*

The table above displays that in the surveys of 1993 and 1994 more Indicator species could be found than in other years.

Table 4-4: Indicator Species of the Rosskopfarm Oxbow System.

	HT 4	HT 3
1987	*Nuphar lutea*	
1993	*Hippuris vulgaris* *Myriophyllum spicatum* *Najas marina* *Nuphar lutea* *Nymphaea alba* *Schoenoplectus lacustris* *Sparganium emersum*	*Callitriche sp.* *Eleocharis sp.* *Lemna minor* *Lysimachia nummularia* *Myosotis palustre* *Poa palustre* *Rorippa sp.*
1994	*Hippuris vulgaris* *Nymphaea alba* *Najas marina* *Nuphar lutea* *Schoenoplectus lacustis* *Sparganium emersum*	*Callitriche sp.* *Eleocharis palustris* *Elodea nutallii* *Polygonum hydropiper* *Myosotis palustre* *Potamogeton sp.* *Ranunculus cirrcinatus* *Rorippa sp.*
ISS 1994		
2009		

The ISA concerning the Connectivity related Habitat Types shows again a more frequent occurrence of Indicator species in the surveys of 1993 and 1994. No indicator species were found for the Introductory Students Survey 1994 and the record of 2009.

4.4.3. Multi-Response Permutation Procedure (MRPP)

Table 4-5: MRPP in 1987

Groups Compared	(identifiers)		T	A	p
RK II	vs.	RK III	0.77385179	-0.04697322	0.77101834
RK II	vs.	RKIV	-0.19391564	0.01252047	0.36046959
RK II	vs.	KA	-0.51371075	0.04576867	0.31535651
RK II	vs.	SH	-0.40132882	0.02188142	0.34332702
RK III	vs.	RK IV	-0.01429350	0.00068616	0.38836176
RK III	vs.	KA	-0.70722689	0.04382187	0.21004201
RK III	vs.	SH	-0.98629652	0.04139101	0.15866133
RK IV	vs.	KA	-0.28774751	0.02309244	0.33511655
RK IV	vs.	SH	-119.017.474	0.05864960	0.11996518
KA	vs.	SH	-0.56817975	0.03607379	0.28335951

H4 vs. H3: Probability of a smaller or equal delta, p = 0.08841515

In 1987 no significant differences among the H and the Rosskopfarm System sections were detected.

Table 4-6: MRPP in 1993

Groups Compared	(identifiers)		T	A	p
RK II	vs.	RK III	-591.519.095	0.08541480	**0.00019859**
RK II	vs.	RK IV	-413.699.535	0.05770252	**0.00212154**
RK II	vs.	SH	-924.439.779	0.13556901	**0.00000204**
RK II	vs.	KA	-626.039.330	0.24428103	**0.00033302**
RK III	vs.	RK IV	-785.482.924	0.06100121	**0.00000179**
RK III	vs.	SH	-1.583.574.130	0.13286154	**0.00000000**
RK III	vs.	KA	-1.186.135.259	0.16626185	**0.00000005**
RK IV	vs.	SH	-745.462.945	0.05757881	**0.00001259**
RK IV	vs.	KA	-734.480.038	0.09574910	**0.00001375**
SH	vs.	KA	-462.734.903	0.05600837	**0.00041744**

H4 vs. H3: Probability of a smaller or equal delta, **p = 0.00000000**

The record of 1993 displays a significant difference in all compared sections and amongst the H´s.

Table 4-7: MRPP in 1994

Groups Compared	(identifiers)		T	A	p
RK II	vs.	RK III	-326.942.165	0.04406955	**0.00870401**
RK II	vs.	RK IV	-460.776.952	0.06489105	**0.00108389**
RK II	vs.	SH	-851.176.327	0.15514413	**0.00001099**
RK II	vs.	KA	-612.778.888	0.18886499	**0.00028148**
RK III	vs.	RK IV	-581.344.104	0.04720948	**0.00013840**
RK III	vs.	SH	-1.242.522.401	0.11653722	**0.00000003**
RK III	vs.	KA	-869.500.501	0.10636611	**0.00000368**
RK IV	vs.	SH	-673.192.745	0.06174255	**0.00002881**
RK IV	vs.	KA	-559.089.721	0.07017685	**0.00021478**
SH	vs.	KA	-136.011.140	0.01996021	0.09771032

H4 vs. H3: Probability of a smaller or equal delta, **p = 0.00000000**

In 1994 the sections are significantly different except for *Schanzelhaufen* and *Karpfenarm*. Both Sections are statistical equal
The H´s are significantly different.

Table 4-8: MRPP in Students Survey 1994

Groups (identifiers) Compared			T	A	p
RK II	vs.	RK III	0.01124942	-0.00042796	0.44320605
RK II	vs.	RK IV	-0.49719825	0.01421604	0.27558008
RK II	vs.	SH	0.04250774	-0.00103522	0.46273591
RK III	vs.	RK IV	-116.574.908	0.02507972	0.12439253
RK III	vs.	SH	0.28712786	-0.00614668	0.55076501
RK IV	vs.	SH	134.061.877	-0.02885741	0.93658162

H4 vs. H3: Probability of a smaller or equal delta, p = 0.97862001

In the ISS results no significant difference can be seen among the Sections and the H´s. No survey was conducted for the *Karpfenarm* in that year.

Table 4-9: MRPP in 2009

Groups	(identifiers)				
Compared			T	A	p
RK II	vs.	RK III	-523.336.155	0.14456255	**0.00027599**
RK II	vs.	RK IV	-240.171.714	0.09717144	**0.01506790**
RK II	vs.	SH	-871.503.613	0.19806624	**0.00002985**
RK III	vs.	RK IV	-227.419.850	0.16630281	**0.02113585**
RK III	vs.	SH	-626.308.425	0.21624084	**0.00024866**
RK IV	vs.	SH	-352.526.615	0.12716921	**0.00859054**

H4 vs. H3: Probability of a smaller or equal delta, **p = 0.00000059**

The MRPP delivers no significant differences amongst all regarded issues in 1987. (Table 4-5) The situation completely changed 6 years later in 1993 where a clear significance can be observed especially between H3 and H4 (Table 4-6). A similar situation was found in 1994 with significant differences amongst all Issues except KA vs. SH (Table 4-7).

The Introductory Students Survey 1994 shows no statistical regional distinctions because of the inexperienced surveyors (Table 4-8).

Table 4-9 displays again clear statistically distinction amongst all sections in 2009.

4.5. Correlation Analysis: Survey Unit Length-Species number

Table 4-10: Correlation values of all sections among all years. Numbers in bold indicate significant correlation of Survey Unit length and species number.

considering survey bounderies	RK II	RK III	RK IV	KA	SH
1987	XX	0,705	0,697	XX	0,749
1993	0,148	**0,028**	0,275	0,093	0,093
1994	0,701	0,433	0,525	0,305	0,305
Introductory Students Survey 1994	0,705	**0,041**	0,503	XX	0,444
2009	0,112	0,057	XX	XX	0,310

considering habitat bounderies	H4	H3
1987	0,425	0,671
1993	0,652	0,819
1994	0,368	0,221
Introductory Students Survey 1994	0,607	0,444
2009	0,066	0,310

Table 4-10 shows that in the majority of the sections no correlation of Survey Unit lenght and species number occurs. Only RK IV 1993 and H4 of 1994 show a correlation. Sections where no analysis was conducted because of too few number of sections or where no record was taken are marked with “XX”.

4.6. Habitat types related to the FFH-Directive

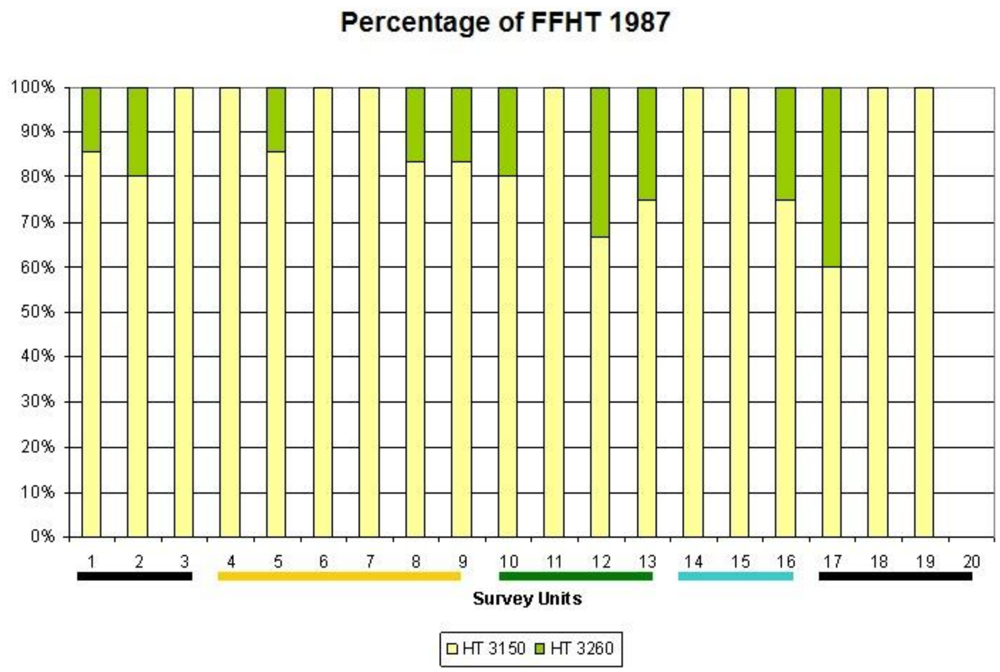

Figure 4-31: Rosskopf Oxbow System (ROS) 1987. RK II: Survey units 1-3; RK III: Survey Units 4-9; RK IV: Survey Units 10-13; Karpfenarm: Survey Units 14-16; Schanzelhaufen: Survey Units 17-20

Figure 4-31 displays the predominant position of FFHT-3150 in the year 1987. Mixed types are present in all sections of the ROS.

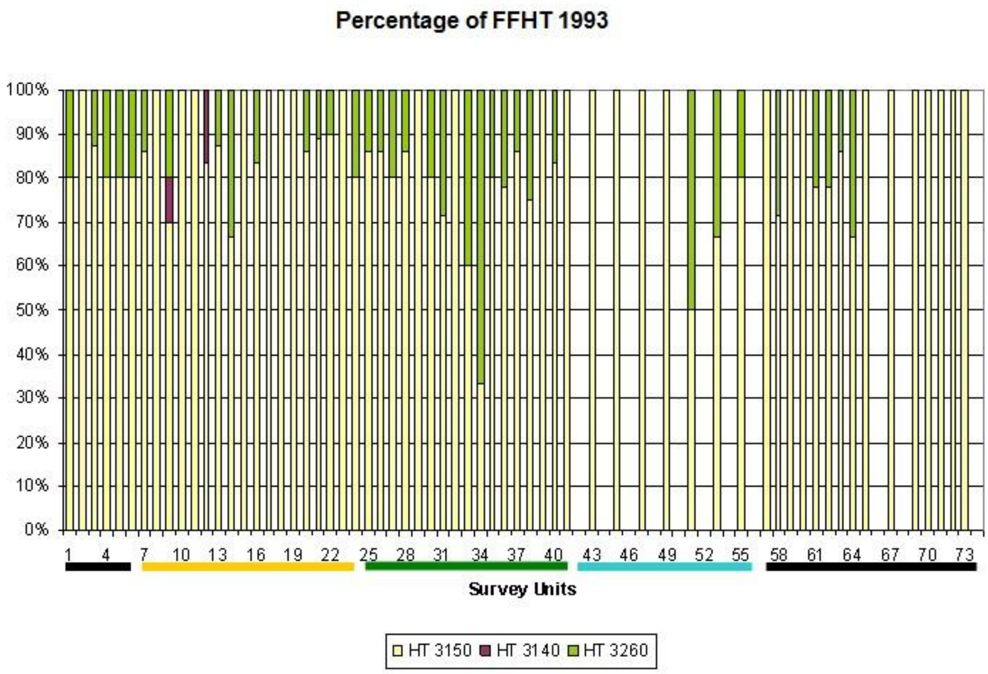

Figure 4-32: Rosskopf Oxbow System (ROS) 1993. RK II: Survey units 1-6; RK III: Survey Units 7-24; RK IV: Survey Units 25-41; KA: Survey Units 42-56; SH: Survey Units 57-74

In 1993 FFHT-3150 is predominant and can reach 100% in several survey units. Two survey units in RK III are made up of 3 habitat types, including FFHT-3140.

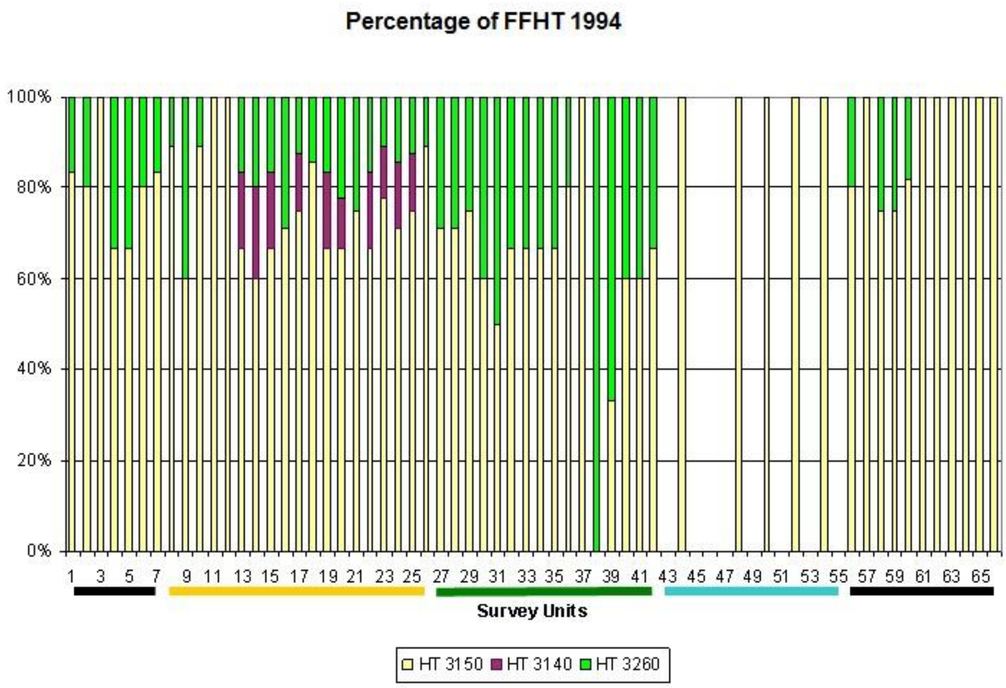

Figure 4-33: Rosskopf Oxbow System (ROS) 1994. RK II: Survey units 1-7; RK III: Survey Units 8-26; RK IV: Survey Units 27-42; KA: Survey Units 43-55; SH: Survey Units 56-68

Figure 4-33 shows that FFHT-3150 has a predominant position in 1994, especially in KA. FFHT-3260 reaches 100% for one survey unit in RK IV. In RK III FFHT-3140 is also present.

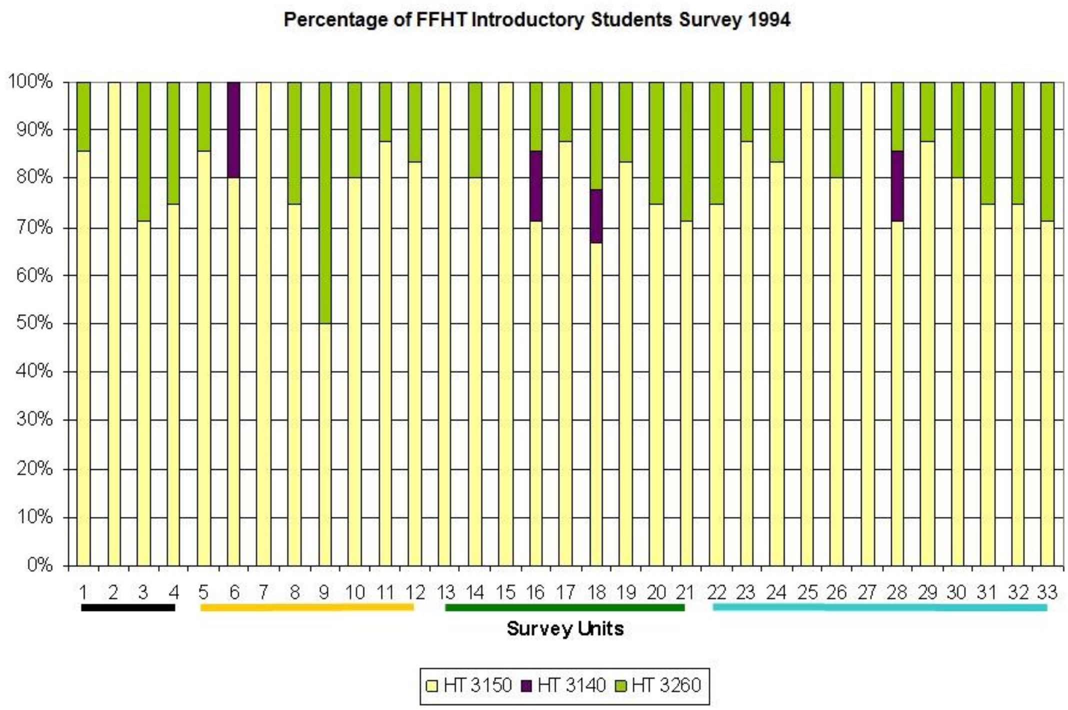

Figure 4-34: Rosskopf Oxbow System (ROS). RK II: Survey units 1-4; RK III: Survey Units 5-12; RK IV: Survey Units 13-21; SH: Survey Units 22-33

The FFHT´s are mixed among the RK-Sections. FFHT-3140 was detected in the ROS sections RK III, RK IV and SH.

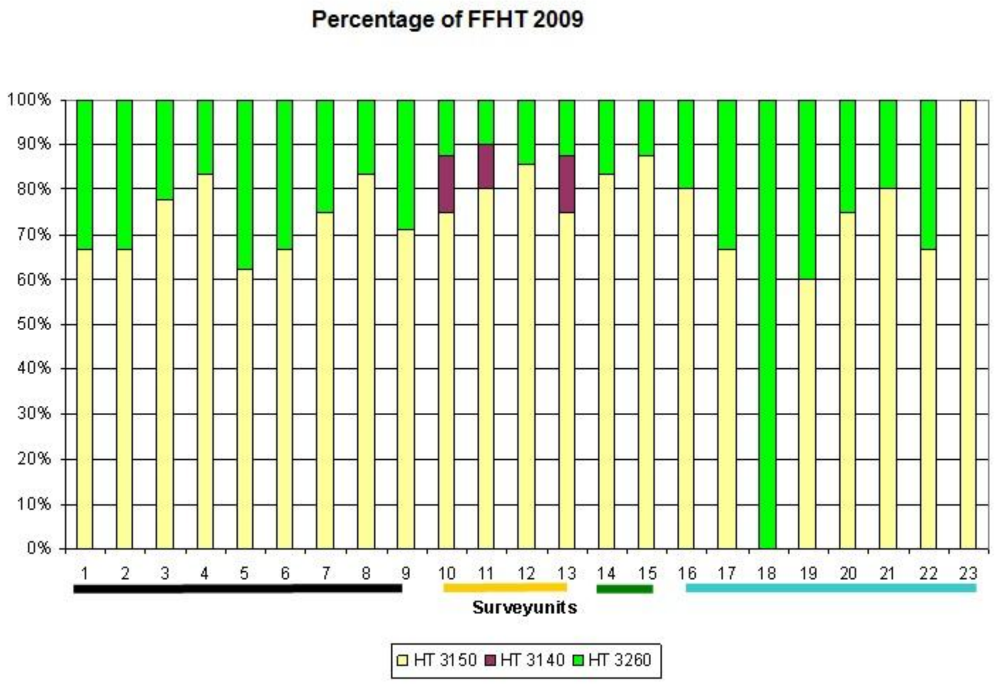

Figure 4-35: Rosskopf Oxbow System (ROS). RK II: Survey units 1-9; RK III: Survey Units 10-13; RK IV: Survey Units 14-15; SH: Survey Units 16-23

In this year mainly FFHTs 3150 and 3260 were identified in mixed arrangements. Three Survey Units of RK III have an additional contribution of 3140-FFHT. KA possessed one survey unit with 100% FFHT-3150 and one with 100% FFHT-3260.

5. Discussion

This thesis analyses the effects of connectivity with the main river on the macrophyte assemblage of an oxbow system. In particular the data basis consists of five different surveys covering a period of 22 years. Directly comparable literature, especially concerning the method, length of the period and the type of water bodies, could not be found. Though, long-time studies have been conducted on other water bodies using presence-absence analysis and the Kohler-survey method. Heller-Meixner (2011) showed the difference of macrophyte vegetation over 20 years of two adjacent New Danube reaches. Moreover Janauer et Wychera (1999) ascertained water plant abundance and presence-absence for a ten year period for the same Danube sections.

A further long-time study was conducted to ascertain indicator plants for water pollution by Blumenthal et al (1994) and for the state and development of running waters by Veit et Kohler (2003).

The species numbers are varying among the surveys, this fact is explained primarily by the different focus of the survey teams and the different types of water bodies studied. Among the data analysed in the present study the Introductory Students Survey in 1994 was conducted by students with no earlier experience, so e.g. the reporting of rare species may have biased the available data. The surveys in 1993 and 1994 were conducted by the same team resulting in a high consistency regarding the individual error base.

The presence-absence list shows that 3 helophyte species are constantly occurring in every survey, whereas 11 hydrophytes species are present in all years. Hence the Rosskopf Oxbow System (ROS) is more suitable for certain hydrophytes, this is in accordance with Janauer (2008) where a dominance of hydrophytes was shown for the ROS. The lack of mosses in the study area matches with the set-up of habitats published by Janauer (2008). Four water plant species are occurring in every survey year of this study as well as in the 10-year survey of Janauer et Wychera (1999) where the period from 1987 to 1997 was covered. Those species are: *Potamogeton pectinatus, Potamogeton crispus, Potamogeton lucens* and *Myriophyllum spicatum.* The same species are also, with the exception of *Potamogeton lucens,* occurring in the next period from 1997 to 2007 (Heller-Meixner 2011).

The number of recorded helophytes increased from 1987 to 2009 from 6 species in 1987 to 28 species in 2009. This can be an indicator for an aggrading process. A high number of helophytes in combination with high plant abundance was already mentioned as aggradation indicator by Pall et Kum (2006).

The surveyors of 2009 recorded *Polygunum aviculare* which is definitely a dry site related plant, so it was not considered in the results.

The survey of 1987 shows a considerable change of the vegetation in the survey units downriver of the ends of the oxbow sections. This may be a result of flushing in the area down of the barrages which are separating the sections of the Rosskopf Oxbow System (ROS). The flushing areas are characterised by accelerated current velocities, especially during floods, which affect the macrophytic vegetation and cause a “distribution-gap” in the distribution diagram.

This change of distribution can easily be seen at the changeover from *Rosskopfarm III* (RK III) to *Rosskopfarm* IV (RK IV). After this changeover the abundance of *Myriophyllum spicatum, Myriophyllum verticillatum, Nuphar lutea* and *Potamageton crispus* is lower. But some other species seem to benefit from this situation, like *Lemna trisulca and Lemna minor*. *Ceratophyllum demersum* occurred in high abundance close to the flushing zones in this year. Those plants are not growing directly in the middle overtopping part but in slow-flow parts of the cross section close to the bank. The other changeovers (*Rosskopfarm* II (RK II), *Karpfenarm* (KA), *Schanzelhaufen* (SH)) do not show a clear change of vegetation.

Related to the relative abundance, species with high percentage like *Myriophyllum spicatum,* show the “distribution-gap” more frequently than less contributing species like *Hydrochorus morsus-ranae.* They are more affected by the changeovers.

For 1993 no clear “distribution-gaps” were detected. *Myriophyllum spicatum* and *Nuphar lutea* were again present with high abundance and well distributed over the whole ROS in this year. Regarding the Distribution-Diagram a decrease of abundance and occurrence of all species can be ascertained for the *Karpfenarm* (KA). This may be a result at least in part of shading in this section of the ROS. This shading effect is most certainly the reason for the long survey unit at the initial part of the KA, where no aquatic vegetation could be recorded. The “distribution-gaps” of the 1993 record are not so clearly confined.

Different to the surveys of 1987 and 1993 the year 1994 does not have clear changes of vegetation at the ROS changeovers. However the KA features, similar to the other years, a low number of species which are also low in plant abundance. The survey 1994 was conducted in September and the shading effect of the bank vegetation consisting to a great part of trees can explain this result. *Nuphar lutea* is, like in the preceding records, the plant species with the highest relative abundance.

The Introductory Students Survey (ISS) of 1994 was of purely training character, which renders the precision of its results a bit problematic. However, also in this survey significant differences were detected among the sections. Because this was conducted only a period of three months earlier than the 1994 survey carried out by experienced surveyors, both results can be compared, and can be used for underlining the specifics of that year. The ISS was conducted in mid-June 1994 and the second survey in mid-September 1994. Hence it is possible to compare the ROS in early and late summer. No survey was carried out on KA for during the ISS 1994. *Nuphar lutea* is clearly dominant in the ISS Distribution Diagram and regarding species abundance. This is similar to the record of September 1994. A clear difference can be ascertained regarding *Ranunculus circinatus*. In the ISS of 1994 this species was concentrated in three patches and showed a relative abundance of more than 10%. This is in contrast to the record conducted three months later were *Ranunculus circinatus* is barely distributed and it´s relative abundance belongs to the group of the residuals (relative abundance less than 1%). The distribution-Diagram indicates a similar situation amongst the distribution of helophytes and hydrophytes. The helophytes are scarcely distributed and the abundance is concentrated on *Schoenoplectus lacustris* and *Hippuris vulgaris*.

The survey in 2009 shows no “distribution-gaps” in the distribution diagram. Noticeable for that year is that the section RK III has the highest plant abundance estimate of all surveys.

The number of residuals, which are plants of a relative abundance less than 1%, increased from 9 in 1987, 19 in 1993 up to 24 in 1994. In the survey of 2009 the only 16 species were ascertained as residuals. For all surveys very few plants have a T/O-ration more than 0.5. Only for the ISS 1994 (*Hippuris vulgaris, Schoenoplectus lacustris)* and the record of 2009 (*Sagittaria sagittifolia)* helophyte species reaches a T/O-ratio greater than 0.5 so they are constant in abundance. The differences can be explained by means of different survey focus. Furthermore flood events have an impact on the bank structure which leads to a variation of helophytes.

Nuphar lutea contributes about 10% to the relative abundance in every survey except 1987 and it is an indicator species for Habitat Type 4 (H4) following the Floodplain Index (FI) approach (also corresponds to flooded days less than five) in 1987, 1993, 1994 and 2009. The result of the student’s survey (ISS) for *Nuphar lutea* may be regarded problematic due to the training character of this field work, but it is worth noticing that although this species has a high relative abundance value it is no

statistically specified Indicator Species (IS) for H4. *Nuphar lutea* serves as an IS only in the other 4 of the 5 records of H4. Yet, it was considered an indicator for H4 by Chovanec et al. (2005), who used the phyto-sociologic association '*Myriophyllo-Nupharetum*', a complex species community, to characterize H4.
No plant species could be identified as an indicator for H3, the IS are varying among the years.

The results are not indicating further Indicator Species related to a certain FI-related Habitat type. To create a macrophytic system of habitat values and indicator weights according to Waringer et al. (2005), a larger database and additional investigations may be needed.
The results of the Indicator Species are completely different for H3 and H4 in each of the survey years. The number of IS for H3 is much higher in 2009 (11 species) than for H4 (3 species). The number of IS for H3 decreased from 8 species in 1994 to 3 species in 2009. Bearing in mind the natural deepening processes of the Danube, which are about 30 cm in 15 years, the loss of IS´s can be related to the dynamic attributes of river systems. RK II shows the lowest IS numbers of all ROS sections of H4, which can be related to its greater distance to the main river channel.

The records of 1993, 1994 and 2009 show a decrease of IS from RK III via RK IV to KA. Thus a decrease of IS in parallel with a decrease of the distance to the main river can be shown. A similar relationship was indicated by Janauer (2006) where decreasing species number in parallel with decreasing distance to the main current was ascertained for the same area.
The results of the MRPP indicate that the significant differences are varying among the surveys and the correlation analysis indicates no significance of the relationship between survey length and species number amongst the majority of the sections.

The results of Habitat Types related to the Habitat Directive indicate a higher abundance of species preferring flowing waters in 1994 and 2009. This means that within 15 years the number of macrophytes related to standing water bodies decreased. Comparing all figures one ascertains that the FFH related habitat types possess a dynamic within certain confines.

Comparing the results of the KI^3 it attracts attention that the highest results for species abundance are related to the sections RK II, RK III and RK IV amongst all years. These sections belong to the H4 connectivity type. The H3 related sections possess lower values, especially the KA shows low amounts in 1993 and 1994. The shading effect of bank vegetation can be an explanation for the low KI^3 values. In 2009 no macrophytic vegetation occurred in KA and during the students survey 1994 it was not recorded. The record of 1993 shows a decrease of plant mass for the crossing from RK III to RK IV. This can be related to the presence of the embankment which causes a flushing effect. The increased stream velocity can be an explanation for the decrease of plant mass in the area of the crossing.
The KI^3 peaks are between 200 and 250 each year, but the sections RK III and RK IV reach values up to 800 in 2009. This is almost double the highest result of 1987. The sections KA and SH, which are related to another connectivity type, show lower values For 1987 Simpson Index of Diversity and Berger-Parker Dominance (BPD) indicate that SH has a lower SI and a higher BPD compared to the other sections of the ROS. With diminishing distance to the main current the diversity of the ROS-sections decreases, and the dominance increases. The connectivity related Habitat Types underline this result. HT 4 Type (Connectivity C^d < 5days) has a higher diversity and therefore a lower dominance than HT 3. This is according to the results of Janauer et al. (2012). In this publication a slightly increased diversity of HT 4 was shown. This is also valid for the H4 type (Litoral permanent standing waters, high sedimentation, significantly reduced connectivity and dynamics), which is also complying with HT 4 (see Introduction). However it has to be considered that for this survey few SU were set up for RK II (3 SU), KA (3 SU) and SH (3 SU) so the approach of habitats has a more accurate statistical information.

In the survey of 1993 a larger number of SU could be recorded and hence the results for each ROS-section (RK II-RK IV, KA SH) have a better statistical credibility. In this year section the highest SI and a low dominance value were recorded for RK III. Comparing this section with the records of 1994 and 2009 a similar result is indicated. This situation can be related to the position of this section amongst the ROS. It receives enough input from the main river channel but is also far enough from it to serve as a refuge for species.

The Introductory Students Survey 1994 is not attesting this situation, but it can be neglected due to its training character. Moreover the SI-median values for KA and SH are at a high level in 1993 which is mirrored in a high SI-result for H3. The SI and BPD results of the Introductory Students Survey 1994 are in contrast to the others. High values of diversity and low ones for dominance are indicated. As mentioned above this survey had a training character so the statistical credibility is low.

In 1994 KA shows low diversity and high dominance but the SH has high results for SI and BPD, so the H3 also indicates a high SI and low BPD. A relationship with Janauer et al. (2012), where a slightly increased diversity of HT 4 was indicated, cannot be ascertained for that survey.
For 2009 the comparison of the habitat types H4 and H3 shows that H4 has, again in accordance to Janauer (2012), a higher diversity and a lower dominance. So coherence between connectivity type and diversity is indicated for that survey.

The above mentioned topic addresses the differences in connectivity (change H4 to H3), plant abundance (Distribution diagram) and diversity (SI) in the Rosskopf Oxbow System. These issues parallel the biological (taxonomic composition) and hydrological (River continuity) quality elements of the Definition for high, good and moderate ecological status in rivers of the Water Framework Directive (WFD) (European Council, 2000). Moreover in the study area are habitats occurring which are addressed by the Flora Fauna Habitat Directive (FFDD).

CHOVANEC et al. published 2005 a combination of habitat (H) information with the WFD to make a statement about the ecologic status.

In the study area the Austrian Danube consists of the main channel primarily, as the result of the former river regulation. H1 is not explicitly present in the whole area but H1 is certainly relevant for the variable, but short length of mouth sections of the different oxbow systems. However the application of the Floodplain Index related habitat types allows some interpretation (Reckendorfer, personal communication 2012). For the Rosskopfarm Oxbow System (ROS) some parts can be considered as H1,as well as e.g. the mouth sections of the large oxbow on the right bank of the river. According to Chovanec et al. (2005) the ecological status of the north bank of the Danube as related to WFD conditions can be classified as III/moderate for most parts, because of lacking H1 to a great extent when considering the reference conditions of the unregulated river course. This addresses the ROS since only a very short part could be clearly defined as H1 in the mouth region. Moreover, some parts of the ROS, which had been one of the main channels prior to regulation, may be considered class II/good or rather class III/moderate, regarding WFD reference conditions. The classification scheme is depicted by**Fehler! Verweisquelle konnte nicht gefunden werden.**. As WFD requires to achieve class II/good status structural measures would be needed to reconstruct the highly connected H1 type in the ROS and in many other water bodies in the Austrian flood plains.

Table 5-1: Classification scheme for assessing the ecological status of river/floodplain systems (CHOVANEC et al. 2005)

	I / high	II / good	III / moderate	IV / poor	V/ bad
Species community	(nearly) totally corresponds to the type-specific reference condition	slightly deviates from the type-specific reference condition	significantly deviates from the type-specific reference condition	only remnants of the type-specific community are present	few if any species are present that correspond to the type-specific reference community
ecological integrity	(nearly) undisturbed	slightly disturbed	significantly disturbed	heavily disturbed	completely disrupted
FI	Distribution and range of the FI correspond to the reference situation and indicate that all habitat types are present with H1 dominating	Distribution and range of the FI indi-cate that all habitat types are present with H1 not dominating or one habi-tat type (with the exception of H1) is missing	Distribution and range of the FI indicate that at least H1 or two habitat types are missing	Distribution and range of the FI indicate that one or two habitat types are present; few sensitive species are found	Floodplain is missing or dis-tribution and range of the FI indicate that only one habitat type is found; no or nearly no sensitive species are found

Constructions to improve the flood protection and the navigability in the 19^{th} century led to a straightening of the main channel and to a disconnection of the backwaters. Backwaters like the ROS could no longer fulfil their function in riverine landscape. Former floodplain oxbows enabled the exchange at flood events of dissolved material, sediments, biomass and organisms. Together with the transformation from the formerly braided Danube river to a straightened river a loss of habitat diversity was the result. (Hohensinner et. al. 2004)

Moreover the construction of the flood protection dyke caused a further disturbance of the floodplain environment. Especially the wetlands outside of the dyke were affected by these measures. They lost the permanent connection with the side arms and changed from a meandering stream into standing water bodies.

If the WFD would be strictly applied in this case, a removal of the dyke would be necessary to achieve the pristine situation. To maintain the flood protection a relocation of the dyke behind the "*Fadenbach"* would be required (Figure 5-1). Yet, this measure is not feasible due to socio-economic conditions. Corresponding to the opinion of experts, relocation would affect the hydrologic condition, the navigability and would cause wide utilisation losses in the floodplain area between Vienna and Bratislava. Summing up, a pristine situation cannot be induced, so a near natural status must be the objective. A strong application of the WFD would increase the connectivity in the Rosskopfarm Oxbow System (ROS) hence, the standing water bodies would diminish so species related to this habitat would be eliminated.

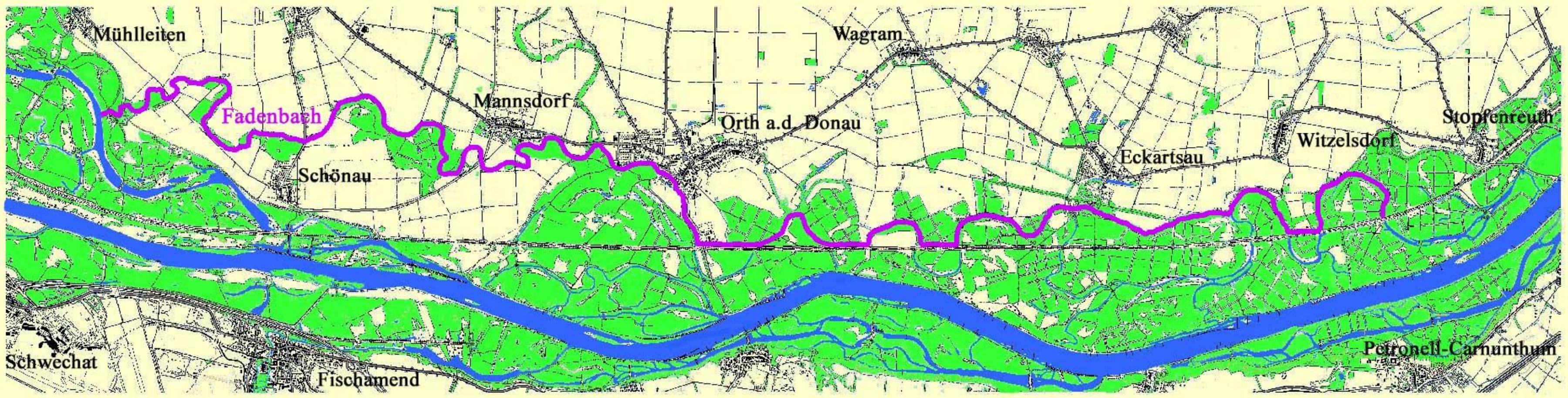

Figure 5-1: An overview map of the Danube between Vienna and Bratislava including the *Fadenbach (Source: http://www.fadenbach.at)*

The requirements of the Flora Fauna Habitat Directive (FFHD) (European Council 2012) demands the "…*conservation…*" [of] "…*habitat types of common community interests*…". The results of Chapter 4.6 (Habitat types related to the FFH-Directive) provide the fact that the Flora Fauna Habitat Types (FFHT) are predominately related to FFHT-3150. This type is a *natural* standing water body according to the FFHT-code. As mentioned above the situation in the active floodplain is a result of their construction.

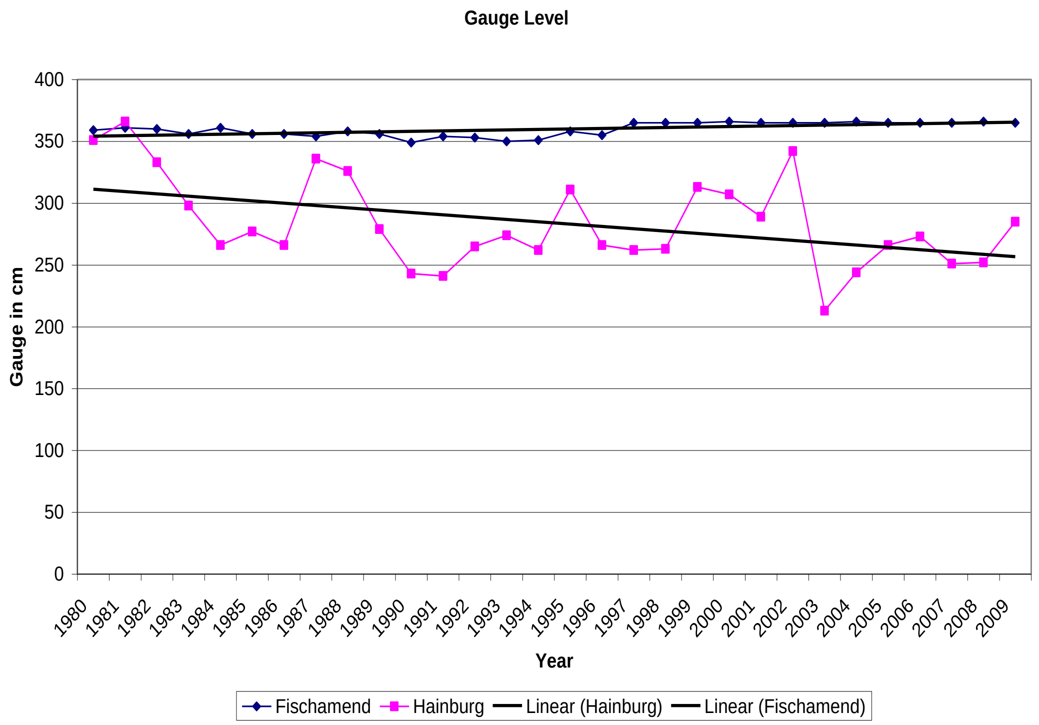

Figure 5-2: The gauge level of Hainburg and Fischamend. The level is not decreasing in Fischamend due to the charge of additional bed load downriver of the hydro power plant in Freudenau. Between Freudenau and Hainburg is a distance of nearly 26km where bed erosion takes place according to the steeper gradient of the regulated river course. The mean difference at the site Hainburg between 1980 and 2009 is about 50 cm. The outlier of the Hainburg gauge level is caused by a flood event. (VIADONAU 2012)

Natural remaining habitats in the oxbows can be regarded as “relict biotopes” which will definitely disappear due to the change in connectivity.

The existing habitat types protected under the Habitat Directive in the Rosskopfarm Oxbow System (ROS) can be regarded as “License-Habitats” (Grabherr, personal communication 2012). Those License-Habitats evolved because of the man-made disturbances and the reduced river dynamics following the regulation. This resulted in protection by conservation measures such as the Flora Fauna Habitat Directive (FFHD). A strict appliance of the WFD, a relocation of the dyke and the reconnection of the oxbows with the main river, would lead to the disappearance of species protected by the FFHD.

Furthermore in a dynamic system it is not possible to maintain the area designated by the FFHD at the exact same size. This can be seen by comparing Figure 4-32 and Figure 4-33 of chapter 4.6. The extent of FFHT-3140 is varying between 1993 and 1994. Sticking on a percentage related FFHD designation makes no sense.

For the ROS waterbody it is the same situation as for the whole Floodplain area between Vienna and Bratislava. The appliance of the WFD and the FFHD at the same time causes uncertainties. According to the WFD Art.4.2 the more stringent directive shall apply. In this case the objectives of the WFD would be more stringent. The FFHD is species orientated and the flora and fauna assemblage of rivers is depending on the connectivity with the main channel. Diminishing connectivity leads to aggradation which is a threat to riverine ecosystems, so a total disconnection should be avoided by the application of the WFD. However, many interests are connected with the present situation of the Danube. For example, the navigability would decrease after fulfilling the requirements of the WFD. This would eliminate an important west-to-east route for goods transport. In 2011 about 9.9 million tons of goods were transported on the Danube by ship (Statistik Austria 2012). The loss of this route would lead to an economic damage for Austria. The renaturalization of the Danube, which is an international navigation corridor, might lead to a violation of international treaties and regulations for navigation. According to a report of the European Commission (2011) [Note:" …*the authorities need to determine precisely which objective is actually the more stringent*"]. For the Danube River the perpetuation of the navigability is regarded as more important than the modification into a more pristine river. This means for the *Rosskopf* Oxbow System that the connectivity will not be improved so the pristine situation will not be represented.

6. Conclusion

The connectivity and the flow velocity of running water bodies definitely affect the macrophytic assemblages. This is demonstrated by the distribution diagrams on the one hand and by the differences in the Simpson Index of Diversity, Berger-Parker-Index of Dominance, and in the change of the habitat types described by the Habitat Directive on the other hand. Clear differences of Simpson Index of Diversity and Berger-Parker-Index of Dominance amongst hydrological Habitat Type 3 (connected with the main river less than 120 days/year) and Habitat Type 4 (connected with the main river less than 5 days/year) can be seen. The variability of these diversity indicators in the time span of 1987-2009 can be related to the flood dynamics of the Danube as well as to the deepening processes of this riverine system. Moreover the deepening affects the number of Indicator Species of the Rosskopfarm Oxbow System. Furthermore the change of the number of Indicator Species can be used to demonstrate changes in a dynamic system. In a stable system the Simpson Index, Indicator Species and Berger Parker Dominance would be within a certain limit of fluctuation. This is not applicable for the Rosskopf Oxbow system.

Concerning the Habitat Directive these dynamics are modifying the addressed areas. To adhere to a fixed percentage of area related to designations and to stick on thresholds in a dynamic area cannot be considered meaningful.

To adhere strictly to the objectives of the Water Framework Directive would need a relocation of the flood protection dyke. This measure would result in a change of macrophytic vegetation of the areas designated by the Habitat Directive.

It is challenging to improve the environmental status of dynamic systems by obeying all published Directives. Interdisciplinary approaches and sufficient freedom of action amongst the directives is needed to act sustainably.

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