University of Natural Resources and Life Sciences, Vienna

Department of Water, Atmosphere and Environment

Institute of Hydrobiology and Aquatic Ecosystem Management

Master thesis

Macrophytes as habitat for aquatic invertebrates in the Lower Lobau floodplains

Sabrina Eidinger

01104213

Submitted in fulfilment of the requirements for the degree of

Master of Science

Master programme: Applied Limnology H 066 448

Supervisor: Assoc. Prof. Dr. Wolfram Graf

Vienna, March 2018

Acknowledgement

Foremost, I want especially thank my supervisor Wolfram Graf for his support throughout this study. His constant help, advice and critical lecture was essential throughout my entire working process.

I would also like to thank the National Park Danube Flood Plains for the opportunity to do research in a conservation area. A special thank goes to Sigrid Scheikl, who supplied lots of knowledge and hints for preparation of my first research proposal. Many thanks to Thomas Huber for his support in the lab, to Patrick Leitner for his assistance in the field and in data analysis and to all other persons who contributed to my master thesis.

Thanks also to my study colleagues, lab mates, friends and my family. I am extremely grateful to my parents who gave me the opportunity to follow my personal interests and supported me during my years of studying.

My final thank goes to Markus – for his patience, support, motivating words and the wonderful time together.

“*Little things run the world.*“

E. O. Wilson

Abstract

Due to systematic regulation the Danube and its related floodplain changed from a dynamic system to a static one (Hohensinner et al. 2008). Missing dynamics caused establishment of macrophytes in the floodplain water bodies. As aquatic vegetation provides high heterogeneity it is important habitat for fauna (Papas 2007). The present study assignes the study sites to floodplain habitat types. Focus is on influences of season, site-specific properties, macrophyte complexity at water body scale, macrophyte species and leaf types on the epiphytic invertebrate community. Four study sites were sampled in June and October 2016 via cutting diverse macrophyte species in the Lower Lobau floodplains east of Vienna. Macrophytes and aquatic invertebrates were identified in the lab and data were analyzed statistically. The results show that three sites are according to biological responses classified as Plesio-/Paläopotamon. One site is classified as a Pseudopotamon, an ecotone affected by frequent changes in hydrology. Different factors operating at various scales influence the invertebrate community associated with aquatic vegetation: The fauna shows a clear seasonality. Site-specific factors like distance to the Danube, water surface area and hydrology impact the invertebrate coenosis. Macrophyte complexity at water body scale is in a relation to increasing faunal abundance and diversity. Furthermore leaf morphology and occurrence of specific macrophyte species play a role for invertebrate colonization. Almost all those parameters are linked to each other. Due to ongoing sedimentation processes changes in macrophyte community are expected in future (Pall et al. 2014) – causing an impact on invertebrate community. Further homogenization and fragmentation of the Lower Lobau water bodies should be prevented and hydrological dynamization generated. Conservation of floodplain water bodies is essential for maintaining a high level of species richness.

Zusammenfassung

Durch die systematische Regulierung der Donau und der zugehörigen Auen fand ein Wandel von einem dynamischen zu einem statischen System statt (Hohensinner et al. 2008), wodurch es zur Etablierung von Makrophyten in den Augewässern kam. Aquatische Vegetation ist durch die hohe Heterogenität ein wichtiges Habitat für die Fauna (Papas 2007). Die vorliegende Studie ordnet die Untersuchungsstellen den Auen-Habitat-Typen zu und untersucht den Einfluss von Jahreszeit, Standort-spezifischen Faktoren, Makrophytenkomplexität auf Gewässerebene, Makrophytenart und Blatttyp auf die epiphytische Invertebratengemeinschaft. Vier Stellen wurden im Juni und Oktober 2016 durch Abschneiden diverser Makrophytenarten in der Unter Lobau östlich von Wien beprobt. Diese und die damit assoziierten aquatischen Invertebraten wurden im Labor identifiziert und die Daten anschließend statistisch ausgewertet. Die Ergebnisse zeigen, dass drei der Untersuchungsstellen dem Plesio-/Paläopotamon zugeordnet werden können. Bei der vierten Stelle handelt es sich um ein Pseudopotamon, das von regelmäßigen hydrologischen Änderungen beeinflusst ist. Diverse Faktoren beeinflussen die Invertebratengemeinschaft: Die Fauna zeigt eine klare Saisonalität und ist von Standort-spezifische Faktoren wie Distanz zur Donau, Größe der Wasserfläche und Hydrologie geprägt. Makrophytenkomplexität auf Gewässerebene steht im Zusammenhang mit steigender faunaler Abundanz sowie Diversität. Weiters spielen Blatttyp und das Vorkommen spezifischer Makrophytenarten eine Rolle für die Invertebratenkolonisierung. Beinahe all diese Faktoren stehen in wechselseitiger Beeinflussung zueinander. Durch die fortschreitende Verlandung sind zukünftige Änderungen in der Makrophytengemeinschaft (Pall et al. 2014) und in weiterer Folge der Invertebratengemeinschaft zu erwarten. Weitere Homogenisierung und Fragmentierung der Unteren Lobau sollte verhindert werden. Der Schutz der Auen ist essentiell für den Erhalt hoher Biodiversität.

Content

1 Introduction

1.1 Wetlands, floodplains and their connection to the river

Humans have always been inspired but also challenged by rivers and their relating wetlands as they are shaping our natural and cultural landscape. As wetlands are influenced by terrestric as well as aquatic parameters they are defined as intermediary systems or ecotones. Modern definitions of the term "wetland" emphasize nutrient and water content, substrate and soil properties as well as biological-ecological processes (Lazowski 1997). Floodplains represent a primary wetland type (Tockner & Stanford 2002).

Floodplain systems are ecologically seen highly influenced by inundation events as they cause change between dry and wet periods. They are frequently coupled and decoupled from the river channel by the terrestric-aquatic transition zone. Four water sources are contributing to flooding via multiple pathways: Lateral overspill of the river, ground water, precipitation and upland sources. In natural river systems floodplain water bodies develop as a consequence of river morphological processes when perfused parts of the river channel are disconnected. Loops are pinched off or cut through in meandering rivers and siltation processes cause creation of floodplain waters in branched rivers. Often side arms are perfused until siltation causes total isolation. Such processes are no longer observable in cultural landscape in Middle Europe. Today most floodplain waters are disconnected artificially from the main channel – they are remnants of stabilized river channels. Development of floodplain water bodies is closely related to ecology of the river main channel (Junk et al. 1989; Lazowski 1997; Tockner & Stanford 2002).

Hydrological connectivity is the most important factor for river-floodplain systems and ecosystem functioning: Ground water, surface water and flood events generate lateral connectivity, interchange and production processes. Intensity, duration and dynamics of connectivity are regulated by the river channel - geomorphological and hydrological conditions produce flood pulses that are unpredictable or predictable, last short to long term periods and have low or high amplitude. The Flood Pulse Concept defines flood events as strongest force in the river-floodplain ecosystem. They produce a dynamic equilibrium between sedimentation and erosion, initiate biogeochemical cycles and succession processes and support habitat- and biodiversity. Inundation events have high importance for ecological integration of rivers and their relating wetlands.

Water bodies in a hypothetical floodplain area are classified according to their intensity of hydrological connection to the main channel. Most important criteria for categorization are furthermore water supply (permanent/temporary) as well as macrophyte coverage (Figure 11 and Table 3) (Waringer et al. 2005). There are five different habitat types (Figure 1): The main channel and water bodies that are connected at both ends to the main channel are defined as Eupotamon (H1). Those water bodies are hydrologically seen very dynamic, characterized by high flow velocity and therefore not inhabited by macrophyte communities in the open water area. Dominating substrate is sand and gravel. The Parapotamon (H2) is defined as water body that lacks unidirectional flow as it is connected to the main channel only at the downstream end. It is semi-lotic and hydrological dynamics are reduced – therefore a few macrophytes are able to establish. The Plesiopotamon (H3) is a lentic water body without connection to the main channel at mean water level. As it is still highly influenced by the river discharge macrophyte coverage increases but does not exceed 20% of open water area. Due to reduced hydrological dynamics terrestrialization processes are going on and the degree of sedimentation is increased. The Paläopotamon (H4) is an isolated lentic water body. It has no connectivity to the main channel at mean water level. As dynamics are further reduced higher terrestrialization processes are going on and the degree of sedimentation is increased - therefore macrophyte coverage exceeds 20% of open water area. Temporary water bodies (H5) are periodically with water and dependent on the ground water level (Amoros et al. 1987; Amoros & Roux 1988; Junk et al. 1989; Ward & Stanford 1995; Chovanec & Waringer 2001; Hein 2006). Floodplain water bodies are characterized by a gradient with increasing distance from the main channel of the river: Current velocity during floods, water level fluctuations, erosion, sediment grain size and nutrient level are decreasing while terrestrialization processes and aquatic vegetation are increasing (Nienhuis 2008).

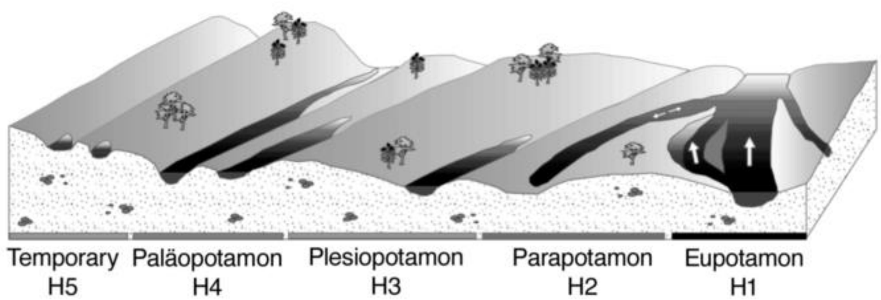

Figure 1: *Scheme of a hypothetical floodplain system after* Amoros et al. (1987).

1.2 Hydromorphological impacts on floodplain systems

Floodplains belong to most endangered ecosystems on earth as rivers in their original dynamic became rare. Already 90% of floodplain systems in North America and Europe are degraded as human impacts in river landscape caused longitudinal and lateral fragmentation (Lazowski 1997; Tockner & Stanford 2002; Graf & Chovanec 2016). Hydro power, flood protection measurements, discharge of waste water, commercial fishery, water extraction and navigation are most important stressors. Especially largest rivers within Europe like the Danube, Rhine or Elbe are used in many diverse ways and underlie massive impacts in their related floodplain areas (Schöll et al. 2012). In Austria floodplain systems were and still are characterizing elements within the river landscapes. Once total floodplain area at the 53 largest rivers accounted 7750 km² - today only 15% are left (Haidvogl et al. 2009). River regulations, drainage of wetlands for gain of agricultural area and construction of hydro power plants are most important reasons for the loss in the 19th and 20th century (Pühringer et al. 2015; Graf & Chovanec 2016).

1.2.1 The Danube floodplains

General river type

Before systematic regulation works were done in the 19th century the Danube floodplain system consisted of diverse river channels, gravel bars and islands – a status that is defined as “gravel-dominated laterally active anabranching river” with high dynamics in hydrology as well as morphology (Nanson & Knighton 1996). The system was characterized by 90% main channel as well as connected side arms (Eupotamon). To a small extent also oxbow lakes occurred. Between sedimentation and erosion a dynamic equilibrium defined as “shifting-mosaic steady-state” existed. Morphologically riverscape was very young as there was balance between habitat succession and regeneration. Dominating vegetation consisted of pioneer societies as well as willows (Hohensinner 2008).

Systematic regulation

Due to regulation works in the 19th century and construction of hydro power plants in the 20th century riverscape of the Danube was stabilized. Dynamics in biotopes like e.g. eupotamal side arms, temporal connected oxbow lakes and young floodplain habitats were reduced. Whereas sites impacted by sedimentation processes increased. The natural balance between sedimentation and erosion became disturbed what resulted in missing habitat regeneration and over aging of water bodies. The riverscape of the Danube became a static one. Vegetation is dominated by older and further developed societies. The system today is defined as “static-state” (Hohensinner 2008).

1.2.2 The Lower Lobau floodplains

Reference situation in 1817

In 1817 36% of fluvial active zone were water bodies. Side arms with constant flow (Eupotamon B) accounted for about 65%, dynamic side arms with temporary flow conditions (Parapotamon A) accounted for about 20%, side arms connected at one end to the main channel (Parapotamon B) for 12% and isolated old arms (Plesio-/Paläopotamon) for 1,4%. Once the Danube system had a primary lotic character (Table 1 and Figure 2).

Situation today

In the middle of the 19th century flood protection levees were built what resulted in change of water body distribution - former side arms and floodplain waters were separated from the main channel. As consequence extension of water bodies in the fluvial active zone decreased to 15%. Focusing floodplain waters there was a quantitative decrease for more than the half: Side arms with constant flow (Eupotamon B) disappeared, dynamic side arms and side arms connected at one end (Parapotamon A and B) were reduced and isolated waters (Plesio-/Paläopotamon) increased – they account for 2/3 of floodplain water bodies today (Table 1 and Figure 2). Water bodies, also those close to the main channel, are impacted by missing dynamics, sedimentation, terrestrialization processes and establishment of macrophytes. The flood pulse is modified, hydrological connectivity and water level fluctuations are reduced. As periodical and episodic renewal of water bodies is missing there is a loss in water habitats, a change in quality and habitat age. Therefore substrate, O_2 content and environmental conditions are impacted (Barta et al. 2009; Hein 2006; Graf et al. 2013). Figure 3 and Figure 4 show hydromorphological changes between 1817 and today.

Table 1: *Habitat and water body types in Lower Lobau in 1817 and today* (Graf et al. 2013).

Habitat-/Water body type	1817	Today
H1: Eupotamon B	66,2	0,0
H1-H2: Parapotamon A	20,0	13,9
H2: Parapotamon B	12,4	8,7
H3+H4: Plesio-/Paläopotamon	1,4	76,9
Pseudopotamon	0,0	0,5

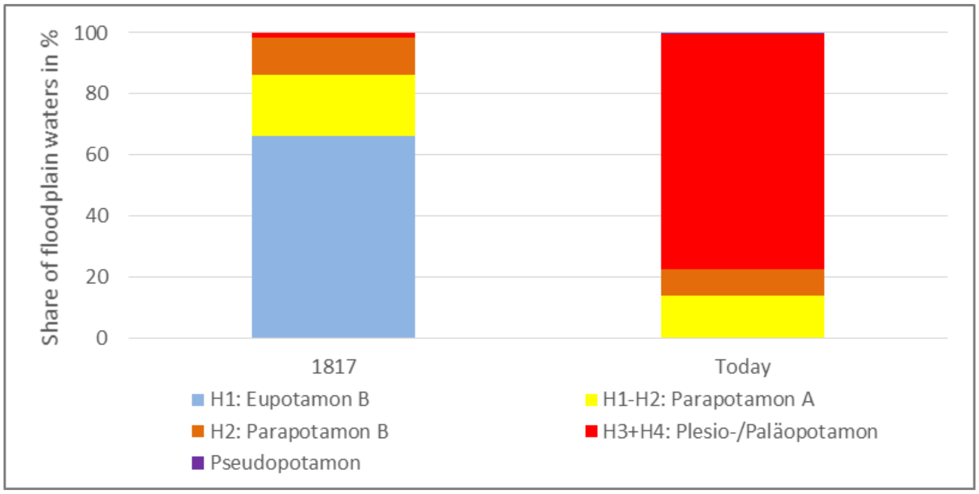

Figure 2: *Qualitative change of floodplain water bodies between 1817 and today: Share of habitat types of total floodplain water bodies in the Lower Lobau* (Graf et al. 2013).

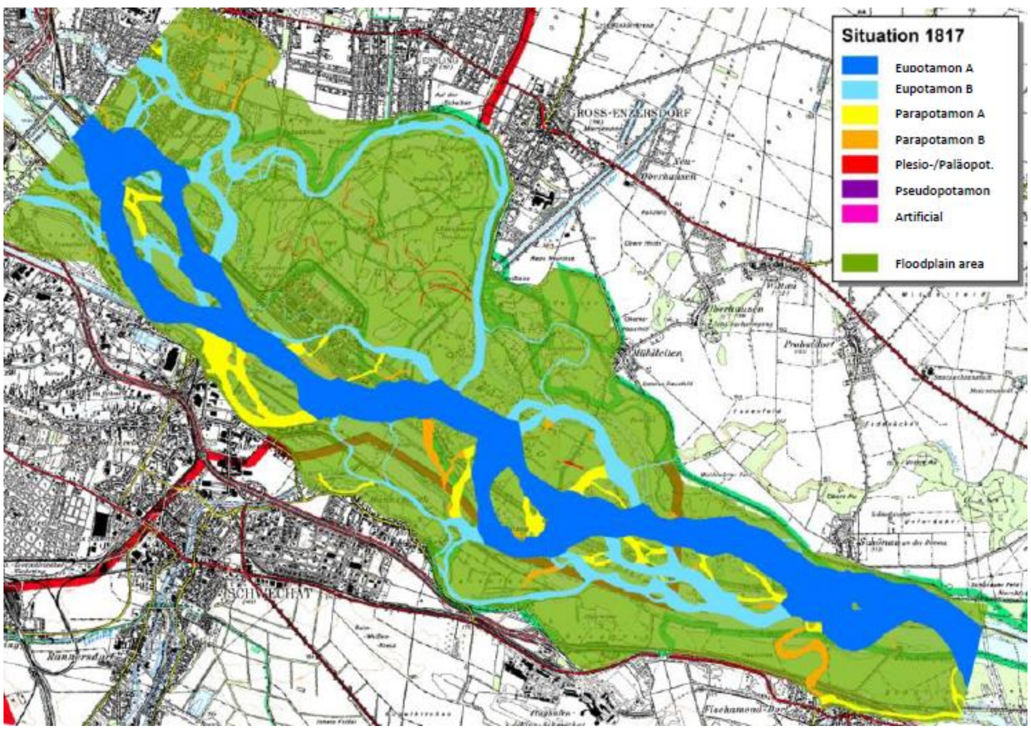

Figure 3: *Hydromorphological classification in the Upper and Lower Lobau in 1817* (Graf et al. 2013).

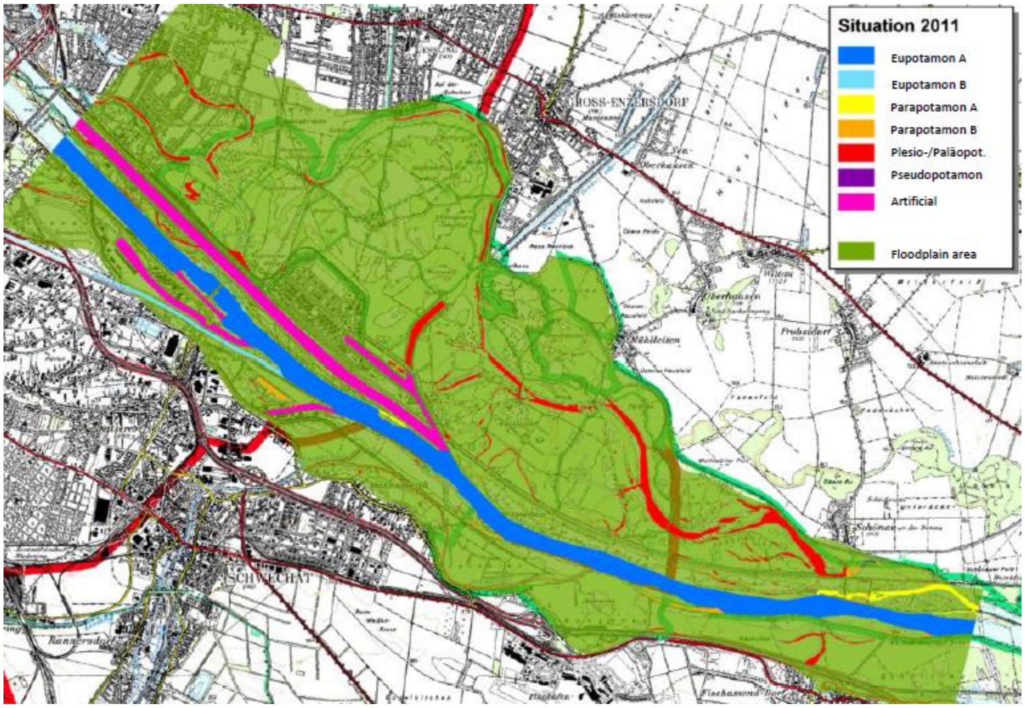

Figure 4: *Hydromorphological classification in the Upper and Lower Lobau today* (Graf et al. 2013).

1.3 Conservation strategies

As water is one of the most valuable ecosystem services wise management of biodiversity and wetlands is essential. They are therefore protected via the Convention on Biological Diversity (CBD) that was founded in 1992 and was signed by 150 governments (Secretariat of the Convention on Biological Diversity 2017). It recognizes the ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values of biological diversity (IUCN 1994). In Austria the "Biodiversity Strategy Austria 2020+" implements recommendations provided by the CBD. International RAMSAR convention regulates conservation and cultivation of wetlands in a sustainable way since 1975. As intergovernmental treaty it provides frameworks for national actions and international cooperations (The Ramsar Convention Secretariat 2017). The Austrian "Floodplain Strategy 2020+" was invented to implement the framework on national scale (Pühringer et al. 2015).

Furthermore protection of terrestric and wetland habitats connected to aquatic bodies is included in the Water Framework Directive (WFD) (Directive 2000/60/EG). The European Union invented the WFD as a basis for common water policy in 2000. Protection of surface, transitional, coastal and ground water as well as maintenance and improvement of the chemical and ecological status are defined as objective. The purpose is to reach a good quality status and any degradation is prohibited (European Commission 2000). Assessment within the framework is based on the status quo of aquatic communities in relation to water body type specific reference conditions that describe minimally impacted and near pristine water bodies (Chovanec et al. 2004).

As largest rivers are very often degraded intact floodplains play an important role as refugee habitat for fauna. There is international consensus that wetland systems are essential for water body type specific processes as well as biodiversity (Chovanec et al. 2005; Graf & Chovanec 2016). One problem in assessment culture is that floodplains are often not captured as focus is on the water body itself. Basis for management, measurements, planning and implementation of floodplains is missing. Therefore assessment schemes based on Odonata and Trichoptera were developed in accordance to the WFD at the Danube in Austria (Chovanec & Waringer 2001; Waringer & Graf 2002; Graf & Chovanec 2016). Based on these methods a multi species approach was developed and resulted in creation of the Floodplain Index (FI). Mollusca, Trichoptera, Odonata, amphibians and fish are used as biological indicators for river connectivity pattern assessment. Lateral connectivity and its related processes between the main channel and the floodplain area are seen as most important feature of a coherent floodplain system (Chovanec et al. 2005; Waringer et al. 2005). It might change over time due to natural or human induced processes and has impact on environmental conditions as well as on biodiversity. As species have habitat preferences conclusions about connectivity status can be drawn (Schönborn 1992; Chovanec et al. 2005; Jäger 2013).

1.4 Biota in floodplain systems

Dynamic processes cause high heterogeneity in habitats and at spatial-temporal scale – therefore wetlands are centers of biodiversity and belong to the most diverse systems on earth. In most regions of the world more plant and animal species occur in floodplains than in any other landscape. Furthermore they are centers of biological diversification and bio-complexity. Floodplains belong to the most biological productive ecosystems on earth. Production rate for riparian forest, wetland animals, fish and aquatic invertebrates is often increased (Lazowski 1997; Tockner & Stanford 2002).

Biota in floodplain zones is primary regulated by flood pulses. Inundation events are driving force for existence, productivity and interactions of organisms. Regulating factors are predictability, frequency and amplitude of floods, but also parameters influenced by lateral exchange processes like sedimentation, erosion, biogeochemical processes, turbidity, etc.. Nutrient transfer between terrestrial and aquatic phase impacts primary and secondary production, decomposition and nutrient cycles. Flood pulses also cause community setbacks and maintain the system in a highly productive stage. During low water periods the main channel is refugee habitat for aquatic organisms, furthermore it is migration route for active and passive dispersal. All those impacts cause morphological, anatomical, physiological and phenological adaptions of biota and therefore specific communities (Junk et al. 1989).

One characterizing element of all floodplain systems is aquatic vegetation (Pall et al. 2014). Macrophytes are primary producers and therefore important for production of O_2 as well as biomass (Jeppesen et al. 1998). They impact abiotic environment and offer structure that is used as habitat by bacteria, invertebrates, fish and birds. (Jorga & Weise 1979; Wiegleb 1988; Jeppesen et al. 1998; Kemp et al. 1990; Miranda & Hodges 2000; Wetzel 2001; Scheffer et al. 2003; Baart 2005; Horppila & Nurminen 2005; Harrison et al. 2005; Caraco et al. 2006; Barta et al. 2009; Zbikowski et al. 2010). Macrophytes play an important role for animals as they provide habitat complexity, heterogeneity, shelter, breeding area and substrate for growth of periphyton and food production (Lodge 1991; Diehl 1992; Schönborn 1992; Zimmer et al. 2000; Rennie & Jackson 2005; Ali et al. 2007; Papas 2007). Reckendorfer et al. 2012 highlighted the importance of macrophytes as habitat for aquatic invertebrates in the Danube floodplains.

1.4.1 Macrophytes as habitat for aquatic invertebrates

Within water bodies the phytal zone belongs to the taxa- and specimen richest biotope - macrophytes provide majority of habitat complexity within aquatic ecosystems (Heck Jr. & Crowder 1991). Plants offer larger surfaces and exceed that of stones (Schönborn 1992). Bazzanti et al. (2010) determined highest invertebrate richness and density in macrophytes compared to bottom substrate. Aquatic vegetation provides microhabitats with diverse characteristics that support establishment as well as colonization of invertebrates (Ali et al. 2007). As aquatic vegetation offers habitat structure it is essential in structuring of ecological communities and preservation of integrity in ecosystems (Phiri et al. 2012). As in many cases macrophytes are not sampled for aquatic invertebrate status assessment Bazzanti et al. (2010) suggest to do that. Reason therefore is exhaustive collection of species as emergent and submergent plants have high influence on biodiversity. So good insights from ecosystem functioning, for conservation and management can be gained.

There are different factors operating at different scales that have impact on invertebrates associated with macrophytes - from individual leaves of a plant to macrophyte beds (leaf architecture, plant morphology, surface texture, epiphytic periphyton, nutrient content, chemical defense, etc.) (Cyr & Downing 1988). External parameters impacted by flood pulses and season might also have influence (Junk et al. 1989; Strayer et al. 2003; Papas 2007; Shupryt & Stelzer 2009).

Importance of leaf structure

According to Krecker (1939), Cheruvelil et al. (2001), Balci & Kennedy (2003) and Papas (2007) complexity of leaves (physical shape, surface area and leaf dissectedness) is related to invertebrate abundance and diversity. On the one hand Krecker (1939) and Cheruvelil et al. (2001) observed larger invertebrate populations at dissected leaves compared to broad ones as colonizable area is larger. Stark (2001) found in his study that fine divided leaves are related to higher invertebrate abundance of Ephemeroptera, Oligochaeta, Mysidacea and Mollusca than leaves with large surface. Leaves that are finely dissected are characterized by a higher surface to volume ratio and support greater biomass of growing periphyton that is important for grazers (Cattaneo & Kalff 1980). Moreover higher leaf complexity is suggested to be better refugee habitat from predators (Balci & Kennedy 2003).

Role of periphyton

Epiphytic material is food for fauna and basis for life. Occurrence of most epiphytic living organisms can be related to quality and quantity of epiphytic sediment and periphyton (Weigand 1994). Periphyton as food source is available for grazers during growing season. Whereas macrophytes should contribute to herbivores as well as detritivores at the end of the growing season. Importance of periphyton changes with season, macrophyte morphology, depth of the water body and trophical status (Cattaneo & Kalff 1980). In 1996 Weigand observed that pattern of invertebrates on *Potamogeton pectinatus* is related to quantity and quality of periphyton growing on the plant surface. There is no relation to the macrophyte itself. In an experiment by Jones et al. (1999) it was found out that plant growth and survival increases significantly with presence of periphyton grazers.

Nutritional value and chemical compounds in leaves

According to Lodge (1991) nutrient content is not likely to limit grazing. Grazing is unrelated to measured plant physical and chemical properties like cellulose content. There is evidence that phenolic compounds have impact. Ervin & Wetzel (2003) reviewed that allelochemical compounds are influenced by nutrients, light as well as carbon. They are known to have impact an algal growth on macrophytes like *Myriophyllum* sp. or *Ceratophyllum* sp.. In turn effect on algal growth has indirectly impact on grazing of invertebrates.

Plant morphology

Cyr & Downing (1988) investigated that sturdiness of macrophytes affects invertebrate coenosis as larger plants can support heavier fauna. In accordance to this pattern Kufikowski (1974) and Soszka (1975) found out that fragile plants like *Myriophyllum* sp. support less Gastropoda than *Elodea* sp.. Another observation done by Timms (1981) is that differences in invertebrate coenosis between macrophytes are caused by proximity of leaves to the substrate. Furthermore macrofauna tends to be more abundant on morpholigically complex plants because they offer larger surface for attachment and more refugee sites (Thomaz et al. 2008). As increased complexity leads to high detritus trapping ability diversity of detritivors is high (Taniguchi et al. 2003).

Plant growth type

There are macrophytes forming thick homogeneous beds with low light penetration. They often inhibit growth of periphyton and change temperature and dissolved oxygen what results in inhospitable conditions and low invertebrate diversity (Cheruvelil et al. 2001). Whereas Sandilands & Hann (1996) found dense aquatic plant stands colonized by high abundances of invertebrates concluding that protection from predation is best there. Explanation of Dvořaki & Bestz (1982) who observed the same pattern are large colonizable surface areas.

Smock & Stoneburner (1980) stated that seasonal die-off of dense macrophytes consequently leads to accumulation, breakdown of organic matter and changed dissolved oxygen levels what has also impact on invertebrates. Another factor that might affect composition of invertebrate coenosis in stands of macrophytes is gradient from shoreline to open water zone. Reasons therefore are isolation of water from the open pond, shading from terrestric vegetation as well as decomposition processes (Dvořák 1969).

Macrophyte community and exotic species

That different macrophyte communities are colonized by different invertebrate communities in a Canadian lake was investigated by Hanson (1990). In another study greater numbers of invertebrates were found on beds with two native species compared to a monospecific bed with an exotic macrophyte (Keast 1984). Results of studies that observed preference of invertebrates for native macrophytes in comparison to exotic ones are mixed: Keast (1984) observed increased emergence rates above native plant species compared to exotic ones, whereas Balci & Kennedy (2003) found no difference between native and non-native macrophytes.

1.5 Habitat heterogeneity hypothesis

The habitat heterogeneity hypothesis suggests as a very fundamental concept in ecology that an increase in number of habitats has influence on ecological communities and can support more species in a landscape as number of partitionable niche dimensions is expanded (MacArthur & MacArthur 1961). “Fundamental niches” are also known as n-dimensional hyper volumes defined by environmental variables and ecological properties under which a certain species can exist. As more niches are available when habitat heterogeneity increases, more species can coexist in an ecosystem leading to a positive association between niche availability and species diversity (Hutchinson 1957; Cramer & Willig 2005). Floodplain systems are ecosystems that are very diverse at spatial as well as at temporal scale and are highly influenced by dynamic processes – high number of habitats and niches causes that these ecosystems belong to the most diverse on earth (Tockner & Stanford 2002).

2 Rationale, research questions & hypotheses

2.1 Rationale

This study is one more puzzle piece for understanding floodplain systems in a holistic view and has its focus on macrophytes as habitat for aquatic invertebrates. As aquatic plants are known to structure freshwater communities, to impact prey-predator relationships and food source (Jeppesen et al. 1998) it is essential to describe ecological role of different components of aquatic plants for inhabting fauna. Observation of these ecological relationships and interactions supports insights in the importance of macrophytes for invertebrates.

Floodplain water bodies in the Lower Lobau are essential habitat for diverse macrophytes. Reckendorfer et al. (2012) observed already the importance of hydrology and macrophytes for invertebrates in the Lobau. As many studies were carried out on macroinvertebrates in the Danube floodplains this investigation is one more observation for getting a full picture of the system. Focus is on the Floodplain Index, on macrophyte invertebrate relations and further factors impacting the community. As samples were taken from different water bodies effects of water variables are observed. Moreover effects of macrophyte richness, density and architectural complexity on diversity and abundance of epiphytic invertebrates are elucidated.

The present study focus is to get insights into macrophyte and related invertebrate interactions. Verdonschot et al. (2012) states that patterns in invertebrate assemblage deriving from habitat structures like epiphytic fauna of macrophytes gives insights into large scale patterns and processes acting within an ecosystem.

2.2 Research questions

1. Does biological classification of habitat types correspond to hydro morphological patterns in consideration of macrophyte inhabiting Trichoptera, Odonata, Mollusca and Ephemeroptera species?
2. a) Is there a difference in aquatic invertebrate community inhabiting the different study sites, macrophyte species and macrophyte leaf types?
   b) Do diversity, architectural complexity and density of macrophytes mediate the number of invertebrate taxa and density at the different study sites?
   c) Is a seasonal influence on faunal community observable?

2.3 Hypotheses

1. It is expected that hydro morphological classification of floodplain habitat types is corresponding with biological responses (Trichoptera, Odonata, Mollusca and Ephemeroptera communities).
2. a) There is a difference in invertebrate community inhabiting the different study sites, macrophyte species and leaf types.
   b) Higher invertebrate richness as well as density is expected with an increase in macrophyte diversity, density and structural complexity at the different study sites.
   c) A seasonal influence on the faunal community is observable.

3 Study area

The Lower Lobau is part of the Danube floodplains. It is located east of Vienna on the left shore of the Danube and is split in an upper and a lower part by the Danube-Oder-Canal. Two thirds of the nature reserve are located in Vienna, one third belongs to the administrative sector of Lower Austria. In the reach of the Lower Lobau the Danube river was characterized as “medium-energy non-cohesive floodplain” before regulation. Hydrological and sediment regime were typically alpine and the floodplain area consisted of primary loosely bedded sediment (Nanson & Croke 1992). In the middle of the 19th century flood protection levees were built what resulted in change of water body distribution (Graf et al. 2013).

3.1 Land use and management

The Lower Lobau is used for drinking water removal and recreation as the floodplains are close to Vienna (Pall et al. 2014). To ensure the persistence of the ecosystem management is going on: The Lower Lobau is protected as RAMSAR area, Natura 2000 area, UNESCO-biosphere reserve and is also part of the National Park Danube Floodplains (Riedler et al. 2013). Since 2011 a dotation project provides water availability: Through a water enhancement scheme water enters the Upper Lobau and reaches the lower part. Furthermore it is connected to the Danube main channel via the Schönauer Schlitz and filled during flood. The floodplain is separated: Sites between levee and main channel of the Danube belong to the active floodplain whereas sites behind the levee are semi-separated.

3.2 Climate

Influenced by pannonian and continental weather conditions the study area is exposed dry winds, precipitation <600 mm a year, dry summer months with maximum mean temperature around 20 °C and winters with little snow and temperatures around freezing point (Lazowski 1997; Barta et al. 2009; Edinger 2009; Pall et al. 2013; Pall et al. 2014;).

3.3 Study sites

The sampled study sites are shown in Figure 5 and Figure 6. The four study sites lie behind the flood protection levee in the sheltered zone. They are impacted by backflow-floods as well as groundwater and show higher macrophyte species diversity than water bodies in the active floodplain zone (Barta et al. 2009).

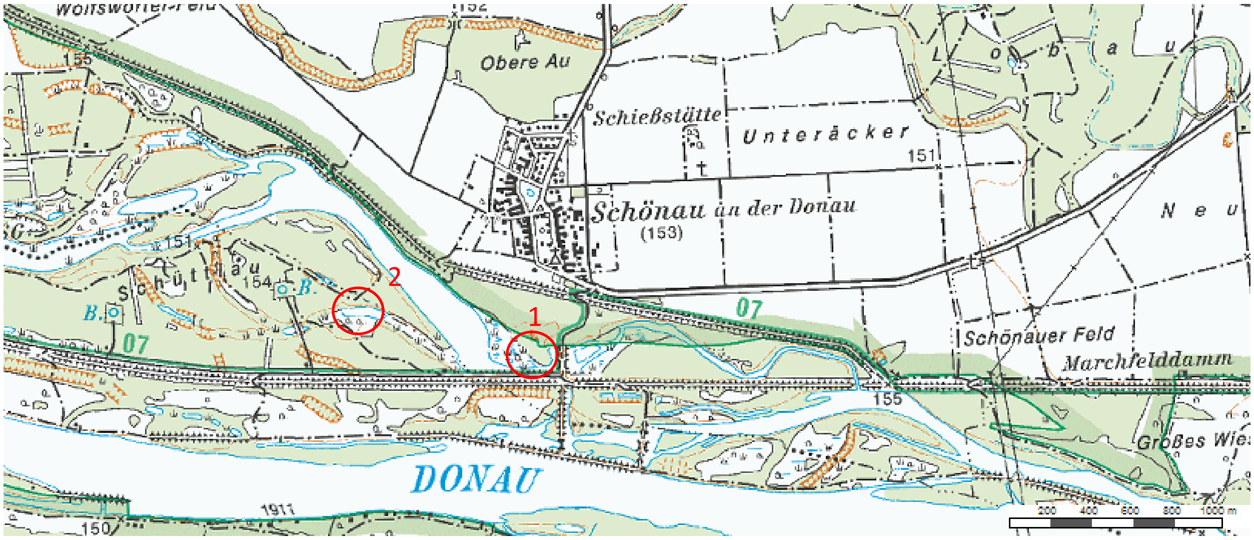

Figure 5: *Study sites in the eastern Lower Lobau (©AMap 2017).*

Figure 6: *Study sites in the western Lower Lobau (©AMap 2017).*

3.3.1 Study site 1

Figure 7: *Study site 1.*

First study site is located in the Schönauer Wasser and lies within a large permanent water body that is connected up- and downstream. In flood situations the water body is perfused via a traverse from downstream, during mean and low flow it is standing (Pall et al. 2014).

Larger water bodies in the Lower Lobau are characterized by occurrence of reeds and sedges, floating leaf societies and open water area in an equal share (Pall et al. 2013).

Coordinates: 16°36‘38‘‘E, 48°08‘13‘‘N

3.3.2 Study site 2

Study site 2 is a small standing water body in Schüttlau that was once connected to Schönauer Wasser. It is impacted by high fluctuations in water level.

Small backwaters are generally characterized by occurrence of 50% reeds and sedges, 30% amphiphytes, 15% open water area and 4% floating leaf societies (Pall et al. 2013).

Coordinates: 16°36’05’’E, 48°08’21’’N

Figure 8: *Study site 2.*

3.3.3 Study site 3

Study site 3 is a permanent standing water body east of Künigltraverse that was once connected to Kühwörter Wasser.

Small backwaters are generally characterized by occurrence of 50% reeds and sedges, 30% amphiphytes, 15% open water area and 4% floating leaf societies (Pall et al. 2013).

Coordinates: 16°*34’03’’E, 48°08’53’’N*

Figure 9: *Study site 3.*

3.3.4 Study site 4

Study site 4 is a small side arm connecting Eberschütt- and Mittelwasser and is located east of Kreuzgrundtraverse. It has permanent water supply and is periodically flowing as there are ground water fluctuations due to management via a pumping station (Graf et al. 2012).

Coordinates: 16°32’44’’E, 48°09’43’’N

Figure 10: *Study site 4.*

3.3.5 Physical-chemical parameters, distance to the main channel and water surface area

Physical-chemical parameters were measured on October 13th 2016. Distance to the Danube main channel and water surface area are shown as well (Table 2).

Table 2: *Physical-chemical parameters, distance to the Danube main channel and water surface area for the four study sites.*

	Study site 1	Study site 2	Study site 3	Study site 4
Conductivity (in µS)	412	431	506	487
O_2 (in mg/l and %)	5,47 / 50,3%	9,37 / 86,1	3,77 / 34,3	9,62 / 86,2
Temperature (in C°)	11,2	11,4	10,6	10,0
pH	7,52	8,32	8,21	8,35
Distance to the main channel (in m) (AMap 2017)	400	650	1000	1500
Surface area (in ha) (QGis 2.18.3; Bing Satellite map 2017)	34,7	0,5	0,1	0,2

4 Methods

4.1 Classification of habitat types in a floodplain system

Floodplain water bodies are classified according to their intensity of hydrological connection to the main channel, their water supply and macrophyte coverage (Figure 11 and Table 3) (Waringer et al. 2005).

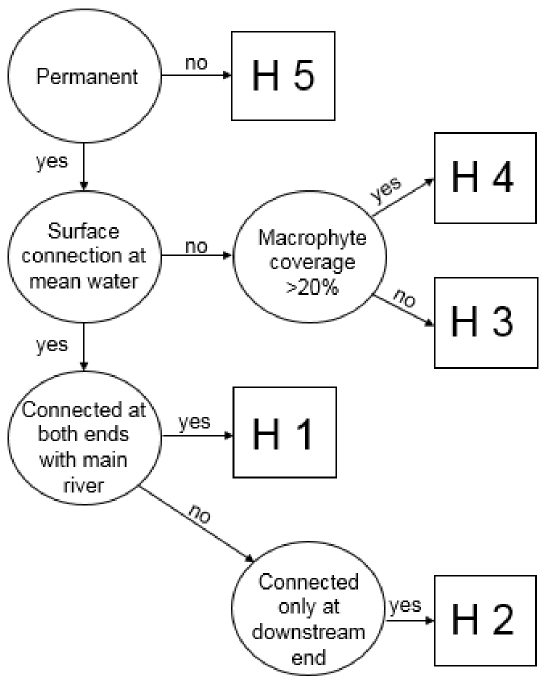

Figure 11: *Criteria for categorization of the five different habitat types after* Waringer et al. (2005).

Table 3: *Definition of habitat types after* Ward & Stanford (1995) *and* Waringer et al. (2005).

Habitat type	Characterization
H1	Hydrologically dynamic water bodies, full-width surface connection with the main channel at both ends at mean water discharge and not fragmented by impoundments (e.g. small weirs); generally high water velocities; no macrophyte communities in the open water; open banks or Phalaridetum stands in the littoral area; sand and gravel substrate are dominating, occurrence of sand and gravel bars.
H2	Water bodies which lack unidirectional current; full-width surface connection which also lacks fragmentation by impoundments (e.g. small weirs) only at the downstream end at mean water level; only few macrophytes (e.g. Phalaridetum); high proportion of sand and gravel substrates, occurrence of sand and gravel bars.
H3	No connectivity with the main channel at mean water level; terrestrialisation processes; macrophyte cover of open water areas does not exceed 20% of open water area; dominating macrophyte communities: Phragmitetum, Typhetum, Sagittario-Sparganietum, Myriophyllo-Nupharetum, Magnocaricetum; increased degree of sedimentation.

H4	No connectivity with the main channel at mean water level; terrestrialisation processes; macrophyte cover of open water areas exceeds 20% of open water area; dominating macrophyte communities: Phragmitetum, Typhetum, Sagittario-Sparganietum, Myriophyllo-Nupharetum, Magnocaricetum; high degree of sedimentation.
H5	Temporary pools; sedimentation high; most years with at least one dried-up period (mainly summer-autumn); dominating macrophyte communities: Phragmitetum, Typhetum, Sagittario-Sparganietum, Magnocaricetum; terrestrial vegetation.

4.2 Aquatic invertebrate & macrophyte sampling

Sampling took place on June 14th and October 13th 2016. Aquatic plants that were used for investigation are *Agrostis stolonifera*, *Ceratophyllum demersum*, *Mentha aquatica*, *Myosotis palustris*, *Myriophyllum* sp., *Nuphar lutea*, *Poaceae* Gen. sp., *Potamogeton berchtoldii*, *Potamogeton lucens*, *Potamogeton pectinatus*, *Potamogeton perfoliatus* and *Stachys palustris*. Epiphytic invertebrates were sampled via cutting the diverse macrophytes from an area of 25 x 25 cm (0.0625 m^2) in a drift net (mesh size 100 µm). For *N. lutea* three floating leaves of same size were taken for each sample. Each sample was put in a plastic bucket, labeled and fixed with 96% formaldehyde. The sampling design is shown in Table 4 and

Table **5**.

Table 4: *Sampling design June 14th 2016.*

14.06.2016	
Study site 1	**Macrophyte taxa (dominance per sample in %)**
Sample 1	*N. lutea* (100%)
Sample 2	*N. lutea* (100%)
Sample 3	*N. lutea* (100%)
Study site 2	
Sample 1	*S. palustris* (33%); *A. stolonifera, P. berchtoldi*i & *Poaceae* Gen. sp. (66%)
Sample 2	*S. palustris* (20%); *M. palustris* (70%); *A. stolonifera, P. berchtoldii* & *Poaceae* Gen. sp. (10%)
Sample 3	*S. palustris* (10%); *M. palustris* (20%); *A. stolonifera, P. berchtoldii* & *Poaceae* Gen. sp. (70%)
Study site 3	
Sample 1	*P. lucens* (100%)
Sample 2	*P. lucens* (100%)
Sample 3	*P. lucens* (95%); *C. demersum* (5%)
Sample 4	*C. demersum* (100%)
Sample 5	*N. lutea* (100%)
Sample 6	*N. lutea* (100%)
Sample 7	*N. lutea* (100%)
Study site 4	
Sample 1	*M. palustris* (92%); *A. stolonifera* (8%)
Sample 2	*M. palustris* (90%); *Hypales* Gen. sp. (10%)
Sample 3	*M. palustris* (90%); *Hypales* Gen. sp. (10%)
Sample 4	*P. perfoliatus* (100%)

Sample 5	*P. perfoliatus* (100%)
Sample 6	*P. perfoliatus* (100%)
Sample 7	*M. palustris* (30%); *M. aquatica* (70%)
Sample 8	*M. aquatica* (90%); *Hypales* Gen. sp. (10%)
Sample 9	*N. lutea* (100%)
Sample 10	*N. lutea* (100%)
Sample 11	*N. lutea* (100%)

Table 5: *Sampling design October 13th 2016.*

13.10.2016	
Study site 1	**Macrophyte taxa (dominance per sample in %)**
Sample 1	*N. lutea* (100%)
Sample 2	*N. lutea* (100%)
Sample 3	*N. lutea* (100%)
Study site 2	
Sample 1	*Myriophyllum* sp. (55%); *P. perfoliatus* (45%)
Sample 2	*Myriophyllum* sp. (80%); *P. pectinatus* (20%)
Sample 3	*P. pectinatus* (55%); *Myriophyllum* (40%); *P. lucens* (5%)
Study site 3	
Sample 1	*P. lucens* (98%); *C. demersum* (2%)
Sample 2	*P. lucens* (98%); *C. demersum* (2%)
Sample 3	*P. lucens* (95%); *Myriophyllum* sp. (5%)
Sample 4	*C. demersum* (100%)
Sample 5	*C. demersum* (100%)
Sample 6	*C. demersum* (100%)
Sample 7	*N. lutea* (100%)
Sample 8	*N. lutea* (100%)
Sample 9	*N. lutea* (100%)
Study site 4	
Sample 1	*M. palustris* (95%); *Hypales* Gen. sp. (5%)
Sample 2	*M. palustris* (95%); *Hypales* Gen. sp. (5%)
Sample 3	*M. palustris* (95%); *Hypales* Gen. sp. (5%)
Sample 4	*M. palustris* (100%)
Sample 5	*M. palustris* (90%); *M. aquatica* (10%)
Sample 6	*M. palustris* (100%)
Sample 7	*P. lucens* (65%); *P. pectinatus* (35%)
Sample 8	*P. lucens* (95%); *P. pectinatus* (5%)
Sample 9	*P. lucens* (100%)

4.3 Macrophyte abundance estimation after Kohler's method (1978)

During field work the abundances of the sampled vegetation was surveyed via Kohler's (1978) method at the different study sites. Quantities of macrophytes were classified in 1 – very rare (single plants), 2 – rare (single plant populations), 3 – moderate occurrence (moderate dense plant populations), 4 – general (dense plant populations) and 5 – frequent (very dense plant populations) (Pall et al. 2011).

4.4 Lab work

Macrophytes were washed in sieves using mesh sizes down to 500 µm to separate invertebrates from organic material and formaldehyde. Because of identification difficulties Diptera of the families *Simuliidae* Gen. sp. and *Chironomidae* Gen. sp. were not taken into account. Sampled animals were identified to lowest taxonomic level possible and counted by using a binocular. A presence/absence taxa list can be found in the results, a detailed one with invertebrate abundances per sample in the appendix.

Keys that were used for identification:

- General (Tachet et al. 2000; Graf et al. 2016)
- Ephemeroptera (Bauernfeind & Humpesch 2001; Eiseler 2010)
- Trichoptera (Waringer & Graf 2011)
- Molluska (Glöer 2015)
- Hirudinea (Nesemann 1997; Eiseler 2010)
- Heteroptera (Rabitsch 2005)
- Odonata (Dreyer & Franke 1987)
- Coleoptera (Eiseler & Hess 2013)
- Lepidoptera (Vallenduuk & Cippen 2004)

Aquatic plants were identified with help of Univ.Prof. Dipl.Geograph Dr. Karl Georg Bernhardt from the Institute of Botany from University of Natural Resources and Life Sciences Vienna via photos and a herbarium.

4.5 Ecological characterization of macrophytes

4.5.1 Hydrophytes

Hydrophytes are defined as the "real" water plants. Three different types of hydrophytes were sampled in the Lower Lobau floodplains – one species with floating leaves, one covering the ground and taxa that are growing taller (Pall et al. 2011).

Nuphar lutea

Figure 12: *Nuphar lutea.*

N. lutea is a hydrophyte with floating leaves rooted in the ground of the water body and is listed as endangered (category 3) in the red list of threatened species in Austria (Niklfeld & Schratt-Ehrendorfer 1999). It occurs in standing water bodies but is also adapted to more dynamic conditions like flow velocity and fluctuations in water level. Inhabiting meso- to eutrophic waters it roots in humous, sandy or gravelly surroundings up to 6 m depth from the lowland up to the highlands. Pollination is done by insects or by the plant itself (Oberdorfer 2001; Jäger & Werner 2005; Pall & Kum 2006; Pall et al. 2014). *N. lutea* is together with *Nymphaea alba* a character species for the floating leaf associations of Nymphaion albae (Grabherr & Mucina 1993). The hydrophyte consists of submerged and floating leaves that are heart-shaped reaching 12 to 40 cm in length as well as 8 to 30 cm in width. *N. lutea* is a perennial plant flowering yellow (Krausch 1996).

Potamogeton berchtoldii

Figure 13: *Potamogeton berchtoldii. (Source: www.flora.nhm-wien.ac.at 2017)*

P. berchtoldii is a taller growing hydrophyte and also defined as submerse rhizophyte – meaning that it is rooted and lives under the water surface. It inhabits meso- to eutrophic standing or slowly flowing water bodies up to 2,5 m depth. Typical for alkaline- and nutrient rich waters it prefers slightly polluted quality in more or less shaded backwaters and roots in humous muddy soil. *P. berchtoldii* occurs from the low- up to the highland and is characteristic for the order Potametalia, the pondweed and floating leaf societies in standing and flowing water bodies (Oberdorfer 2001; Jäger & Werner 2005; Pall et al. 2014). It grows up to 1 m in length, has stalks that are maximally 0,3 m long and the leaves are slender reaching up to 4,5 cm in length. *P. berchtoldii* is perennial (Krausch 1996).

Potamogeton lucens

Figure 14: *Potamogeton lucens.*

The taller growing macrophyte is listed as endangered (category 3) in the red list of threatened species in Austria (Niklfeld & Schratt-Ehrendorfer 1999) and is a submerse rhizophyte. It inhabits lakes and backwaters in oligo- to beta-mesosaprobic water quality and is adapted to standing and slowly flowing conditions. *P. lucens* is typical for alkaline- and nutrient rich waters and roots in humous mud from 0,5 up to 6 m depth. Occurring in pondweed populations it is characteristic for the society Potameton lucentis but also overlaps with the Nymphaion albae association from low- up to the highlands (Jorga & Weise 1979; Pall et al. 2014). *P. lucens* has branched stalks reaching 2 to 6 m in length and 10 to 25 cm oval to lanceolate shaped leaves. It is annual to perennial (Krausch 1996).

Potamogeton pectinatus

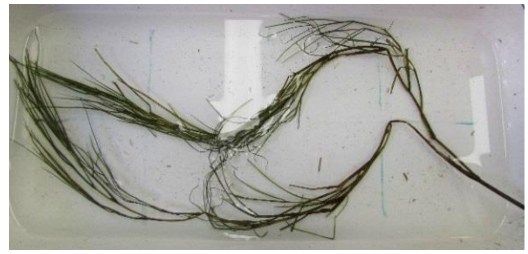

Figure 15: *Potamogeton pectinatus.*

P. pectinatus is a submersed rhizophyte and adapted to more dynamic conditions. Related to saprobity it is an euryoecious species as it inhabits beta-meso- to polysaprobic waters. It occurs in standing or slowly flowing lakes, pools and backwaters from 0,2 to 3,5 m depth that are alkaline rich and have humous mud. Often it is the only remaining plant in highly polluted and turbid water. The macrophyte is characteristic for the order Potametalia and occurs in submerged pondweed populations from the low- to the highlands (Jorga & Weise 1979; Krausch 1996; Pall et al. 2014). Having stems that reach up to 3 m in length it is highly branched and has filamentous leaves. According to the environment it grows in slightly different shapes. *P. pectinatus* is a perennial macrophyte (Krausch 1996).

Potamogeton perfoliatus

Figure 16: *Potamogeton perfoliatus.*

Like *P. lucens P. perfoliatus* belongs to the taller growing macrophytes, is a submerse rhizophyte and listed as endangered (category 3) in the red list of threatened species in Austria (Niklfeld & Schratt-Ehrendorfer 1999). Growing in meso- to eutrophic water bodies it is adapted to lentic or slowly flowing conditions, meso- to eutrophic, alkaline- and nutrient rich water quality and roots in humous mud from 0,5 to 7 m depth. Occurring in slightly polluted waters it is also adapted to turbid conditions. It occurs from low- to the highland in the order Potametalia in pondweed societies and often grows in pure *P. perfoliatus* populations (Krausch 1996; Oberdorfer 2001; Jäger & Werner 2005; Pall et al. 2014). The stems of *P. perfoliatus* can grow up to 6 m in length and have 6 to 12 cm long oval-lanceolate heart shaped leaves. It is a perennial hydrophyte (Krausch 1996).

Myriophyllum sp.

Figure 17: *Myriophyllum sp..*

Myriophyllum sp. is a submerged rhizophyte and could not be identified to species level. According to Pall et al. 2011 and Pall et al. 2014 two species of the genus *Myriophyllum* occur in the Lower Lobau floodplains – *M. spicatum* L. and *M. verticillatum* L.. Both species are typical for the order Potametalia and occur in floating leaf societies from the low- to the highlands. *M. spicatum* is adapted to lentic as well as flowing water bodies that are nutrient rich, more or less limy and grows from 1 to 5 m depth. Pollination is done by wind. *M. verticillatum* prefers lentic waters that are more or less nutrient rich and limy. It is sensitive to pollution but adapted to desiccation. It roots from 0,5 to 3 m depth in humous mud in warm backwaters and is pollinated by wind (Krausch 1996; Oberdorfer 2001; Pall et al. 2014). Depending on the species *Myriophyllum* sp. can grow up to 2,75 or rather 2 m in length and has highly dissected leaves forming whorls on the shoots. Both species are perennial (Krausch 1996).

Ceratophyllum demersum

Figure 18: *Ceratophyllum demersum.*

C. demersum belongs to the ground covering hydrophyte species and occurs rooted in spring and later in season also freely floating. Therefore it is also called pleustophyte. The macrophyte is not adapted to current, underlines stagnant conditions and is typical for summer warm eutrophic waters. Preferring alkaline- and nutrient rich conditions it usually inhabits ponds as well as backwaters with humous mud from 0,5 to 10 m depth. *C. demersum* is typical for floating leaf societies and pondweed populations. It occurs in the society Nymphaetum albo-luteae but also in Potameton lucentis or builds own populations (Grabherr & Mucina 1993; Krausch 1996; Oberdorfer 2001; Jäger & Werner 2005; Pall et al. 2014). Its shoots are 0,3 to 1 m long and highly branched. The leaves grow in dense whorls and are one to two times split. It is a perennial plant (Krausch 1996).

4.5.2 Amphiphytes

Amphiphytes are macrophytes that can grow on land without water but also submerged below water (Pall et al. 2011).

Agrostis stolonifera

Figure 19: *Agrostis stolonifera.*

A. stolonifera is a species from the family Poaceae and is according to Pall et al. 2014 typical for small water bodies that have to deal with dry periods. It also grows in wet meadows, at shorelines, in ditches and sinks that are nutrient rich (Jäger & Werner 2005). The amphiphyte has typical growing type of a Poaceae.

Mentha aquatica

Figure 20: *Mentha aquatica.*

M. aquatica is characteristic for wet meadows, sedge-reeds, streams, shorelines of lakes, willows, swamp forests and needs high nutrient content (Jäger & Werner 2005; Pall et al. 2014). The amphiphyte can also grow in a submerged form in flowing water bodies close to springs and can reach up to 0,5 m in length. Its leaves are oval-elliptic and 2 to 8 cm long. *M. aquatica* is perennial (Krausch 1996).

Myosotis palustris

Figure 21: *Myosotis palustris.*

M. palustris is according to Pall et al. 2014 typical for small water bodies that have to deal with dry periods or are flooded in summer. It grows in wet meadows, at shorelines, in reed beds, ditches and swamp forests that are rich in nutrients. It prefers mild to moderate acid humous, sandy clayey or loamy conditions. The amphiphyte grows in more or less shady areas, is pollinated by insects and occurs in the wet meadow associations, but also in reed associations from the low- to the highlands (Krausch 1996; Oberdorfer 2001; Jäger & Werner 2005). *M. palustris* is an indicator for a fluctuating water level. Depending on the nutrient content it can grow up to 0,9 m in length and has oval to lanceolate shaped leaves (Stiftung Natur und Umwelt Rheinland-Pfalz 2017).

4.5.3 Other species related to aquatic conditions

Stachys palustris

S. palustris grows in wet loamy farmland, wet meadows, shoreline shrubs and ditches that are periodically under water as well as at shorelines of waters that have to deal with siltation. It has a high nutrient demand and prefers alkaline soils that are mild to moderate in acidic content and is adapted to water level fluctuations. Roots can go 0,6 m deep in humous clayey or loamy soil. *S. palustris* prefers shade, is pollinated by insects or by itself and indicator for mud accumulation. It occurs in wet meadow associations (Krausch 1996; Oberdorfer 2001; Jäger & Werner 2005; Pall et al. 2014). The plant can reach heights of 1 m and has lanceolate shaped leaves, it is perennial (Krausch 1996).

Figure 22: *Stachys palustris.*

4.6 Index calculations

4.6.1 Floodplain Index (FI)

The Floodplain Index (FI) bases on addition of species specific habitat values (HV) and indication weights (IW). All species of one sampling site are taken into account for the calculation.

$$FI = \sum(HV * IW) \div \sum IW$$

Habitat preference of a species is described by 10 valence points distributed among the five habitat types (H1 – H5) and calculated this way:

$$HV = (1 * H1 + 2 * H2 + 3 * H3 + 4 * H4 + 5 * H5)/10$$

Indication weights range from 1 to 5 and are used for identification of sensitive species (IW >3). 1 describes eurytopic and 5 stenotopic species.

Table 6: *Example of Bithynia tentaculata as indicator species for floodplain systems. H1-H5: habitat types. HV: habitat value. IW: indication weight* (Chovanec et al. 2005).

Species	H1	H2	H3	H4	H5	HV	IW
Bithynia tentaculata	1	1	3	5	-	3,2	1

The FI can be calculated for presence/absence data as well as for abundance data. In case of individuals that could not explicitly been identified as a certain species e.g. *Mystacides azurea/nigra* mean was taken for HV and IW. The FI results in a value between 1 and 5 and indicates preference of a community for a certain habitat type. Indication is presented in Table 7 (Chovanec et al. 2005; Graf & Chovanec 2016).

Table 7: *Floodplain Index values indicating the five habitat types* (Chovanec et al. 2005).

FI range	Habitat type
1,0-1,8	H1
1,9-2,6	H2
2,7-3,4	H3
3,5-4,2	H4
4,3-5,0	H5

Species within the orders Trichoptera, Ephemeroptera, Odonata and Mollusca were included in calculation of the FI. Habitat values and indication weights can be found in Schmidt-Kloiber & Hering (2015).

4.6.2 Epiphytic Invertebrate Index (EII)

The Epiphytic Invertebrate Index (EII) is the sum of macrophyte structure (S) times macrophyte density (D) for each sampled plant species within one water body. Plant diversity, architectural complexity and density describe the habitat complexity at a certain study site. The EII bases on Krecker (1939) and Thomaz et al. (2008). They expected higher invertebrate abundance and diversity in plants with finely dissected leaves compared to broad leaves.

$$EII = \sum S * D$$

For macrophyte structure and density specific values need to be used for calculation of the index:

Table 8: *Values for macrophyte structure and density.*

Macrophyte structure	
1	large floated leaved
2	small leaved
3	gramineous leaved
4	pinnate leaved

Macrophyte density	
1	very low
2	low
3	medium
4	high
5	very high

The higher the EII is the higher is habitat complexity – therefore higher invertebrate abundance and diversity is expected. This can be tested by comparing EII with abundance and diversity data of invertebrates.

4.7 Further statistical analyses

Data were evaluated statistically and graphically in Ecoprof 4.0, IBM SPSS Statistics 21, PCORD 5.33 and RStudio 0.99.486.0. Descriptive statistics was done in Microsoft Excel 2013.

4.7.1 Box- and Whisker plot

The Box- and Whisker plots were prepared in RStudio and show graphically frequency distribution of data. Outliers are shown (Eckey et al. 2005).

4.7.2 Cluster analysis

The cluster analysis was executed in PCORD and defines groups according to their similarities. Clusters are presented in form of a dendrogram (McCune & Mefford 2006).

For calculation of the cluster analysis abundance data were logarithmised, “Sorensen (Bray-Curtis)” was used as distance measure and “Flexible Beta” as cluster-algorithm. -0,25 was taken as β-value.

4.7.3 Detrended correspondence analysis (DCA)

The DCA-analysis (Hill & Gauch 1980) was performed in PCORD. It is an ordination technique, bases on reciprocal averaging and is used for ecological datasets (Hill 1973).

For the calculation of the DCA-analysis data were logarithmised.

4.7.4 Decision Tree

The procedure “decision tree” was executed in SPPS and created a classification model based on a tree. Values for a dependent variables are predicted based on values of independent variables (IBM 2011).

“Exhaustive chaid” was chosen as construction method.

4.7.5 Indicator species analysis

The indicator species analysis was performed in PCORD and detects the value of different taxa for certain environmental conditions. Abundance and frequency data of taxa are combined and finally each species gets an indicator value for each group of environmental conditions. Statistical significance is tested via randomization technique. Indicator values range from 0 to 100 whereby 100 means that presence of a species points to a particular group without error (McCune & Mefford 2006).

For the calculation abundance data were used. In the results all indicator taxa with indication values >20 are shown.

4.7.6 Linear regression

Linear regression was performed in Microsoft Excel and shows the relationship between dependent and explanatory variable (Engel 1997). As sampling size is very small geometric mean (Elliot 1977) and median were taken for testing the connection between EII and invertebrate abundance and diversity.

4.7.7 Non-metric multidimensional scaling analysis (NMS)

The NMS-analysis was executed in PCORD and evaluates similarities of invertebrate data from different samples. The algorithm begins with creation of a similarity matrix and assigns position for each sample in a 2- or 3-dimensional graphical figure. Similar samples are closer to each other, different samples have more distance to each other (Graf et al. 2012).

For the calculation abundance data were logarithmised, “Sorensen (Bray-Curtis)” was used as distance measure, number of runs was 50 and results are shown as scatterplot. Stress values <5 are very good, values between 10 and 15 are satisfactory and values between 15 and 20 are sufficient (Kruskal 1964; Hartung & Elpelt 1999).

4.7.8 Saprobity, feeding types and longitudinal zonation

Figures for saprobic valences, feeding types and longitudinal zonation were calculated in Ecoprof. Calculations based on ecological data from the Fauna Aquatica Austriaca (Moog 2002).

5 Results

5.1 Taxa list

Table 9 shows a presence/absence taxa list for all four study sites and both seasons. Similarities but also differences in the taxa composition are observable for the different study sites. A seasonal difference can be seen as well. Study site 1 has the lowest taxa number in June as well as in October 2016, study site 4 highest one. A taxa list with detailed abundances can be found in Table 30 and Table 31.

Table 9: *Presence/absence taxa list for all study sites and both seasons.*

Taxon	**Study sites**							
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
	14.06.2016				**13.10.2016**			
Turbellaria								
Turbellaria Gen. sp.		x	x	x	x			x
Gastropoda								
Acroloxus lacustris				x	x			x
Bithynia tentaculata		x	x	x				x
Potamopyrgus antipodarum			x					
Radix auricularia						x		
Radix ovata/peregra	x	x		x	x	x	x	x
Radix sp. juv.			x			x		
Stagnicola sp.			x	x				
Physidae Gen. sp.	x	x	x		x	x	x	
Ancylus fluviatilis					x			x
Anisus sp.				x				x
Gyraulus crista		x	x	x		x		x
Gyraulus laevis/parvus		x	x	x		x	x	x
Planorbarius corneus				x				x
Planorbidae Gen. sp. juv.	x	x	x	x		x	x	x
Planorbis carinatus				x				x
Planorbis planorbis	x		x	x				
Planorbis sp. juv.				x				
Segmentina nitida								x
Valvatidae Gen. sp. juv.				x				x
Valvata piscinalis spp.		x						x
Bivalvia								
Musculium lacustre		x						
Pisidium casertanum spp.				x				
Pisidium nitidum								x
Pisidium sp. juv.	x	x		x				x
Pisidium subtruncatum				x				x
Oligochaeta								

Oligochaeta Gen. sp.	x	x	x	x	x	x	x	x
Eiseniella tetraedra		x		x				
Stylaria lacustris	x	x		x	x	x		x
Hirudinea								
Erpobdella octoculata	x	x	x	x		x	x	x
Alboglossiphonia hyalina	x	x	x					
Alboglossiphonia sp. juv.	x	x	x			x	x	x
Helobdella stagnalis		x						
Glossiphonia concolor	x	x						
Glossiphonia sp. juv.		x	x	x				
Piscicolidae Gen. sp.		x			x			x
Crustacea								
Argulus sp.		x						
Asellus aquaticus		x	x	x			x	x
Corophium sp.	x							
Gammaridae Gen. sp. juv.				x				x
Jaera istri			x					x
Limnomysis benedeni	x							
Ephemeroptera								
Baetis lutheri/vardarensis								x
Baetis bucertus/nexus				x				x
Baetis sp. juv.				x			x	x
Centroptilum luteolum				x				
Centroptilum/Cloeon sp. juv.	x		x				x	x
Cloeon dipterum	x	x	x	x	x	x	x	x
Caenis horaria								x
Caenis luctuosa								x
Caenis robusta						x	x	x
Caenis sp. juv.		x	x	x	x	x	x	x
Serratella ignita				x				
Paraleoptophlebia sp.								x
Habrophlebia cf. *fusca*				x				
Odonata								
Zygoptera juv.	x	x	x	x	x	x	x	x
Coenagrionidae Gen. sp. juv.	x			x	x	x	x	x
Coenagrionidae/Platycnemidae Gen. sp.						x	x	x
Aeshnidae Gen. sp. juv.		x					x	
Aeshna cf. *cyanea*				x		x	x	x
Somatochlora metallica		x						
Lestidae Gen. sp. juv.		x						
Lestes virens				x				
Sympecma fusca		x	x					

Gomphus vulgatissimus								x
Corduliidae/Libellulidae Gen. sp.						x		x
Libellulidae Gen. sp. juv.				x				
Sympetrum sanguineum		x	x	x				
Calopteryx splendens								x
Heteroptera								
Gerris argentatus							x	
Notonecta glauca spp.						x	x	x
Ranatra linearis						x		
Corixidae Gen. sp.		x	x		x	x	x	
Ilyocoris cimicoides spp.	x		x	x			x	
Plea minutissima spp.		x	x				x	
Coleoptera								
Chrysomelidae Gen. sp. Ad.	x							
Dryopidae Gen. sp. Ad.			x					
Dryops sp. Lv.				x				x
Dytiscidae Gen. sp. Ad.								x
Dytiscidae Gen. sp. Lv.	x	x	x	x			x	x
Platambus maculatus Ad.								x
Haliplus sp. Ad.			x				x	
Haliplus sp. Lv.		x	x	x		x	x	
Peltodytes caesus Ad.							x	
Peltodytes caesus Lv.		x	x	x		x		x
Hydraena sp. Ad.			x					
Oulimnius sp. Lv.								x
Hydrophilidae Gen. sp. Ad.			x	x				
Hydrophilidae Gen. sp. Lv.	x	x	x	x				
Trichoptera								
Trichoptera juv.							x	x
Hydropsyche angustipennis spp.				x				x
Hydroptilidae Gen. sp. juv.				x		x	x	x
Agraylea multipunctata				x				
Agraylea sexmaculata			x	x		x	x	x
Hydroptila sp.				x				x
Hydroptila sparsa								
Orthotrichia sp.							x	x
Oxyethira flavicornis							x	x
Ecnomus tenellus								x
Leptoceridae Gen. sp. juv.		x	x	x				x
Athripsodes cinereus								x
Athripsodes sp. juv.								x
Mystacides azurea/nigra				x				x

Mystacides sp.								x
Oecetis furva		x						
Oecetis lacustris		x						
Oecetis sp. juv.		x				x	x	x
Oecetis testacea		x						x
Triaenodes bicolor			x				x	x
Agrypnia varia							x	
Lype sp. juv.								x
Diptera								
Brachycera Gen. sp.	x			x	x		x	x
Nematocera Gen. sp.								x
Ceratopogonidae Gen. sp.	x	x	x	x	x	x	x	x
Chaoborus crystallinus		x	x			x	x	
Anopheles maculipennis							x	x
Stratiomyidae Gen. sp.	x		x	x				
Tabanidae Gen. sp.		x					x	
Dixidae Gen. sp.							x	x
Empididae Gen. sp.								x
Limoniidae/Pediciidae Gen. sp.								x
Tipulidae Gen. sp.								x
Lepidoptera								
Acentria ephemerella		x	x	x		x		x
Elophila nymphaeata/rivulalis				x	x		x	x
Parapoynx stratiotata				x		x	x	x
Acari								
Hydrachnidia Gen. sp.		x	x	x	x		x	x
NUMBER OF TAXA	**24**	**46**	**42**	**58**	**17**	**31**	**44**	**78**

5.2 Floodplain Index (FI)

5.2.1 Presence/absence data analysis

Habitat types and index-values (summer)

Table 10 shows the Floodplain Index (FI) and habitat type for epiphytic invertebrates at each study site in June. The FI is listed for each study site in total and separately for the orders Mollusca, Odonata, Trichoptera and Ephemeroptera. In study site 1 only Mollusca and Ephemeroptera were considered as Odonata and Trichoptera were not present or could not be identified to the species level.

In June all study sites belong to the habitat type Plesiopotamon. Considering study sites 1 and 2 more in detail it is observable that all incorporated orders show preference for plesiopotamal conditions. The FI of 3,41 at study site 3 still belongs to the habitat type Plesiopotamon but is already close to Paläopotamon: Mollusca, Odonata and Ephemeroptera indicate plesiopotamal characteristics, whereas Trichoptera are typical for paläopotamal conditions. The FI at study site 4 is close to the threshold of the type Parapotamon: Mollusca and Odonata are typical for the Paläopotamon, Trichoptera for the Plesiopotamon and Ephemeroptera for the Eupotamon (Table 10).

Table 10: *FI, habitat type and number of incorporated species of Mollusca, Odonata, Trichoptera and Ephemeroptera at the four study sites in June (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11;).*

Study site June	**FI / Habitat type**	**FI Mollusca / Number of species**	**FI Odonata / Number of species**	**FI Trichoptera / Number of species**	**FI Ephemeroptera / Number of species**
1	3,32 / H3	3,33 / 5	- / 0	- / 0	3,10 / 1
2	3,11 / H3	3,09 / 7	3,18 / 3	3,11 / 3	3,10 / 1
3	3,41 / H3	3,21 / 7	3,35 / 2	3,85 / 2	3,10 / 1
4	2,75 / H3	3,47 / 11	3,90 / 3	2,70 / 4	1,34 / 6

Figure 23 shows a Box- and Whisker plot presenting the frequency distribution of habitat values that were incorporated in calculation of the FI in June. It is split in invertebrate order per study site. At study site 1 medians for Mollusca and Ephemeroptera are similar. Distribution of habitat values for Mollusca species is narrow, outlier is *Planorbis planorbis* with 4,3. For the order Ephemeroptera only *Cloeon dipterum* was considered indicating a habitat value of 3,1.

At study site 2 medians of Mollusca, Odonata and Ephemeroptera are similar, for Trichoptera median is higher. Distribution of habitat values is largest for Trichoptera species, ranging between 1,7 (*Oecetis testacea*) and 4,0 (*Oecetis furva*). In return distribution of habitat values for Mollusca, Odonata and Ephemeroptera is narrow (Figure 23).

Medians of Mollusca and Ephemeroptera are similar at study site 3, for Odonata and especially Trichoptera species they are higher. Distribution of habitat values is largest for Mollusca species, ranging between 2,3 (*Potamopyrgus antipodarum*) and 3,3 (*Gyraulus crista*). *P. planorbis* is an outlier. For Odonata, Trichoptera and Ephemeroptera the distribution is narrow (Figure 23).

Medians for the orders Mollusca, Odonata and Trichoptera are similar at study site 4. Whereas for Ephemeroptera species it is much lower indicating the habitat type Eupotamon. Distribution of habitat values is large, all orders together cover more or less the whole hydrological connectivity range from the Eupotamon to temporal water bodies. Within Ephemeroptera *Serratella ignita* and *Habrophlebia fusca* have the lowest values and *C. dipterum* the highest, within Trichoptera *Hydropsyche angustipennis* has the lowest value and *Agraylea sexmaculata* as well as *Agraylea multipunctata* highest ones. *Pisidium subtruncatum* has the lowest value within Mollusca, *P. planorbis* the highest. For Odonata *Aeshna cyanea* as well as *Sympetrum sanguineum* have lowest habitat values, *Lestes virens* the highest one (Figure 23).

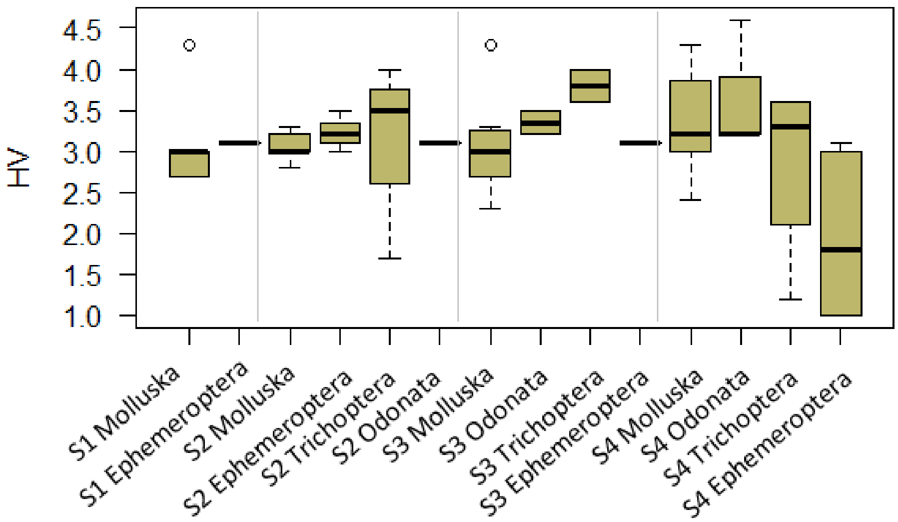

Figure 23: *Box- and Whiskerplot presenting the habitat values of all in FI incorporated species in June. S1-S4: Study site 1 to 4 (Samples N for each study site: N_1=3, N_2=3, N_3=7, N_4=11).*

Habitat types and index-values (autumn)

Table 11 shows the Fl and habitat type for epiphytic invertebrates for each study site in October.

According to epiphytic invertebrates in October study sites 1, 2 and 3 are classified as the habitat type Plesiopotamon, study site 4 as Parapotamon. Like in June Mollusca and Ephemeroptera indicate the type Plesiopotamon at study site 1. At study sites 2 and 3 Mollusca, Odonata and Ephemeroptera indicate plesiopotamal preference whereas Trichoptera show paläopotamal tendencies. Study site 4 is classified as a Parapotamon whereby Mollusca indicate a Plesiopotamon, Trichoptera a Parapotamon, Odonata and Ephemeroptera an Eupotamon. The FI from Odonata is extremely different from June as it indicates paläopotamal conditions there (Table 11).

Table 11: *FI, habitat type and number of incorporated species of Mollusca, Odonata, Trichoptera and Ephemeroptera at the four study sites in October (Samples N for each study site: October N_1=3, N_2=3, N_3=9, N_4=9).*

Study site October	**FI / Habitat type**	**Mollusca / Number of species**	**FI Odonata / Number of species**	**FI Trichoptera / Number of species**	**FI Ephemeroptera / Number of species**
1	3,06 / H3	3,05 / 5	- / 0	- / 0	3,10 / 1
2	3,07 / H3	2,92 / 7	3,20 / 1	3,60 / 1	3,17 / 2
3	3,40 / H3	3,00 / 3	3,20 / 1	3,75 / 3	3,17 / 2
4	2,41 / H2	3,23 / 13	1,76 / 3	2,39 / 11	1,62 / 8

Another Box- and Whisker plot is shown in Figure 24, presenting the habitat values incorporated in the FI calculation in October. Like in Figure 23 results are split in invertebrate order per study site. At study site 1 distribution and medians are similar to June, outlier is *Acroloxus lacustris*.

The same pattern like in June can be also seen at study site 2 – medians for Mollusca, Odonata and Ephemeroptera are similar, for Trichoptera the median is higher. In turn distribution of Trichoptera is very narrow in October. Reason therefore is that only one Trichoptera species was incorporated in calculation (Figure 24).

Considering study site 3 it is visible that medians are similar for all orders except Trichoptera species, that have a much higher median of 3,75. This is a similar pattern to June. The istribution of habitat values is narrow (Figure 24).

Study site 4 shows a very different pattern from June. Mollusca have the highest median of 3 and Odonata the lowest of 1,4. Like in June distribution is larger than at the other study sites, all species together cover a hydrological range from the Eu- to Paläopotamon. Within Ephemeroptera *Baetis lutheri/vardarensis* have lowest values and *Caenis robusta* highest, within Trichoptera *H. angustipennis* as well as *Athripsodes cinereus* have lowest and *A. sexmaculata* the highest one. *Ancylus fluviatilis* has the lowest value within the order Mollusca, *Planorbarius corneus* as well as *Planorbis carinatus* highest ones. *Calopteryx splendens* has the lowest value within Odonata and *A. cyanea* highest one (Figure 24).

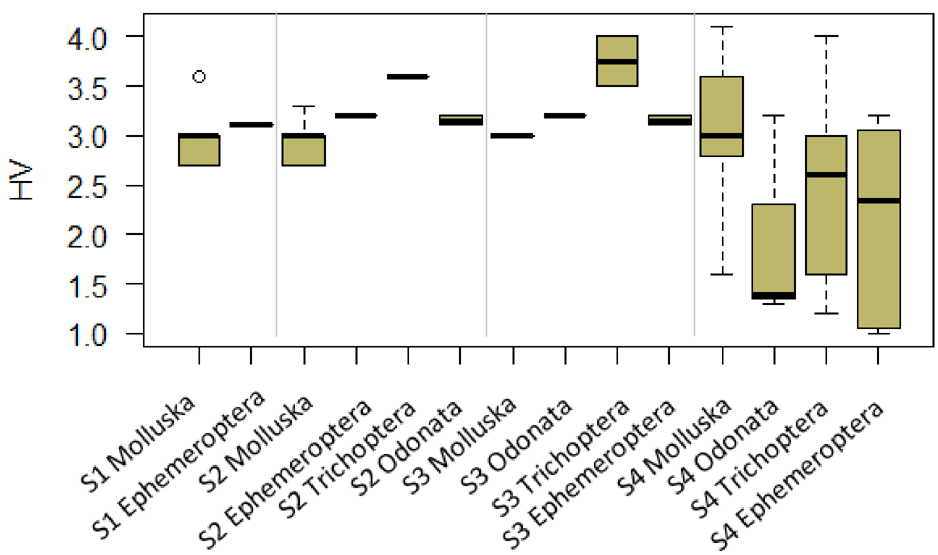

Figure 24: *Box- and Whiskerplot presenting habitat values of all in FI incorporated species in October. S1-S4: Study site 1 to 4 (Samples N for each study site:* N_1*=3,* N_2*=3,* N_3*=9,* N_4*=9).*

Summary: Considering **presence/absence data** analysis **all study sites** are characterized as a **Plesiopotamon in June** - with **study site 3 tending towards a Paläopotamon** and **study site 4 towards a Parapotamon**. In **October** the **same pattern** is visible – with the exception of **study site 4** indicating a **Parapotamon**. The Box- and Whisker plots show **highest distribution of habitat values at study site 4** which incorporates most species in calculation of the FI.

5.2.2 Abundance data analysis

Habitat types and index-values (summer)

Table 12 shows the FI and habitat type for each study site in June for abundance data. Like in Table 10 the FI is listed for each study site in total and separately for the orders Mollusca, Odonata, Trichoptera and Ephemeroptera. At study site 1 only Mollusca and Ephemeroptera were considered.

Comparing June data in presence/absence and abundance data analysis it is visible that there are only small differences. Almost all FI values are similar. One difference is that total FI values of study sites 2 and 3 are closer to each other in abundance data analysis, study site 3 does not show paläopotamal tendencies there (Table 12).

Table 12: *FI, habitat type and number of incorporated species of Mollusca, Odonata, Trichoptera and Ephemeroptera at the study sites in June and October (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11).*

Study site June	FI / Habitat type	FI Mollusca / Number of species	FI Odonata / Number of species	FI Trichoptera / Number of species	FI Ephemeroptera / Number of species
1	3,26 / H3	3,31 / 5	- / 0	- / 0	3,10 / 1
2	3,03 / H3	3,01 / 7	3,31 / 3	3,06 / 3	3,10 / 1
3	3,07 / H3	3,02 / 7	3,40 / 2	3,91 / 2	3,10 / 1
4	2,69 / H2	3,15 / 11 H3	3,96 / 3	1,56 / 4 H1	1,18 / 6

Figure 25 shows a Box- and Whisker plot presenting the frequency distribution of habitat values that were incorporated in calculation of the FI in abundance data analysis in June. Results are again split in invertebrate order per study site.

Comparing presence/absence and abundance data small differences can be seen: At study site 3 distribution is broader for Mollusca in presence/absence data analysis, the same can be seen for Mollusca and Trichoptera at study site 4. Median of habitat values for Trichoptera is much smaller in abundance analysis at study site 4. More outliers are within the Boxplot (Figure 25).

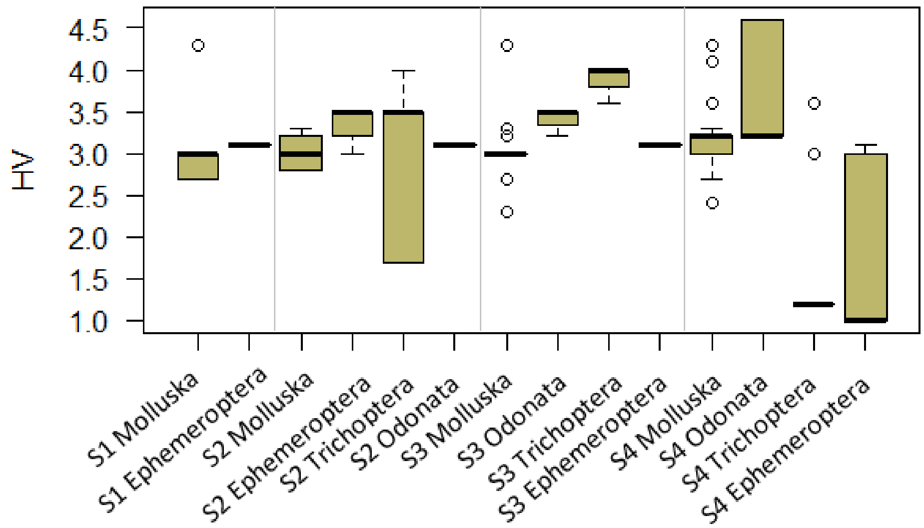

Figure 25: *Box- and Whiskerplot presenting habitat values of all in FI incorporated species in June. S1-S4: Study site 1 to 4 (Samples N for each study site: N_1=3, N_2=3, N_3=7, N_4=11).*

Habitat types and index-values (autumn)

Table 13 shows the FI and habitat type for each study site in October for abundance data.

In October study sites 2 and 3 show higher similarity in total FI in abundance data than in presence/absence data analysis. Another difference between the two methods is that total FI for study site 4 is higher in abundance data analysis (Table 13).

Table 13: *FI, habitat type and number of incorporated species of Mollusca, Odonata, Trichoptera and Ephemeroptera at the four study sites in June and October (Samples N for each study site: October N_1=3, N_2=3, N_3=9, N_4=9).*

Study site October	FI / Habitat type	Mollusca / Number of species	FI Odonata / Number of species	FI Trichoptera / Number of species	FI Ephemeroptera / Number of species
1	3,20 / H3	3,38 / 5	- / 0	- / 0	3,10 / 1
2	3,11 / H3	3,01 / 7	3,20 / 1	3,60 / 1	3,10 / 2
3	3,14 / H3	3,00 / 3	3,20 / 1	3,60 / 3	3,12 / 2
4	2,68 / H2	3,20 / 13	1,32 / 3	2,74 / 11	2,72 / 8

Figure 26 shows another Box- and Whisker plot presenting the habitat values that were used in calculation of the FI with abundance data.

Comparing presence/absence and abundance data analysis it is observable that distribution of habitat values is narrower for abundance data and much more outliers are within the Boxplot. Especially broad habitat value distribution of Odonata and Trichoptera at study site 4 disappears in abundance data analysis (Figure 26).

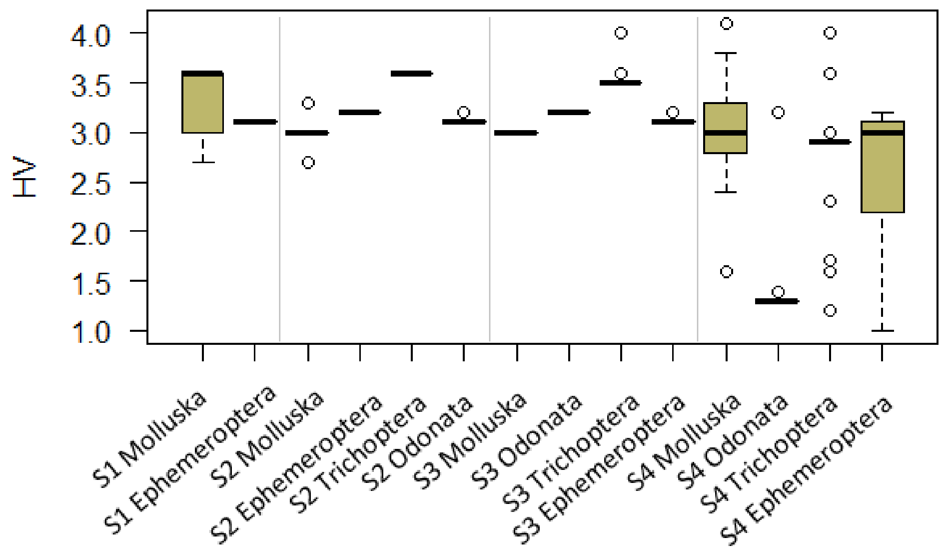

Figure 26: *Box- and Whiskerplot presenting habitat values of all in FI incorporated species in October. S1-S4: Study 1 to 4 (Samples N for each study site: N_1=3, N_2=3, N_3=7, N_4=11).*

Summary: Comparing presence/absence and **abundance data** analysis **small differences** are observable in the calculation of the FI. **In abundance data analysis all study sites** are defined as a **Plesiopotamon except study site 4 as a Parapotamon in both seasons**. Tendency of stud site 3 towards a Paläopotamon cannot be seen herein – describing similarity between study sites 2 and 3. In the Box- and Whisker plots the distribution of habitat values is narrower and more outliers can be seen.

5.3 Macrophyte communities

5.3.1 Macrophyte communities at the different sites

Study site 1

At study site 1 only *N. lutea* was sampled. *N. lutea* belongs to the class Potametea, the pondweed and water lily societies that include all water plant societies of lotic and lentic water bodies. Habitats are oligo- and eutrophic water bodies with various lime content down to 7 m depth in lowlands. Typically reed societies are close - indicating siltation processes. Within the Potametea mainly hydrophytes, the "real" water plants, give structure. Amphiphytes and helophytes occur as well. In Middle Europe this class includes 50 to 60 species and is characterized by few dominant species. Factors like calcium, hydro carbonate, depth, nutrient content, water movement, temperature, substrate, light, etc. influence the vegetation forms. Within the Potametea *N. lutea* belongs to the order Potametalia and within the Potametalia it refers to the association of Nymphaeion albae (Table 14). This association is characterized by occurrence of *N. lutea* and *N. alba.* It consists of rooted floating leaf communities complex and rich in structure. *N. lutea* is one of the character species indicating the society Nymphaeetum albo-luteae. In lentic to slowly flowing water bodies that are rich in mud content it is the most common society in Austria (Grabherr & Mucina 1993).

Table 14: *Macrophyte species and related communities at study site 1.*

Plant species	Class	Order	Association	Society
N. lutea	Potametea R. Tx. et Preising 1942	Potametalia Koch 1926	Nymphaeion albae Oberd. 1957	Nymphaeetum albo-lutea Nowiński 1928

Society of Nymphaeetum albo-luteae indicates the Plesio-Paläopotamon habitat type. As macrophyte coverage is larger than 20% there is a trend towards a Paläopotamon (Ward & Stanford 1995; Chovanec et al. 2005).

Study site 2

P. berchtoldii, A. stolonifera, S. palustris and *M. palustris* were sampled at study site 2 in June. *P. berchtoldii* belongs to the class Potametea and therein to the order Potametalia, the pondweed and floating leaf societies in standing and flowing water bodies. The hydrophyte is no characteristic species for certain associations as well as plant societies (Table 15) (Grabherr & Mucina 1993).

S. palustris is part of the class Molinio-Arrhenatheretea, the nutrient rich pastures, semi-natural and flooded grassland formations. It is characterized by high nutrient and water content. The plant is furthermore part of the order Molinietalia, the wet meadows and tall herb fringe communities that are typical for semi-humid and wet soil. At rivers, lakes or ditches water level is high and results in gleyification, but also in spring certain sites are saturated. Within the order Molinietalia *S. palustris* can belong to two associations: On the one hand to the association Molinion. The Molinion indicates semi-humid to humid, humous to peaty soil that is low in nutrient content. At least one time of the year ground water level is high. On the other hand *S. palustris* can be referred to the association of Filipendulenion. It is characterized by ditches, rivers and lakes that are nutrient rich and sometimes flooded (Table 15) (Grabherr et al. 1993; Oberdorfer 2001).

A. stolonifera is another indicator species for the class Molinio-Arrhenatheretea. It belongs to the order Potentillo-Polygonetalia, the flooded grassland formations of humid and flooded sites. This order is characterized as grassland close to water bodies that are flooded regularly. The Potentillo-Polygonetalia is impacted by soil humidity, high ground water level and typical for water bodies that dry out in summer and for natural floodplain soils. Therein the Poaceae is referred to the association of Potentillion anserinae, but it cannot be related to a certain plant society (Table 15).

M. palustris belongs to the class Molinio-Arrhenatheretea and therein to the order Molinietalia. It is part of the association Calthion, the wet meadows that are typical for floodplains of streams and rivers which are ground and day water influenced. The amphiphyte cannot be referred to a certain plant society (Grabherr & Mucina 1993). On the other hand the macrophyte is also indicator species for the class of Phragmiti-Magnocaricetea, the reeds and sedges (Ellenberg 1996). This class is characterized by plant societies growing in sedimentation and siltation zones or at sites that are flooded. Typical water bodies are stagnant and oligo- to eutrophic like backwaters, ponds and lakes. Vegetative zonation is impacted by duration and intensity of the flood, furthermore substrate type has influence. *M. palustris* belongs to the order Phragmietalia. This order is indicator for sedimentation and siltation of eutrophic lentic waters with high ground water level that are flooded at least one time during vegetation period. It is indicator species for the association Phragmition, the reeds and sedges of lentic waters (Table 15) (Grabherr & Mucina 1993; Grabherr et al. 1993; Ellenberg 1996).

Table 15: *Macrophyte species and related communities at study site 2 in June.*

Plant species	**Class**	**Order**	**Association**	**Society**
P. berchtoldii	Potametea R. Tx. et Preising 1942	Potametalia Koch 1926	*Not assignable*	*Not assignable*

S. palustris	Molinio-Arrhenatheretea R. Tx. 1937 em. R. Tx. 1970	Molinietalia Koch 1926	Molinion Koch 1926 or Filipendulenion (Lohmeyer in Oberd. et al. 1967) Bal.-Tul. 1978	*Not assignable*
A. stolonifera	Molinio-Arrhenatheretea R. Tx. 1937 em. R. Tx. 1970	Potentillo-Polygonetalia R. TX. 1947	Potentillion anserinae R. Tx. 1947	*Not assignable*
M. palustris	Molinio-Arrhenatheretea R. Tx. 1937 em. R. Tx. 1970	Molinietalia Koch 1926	Calthion R. Tx. 1937 Em. Bal.-Tzl. 1978	*Not assignable*
	Phragmiti-Magnocaricetea Klika in Klika et Novak 1941	Phragmietalia Koch 1926	Phragmition Koch 1926	*Not assignable*

P. pectinatus, P. perfoliatus, P. lucens and *Myriophyllum* sp. were sampled at study site 2 in October. All four taxa belong to the class Potametea as they are "real" water plants. The macrophytes are part of the order Potametalia. Therein they occur in the association Potamion pectinati, the submerged pondweed communities. This association is characterized by missing floating leaf societies, is adapted to a large spectrum of ecological factors and consists of more societies that could be worth considering at study site 2: The society Potameton lucentis is dominated by *P. lucens* and *P. perfoliatus* and occurs in standing to slowly flowing waters that are meso- to eutrophic. It is typical for muddy soil, often in contact with the society of Nymphaetum albo-lutea and very common in Austria. Myriophyllo-Potametum lucentis is characterized by *P. lucens, M. spicatum* and *M. verticillatum*, very similar in ecological factors to Potameton lucentis and common in the Danube floodplains. Potamo-perfoliati-Ranunculetum circinati is characterized by *Ranunculus circinatus* and *P. perfoliatus* and common in nutrient rich waters with muddy soil in the Danube floodplains. The Potamogeton perfoliatus-(Potamion)-Society is indicated by *P. perfoliatus* and *P. pectinatus*, typical for nutrient rich waters with muddy soil and prefers more eutrophic conditions than Potametum lucentis. The Potamogeton pectinatus-(Potamion)-Society occurs in muddy nutrient rich standing waters and prefers eutrophication (Table 16) (Grabherr & Mucina 1993).

Table 16: *Macrophyte species and related communities at study site 2 in October.*

Plant species	Class	Order	Association	Society
P. pectinatus	Potametea R. Tx. et Preising 1942	Potametalia Koch 1926	Potamion pectinati (Koch 1926) Gors 1977	Potamogeton perfoliatus-(Potamion)-Society Den Hartog et Segal 1964 or Potamogeton pectinatus-(Potamion)-Society Den Hartog et Segal 1964
P. perfoliatus	Potametea R. Tx. et Preising 1942	Potametalia Koch 1926	Potamion pectinati (Koch 1926) Gors 1977	Potameton lucentis Hueck 1931 or Potamo-perfoliati-Ranunculetum circinati Sauer 1937 or Potamogeton perfolia-

				tus-(Potamion)-Society DEN HARTOG ET SEGAL 1964
P. lucens	Potametea R. TX. ET PREISING 1942	Potametalia KOCH 1926	Potamion pectinati (KOCH 1926) GORS 1977	Potameton lucentis HUECK 1931 or Myriophyllo-Potametum lucentis SOO 1934
Myriophyllum sp.	Potametea R. TX. ET PREISING 1942	Potametalia KOCH 1926	Potamion pectinati (KOCH 1926) GORS 1977	Myriophyllo-Potametum lucentis SOO 1934

These macrophyte communities are not listed in the description of the different habitat types. As macrophyte coverage of open water area is higher than 20% and sedimentation processes are going on the macrophyte community at study site 2 indicates a Paläopotamon (Ward & Stanford 1995; Chovanec et al. 2005).

Study site 3

In June *N. lutea, C. demersum* and *P. lucens* were sampled, *Myriophyllum* sp. was added in October. All four taxa belong to the class Potametea and therein to the order Potametalia. Combination of the species *N. lutea* and *C. demersum* in June indicates the association of Nymphaion albae and therein society of Nymphaeetum albo-luteae. *P. lucens* is indicator for the association of Potamion pectinati and indicates one of its societies like Potameton lucentis or Myriophyllo-Potametum (Table 17).

In October combination of *N. lutea*, *C. demersum* and *Myriophyllum* sp. is indicator for the floating leaf society of Nymphaeetum albo-luteae. It is overlapping with the pondweed society of Myriophyllo-Potametum lucentis as it is characterized by occurrence of *P. lucens* and *M. spicatum/verticillatum* (Table 17) (Grabherr & Mucina 1993; Ellenberg 1996).

Table 17: *Macrophyte species and related communities at study site 3.*

Plant species	Class	Order	Association	Society
N. lutea	Potametea R. TX. ET PREISING 1942	Potametalia KOCH 1926	Nymphaeion albae OBERD. 1957	Nymphaeetum albo-lutea NOWIŃSKI 1928
C. demersum	Potametea R. TX. ET PREISING 1942	Potametalia KOCH 1926	Nymphaeion albae OBERD. 1957	Nymphaeetum albo-lutea NOWIŃSKI 1928
P. lucens	Potametea R. TX. ET PREISING 1942	Potametalia KOCH 1926	Potamion pectinati (KOCH 1926) GORS 1977	Potameton lucentis HUECK 1931 or Myriophyllo-Potametum lucentis SOO 1934
Myriophyllum sp.	Potametea R. TX. ET PREISING 1942	Potametalia KOCH 1926	Nymphaeion albae OBERD. 1957	Nymphaeetum albo-lutea NOWIŃSKI 1928
	Potametea R. TX. ET PREISING 1942	Potametalia KOCH 1926	Potamion pectinati (KOCH 1926) GORS 1977	Myriophyllo-Potametum lucentis SOO 1934

The Nymphaeetum albo-luteae society indicates water bodies with plesio- and paläopotamal habitat type. In the sampled area macrophyte coverage is larger than 20% of open water area and as sedimentation processes are going on the trend is towards a Paläopotamon (Ward & Stanford 1995; Chovanec et al. 2005).

Study site 4

In June *N. lutea, P. perfoliatus, M. palustris, A. stolonifera* and *M. aquatica* were sampled. *N. lutea* and *P. perfoliatus* belong to the class Potametea and therein to the order Potametalia. *N. lutea* indicates the floating leaf societies of Nymphaeion albae and therein the Nymphaeetum albo-luteae. *P. perfoliatus* belongs to the submerged pondweeds, the association of Potamion pectinate and therein it indicates one of its societies Potameton lucentis, Potamo-perfoliati-Ranunculetum circinati or the Potamogeton perfoliatus-(Potamion) (Table 18).

A. stolonifera and *M. palustris* indicate the class Molinio-Arrhenatheretea. *A. stolonifera* is related to the order Potentillo-Polygonetalia, the flooded grassland formations of humid and flooded sites and therein to the association of Potentillion anserinae (Table 18).

M. palustris belongs to the order Molinietalia. Therein it is related to the association of Calthion, the wet meadows that are typical for floodplains of streams as wells as rivers. It is also indicator species for the class of Phragmiti-Magnocaricetea, the reeds and sedges. *M. palustris* is typical for the order Phragmitetalia and the association Phragmition, the reeds and sedges of lentic waters. Furthermore *M. aquatica* is indicator species for this association (Table 18) (Grabherr & Mucina 1993; Grabherr et al. 1993; Ellenberg 1996).

In October N*. lutea, P. lucens, P. pectinatus, M. palustris* and *M. aquatica* were sampled. *N. lutea*, *M. palustris* and *M. aquatica* indicate the same plant communities like in June. *P. lucens* and *P. pectinatus* indicate the association of Potamion pectinate and therein the societies of Potameton lucentis, Myriophyllo-Potametum lucentis, Potamogeton perfoliatus-(Potamion)-Society or Potamogeton pectinatus-(Potamion)-Society (Table 18) (Grabherr & Mucina 1993).

Table 18: *Macrophyte species and related communities at study site 4.*

Plant species	Class	Order	Association	Society
N. lutea	Potametea R. Tx. et Preising 1942	Potametalia Koch 1926	Nymphaeion albae Oberd. 1957	Nymphaeetum albo-lutea Nowiński 1928
P. perfoliatus	Potametea R. Tx. et Preising 1942	Potametalia Koch 1926	Potamion pectinati (Koch 1926) Gors 1977	Potameton lucentis Hueck 1931 or Potamo-perfoliati-Ranunculetum circinati Sauer 1937 or Potamogeton perfoliatus-(Potamion)-Society Den Hartog et Segal 1964
M. palustris	Molinio-Arrhenatheretea R. Tx. 1937 em. R. Tx. 1970	Molinietalia Koch 1926	Calthion R. Tx. 1937 Em. Bal.-Tzl. 1978	*Not assignable*
	Phragmiti-Magnocaricetea Klika in Klika et Novak 1941	Phragmietalia Koch 1926	Phragmition Koch 1926	*Not assignable*

A. stolonifera	Molinio-Arrhenatheretea R. Tx. 1937 em. R. Tx. 1970	Potentillo-Polygonetalia R. TX. 1947	Potentillion anserinae R. Tx. 1947	*Not assignable*
M. aquatica	Phragmiti-Magnocaricetea Klika in Klika et Novak 1941	Phragmietalia Koch 1926	Phragmition Koch 1926	*Not assignable*
P. lucens	Potametea R. Tx. et Preising 1942	Potametalia Koch 1926	Potamion pectinati (Koch 1926) Gors 1977	Potameton lucentis Hueck 1931 or Myriophyllo-Potametum lucentis Soo 1934 or Potamogeton perfoliatus-(Potamion)-Society Den Hartog et Segal 1964 or Potamogeton pectinatus-(Potamion)-Society Den Hartog et Segal 1964
P. pectinatus	Potametea R. Tx. et Preising 1942	Potametalia Koch 1926	Potamion pectinati (Koch 1926) Gors 1977	Potameton lucentis Hueck 1931 or Myriophyllo-Potametum lucentis Soo 1934 or Potamogeton perfoliatus-(Potamion)-Society Den Hartog et Segal 1964 or Potamogeton pectinatus-(Potamion)-Society Den Hartog et Segal 1964

The Nymphaeetum albo-luteae society indicates a Plesio- and Paläopotamon habitat type. In the sampled area macrophyte coverage is larger than 20% of open water area, therefore the trend is towards a Paläopotamon. On the contrary the substrate consists of gravel sediment and the study site has periodically unidirectional flow, indicating eu- and parapotamal conditions (Ward & Stanford 1995; Chovanec et al. 2005).

Summary: According to macrophyte communities and densities **study sites 1 and 3** indicate a **Plesio-Paläopotamon** and **study site 2 a Paläopotamon**. **Study site 4** is **unique** as macrophytes show Plesio-Paläopotamon habitat type but unidirectional flow tends to indicate Eu- and Parapotamon conditions.

5.3.2 Sampled macrophyte species, densities and leaf structures at the different sites

Summer

In Figure 27 sampled macrophyte species, densities after Kohler (1978) and leaf structure can be seen for each study site in June. At study site 1 (blue) only *N. lutea* was sampled. The macrophyte that is characterized by large flat floating leaves occurs in density class 5. This species is dominant and makes out about 50% of open water area. Study site 1 is poor in macrophyte species diversity as well as structure.

Study site 2 (green) is inhabited by two small leaved species occurring in density class 2: *S. palustris* and *M. palustris* are spread loosely. The mixture of *A. stolonifera*, *P. berchtoldii* and *Poaceae* Gen. sp. that is characterized by gramineous slender leaves occurs in density class 4. It is very common at the study site. Concluding, diverse macrophyte species in gramineous and small leaved structure inhabit the study site (Figure 27).

N. lutea is also very common at study site 3 (red) and occurs in density class 4. *P. lucens*, characterized by small leaves and *C. demersum,* pinnate leaved, are widespread and are classified as density class 3. Study site 3 is inhabited by several species and very rich in structure (Figure 27).

Study site 4 (brown) is inhabited by *N. lutea* in density class 2 as it is loosely spread. *M. palustris, P. perfoliatus* and *M. aquatica* are widespread but not common (density class 3). Structure is less diverse than at study sites 2 and 3 and shaped by floating and small leaves of several species (Figure 27).

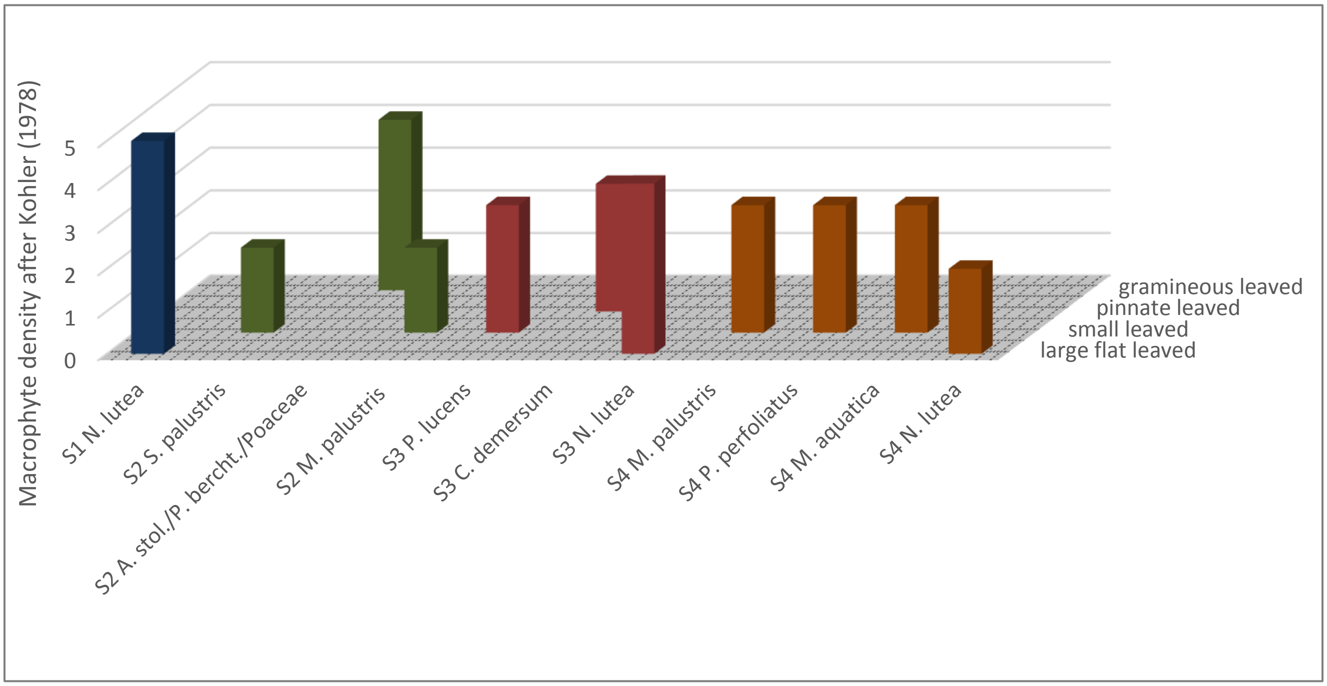

Figure 27: *Macrophyte species, their densities after Kohler (1978) and leaf structure at the different study sites in June. S1-S4: Study site 1 to 4. Study site 1 – blue, 2 – green, 3 – red and 4 – brown.*

Autumn

Macrophyte species sampled in October, their densities and leaf structure are presented in Figure 28. Like in June study site 1 is dominated by *N. lutea* and therefore classified as density category 5. Study site 1 can be considered as poor in macrophyte diversity as well as structure.

At study site 2 *Myriophyllum* sp., characterized as pinnate leaved, is widely spread (density 4). *P. perfoliatus,* defined as small leaved and *P. pectinatus,* defined as gramineous leaved occur in density class 2 as they are loosely spread. Macrophyte structure is rich and species are diverse. Different species from June were sampled (Figure 28).

N. lutea and *C. demersum* are widespread but not common (density class 3) at study site 3. *P. lucens,* characterized as small leaved is spread loosely. The sampled species are rich and diverse in structure (Figure 28).

At study site 4 small leaved *M. palustris* is very common, gramineous *P. pectinatus* and small leaved *P. lucens* are spread loosely. Macrophyte structure is shaped by gramineous and small leaves and is less diverse than at study sites 2 and 3 (Figure 28).

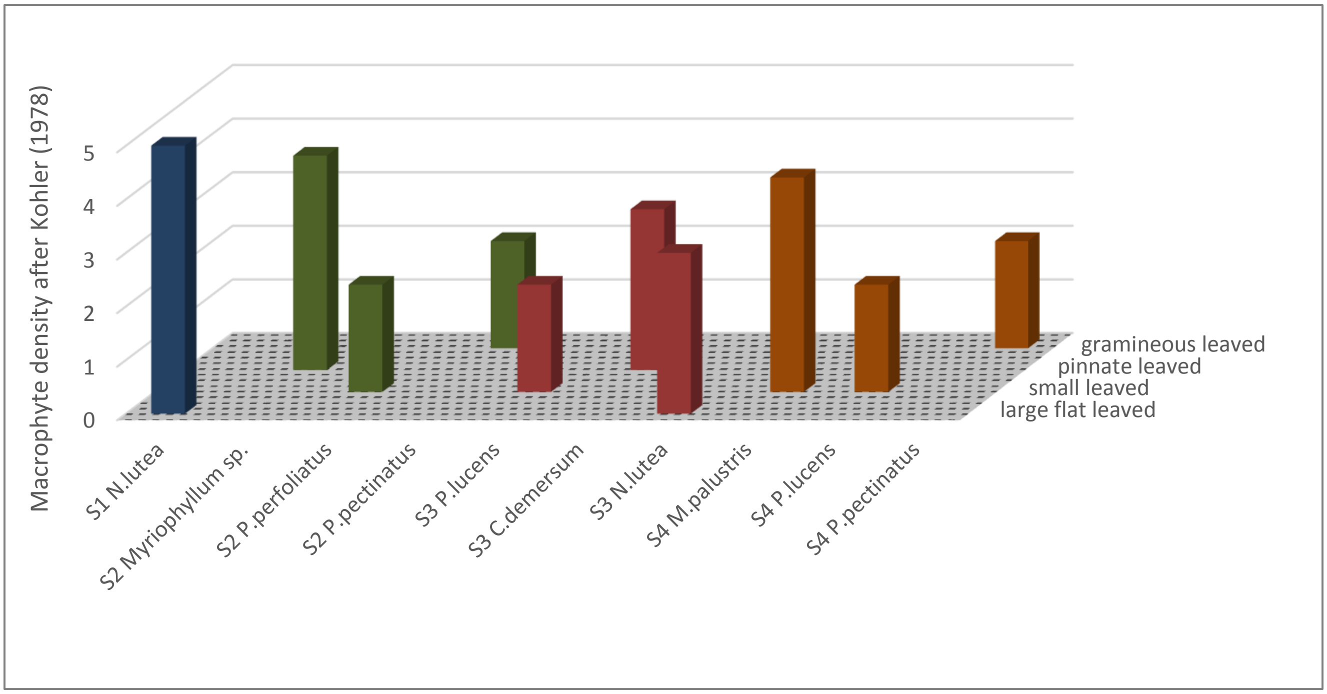

Figure 28: *Macrophyte species, their densities after Kohler (1978) and leaf structure at the different study sites in October. S1-S4: Study site 1 to 4. Study site 1 – blue, 2 – green, 3 – red and 4 – brown.*

Summary: It can be stated that **study site 1** is **poor in macrophyte species richness and structure**. **Study site 2** is definitely the **most complex** regarding macrophyte diversity, density and structure. **Study sites 3 and 4** are **similar** regarding their macrophyte complexity.

5.4 Epiphytic invertebrate communities

5.4.1 Overview of invertebrate communities associated with macrophytes in the study

All study sites

Figure 29 and Figure 30 show diversity and dominance of epiphytic invertebrates. Invertebrate data of all macrophyte samples were summed up for all sites and both seasons.

In Figure 29 invertebrate diversity is shown. Trichoptera show the highest diversity (22 taxa). 20 taxa of Gastropoda were found, 14 of Odonata and Coleoptera, 13 of Ephemeroptera and 11 of Diptera, the remaining orders consist of less than 7 taxa. The taxa list of invertebrates associated with macrophytes can be found in the results chapter 5.1.

Figure 30 shows dominance of each order. It is clearly visible that Oligochaeta reach highest abundance with a share of about 40% of total individual number. Ephemeroptera reach 16%, Trichoptera 14% and

Gastropoda 12%, the rest less than 6%. Oligochaeta that occur in highest abundance consist of three taxa, whereby *Stylaria lacustris* and *Oligochaeta* Gen. sp. occur in highest numbers. Ephemeroptera are dominated by *C. dipterum*, Trichoptera by *Oxyethira flavicornis*, Gastropoda by *Planorbidae* Gen. sp*., Anisus* sp*., Gyraulus laevis/parvus* and *Bithynia tentaculata* and Odonata by *Coenagrionidae/Platycnemidae* Gen. sp. and *Coenagrionidae* Gen. sp..

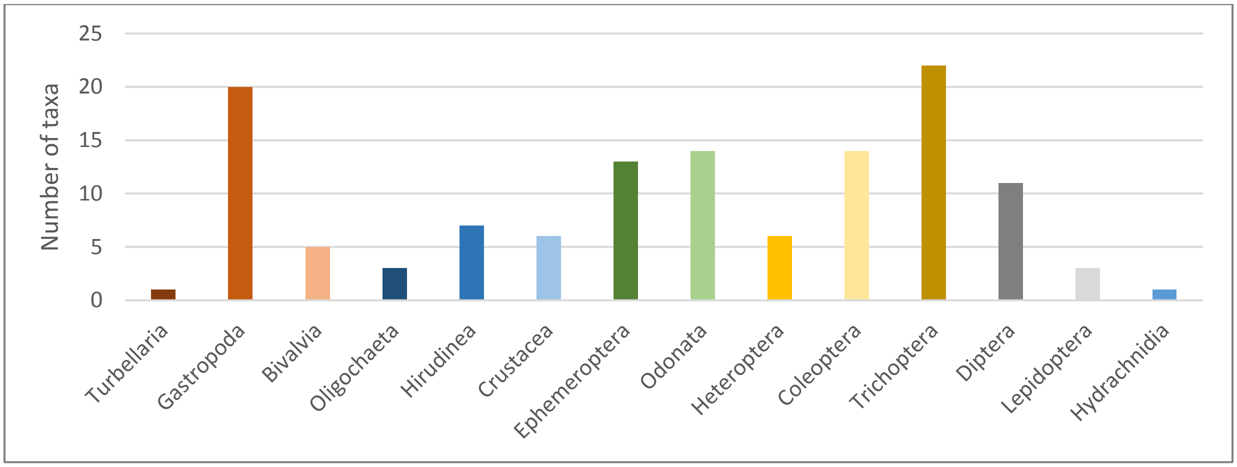

Figure 29: *Number of taxa of different macroinvertebrate groups associated with macrophytes for all sites and both seasons (Samples N=48).*

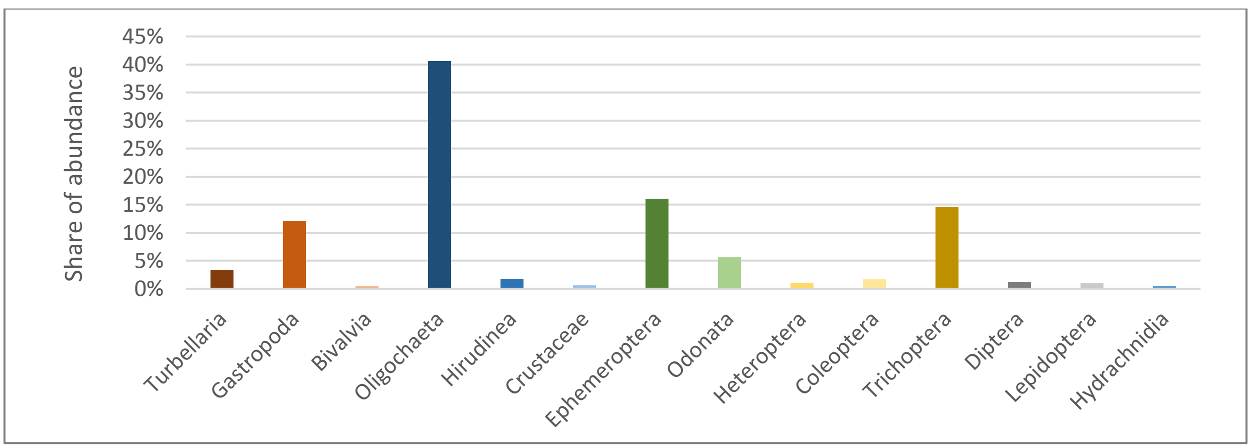

Figure 30: *Dominance of different macroinvertebrate groups associated with macrophytes for all sites and both seasons (Samples N=48).*

Study site 1

Figure 31 shows epiphytic community invertebrate structure for study site 1 in June, Figure 32 for October. Gastropoda and Hirudinea reach highest diversity (4 taxa) in June and Oligochaeta highest abundance (Figure 31). In October most taxa were found for Gastropoda (4 taxa), Ephemeroptera show highest abundance (Figure 32).

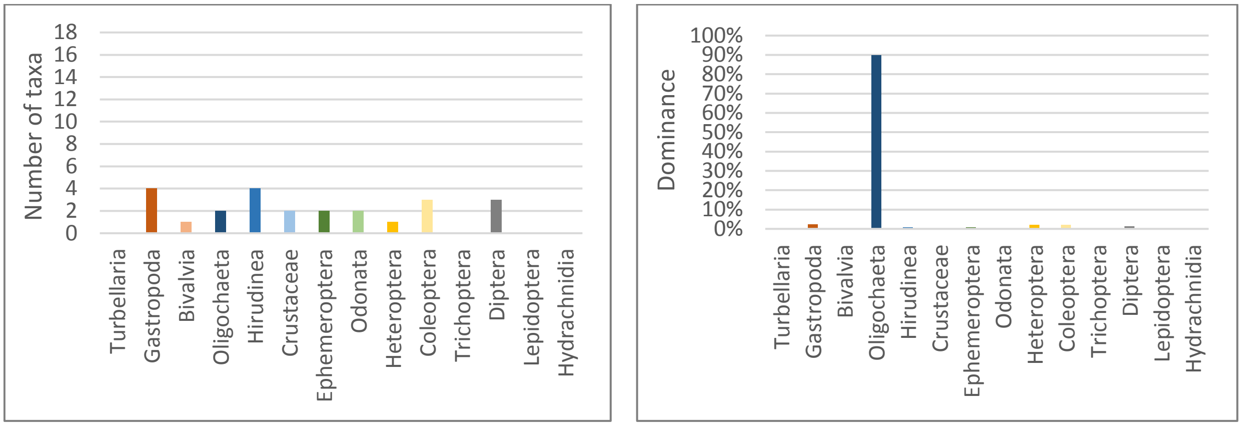

Figure 31: *Number of invertebrate taxa (left) and dominance (right) at study site 1 in June (Samples N=3).*

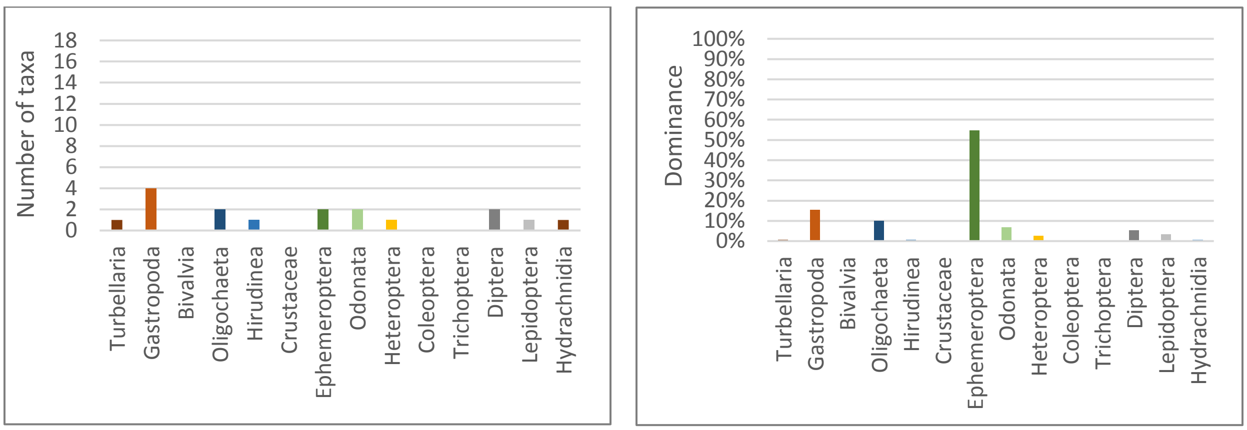

Figure 32: *Number of invertebrate taxa (left) and dominance (right) at study site 1 in October (Samples N=3).*

Study site 2

Figure 33 and Figure 34 show invertebrate community structure associated with macrophytes at study site 2. In June most taxa were found for Gastropoda and Hirudinea (7 taxa), Oligochaeta reach highest abundance (Figure 33). In October Gastropoda show highest diversity (7 taxa), Oligochaeta highest abundance (Figure 34).

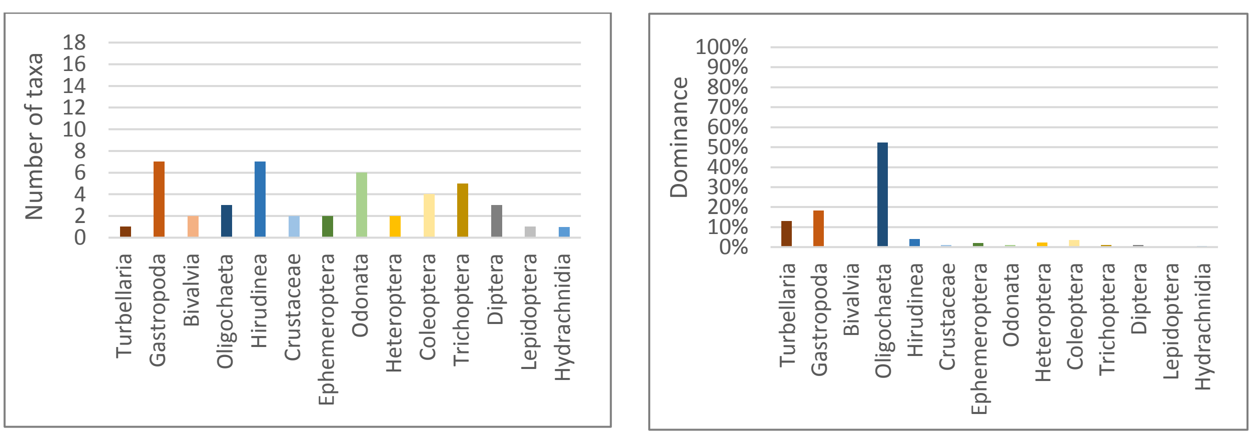

Figure 33: *Number of invertebrate taxa (left) and dominance (right) at study site 2 in June (Samples N=3).*

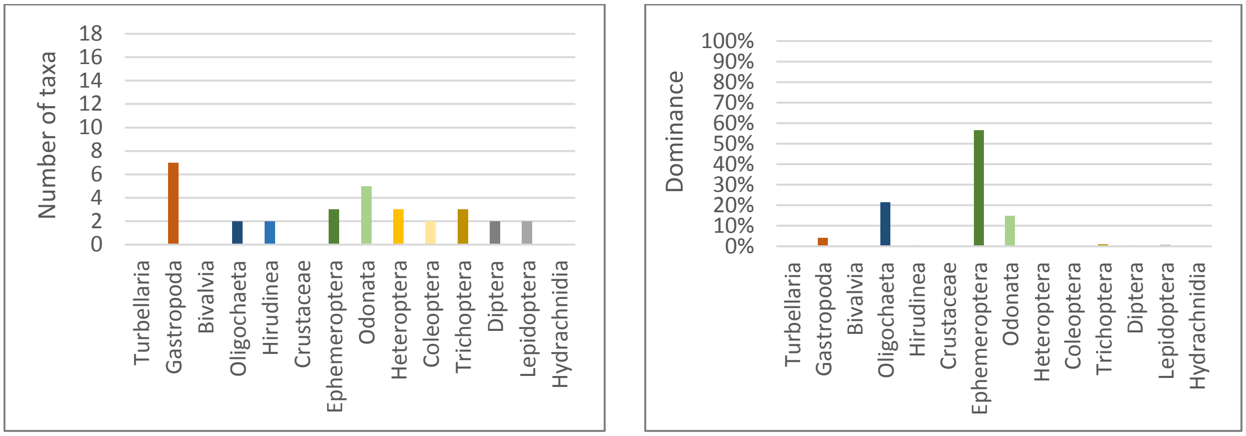

Figure 34: *Number of invertebrate taxa (left) and dominance (right) at study site 2 in October (Samples N=3).*

Study site 3

Figure 35 and Figure 36 present epiphytic invertebrate community structure in both seasons at study site 3. In June Gastropoda (9 taxa) and Coleoptera (8 taxa) reach highest diversity, Gastropoda highest abundance (Figure 35). In October most taxa were found for Trichoptera (8 taxa) and Ephemeroptera are most abundant (Figure 36).

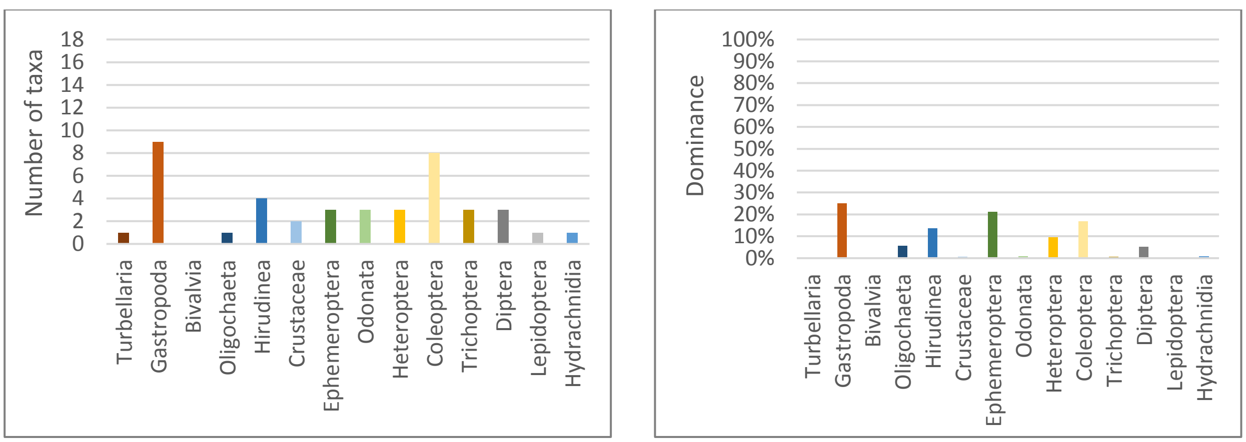

Figure 35: *Number of invertebrate taxa (left) and dominance (right) at study site 3 in June (Samples N=7).*

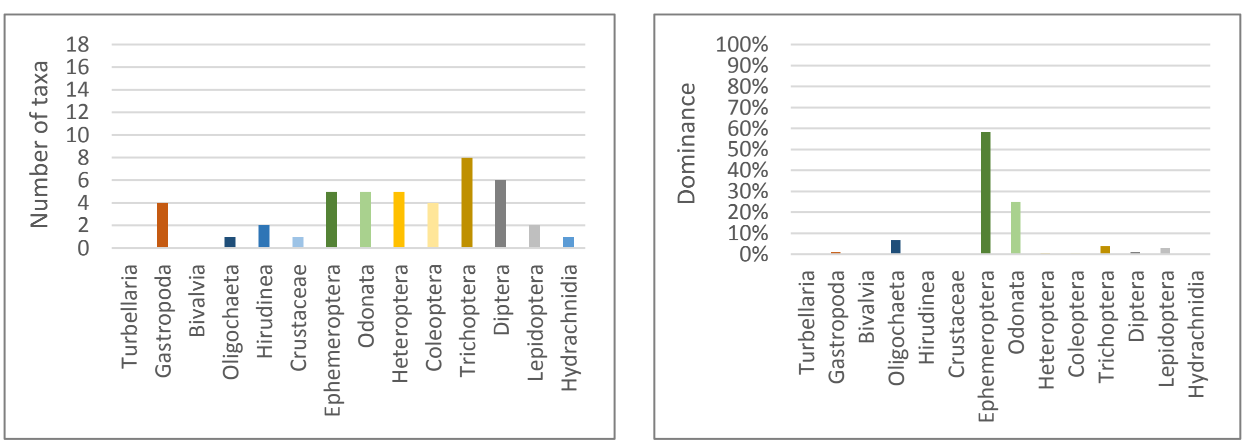

Figure 36: *Number of invertebrate taxa (left) and dominance (right) at study site 3 in October (Samples N=9).*

Study site 4

Figure 37 and Figure 38 present epiphytic invertebrate community structure in both seasons for study site 4. Most taxa were found for Gastropoda (13 taxa) in June, Oligochaeta show highest abundance (Figure 37). In October Trichoptera (17 taxa) reach highest diversity and abundance (Figure 38).

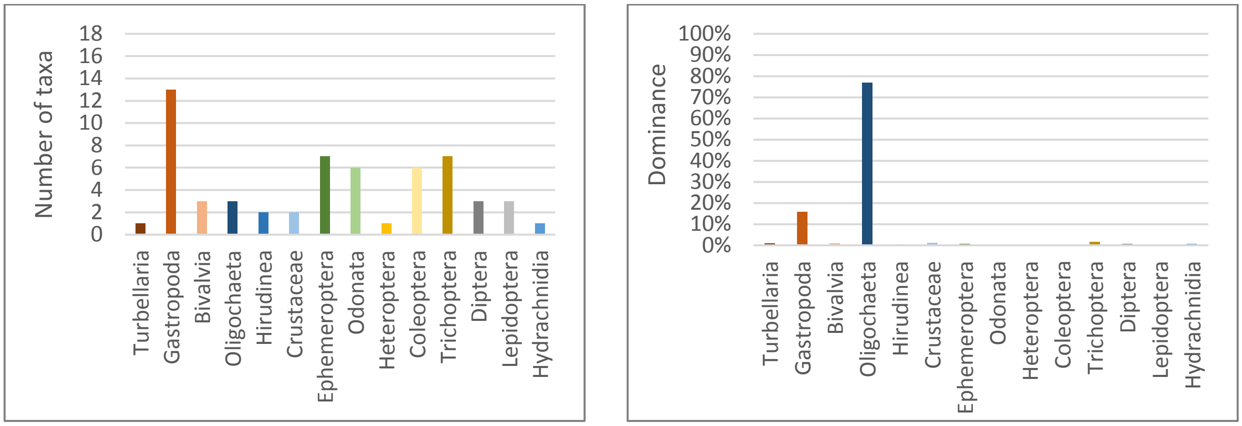

Figure 37: *Number of invertebrate taxa (left) and dominance (right) at study site 4 in June (Samples N=11).*

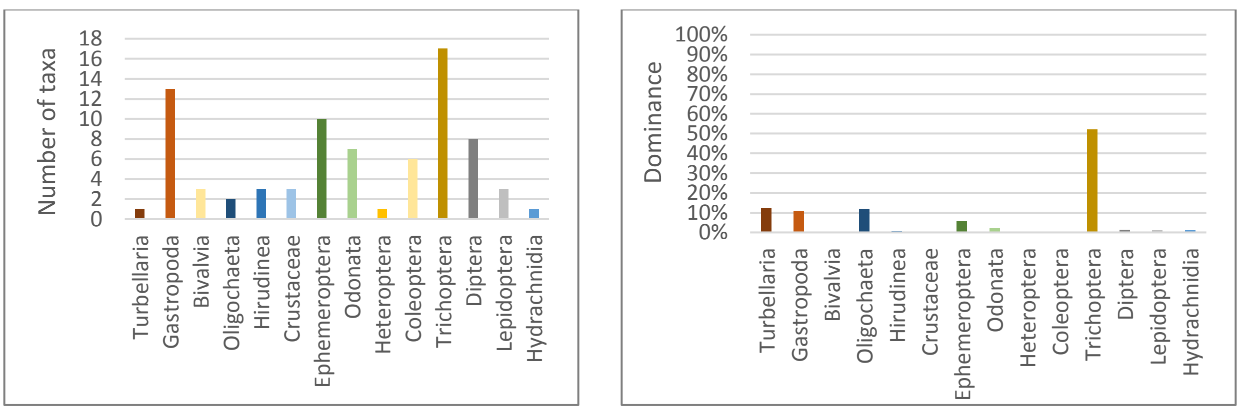

Figure 38: *Number of invertebrate taxa (left) and dominance (right) at study site 4 in October (Samples N=9).*

Summary: Considering all study sites **macrophytes** are important **habitat** for diverse **Trichoptera, Gastropoda, Ephemeroptera, Odonata** and **Diptera** taxa. **Highest abundances** are found for **Oligochaeta**. Focusing on the different study sites **differences** in invertebrate community structure can be seen **between the seasons**.

5.4.2 Invertebrate communities associated with different leaf types

Cluster analysis in Figure 39 is evidence for an influence of macrophyte leaf structure on aquatic invertebrate colonization: Invertebrate community related to large flat leaves builds separated clusters as well as that of small leaves. There is also one cluster for pinnate and one for mixed leaved plants.

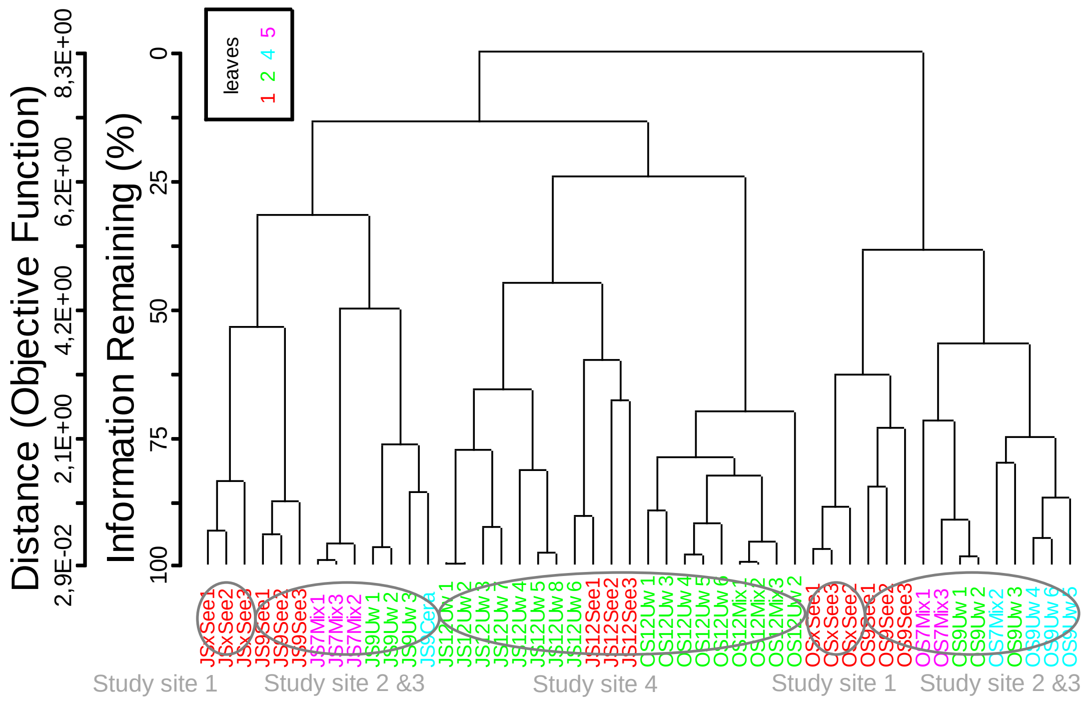

Figure 39: *Cluster analysis for logarithmic abundance data of invertebrates communities and different leaf types for all study sites and both seasons (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9; 1 – large flat leaved, 2 – small leaved, 4 – pinnate leaved, 5 – mixed leaved).*

Invertebrate community structure related to large flat leaves of *Nuphar lutea*

N. lutea was chosen as representative macrophyte for large flat leaves as it was the only sampled species characterized by this leaf type. Gastropoda show the highest diversity at *N. lutea* and inhabit the large flat leaved macrophyte with 10 taxa. Within Coleoptera 8 taxa were found, the remaining orders consist of less than 6 taxa (Figure 40). 56 taxa are related to the macrophyte species (Table 19).

Oligochaeta reach highest abundance (Figure 41). They make out about 70% of the total individual number and are dominated by the taxa *Oligochaeta* Gen. sp. and *S. lacustris*.

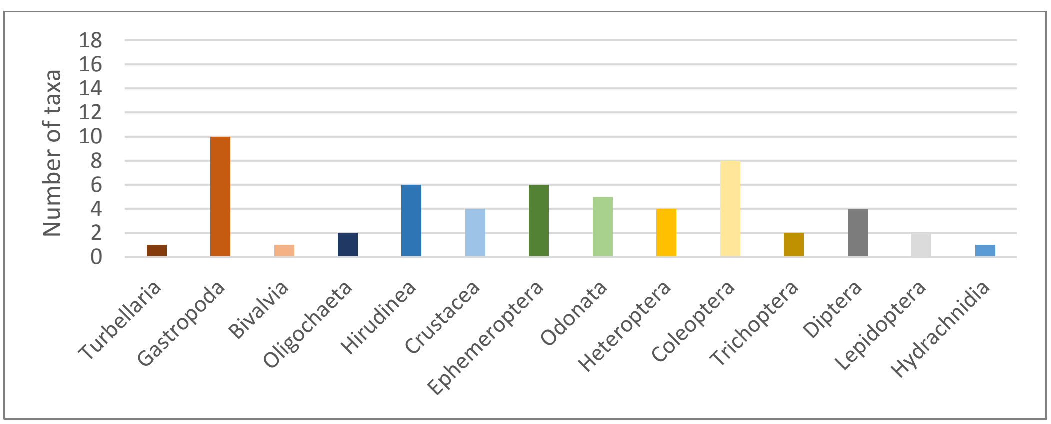

Figure 40: *Number of taxa of different macroinvertebrate groups associated with N. lutea (Samples N=15).*

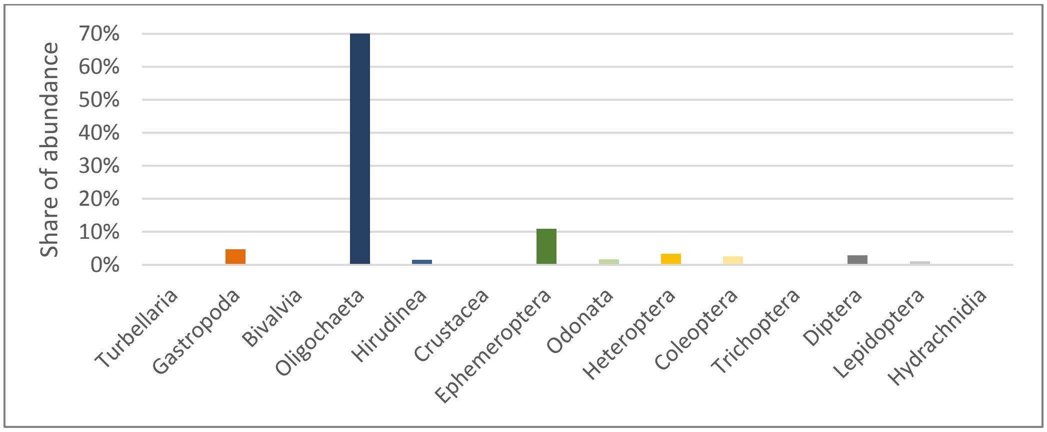

Figure 41: *Dominance of different macroinvertebrate groups associated with N. lutea (Samples N=15).*

Table 19*: Invertebrate taxa list related to large flat leaves of N. lutea.*

Taxa list *Nuphar lutea*	
Turbellaria	*Caenis* sp. juv.
Turbellaria Gen. sp.	*Habrophlebia* cf. *fusca*
Gastropoda	**Odonata**
Acroloxus lacustris	*Zygoptera* juv.
Bithynia tentaculata	*Coenagrionidae* Gen. sp. juv.
Radix ovata/peregra	*Coenagrionidae/Platycnemidae* Gen. sp.
Stagnicola sp.	*Aeshna* cf. *cyanea*
Physidae Gen. sp.	*Lestes virens*
Ancylus fluviatilis	**Heteroptera**
Gyraulus laevis/parvus	*Gerris argentatus*
Planorbidae Gen. sp. juv.	*Corixidae* Gen. sp.
Planorbis planorbis	*Ilyocoris cimicoides*
Valvatidae Gen. sp. juv.	*Plea minutissima*
Bivalvia	**Coleoptera**
Pisidium sp. juv.	*Chrysomelidae* Gen. sp. Ad.
Oligochaeta	*Dryopidae* Gen. sp. Ad.
Oligochaeta Gen. sp. juv.	*Dytiscidae* Gen. sp. Lv.
Stylaria lacustris	*Peltodytes caesus* Ad.
Hirudinea	*Peltodytes caesus* Lv.
Erpobdella octoculata	*Hydraena* sp. Ad.
Alboglossiphonia hyalina	*Hydrophilidae* Gen. sp. Ad.
Alboglossiphonia sp. juv.	*Hydrophilidae* Gen. sp. Lv.
Glossiphonia concolor	**Trichoptera**
Glossiphonia sp. juv.	*Hydropsyche angustipennis*
Piscicolidae Gen. sp.	*Hydroptilidae* Gen. sp. juv.
Crustaceae	**Diptera**
Asellus aquaticus	*Brachycera*Gen. sp.
Corophium sp.	*Ceratopogonidae* Gen. sp.

Jaera istri	*Stratiomyidae* Gen. sp.
Limnomysis benedeni	*Dixidae* Gen. sp.
Ephemeroptera	**Lepidoptera**
Baetis sp. juv.	*Elophila nymphaeata/rivulalis*
Centroptilum/Cloeon sp. juv.	*Parapoynx stratiotata*
Cloeon dipterum	**Acari**
Caenis robusta	*Hydrachnidia* Gen. sp.

Invertebrate community structure related to small leaves of *Myosotis palustris*

M. palustris was chosen as representative for small leaves as it had largest sampling size for this leaf type. Trichoptera reach highest diversity (17 taxa) in *M. palustris*, followed by Gastropoda occurring with 15 and Ephemeroptera with 11 taxa. The remaining orders reach less than 9 taxa (Figure 42). All together 87 taxa inhabit *M. palustris* (Table 20).

Figure 43 presents abundances of the different orders. Oligochaeta reach highest abundance with a share of about 40%. The order is dominated by *S. lacustris*. Trichoptera make out about 25% of total individual number and are dominated by *O. flavicornis* (Figure 43).

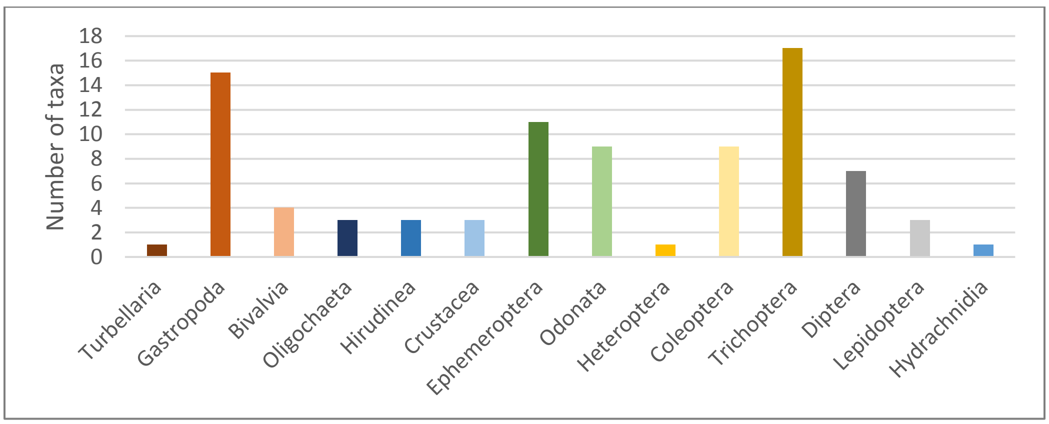

***Figure 42**: Number of taxa of different macroinvertebrate groups associated with M. palustris (Samples N=9).*

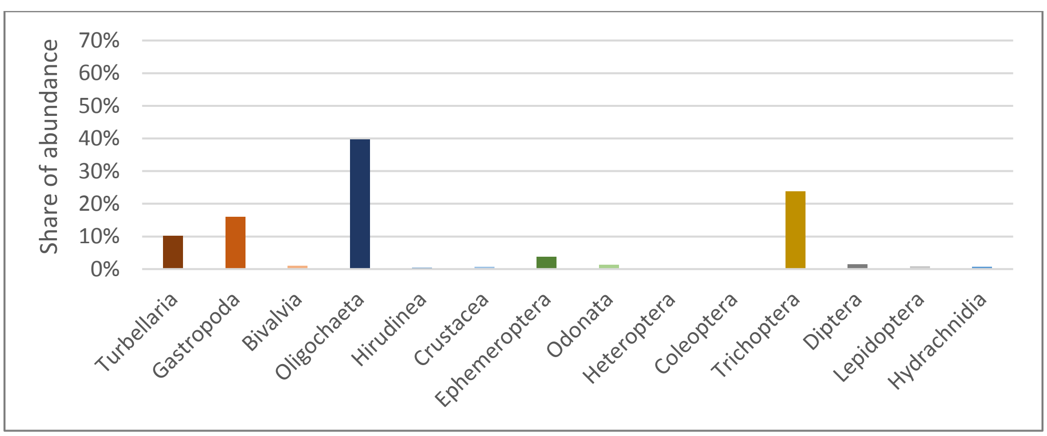

***Figure 43:** Dominance of different macroinvertebrate groups associated with M. palustris (Samples N=9).*

Table 20: Invertebrate taxa list related to small leaves of M. palustris.

Taxa list *Myosotis palustris*	
Turbellaria	*Aeshna* cf. *cyanea*
Turbellaria Gen. sp.	*Gomphus vulgatissimus*
Gastropoda	*Corduliidae/Libellulidae* Gen. sp.
Acroloxus lacustris	*Libellulidae* Gen. sp. juv.
Bithynia tentaculata	*Sympetrum sanguineum*
Radix ovata/peregra	*Calopteryx splendens*
Stagnicola sp.	**Heteroptera**
Ancylus fluviatilis	*Notonecta glauca*
Anisus sp.	**Coleoptera**
Gyraulus crista	*Dryops* sp. Lv.
Gyraulus laevis/parvus	*Dytiscidae* Gen. sp. Ad.
Planorbarius corneus	*Dytiscidae* Gen. sp. Lv.
Planorbidae Gen. sp. juv.	*Platambus maculatus* Ad.
Planorbis carinatus	*Haliplus* sp. Lv.
Planorbis planorbis	*Peltodytes caesus* Lv.
Planorbis sp. juv.	*Oulimnius* sp. Lv.
Valvatidae Gen. sp. juv.	*Hydrophilidae* Gen. sp. Ad.
Valvata piscinalis	*Hydrophilidae* Gen. sp. Lv.
Bivalvia	**Trichoptera**
Pisidium casertanum	*Hydropsyche angustipennis*
Pisidium nitidum	*Hydroptilidae* Gen. sp. juv.
Pisidium sp. juv.	*Agraylea multipunctata*
Pisidium subtruncatum	*Agraylea sexmaculata*
Oligochaeta	*Hydroptila* sp.
*Oligochaeta*Gen. sp.	*Orthotrichia* sp.
Eiseniella tetraedra	*Oxyethira flavicornis*
Stylaria lacustris	*Ecnomus tenellus*
Hirudinea	*Leptoceridae* Gen. sp. juv.
Erpobdella octoculata	*Athripsodes cinereus*
Alboglossiphonia sp. juv.	*Athripsodes* sp. juv.
Piscicolidae Gen. sp.	*Mystacides azurea/nigra*
Crustaceae	*Mystacides* sp.
Asselus aquaticus	*Oecetis* sp. juv.
Gammaridae Gen. sp. juv.	*Oecetis testacea*
Jaera istri	*Triaenodes bicolor*
Ephemeroptera	*Lype* sp. juv.
Baetis lutheri/vardarensis	**Diptera**
Baetis bucertus/nexus	*Brachycera* Gen. sp. juv.
Baetis sp. juv.	*Ceratopogonidae* Gen. sp.
Centroptilum/Cloeon sp. juv.	*Anopheles maculipennis*

Cloeon dipterum	*Stratiomyidae* Gen. sp.
Caenis horaria	*Dixidae* Gen. sp.
Caenis luctuosa	*Empididae* Gen. sp.
Caenis robusta	*Limoniidae/Pediciidae* Gen. sp.
Caenis sp. juv.	**Lepidoptera**
Ephemerella ignita	*Acentria ephemerella*
Paraleoptophlebia sp.	*Elophila nymphaeata/rivulalis*
Odonata	*Parapoynx stratiotata*
Zygoptera juv.	**Acari**
Coenagrionidae Gen. sp. juv.	*Hydrachnidia* Gen. sp. juv.
Coenagrionidae/Platycnemidae Gen. sp.	

Invertebrate community structure related to pinnate leaves of *Ceratophyllum demersum*

C. demersum was chosen as representative for pinnate leaves as sampling size was largest for this macrophyte leaf type. In *C. demersum* Trichoptera reach highest diversity with 8 taxa, followed by Gastropoda and Odonata occurring with 6 taxa. The remaining orders reach less than 4 taxa (Figure 44). 42 taxa are related to *C. demersum* (Table 21).

Figure 45 presents the abundances of the different orders: It is obvious that Ephemeroptera reach highest abundance with a share of about 50% of total individual number. They are dominated by occurrence of *C. dipterum*. Odonata make out about 30% and are dominated by *Coenagrionidae/Platycnemidae* Gen. sp. (Figure 45).

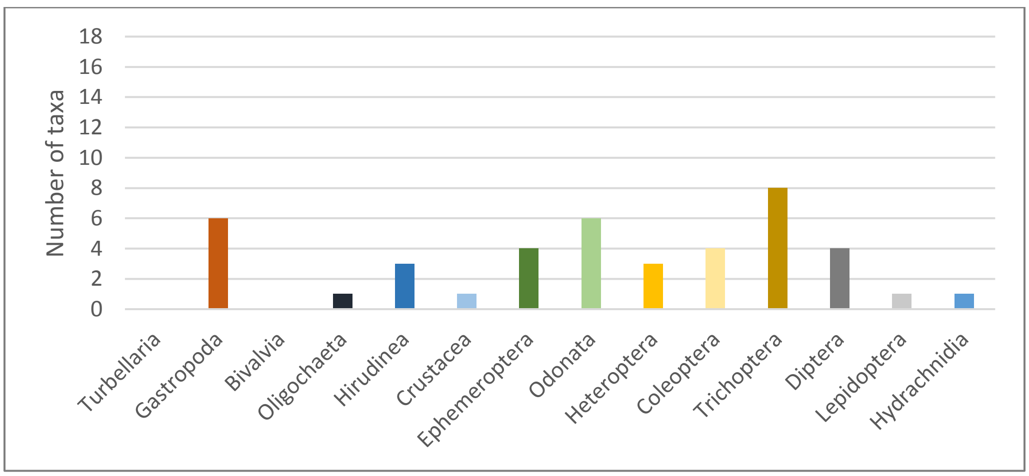

Figure 44: *Number of taxa of different macroinvertebrate groups associated with C. demersum (Samples N=4).*

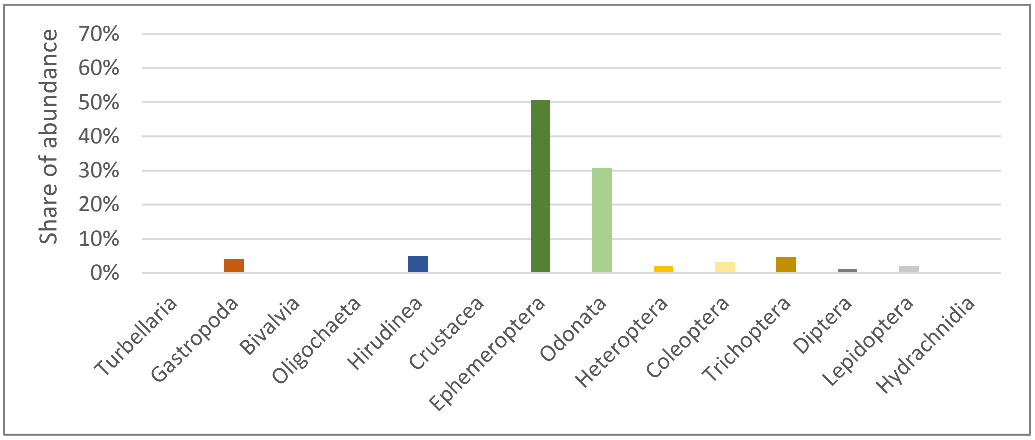

Figure 45: *Dominance of different macroinvertebrate groups associated with C. demersum (Samples N=4).*

Table 21: *Invertebrate taxa list related to small leaves of C. demersum.*

Taxa list *Ceratophyllum demersum*	
Gastropoda	**Heteroptera**
Bithynia tentaculata	*Corixidae* Gen. sp.
Radix ovata/peregra	*Ilyocoris cimicoides*
Physidae Gen. sp.	*Plea minutissima*
Gyraulus crista	**Coleoptera**
Gyraulus laevis/parvus	*Dytiscidae* Gen. sp. juv.
Planorbidae Gen. sp. juv.	*Haliplus* sp. Ad.
Oligochaeta	*Haliplus* sp. Lv.
Oligochaeta Gen. sp.	*Peltodytes caesus* Lv.
Hirudinea	**Trichoptera**
Erpobdella octoculata	*Trichoptera* Gen. sp. juv.
Alboglossiphonia hyalina	*Hydroptilidae* Gen. sp. juv.
Glossiphonia sp. juv.	*Agraylea sexmaculata*
Crustacea	*Orthotrichia* sp.
Asselus aquaticus	*Leptoceridae* Gen. sp. juv.
Ephemeroptera	*Oecetis* sp. juv.
Baetis sp. juv.	*Triaenodes bicolor*
Cloeon dipterum	*Agrypnia varia*
Caenis robusta	**Diptera**
Caenis sp. juv.	*Ceratopogonidae* Gen. sp.
Odonata	*Chaoborus cristallinus*
Zygoptera Gen. sp.	*Anopheles maculipennis* sens. Lat.
Coenagrionidae Gen. sp.	*Stratiomyidae* Gen. sp.
Coenagrionidae/Platycnemidae Gen. sp. juv.	**Lepidoptera**
Aeshnidae Gen. sp. juv.	*Parapoynx stratiotata*
Aeshna cf. *cyanea*	**Acari**
Sympetrum sanguineum	*Hydrachnidia* Gen. sp.

Summary: The DCA shows **differences** in invertebrate **community** structure regarding the **different leaf types**. Focusing on **different leaf types** and macrophyte species **differences** but also **similarities** can be seen in the number of invertebrate taxa and abundances: In *M. palustris* and *C. demersum* Trichoptera, Gastropoda, Ephemeroptera and Odonata reach highest diversities. Oligochaeta reach highest abundances in *N. lutea* and *M. palustris*.

5.4.3 Seasonal patterns of invertebrate communities

Site-specific invertebrate communities in summer

In Figure 46 the similarities of epiphytic invertebrate communities between the four study sites are shown. The cluster analysis highlights the different study sites in diverse colours.

Study site 4 forms a separated cluster that is clearly different from the rest. Epiphytic invertebrate communities at study sites 1, 2 and 3 have similarity to each other as they are part of one larger cluster. *N. lutea* related invertebrates build a group at study site 1 that is similar to *N. lutea* related invertebrates at study site 3. The remaining invertebrates at study site 3 build a separated cluster that is similar to epiphytic invertebrates at study site 2 (Figure 46).

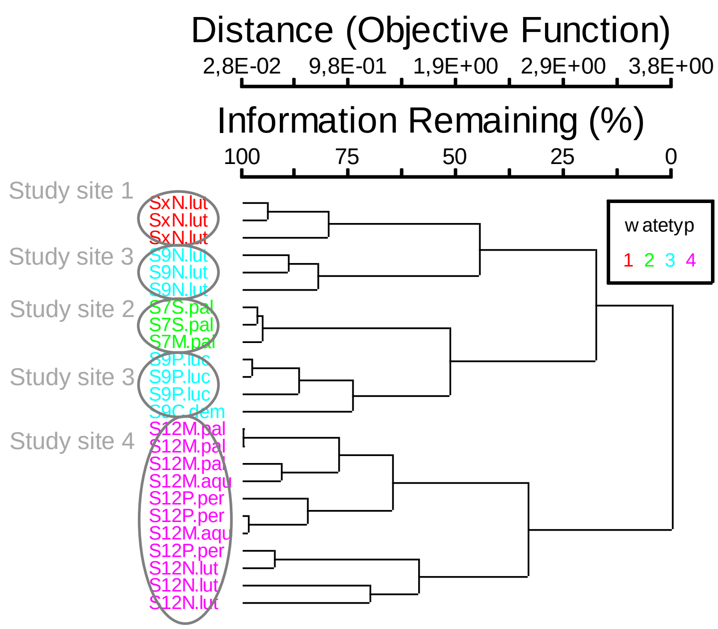

Figure 46: *Cluster analysis for epiphytic invertebrates at the four study sites in June. 1-4: Study site 1 to 4 (Samples N for each study site: N_1=3, N_2=3, N_3=7, N_4=11).*

Table 22 shows an indicator species analysis for the identification of taxa that are related to the different sites in June.

At study site 1 *Hydrophilidae* Gen. sp. Lv., *Ilyocoris cimicoides* and *Physidae* Gen. sp. have highest indication values ranging between 72 and 57. For study site 2 *Valvata piscinalis*, *Lestidae* Gen. sp. juv. and *O. furva* are good indicators with an indication value of 100. Study site 2 has most indicator taxa compared to the other study sites. *Plea minutissima* is the best indicator for study site 3 (indication value 95,6). For study site 4 *Valvatidae* Gen. sp. and *H. angustipennis* are best indicators with indication values of 73 and 55. Indicator taxa are very inherent for this study site (Table 22).

Table 22: *Indicator species analysis for the different study sites in June. Taxa with Indication value >20 and Significance p* <1,00 are shown. Taxa with Significance <0,05 are highlighted grey (Samples N for each study site: N_1=3, N_2=3, N_3=7, N_4=11).*

Indicator species	Study site	Indication value	p*	Indicator species	Study site	Indication value	p*
Hydrophilidae Gen. sp. Lv.	1	72,1	0,0216	*Hydrachnidia* Gen. sp.	2	54,7	0,0664
Ilyocoris cimicoides	1	69,7	0,0188	*Zygoptera* Gen. sp. juv.	2	50,3	0,0454
Physidae Gen. sp.	1	57	0,0268	*Bithynia tentaculata*	2	50,2	0,1184
Coenagrionidae Gen. sp.	1	43,1	0,056	*Radix ovata/peregra*	2	46,7	0,1248
Corophium sp.	1	33,3	0,2505	*Stylaria lacustris*	2	43,6	0,202
Limnomysis benedeni	1	33,3	0,2527	*Pisidium* sp. juv.	2	37,1	0,1276
Chrysomelidae Gen. sp. Ad.	1	33,3	0,2505	*Caenis* sp.	2	35,6	0,199
Alboglossiphonia sp. juv.	1	30,1	0,2246	*Helobdella stagnalis*	2	33,3	0,2599
Brachycera Gen. sp.	1	26,2	0,3439	*Argulus* sp.	2	33,3	0,2523
Valvata piscinalis	2	100	0,0026	*Aeshnidae* Gen. sp. juv.	2	33,3	0,2599
Lestidae Gen. sp. juv.	2	100	0,0026	*Somatochlora metallica*	2	33,3	0,2468
Oecetis furva	2	100	0,0026	*Tabanidae* Gen. sp.	2	33,3	0,2599
Corixidae Gen. sp.	2	99	0,0028	*Leptoceridae* Gen. sp. juv.	2	26,8	0,2691
Chaoborus crystallinus	2	96,2	0,0034	*Eiseniella tetraedra*	2	21	0,5933
Sympecma fusca	2	82,4	0,005	*Plea minutissima*	3	95,6	0,0002
Gyraulus crista	2	82,3	0,0026	*Alboglossiphonia hyalina*	3	67,5	0,0244
Erpobdella octoculata	2	80	0,0032	*Stratiomyidae* Gen. sp.	3	36	0,199
Haliplus sp. Lv.	2	78,5	0,0102	*Haliplus* sp. Ad.	3	28,6	0,106
Planorbidae Gen. sp. juv.	2	70,9	0,0006	*Valvatidae* Gen. sp.	4	72,7	0,0244
Asselus aquaticus	2	69	0,0102	*Hydropsyche angustipennis*	4	54,5	0,0394
Musculium lacustre	2	66,7	0,0246	*Planorbis carinatus*	4	45,5	0,1052
Piscicolidae Gen. sp.	2	66,7	0,0246	*Ephemerella ignita*	4	45,5	0,1002
Oecetis lacustris	2	66,7	0,0246	*Hydroptilidae* Gen. sp. juv.	4	45,5	0,0884
Oecetis sp.	2	66,7	0,0258	*Planorbis* sp. juv.	4	36,4	0,1492
Oecetis testacea	2	66,7	0,0228	*Baetis* sp. juv.	4	36,4	0,1446
Dytiscidae Gen. sp. Lv.	2	63,5	0,0196	*Agraylea multipunctata*	4	36,4	0,1368
Gyraulus laevis/parvus	2	63,2	0,0014	*Hydroptila* sp.	4	36,4	0,1492
Acentria ephemerella	2	61,7	0,0192	*Parapoynx stratiotata*	4	27,3	0,2166
Oligochaeta Gen. sp.	2	55,5	0,1054	*Turbellaria* Gen. sp.	4	26,2	0,3643
Cloeon dipterum	2	55	0,078				

Site-specific invertebrate communities in autumn

Similarities of invertebrate communities between the four study sites are shown in Figure 47. The cluster analysis highlights the different study sites in diverse colours.

A similar pattern to June can be seen in October: Epiphytic invertebrate coenosis at study site 4 is clearly separated from the rest. Again study sites 1, 2 and 3 are similar to each other as they are part of one larger cluster. Furthermore *N. lutea* related invertebrates again build a group at study site 1 that is similar to *N. lutea* related invertebrates at study site 3. Whereas study sites 2 and 3 cannot be separated from each other (Figure 47).

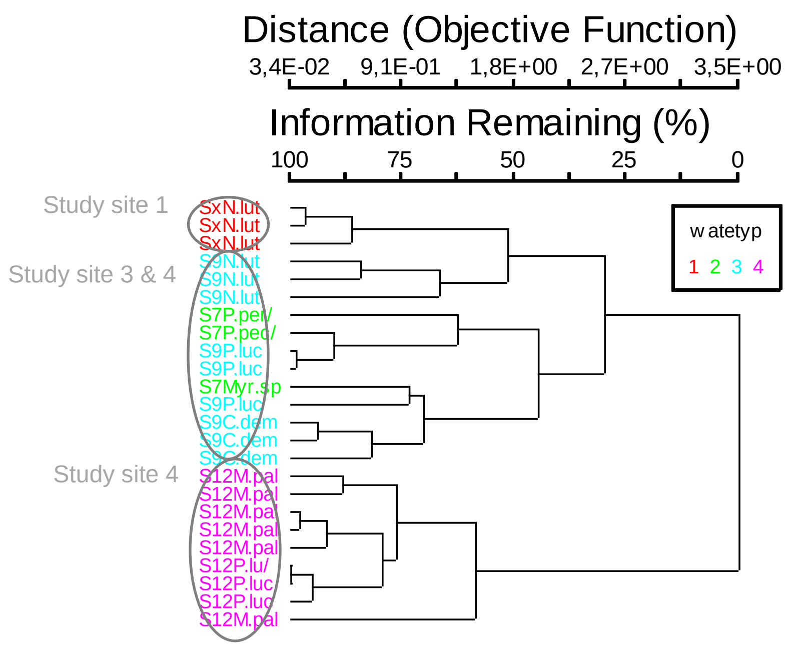

Figure 47: *Cluster analysis for epiphytic invertebrates at the four study sites in October. 1-4: Study site1 to 4 (Samples N for each study site: N_1=3, N_2=3, N_3=9, N_4=9).*

An indicator species analysis for taxa related to the four study sites is shown in Table 23. For study site 1 *Physidae* Gen. sp. is best indicator (indication value 85,7). At study site 2 *A. sexmaculata* has the best match (indication value 90) whereby list of indicator species is shorter than in June. *Zygoptera* Gen. sp. juv. and *C. robusta* are best indicators for study site 3 with indication values of 69,4 and 62,3. Number of indicator taxa for study sites 2 and 3 is similar. For study site 4 *Anisus* sp.*,* *Caenis horaria* and *Empididae* Gen. sp. are good indicators. List of indicator species is longest (Table 23).

Table 23: *Indicator species analysis for the different study sites in October. Taxa with Indication value >20 and Significance p* <1,00 are shown. Taxa with Significance <0,05 are highlighted grey (Samples N for each study site: N_1=3, N_2=3, N_3=9, N_4=9).*

Indicator species	Study site	Indication value	p*	Indicator species	Study site	Indication value	p*
Physidae Gen. sp.	1	85,7	0,0054	*Caenis horaria*	4	100	0,0002
Acroloxus lacustris	1	64,7	0,0076	*Empididae* Gen. sp.	4	100	0,0002

Elophila nymphaeata / rivulalis	1	50	0,0492	*Oxyethira flavicornis*	4	99,8	0,0002
Corixidae Gen. sp.	1	47,1	0,0592	*Turbellaria* Gen. sp.	4	99,5	0,0002
Agraylea sexmaculata	2	90	0,003	*Stylaria lacustris*	4	95,1	0,0002
Radix auricularia	2	66,7	0,0206	*Planorbis carinatus*	4	88,9	0,0002
Radix sp.	2	66,7	0,0206	*Caenis luctuosa*	4	88,9	0,0002
Cloeon dipterum	2	62	0,0974	*Calopteryx splendens*	4	88,9	0,0002
Coenagrionidae Gen. sp.	2	58,5	0,0774	*Hydropsyche angustipennis*	4	88,9	0,0002
Haliplus sp. Lv.	2	51,9	0,0446	*Hydrachnidia* Gen. sp.	4	81,4	0,0002
Coenagrionidae / Platycnemidae Gen. sp. juv.	2	51,2	0,2288	*Bithynia tentaculata*	4	66,7	0,017
Acentria ephemerella	2	50	0,0802	*Valvatidae* Gen. sp. juv.	4	66,7	0,0174
Oligochaeta Gen. sp.	2	48,9	0,2132	*Baetis* sp. juv.	4	65,8	0,0132
Radix ovata / peregra	2	45	0,0996	*Piscicolidae* Gen. sp.	4	58	0,0224
Planorbidae Gen. sp. juv.	2	42,1	0,182	*Hydroptilidae* Gen. sp. juv.	4	58	0,0516
Ranatra linearis	2	33,3	0,2517	*Hydroptila* sp.	4	55,6	0,0292
Alboglossiphonia sp.	2	20	0,5805	*Lype* sp.	4	55,6	0,0146
Peltodytes caesus Lv.	2	20	0,7037	*Gyraulus laevis / parvus*	4	45,9	0,1036
Chaoborus crystallinus	2	20	0,7031	*Athripsodes cinereus*	4	44,4	0,1036
Zygoptera Gen. sp. juv.	3	69,4	0,0512	*Athripsodes* sp.	4	44,4	0,0822
Caenis robusta	3	62,3	0,0624	*Mystacides* sp.	4	44,4	0,0874
Plea minutissima	3	44,4	0,0854	*Orthotrichia* sp.	4	37	0,2086
Parapoynx stratiotata	3	43,9	0,2232	*Valvata piscinalis*	4	33,3	0,1516
Caenis sp.	3	39,2	0,4829	*Baetis lutheri / vardarensis*	4	33,3	0,1444
Agrypnia varia	3	33,3	0,1272	*Mystacides azurea*	4	33,3	0,1412
Trichoptera Gen. sp. juv.	3	30,2	0,4009	*Oecetis testacea*	4	33,3	0,1368
Aeshna cyanea	3	29,6	0,2505	*Gyraulus crista*	4	28,2	0,3327
Ceratopoganidae Gen. sp.	3	25,9	0,7039	*Asselus aquaticus*	4	24,2	0,3923
Oecetis sp. juv.	3	22,9	0,6491	*Pisidium* sp.	4	22,2	0,6793
Ilyocoris cimicoides	3	22,2	0,5069	*Pisidium subtruncatum*	4	22,2	0,5101
Haliplus sp. Ad.	3	22,2	0,5069	*Baetis buceratus / nexus*	4	22,2	0,6737
Peltodytes caesus Ad.	3	22,2	0,6785	*Oulimnius* sp. Lv.	4	22,2	0,5199
Centroptilum / Cloeon sp. juv.	3	21,1	0,3785	*Leptoceridae* Gen. sp. juv.	4	22,2	0,5165
Anisus sp.	4	100	0,0002				

Macrophyte-specific invertebrate communities in summer

The invertebrate community related to *N. lutea* builds an own cluster at study site 1 (Figure 48).

Invertebrates inhabiting *P. lucens* at study site 3 build another group. Coenosis related to *C. demersum* at study site 3 is similar although plant leaf structure is very different among the two species (Figure 48).

At study site 2 invertebrate communities related to *S. palustris/P. berchtoldii/Poaceae* Gen. sp. and *M. palustris* build a cluster (Figure 48).

Study site 4 is not separated so clearly in macrophyte clusters. Epiphytic invertebrates associated with *N. lutea* build a group but integrate animals related to one *P. perfoliatus* sample. Coenosis of *M. palustris*, *P. perfoliatus* and *M. aquatica* build a larger cluster together (Figure 48).

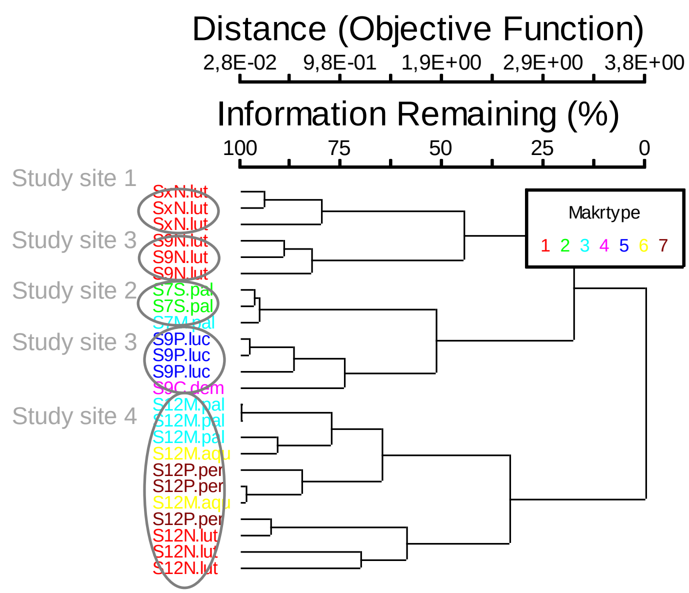

Figure 48: *Cluster analysis for epiphytic invertebrates in June. Macrophyte species: 1 – N. lutea, 2 – S. palustris/A. stolonifera/P. berchtoldii/ Poaceae* Gen.sp.*, 3 – M. palustris, 4 – C. demersum, 5 – P. lucens, 6 – M. aquatica, 7 – P. perfoliatus (Samples N for each study site: $N_1=3$, $N_2=3$, $N_3=7$, $N_4=11$).*

An indicator species analysis for invertebrate taxa that are related to the different macrophytes is shown in Table 24. According to the analysis *I. cimicoides*, *Hydrophilidae* Gen. sp. Lv. and *Stratiomyidae* Gen. sp. are best indicators for *N. lutea* (indication values from 72 to 51). For the plant mixture of *S. palustris, P. berchtoldii, A. stolonifera* and *Poaceae* Gen. sp. The Trichoptera larva *O. testacea* is good indicator. Furthermore *Corixidae* Gen. sp., *Lestidae* Gen. sp. juv., *O. furva*, *Haliplus* sp. Lv. and *Chaoborus crystallinus* are good indicators (indication values from 98 to 82). *M. palustris* is related to the occurrence *of Hydroptila* sp.*, H. angustipennis, Valvatidae* Gen. sp. juv., *G. crista* and *S. ignita* (indication values from 69 to 52). *Alboglossiphonia hyalina* is best indicator for *P. lucens* (indication value 85). *M. aquatica* is perfectly indicated by *Centroptilum luteolum*. *P. perfoliatus* is related to occurrence of *Parapoynx stratiotata*.

Table 24: *Indicator species analysis for the different macrophyte species in June. Taxa with Indication value >20 and Significance p* <1,00 are shown. Taxa with Significance <0,05 are highlighted grey. Macrophyte 1 – N. lutea, 2 – S. palustris/A. stolonifera/P. berchtoldii/Poaceae* Gen. sp., *3 – M. palustris, 5 – P. lucens, 6 – M. aquatica, 7 – P. perfoliatus (Samples N for each study site:* $N_1=3$, $N_2=3$, $N_3=7$, $N_4=11$)*.*

Indicator species	Macrophyte	Indication value	p*	Indicator species	Macrophyte	Indication value	p*
Ilyocoris cimicoides	1	72,4	0,0156	*Eiseniella tetraedra*	3	55,6	0,0852
Hydrophilidae Gen. sp. Lv.	1	52,5	0,1316	*Ephemerella ignita*	3	51,9	0,083
Stratiomyidae Gen. sp.	1	50,8	0,0896	*Acroloxus lacustris*	3	50	0,0552
Physidae Gen. sp.	1	24,8	0,4975	*Planorbarius corneus*	3	50	0,055
Centroptilum / Cloeon sp. juv.	1	22,2	0,6585	*Pisidium subtruncatum*	3	50	0,055
Brachycera Gen. sp.	1	22,2	0,7251	*Libellulidae* Gen. sp. juv.	3	50	0,0552
Oecetis testacea	2	100	0,0058	*Baetis* sp. juv.	3	45	0,0932
Corixidae Gen. sp.	2	98,2	0,0048	*Hydrachnidia* Gen. sp.	3	44,1	0,142
Lestidae Gen. sp. juv.	2	93,7	0,0048	*Asselus aquaticus*	3	43,4	0,166
Oecetis furva	2	88,9	0,0092	*Ceratopoganidae* Gen. sp.	3	43	0,19
Haliplus sp. Lv.	2	84,5	0,0126	*Bithynia tentaculata*	3	41,7	0,186
Chaoborus crystallinus	2	82,4	0,0204	*Turbellaria* Gen. sp.	3	40	0,228
Valvata piscinalis	2	78,1	0,0158	*Stylaria lacustris*	3	40	0,1624
Zygoptera Gen. sp. juv.	2	71,4	0,0134	*Planorbis planorbis*	3	39,5	0,1586
Alboglossiphonia sp. juv.	2	64,3	0,0368	*Planorbis carinatus*	3	34,6	0,2266
Sympecma fusca	2	62,1	0,0394	*Planorbidae* Gen. sp. juv.	3	33,4	0,5427
Dytiscidae Gen. sp. Lv.	2	58,1	0,0306	*Sympetrum sanguineum*	3	30	0,3235
Cloeon dipterum	2	58	0,0368	*Hydroptilidae* Gen. sp. juv.	3	29,2	0,2823
Caenis sp.	2	53,9	0,0706	*Pisidium casertanum*	3	25	0,6051
Argulus sp.	2	50	0,1758	*Helobdella stagnalis*	3	25	0,6143
Somatochlora metallica	2	50	0,167	*Baetis buceratus / nexus*	3	25	0,6051
Erpobdella octoculata	2	44,9	0,2817	*Aeshnidae* Gen. sp. juv.	3	25	0,6143
Oecetis lacustris	2	44,1	0,1644	*Dryops* sp. Lv.	3	25	0,6031
Glossiphonia sp.	2	40,9	0,193	*Mystacides azurea / nigra*	3	25	0,6051
Leptoceridae Gen. sp. juv.	2	40	0,1916	*Tabanidae* Gen. sp.	3	25	0,6143
Gyraulus laevis / parvus	2	39,4	0,1172	*Alboglossiphonia hyalina*	5	85	0,0046
Oligochaeta Gen. sp.	2	37,4	0,4437	*Plea minutissima*	5	40,7	0,203
Pisidium sp. juv.	2	33,6	0,3327	*Potamopyrgos antipodarum*	5	33,3	0,4309
Piscicolidae Gen. sp.	2	28,6	0,3265	*Radix* sp. juv.	5	33,3	0,4309
Oecetis sp. juv.	2	28,6	0,3231	*Haliplus* sp. Ad.	5	33,3	0,4331
Peltodytes caesus Lv.	2	26,5	0,4781	*Centrotpilum luteolum*	6	100	0,007

Acentria ephemerella	2	23,8	0,5723	*Agraylea multipunctata*	6	85,7	0,0148
Hydroptila sp.	3	68,5	0,0354	*Aeshna cyanea*	6	50	0,1796
Hydropsyche an-gustipennis	3	66,4	0,0496	*Anisus* sp.	6	30	0,3551
Valvatidae Gen. sp. juv.	3	60,7	0,0908	*Parapoynx stratiotata*	7	100	0,0012
Gyraulus crista	3	58,5	0,0786	*Gammaridae* Gen. sp. juv.	7	33,3	0,4191

Macrophyte-specific invertebrate communities in autumn

The same pattern like in June can be seen for *N. lutea* related invertebrates at study sites 1 and 3 in October (Figure 49). Epiphytic invertebrate community is specified to occurrence of *C. demersum* at study site 3. The remaining macrophyte related invertebrates cannot be separated according to plant species at study sites 2 and 3.

At study site 4 there is an animal coenosis adapted to occurrence of *P. lucens*. *P. lucens* builds a larger cluster with *M. palustris* associated invertebrates (Figure 49).

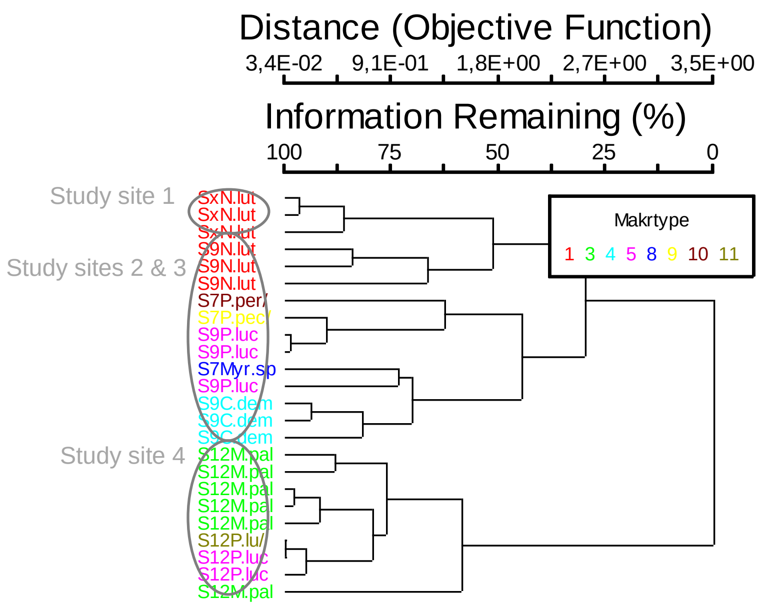

Figure 49: *Cluster analysis for epiphytic invertebrates in October. Macrophyte species 1 – N. lutea, 3 – M. palustris, 4 – C. demersum, 5 – P. lucens, 8 – Myriophyllum* sp.*, 9 – Myriophyllum* sp.*/P. pectinatus, 10 – Myriophyllum* sp.*/P. perfoliatus, 11 – P. lucens/P. pectinatus (Samples N for each study site:* $N_1=3$, $N_2=3$, $N_3=9$, $N_4=9$*).*

Table 25 shows another indicator species analysis. Taxa that are related to certain macrophyte species are identified. No strong indicators can be found for *N. lutea.* List of indicator taxa is longest for *M. palustris: Turbellaria* Gen. sp., *Anisus* sp. and *Empididae* Gen. sp. are good indicators for the macrophyte (indication values from 94 to 89). Strong indicators for *C. demersum* are *Coenagrionidae/Platycnemidae* Gen. sp. juv. and *Zygoptera* Gen. sp. juv. (indication values 95,5 and 93,3). For *P. lucens Oligochatea* Gen. sp. is best indicator with an indication value of 70,5.

Table 25: *Indicator species analysis for the different macrophyte species in October. Taxa with Indication value >20 and Significance p* <1,00 are shown. Taxa with Significance <0,05 are highlighted grey. Macrophyte 1 – N. lutea, 3 – M. palustris, 4 – C. demersum, 5 – P. lucens (Samples N for each study site: N_1=3, N_2=3, N_3=9, N_4=9).*

Indicator species	Makro-phyte	Indication value	p*	Indicator species	Makro-phyte	Indication value	p*
Radix ovata / peregra	1	43,9	0,0966	*Baetis lutheri / vardarensis*	3	23,8	0,3673
Elophila nymphaeata / rivulalis	1	41,7	0,2044	*Triaenodes bicolor*	3	23,1	0,6535
Physidae Gen. sp.	1	40	0,1164	*Valvata piscinalis*	3	21,2	0,4807
Turbellaria Gen. sp.	3	94,4	0,0002	*Coenagrionidae / Platycnemidae* Gen. sp. juv.	4	95,5	0,0012
Anisus sp.	3	93,4	0,0002	*Zygoptera* Gen. sp. juv.	4	93,3	0,0016
Empididae Gen. sp.	3	88,5	0,0004	*Coenagrionidae* Gen. sp.	4	76,7	0,0016
Caenis luctuosa	3	83,3	0,001	*Cloeon dipterum*	4	73,6	0,0326
Stylaria lacustris	3	82,3	0,0006	*Agrypnia varia*	4	65,3	0,032
Planorbis carinatus	3	78,3	0,0008	*Oecetis* sp.	4	63,3	0,02
Caenis horaria	3	76	0,0028	*Plea minutissima*	4	53,3	0,0302
Gyraulus crista	3	74,4	0,0044	*Aeshna cyanea*	4	52,6	0,079
Lype sp.	3	66,7	0,0106	*Caenis robusta*	4	51,3	0,1686
Hydroptila sp.	3	62	0,0184	*Parapoynx stratiotata*	4	50,1	0,08
Bithynia tentaculata	3	59,5	0,0196	*Aeshnidae* Gen. sp. juv.	4	33,3	0,148
Calopteryx splendens	3	59,5	0,0212	*Chaoborus crystallinus*	4	33,3	0,1536
Oxyethira flavicornis	3	54,7	0,0346	*Trichoptera* Gen. sp. juv.	4	30,3	0,4215
Acroloxus lacustris	3	50,7	0,0384	*Ilyocoris cimicoides*	4	25,6	0,3651
Athripsodes cinereus	3	50	0,0682	*Haliplus* sp. Ad.	4	25,6	0,3651
Orthotrichia sp.	3	47,6	0,0342	*Haliplus* sp. Lv.	4	25,6	0,3617
Athripsodes sp. juv.	3	44,6	0,1416	*Dytiscidae* Gen. sp. Lv.	4	22,2	0,4065
Hydropsyche angustipennis	3	43,5	0,1182	*Anopheles maculatus*	4	22,2	0,4225
Hydrachnidia Gen. sp.	3	43,1	0,1352	*Oligochaeta* Gen. sp.	5	70,5	0,016
Planorbidae Gen. sp. juv.	3	41,9	0,187	*Hydroptilidae* Gen. sp. juv.	5	43,6	0,1296
Valvatidae Gen. sp. juv.	3	41,7	0,1174	*Mystacides azurea / nigra*	5	40	0,0694
Mystacides azurea / nigra	3	41	0,1474	*Baetis* sp. juv.	5	33,9	0,2777
Gyraulus laevis / parvus	3	40	0,1666	*Caenis* sp.	5	31,9	0,7684
Piscicolidae Gen. sp.	3	35,4	0,2022	*Erpobdella octoculata*	5	31	0,3663
Pisidium sp. juv.	3	33,3	0,2264	*Ceratopoganidae* Gen. sp.	5	27,5	0,754
Corduliidae / Libellulidae Gen. sp. juv.	3	33,3	0,2354	*Segmentina nitida*	5	20	0,4089
Oulimnius sp. Lv.	3	33,3	0,2264	*Nematocera* Gen. sp.	5	20	0,4089
Oecetis testacea	3	33,3	0,2246	*Tabanidae* Gen. sp.	5	20	0,4133
Acentria ephemerella	3	33,3	0,2236				

Invertebrate community structure at the four study sites in summer

Figure 50 and Table 26 illustrate invertebrate abundance and diversity per site in June. Obvious are highest median and highest geometric mean for invertebrate abundance at study site 2 (Figure 50 and Table 26). At study site 2 values range between about 1500 and 750 - highest abundance was found for *M. palustris*. Study site 3 shows the lowest median (Figure 50) - in each sample less than 400 individuals were found. Also the geometric mean is lowest in comparison to the other study sites (Table 26). Study site 4 shows highest variation of abundances and is characterized by a median of 427 (Figure 50). Lowest abundances occur in *N. lutea* and *P. perfoliatus*, highest abundances in *M. palustris* and *M. aquatica*.

Considering the diversity at each study site it is obvious that highest taxa number occurs at study site 2. Medians and geometric means at study sites 1, 3 and 4 differ only slightly. Largest variation occurs at study site 4 ranging from 3 to 35 taxa per sample (Figure 50 and Table 26).

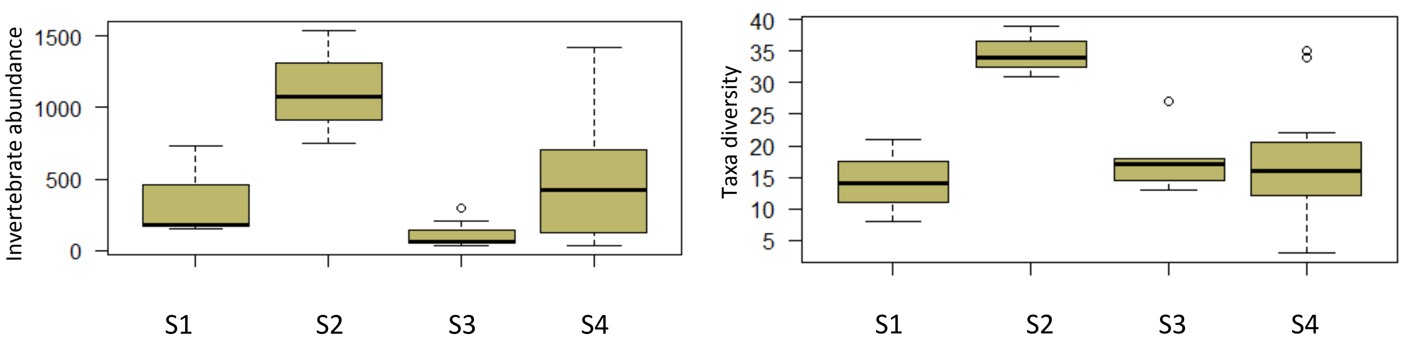

Figure 50: *Box- and Whisker plots of invertebrate abundance (left) and diversity (right) per macrophyte sample in June. S1-S4: Study site 1 to 4 (Samples N for each study site: N_1=3, N_2=3, N_3=7, N_4=11).*

Table 26: *Geometric mean values for invertebrate abundance and diversity per macrophyte sample in June (Samples N for each study site: N_1=3, N_2=3, N_3=7, N_4=11).*

	Study site 1	**Study site 2**	**Study site 3**	**Study site 4**
Geom. mean abundance (Ind./sample)	274	1078	81	284
Geom. mean diversity (Taxa/sample)	13	35	17	18

Invertebrate community structure at the four study sites in autumn

Invertebrate abundance and diversity per macrophyte sample at each study site in October are presented in Figure 51 and Table 27). Lowest median and lowest geometric mean for abundance are reached at study site 1. Both parameters decrease in comparison to June (Figure 50 and Table 26, Figure 51 and Table 27). Decrease in geometric mean and median is also found for study site 2 in October. Variation of abundance values is very high - ranging from 127 individuals in *Myriophyllum* sp./*P. perfoliatus* to 1103 individuals in pure *Myriophyllum* sp.. Study site 3 reaches with a median of 250 and a geometric mean of 187 an increase in abundance compared to June. Values range from under 50 individuals in *N. lutea* to about 1000 individuals in *C. demersum* (Figure 50 and Table 26, Figure 51 and Table 27). Median of about 590 individuals and geometric mean of 546 individuals is highest at study site 4 (Figure 51 and Table 27).

Considering diversity study sites 1, 2 and 3 have only slightly differing medians and geometric means. Whereas study site 4 has highest median and geometric mean of about 34 taxa (Figure 51 and Table 27).

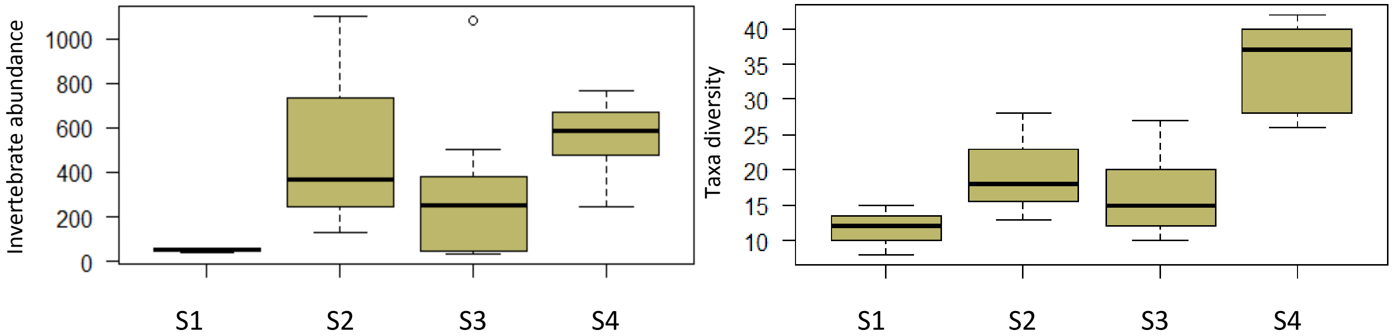

Figure 51: *Box- and Whisker plots of invertebrate abundance (left) and diversity (right) per macrophyte sample in October. S1-S4: Study site 1 to 4 (Samples N for each study site: N_1=3, N_2=3, N_3=9, N_4=9).*

Table 27: *Geometric mean values for invertebrate abundance and diversity per macrophyte sample in October (Samples N for each study site: N_1=3, N_2=3, N_3=9, N_4=9).*

	Study site 1	Study site 2	Study site 3	Study site 4
Geom. mean abundance (Ind./sample)	49	372	187	546
Geom. mean diversity (Taxa/sample)	11	19	16	34

Seasonal patterns of epiphytic invertebrates

Seasonal patterns of epiphytic invertebrate community are illustrated in Figure 52. The cluster analysis presents clusters within study site 4 for each season. Those two clusters have more similarity to each other than to any other study site in the same season. Study sites 1, 2 and 3 form a cluster together for each season.

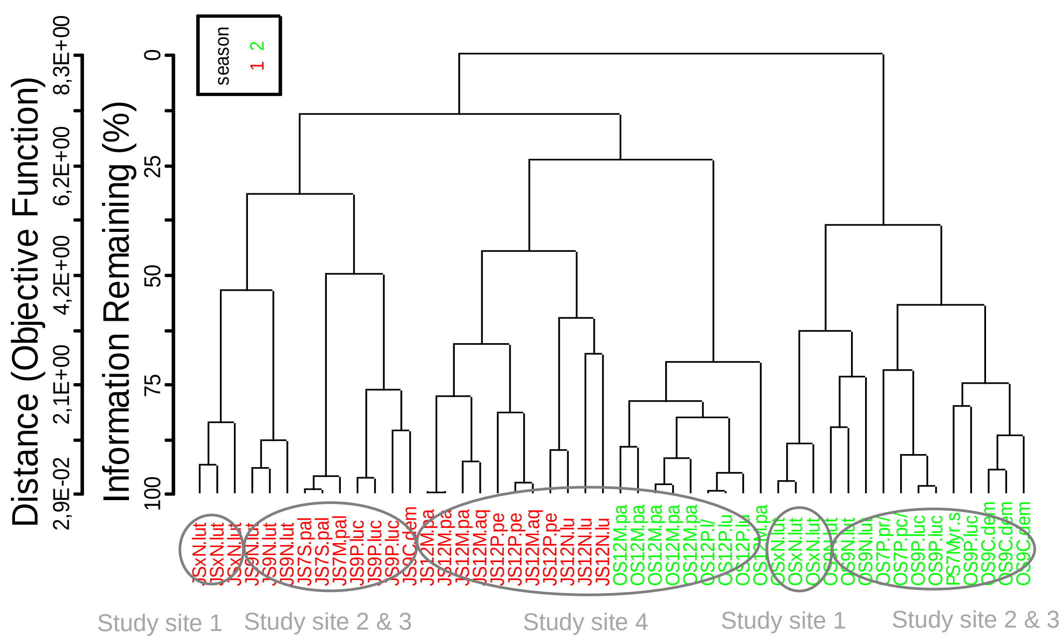

Figure 52: *Cluster analysis for epiphytic invertebrates illustrating the seasonal difference. Season 1 – June, 2 – October. J = June, O = October. (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

Summary: In summer **each study site has a unique invertebrate community**, in **autumn study sites 3 and 4** are **similar**. Invertebrate community is inherent for ***N. lutea***, ***S. palustris/P. berchtoldii/Poaceae* Gen. sp.**, ***P. lucens*** and ***C. demersum.*** In **June** highest number of **indicator species, highest invertebrate diversity and abundance** per sample was found at **study site 2**. In **October diversity of indicator species, invertebrate diversity and abundance** per sample are highest at **study site 4**.

5.4.4 Epiphytic Invertebrate Index (EII)

The Epiphytic Invertebrate Index (EII) describes habitat complexity within a study site caused by macrophyte species, density and structure. In Table 28 EII values can be seen: It is very conspicuous that study site 2 has highest values in both seasons. Especially in June the Index is very high because of high plant species diversity and high densities of gramineous structure. Study sites 3 and 4 are very similar regarding their macrophyte complexity. Lowest Index values can be seen for study site 1.

Table 28: *Epiphytic invertebrate Index for the four study sites in both seasons.*

Study site June	EII
1	5
2	44
3	22
4	20

Study site October	EII
1	5
2	26
3	19
4	20

Summary: Study site 1 is characterized by **lowest macrophyte complexity. Study site 2** is **most complex** site regarding macrophyte diversity, density and structure. **Study sites 3 and 4** are **similar**.

5.4.5 Saprobity, feeding types and longitudinal zonation of epiphytic invertebrate community

Saprobity

Saprobic valencies in the four study sites are illustrated in Figure 53. Beta- and alphamesosaprobic proportions are highest at all study sites in both seasons. For a small proportion all study sites are also inhabited by invertebrates indicating oligosaprobic conditions. Study site 1 October, study site 2 June and October as well as study site 3 June and October are impacted by polysaprobic proportions.

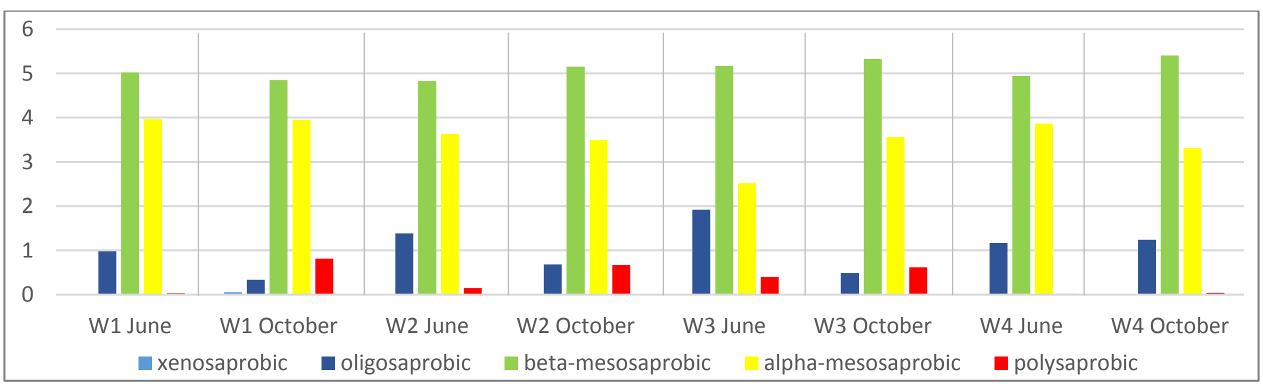

Figure 53: *Saprobic valences at the different study sites comparing June and October samples (Samples N for each study site: June N_1=3, N_2=3, N_2=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

Functional feeding guilds

In Figure 54 functional feeding types are presented for each study site and season. In June at study site 1 detritus feeders are dominating (*Oligochatea* Gen. sp*., S. lacustris*). Some predators occur as well - they are dominated by occurrence of *I. cimicoides*. In October occurrence of *C. dipterum*, that is grazer and detritus feeder for equal share, explains dominance of grazers and detritivors. Furthermore some predators inhabit the study site, most important taxa therefore are *Coenagrionidae* Gen. sp. and *Ceratopoganidae* Gen. sp..

Study site 2 is dominated by detritivors (*Oligochatea* Gen. sp., *S. lacustris, , V. piscinalis, C. dipterum*) in June, also predators (*Erpobdella octoculata, Dytiscidae* Gen. sp. Lv.*, C. cristallinus*) and grazer (*B. tentaculata, G. crista, G. laevis/parvus, C. dipterum*) occur. In October detritus feeders (*C. dipterum, Oligochaeta* Gen. sp.) are dominant again, but also grazers (*C. dipterum*) have an important role. For a smaller proportion predators (*Coenagrionidae* Gen. sp*., Goenagrionidae/Platycnemidae* Gen. sp.*)* inhabit the study site (Figure 54).

At study site 3 in June feeding types are dominated by predators (*E. octoculata, P. minutissima, I. cimicoides, Dytsicidae* Gen. sp. Lv.*)* followed by grazers (*G. laevis/parvus, C. dipterum*) and detritus feeders (*Oligochatea* Gen. sp*., C. dipterum, Caenis* sp.) for almost equal share. In October detritus feeders (*Oligochatea* Gen. sp*., C. dipterum, C. robusta, Caenis* sp.) have highest abundance, followed by predators (*Coeangrionidae* Gen. sp*., Coenagrionidae/Platycnemidae* Gen. sp*., Zygoptera* Gen. sp.*)* and grazers *(C. dipterum)* (Figure 54).

In June at study site 4 detritus feeders (*Oligochatea* Gen. sp*., S. lacustris*) are dominant, for a very small proportion also grazer (*B. tentaculata, G. laevis/parvus*), active filter feeders (*B. tentaculata*) and predators (*Turbellaria* Gen. sp*., Ceratopoganidae* Gen. sp*., Hydrachnidia* Gen. sp.) inhabit the study site. In October a very different pattern characterizes the site: Other feeding types dominate (*O. flavicornis*), followed by detritus feeders (*Oligochaeta* Gen. sp*., S. lacustris*) and predators (*Turbellaria* Gen. sp.) (Figure 54).

Study sites 1, 2 and 4 have a similar pattern concerning feeding type distribution: In June the water bodies are dominated by detritus feeders whereas study site 3 is differently dominated by predators. In October study sites 1, 2 and 3 have similar patterns: They are dominated by detritivores, followed by grazers and predators. Whereas study site 4 is differently dominated by other feeding types.

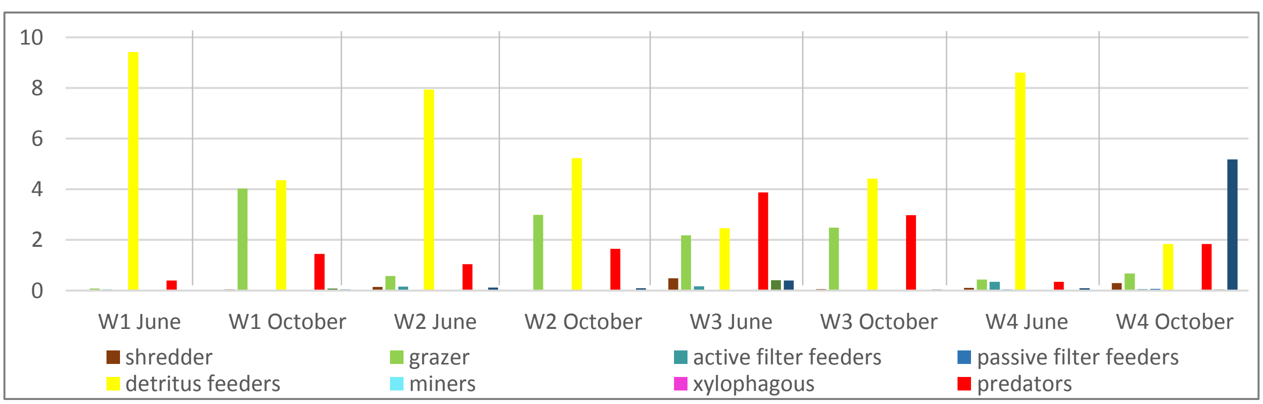

Figure 54: *Functional feeding types at the different study site comparing June and October (Samples N for each study site: June N_1=3, N_2=3, N_2=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

Longitudinal zonation

Distribution of longitudinal zonation is visualized in Figure 55. The proportion of invertebrates indicating littoral zonation is highest. A similar pattern to the feeding type distribution is visible: In June study sites 1, 2 and 4 are similar regarding proportions of longitudinal zonation - whereby littoral is highest, followed by meta-, epipotamal and profundal. In study site 3 proportion of littoral is much higher than in residual water bodies. In October study sites 1, 2 and 3 have a similar pattern: Littoral is much higher than the other zonation types, followed by epipotamal and hyporhithral. Only at study site 4 distribution of proportions is different.

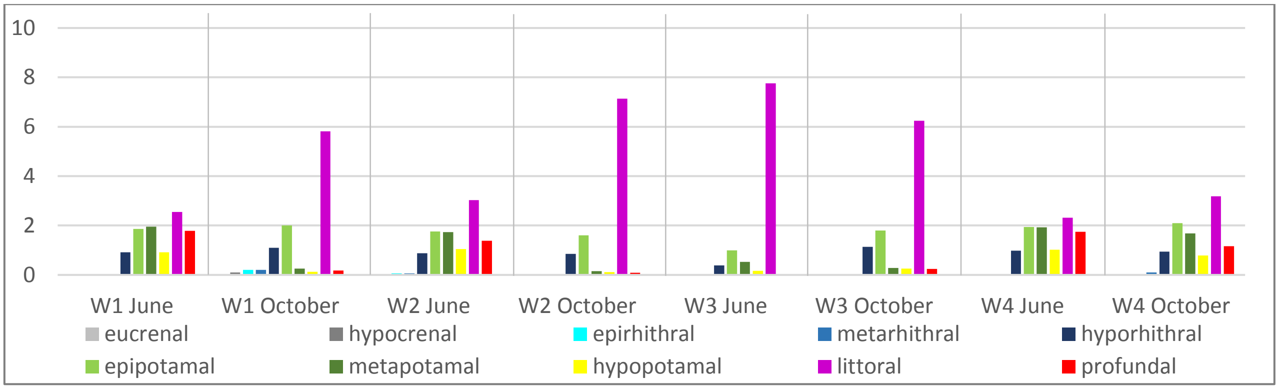

Figure 55: *Longitudinal zonation at the different study sites comparing June and October samples (Samples N for each study site: June N1=3, N2=3, N2=7, N4=11; October N1=3, N2=3, N3=9, N4=9).*

Summary: All study sites are in **both seasons characterized by dominating beta- and alphamesosaprobic valencies**. For a small proportion also oligosaprobic conditions occur.

In **June study sites 1, 2 and 4** are **dominated by detritivors** whereas **study site 3** is dominated **by predators**. In **October study sites 1, 2 as well as 3** are **dominated by detritivors**, followed by high abundances of grazers and predators. **Study site** 4 is dominated by **other feeding types** – *O. flavicornis*, a piercer.

Related to **longitudinal zonation littoral proportion** is highest. In **June study sites 1, 2 and 4** have a similar pattern: **Littoral** is **highest**, **followed by meta-, epipotamal and profundal**. **Study site 3** has a much **higher littoral** proportion. In **October study sites 1, 2 and 3** have a **high littoral proportion** that is **followed by epipotamal and hyporhithral**. **Study site 4** is slightly **different**.

6 Discussion

6.1 Floodplain Index (FI)

In this research the study sites show a deviation from reference situation in the Lower Lobau (Figure 3 and Figure 4) – a fact that was already found out in researches by Graf et al. (2012), Graf et al. (2013), Schulze & Schneeweihs (2013a), Schulze & Schneeweihs (2013b) and Weigelhofer et al. (2014). Three out of four study sites reflect non dynamic and static conditions (Table 29): Before systematic regulation works were done in the 19th century the Danube and the Lower Lobau floodplains were characterized by high dynamics in hydrology as well as morphology. The Danube consisted of diverse channels and a dynamic equilibrium between sedimentation and erosion was going on – resulting in a morphological very young riverscape (Figure 3) (Junk et al. 1989; Nanson & Knighton 1996; Hohensinner et al. 2008). The river-floodplain system experienced a turbulent past that was strongly influenced by anthropogenic changes. Sedimentation as well as siltation processes and a change in distribution of floodplain water bodies were caused by regulation of the main channel. Former side arms and floodplain waters were separated from the main channel of the Danube (Figure 4): Side arms with constant flow disappeared, dynamic arms and arms connected at one end to the main channel were reduced and the proportion of isolated waters increased. Today the Plesio-/Paläopotamon is dominant habitat type in the Lower Lobau floodplains – in contrast to the past when dynamic side arms with unidirectional flow made out highest proportion. The primary lotic character of the system changed to a static one. Before regulation quantitative loss and qualitative change were prohibited by periodical renewal of water bodies. Over aging of habitats today results in substrate and oxygen content changes and different environmental conditions for biota (Amoros et al. 1987; Graf et al. 2012; Graf et al. 2013).

Table 29: *FI values for presence/absence and abundance data analysis for all study sites in both seasons (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

Study site	Presence/absence June	Presence/absence October	Abundance June	Abundance October
1	3,32 / H3	3,06 / H3	3,26 / H3	3,20 / H3
2	3,11 / H3	3,07 / H3	3,03 / H3	3,11 / H3
3	3,41 / H3	3,40 / H3	3,07 / H3	3,14 / H3
4	2,75 / H3	2,41 / H2	2,69 / H2	2,68 / H2

In this master thesis both calculation methods for the Floodplain Index (FI) (presence/absence and abundance data analysis) show by inclusion of macrophyte communities and coverage a plesio-/paläopotamal habitat type for study sites 1, 2 and 3. This fits to hydromorphological classification after Hohensinner et al. (2011) in Figure 4. Regulation works and the flood protection levee inhibit hydrological dynamics at the three sites. They are characterized by lentic conditions, reduced dynamics, terrestrialization processes, siltation, sedimentation and establishment of macrophyte communities (Ward & Stanford 1995; Waringer et al. 2005). Flood events as strongest forces in the river-floodplain system are diminished – therefore lateral connectivity, interchange processes, sedimentation, erosion, succession, biogeochemistry and biotic interaction are disturbed. Ecological integration of the Danube and its relating wetland is impacted. As the water bodies in the study area are hydrologically seen very homogeneous also invertebrate coenosis is similar between the three study sites (Figure 46 and Figure 47). The hypothetical floodplain classification scheme after Amoros et al. 1987 is not applicable to the actual Lower Lobau floodplain system. According to the scheme the three study sites belong to Eupotamon as they are close to the main channel (Figure 1).

Although study sites 2 and 3 are expected to be similar regarding hydrology as they are both small standing backwaters there is a controversial assumption for lateral connectivity in this research: It seems that there is stronger lateral connectivity for study site 2 in presence/absence data analysis (Table 29). Ground water influence, seeping water from the dam or underground connection to the main channel might be reason therefore. This expectation is supported by proximity of study site 2 to the Danube main channel and Schönauerwasser (Figure 5). In abundance data analysis results are different (Table 29) – indicating similarity regarding hydrological connectivity at study sites 2 and 3. Graf et al. (2012) confirm the latter assumption.

Study site 4 represents a special case in this study: It is characterized by eu-, para-, plesio- and paläopotamal characteristics. Invertebrate community covers a broad hydrological connectivity range from Eupotamon to temporal water bodies (Figure 23 and Figure 24). Graf et al. (2012) state that ground water level fluctuations managed by a pumping station cause temporal flow velocity. Apart from these periods the site is characterized as lentic. This site cannot be compared to any habitat type occurring in the past – therefore it is defined as a Pseudopotamon. Pseudopotamal waters occur very isolated and do not show a representative historical situation although they are very typical. As the site is regularly impacted by hydrological dynamics and changes in habitat type no specific invertebrate community can establish on a long-term scale. Animals are typical for very dynamic flowing habitats as well as standing water with terrestrialization processes going on. Therefore faunal diversity is high (Graf et al. 2012). In this research the hydromorphological classification according to Hohensinner et al. (2011) does not correspond to the biological findings – this can be explained by a micro-scale phenomenon not taken into account within the map after Hohensinner et al. (2011) as resolution is too high (Figure 4). The master thesis shows that heterogeneity in hydrological conditions results in a response of biota – fauna is totally different from study sites 1, 2 and 3 (Figure 46 and Figure 47).

The faunal biodiversity in this study demonstrates the importance of the Lower Lobau floodplain system – although the water bodies are hydrologically seen very homogeneous. As wetlands are centers of biodiversity (Tockner & Stanford 2002) the hotspot Lower Lobau is endangered due to ongoing siltation and sedimentation processes. Graf et al. (2012) state that conservation and restoration are important measures to generate stronger connectivity between the Danube and the relating floodplain system. Hydrological dynamisation is a necessity to achieve reference conditions.

6.2 Macrophyte communities

In this research all study sites are inhabited by macrophytes as static conditions within the floodplain and missing hydrological dynamics cause establishment of aquatic vegetation (chapter 5.3). Barta et al. (2009) observed small floodplain water bodies to be important for macrophyte biodiversity. They serve as refugee habitat for aquatic plants.

Macrophytes at the four study sites (chapters 4.5 and 5.3) were found out to be indicators for siltation as well as sedimentation processes, high nutrient content and water level fluctuations – typical characteristics for the static Lower Lobau floodplain system. Flat shoreline areas at study site 2 and 4 enable growth of amphiphyte species. They are indicators for flooding and saturation of shoreline zones caused by ground water fluctuations. Sites 2 and 4 are impacted by pollution and turbid water caused by low water level periods and low water depths. Study site 3 is inhabited by an indicator for stagnant conditions and warm eutrophic waters in summer – fitting to the assumption for a reduced hydrological connection in presence/absence data analysis for calculation of the FI (Table 29).

6.3 Epiphytic invertebrate communities

6.3.1 Overview of invertebrate communities associated with macrophytes in the study

Macrophytes have relevance as habitat for Trichoptera, Gastropoda, Ephemeroptera, Odonata and Diptera taxa in this research (Figure 29). Not all individuals were identified to the same level as this was simply not possible because of small larval stages or identification difficulties. Therefore interpretation of taxa richness has to be treated with caution. Species occurring within the taxa richest order Trichoptera (Table 9) are typical for standing to slowly flowing floodplain water bodies. Some are known to use macrophytes as habitat (e.g. *Hydroptila* sp*., Triaenodes bicolor, O. flavicornis)*, others are specialized on algae that use macrophyte surfaces as substrate (e.g. *A. multipunctata*, *A. sexmaculata).* Also for the remaining orders (Table 9) diverse species are known to be related to aquatic vegetation (e.g. Gastropoda *G. crista* and *P. planorbis;* Ephemeroptera *C. dipterum* and *C. horaria*; Odonata *A. cyanea* and *C. splendens*) (Heidemann & Seidenbusch 2002; Glöer 2015; Schmidt-Kloiber & Hering 2015). Taxa richness for Diptera (Figure 29) might be higher as most individuals were only identified to family level and families *Chironomidae* Gen. sp. as well as *Simuliidae* Gen. sp. were not taken into account. Importance of macrophytes as habitat for invertebrate communities in the Lobau was also observed by Reckendorfer et al. (2012) and Graf et al. (2012). Already other scientists observed aquatic plants to be important habitat for diverse invertebrates as they offer various properties (Lodge 1991; Diehl 1992; Schönborn 1992; Zimmer et al. 2000; Rennie & Jackson 2005; Ali et al. 2007; Papas 2007). Aquatic plants are inhabited by different species than sediment, furthermore alpha- and gamma-diversity is higher in phytal samples (Reckendorfer et al. 2012). Linhart (1999) is summing up that macrophytes generally seem to be preferred by invertebrates as habitat to rare bottom in standing waters.

Oligochaeta that occur in highest abundance in this study (Figure 30) feed as gatherers on detritus and fine organic material accumulating on macrophytes' surfaces. Food source is rich as there is high organic input by dead vegetation - aquatic as well as terrestric - what might be reason for dominance. Also Linhart (1999) found Oligochaeta to be very abundant in phytal habitats. Abundant Ephemeroptera are dominated by *C. dipterum* in this research (Table 30 and Table 31). This species has a bivoltine life cycle, meaning that it occurs as larvae in both seasons. As grazer and detritus feeder food availability is high. Both facts might be reason for high abundance. The species is known to depend on aquatic plants as it feeds on senescent vegetation and periphyton. In general preference of *Baetidae* Gen. sp. larvae is recorded for submersed macrophytes (Bazzanti et al. 2010). Trichoptera are dominated by *O. flavicornis* (Table 30 and Table 31). This species is r-strategist what is reason for high abundance. Moreover it is bivoltine and as a piercer food availability is high due to growth of periphyton on surfaces of macrophytes (Van den Brink et al. 2013; Schmidt-Kloiber & Hering 2015). Gastropoda are dominated by the family *Planorbidae* Gen. sp. in this research (Table 30 and Table 31). It consists of individuals that could not be further identified because of young and therefore very small animals. As grazers, shredders and gatherers high abundance can be explained via high food availability. High abundances of *Anisus* sp., grazer as well as shredder, *G. laevis/parvus*, grazer and *B. tentaculata*, active filterer and grazer, might also result from high food availability. Algae and periphyton are grazed from macrophyte surfaces, dead plant parts are shredded, fine organic material is gathered and high suspended solid content is filtered (Schmidt-Kloiber & Hering 2015).

6.3.2 Invertebrate community associated with different leaf types

In this master thesis an influence of leaf structure (large flat, small and pinnate leaved) on invertebrate community is observable (Figure 39, Figure 40, Figure 41, Figure 42, Figure 43, Figure 44 and Figure 45). Another evidence for faunal leaf type associations is shown in the DCA analysis in Figure 56: Invertebrates related to the large flat leaved plants have similarity to each other. Similarities are also observable for small leaved plants and for pinnate leaved macrophytes. Mixed leaved plants overlap with the other leaf types (Figure 56). The same pattern was shown by Reckendorfer et al. (2012) who found diverse invertebrate associations related to different macrophytes in the Lobau. Papas (2007) reviewed that leaf structure and complexity are known to have influence on invertebrate colonization of macrophytes. Different growth forms of macrophytes result in slightly different invertebrate colonization (Verdonschot et al. 2012). Whereas other authors showed (Dvořaki & Bestz 1982; Rooke 1984; Higler & Verdonschot 1989) that floating, submerged and emergent plants with different structural complexity have high similarities in invertebrate community. Only a small part shows preference for certain morphological growth forms. It can be assumed that vegetation itself is probably the most important factor (Barnes 1983; Downing 1991).

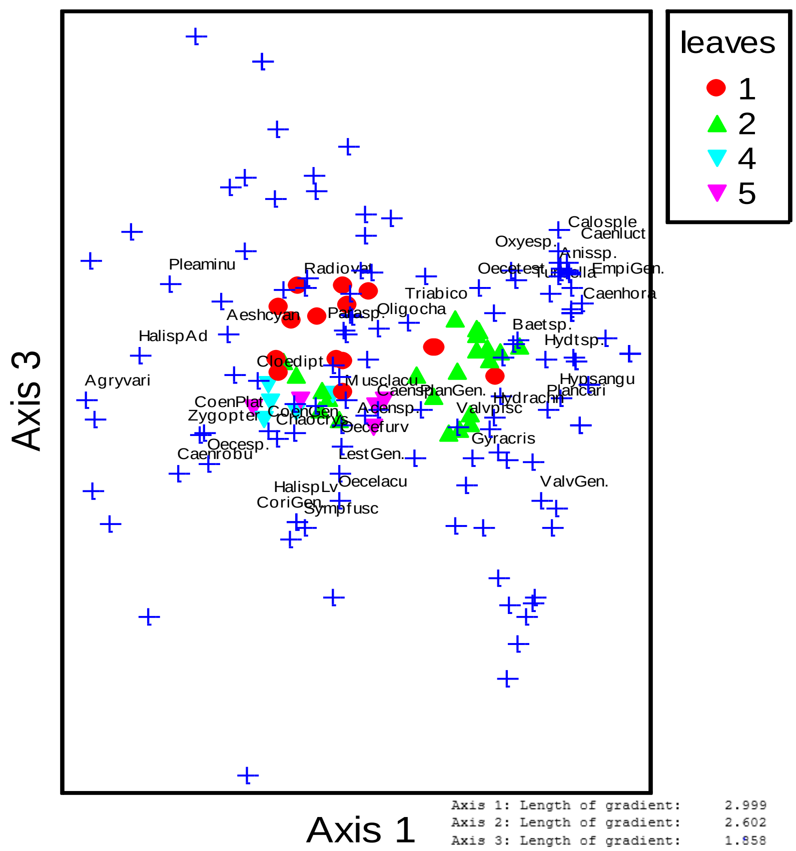

Figure 56: DCA analysis for the different leaf types at the different study sites in both seasons. Leaves: 1 – large flat leaved, 2 – small leaved, 4 – pinnate leaved, 5 – mixed leaved. Indicator species for the different leaf types are shown (Table 32) (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).

6.3.3 Seasonal patterns of invertebrate communities

Site-specific invertebrate communities in summer

Invertebrate samples taken in this study can be separated from each other regarding study site (Figure 46 and Figure 57) – study site specific properties have influence on faunal community. Verdonschot et al. (2012) discovered as well that habitat properties and physiochemical variables on water body scale impact macroinvertebrate composition of macrophytes. Large scale factors are known to have impact on microscale characteristics (Poff 1997).

Three site specific factors are observed to influence the invertebrate community in this investigation – the distance to the Danube main channel, the water surface area and hydrology (Figure 59, Figure 60 and Figure 68). Weigelhofer et al. (2014) observed that sites close to the lower main arm build a group regarding water chemistry in analyses, they are close to the Danube main channel and impacted by bank filtration (e.g. study sites 1 and 2). Sites close to the upper main arm build another group, water bodies are further away from the Danube (e.g. study sites 3 and 4). The main arm itself is characterized by a decrease in trophy, oxygen, nitrogen and a change in geochemistry with increasing distance from the Danube. Impact of the Danube is decreasing with increasing distance from the Schönauer Schlitz in low and medium water situation. Due to large size and connection to the Danube the main arm is a stable water body that is impacted by floods via dilution and sedimentation processes (study site 1). Isolated small water bodies are mainly ground water influenced and characterized by higher concentrations in dissolved organic matter (study sites 2 and 3). Side water bodies are influenced indirectly by floods via ground water level fluctuations and are strongly influenced in their development by inundation events (Riedler 2013; Weigelhofer et al. 2014). Study site 4 represents as a Pseudopotamon a unique hydrology with frequent flow velocity (Graf et al. 2012). As each study site is influenced by specific chemical and physical conditions a particular macroinvertebrate species pool establishes (Walker et al. 2013).

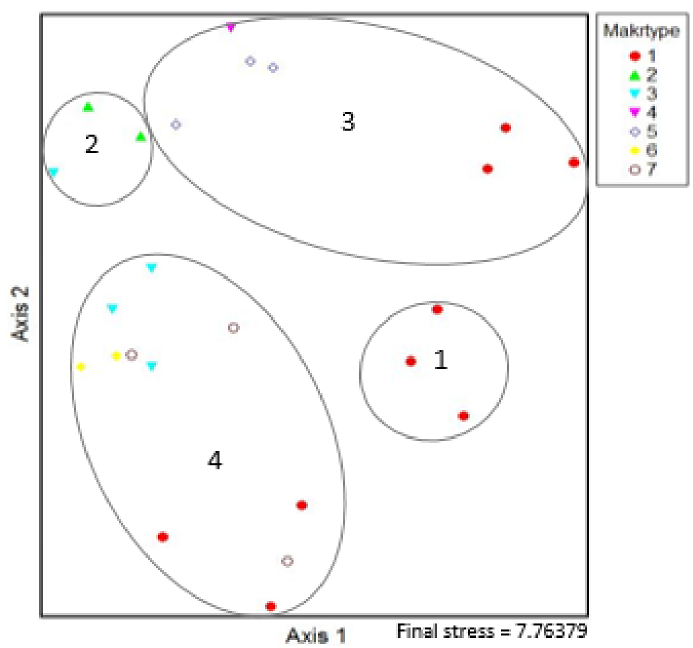

Figure 57: *NMS analysis for invertebrates at the four study sites in June. 1-4: Study sites 1 to 4. Macrophyte type 1 – N. lutea, 2 – S. palustris/ A. stolonifera/ P. berchtoldii/ Poaceae Gen. sp., 3 – M. palustris, 4 – C. demersum, 5 – P. lucens, 6 – M. aquatica, 7 – P. perfoliatus (Samples N for each study site: N1=3, N2=3, N3=7, N4=11).*

Site-specific invertebrate communities in autumn

Study-site specific properties like distance to the Danube, water surface area and hydrology have influence on invertebrate community in October as well (Figure 47, Figure 58, Figure 59, Figure 60 and Figure 68). Assumption of similarity in hydrological connectivity at study sites 2 and 3 is supported by invertebrate coenosis in autumn (Figure 47 and Figure 58) – what is in contrast to June results (Figure 46 and Figure 57).

A species that was found at study site 4 is *A. fluviatilis* (Table 9). It describes the different hydrology as it is typical for flowing waters, Eupotamon and stones (Geldiay 1956; Glöer 2015; Schmidt-Kloiber & Hering 2015). *C. splendens* is an indicator species for study site 4 (Table 23). It is known to be rheophilic and was also observed to be autochthonous at this site by Schulze & Schneeweihs (2013).

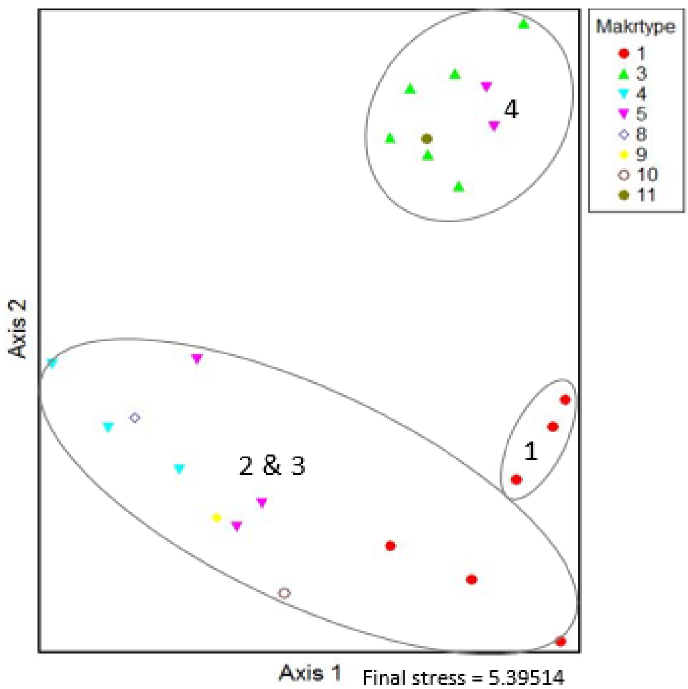

Figure 58: *NMS analysis for invertebrates at the four study sites in October. 1-4: Study sites 1 to 4. Macrophyte type 1 – N. lutea, 3 – M. palustris, 4 – C. demersum, 5 – P. lucens, 8 – Myriophyllum sp., 9 – Myriophyllum sp./P. pectinatus, 10 – Myriophyllum sp./ P. perfoliatus, 11 – P. lucens/P. pectinatus (Samples N for each study site: N1=3, N2=3, N3=9, N4=9).*

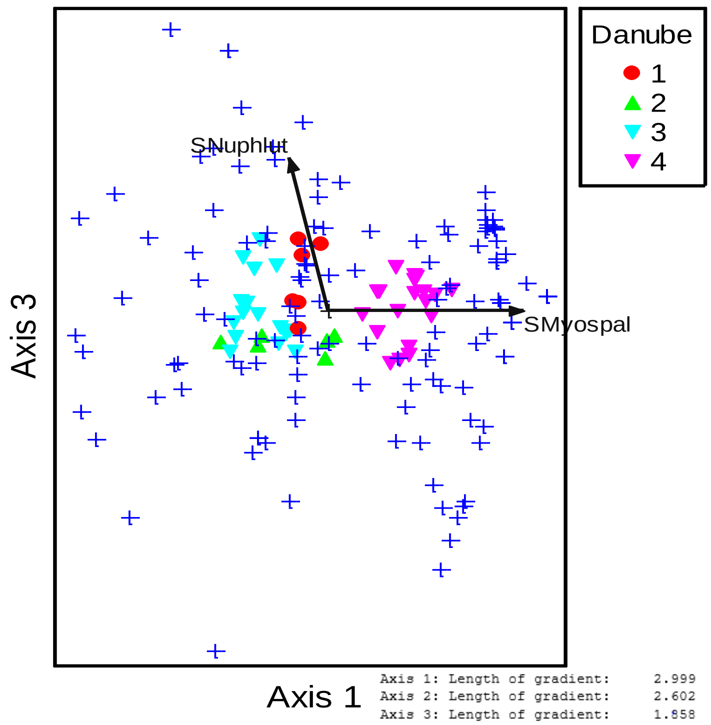

Figure 59: *DCA analysis for invertebrate community at the four study sites in both seasons. Distance to the Danube: 1- 0 to 499m, 2 – 499 to 999m, 3 – 1000 to 1499m, 4 – 1500 to 1999m; (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

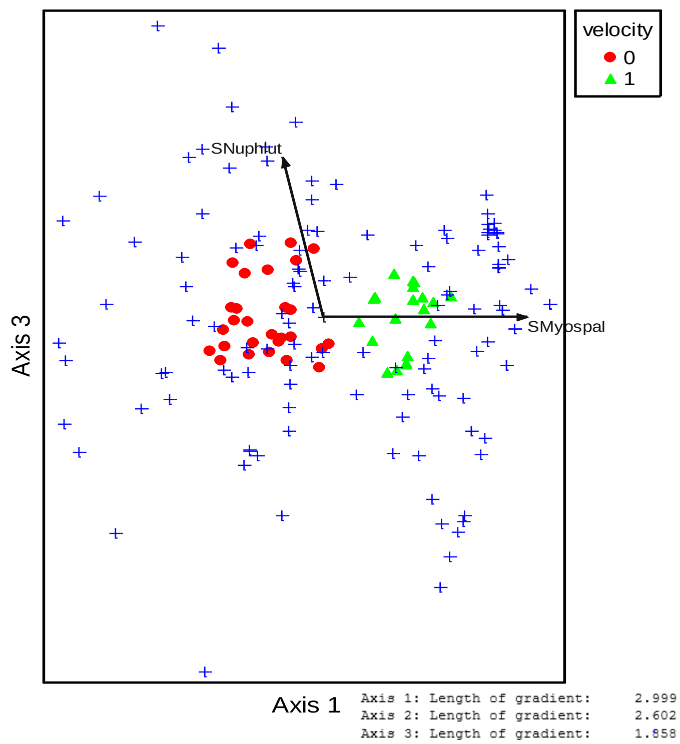

Figure 60: *DCA analysis for invertebrate community at the four study sites in both seasons. Velocity: 1 – standing to lentic, 2 – frequently flowing; (Samples N for each study site: June N1=3, N2=3, N3=7, N4=11; October N1=3, N2=3, N3=9, N4=9).*

Macrophyte-specific invertebrate communities in summer

In this study specific invertebrate communities were found for *N. lutea*, *P. lucens*, *S. palustris*/*P. berchtoldii*/*P. pectinatus*/*Poaceae* Gen. sp. in summer. Poff (1997) stated that the microhabitat structure is one variable that might filter invertebrate species with specific traits from a local species pool to co-exist on a certain macrophyte. This might lead to a correspondence between habitat structure and functional composition of invertebrates. Plant architecture and structure determine if an invertebrate is able to move around in an efficient way and if it is able to use resources. Suitability is reflected in habit, feeding mode and food types (Verdonschot et al. 2012).

A specific invertebrate community is adapted to *N. lutea* in this investigation (Figure 48 and Figure 57). These insights are in contrast to Reckendorfer et al. (2012) who could not observe a difference in invertebrate community between *N. lutea* and other macrophytes. *N. lutea* has very unique plant morphology and architecture: The submerged leaves are salad shaped and less developed, the floating leaves are heart shaped and large. It is obvious that structure is totally different from other macrophytes. Aboveground parts provide low structural heterogeneity and create shade – a fact unfavorable for growth of periphyton and colonization of epiphytic fauna. As perennial plant *N. lutea* has long term effects as underground rhizome system and roots are well developed. Therefore the macrophyte provides food as well as substratum also outside growing season. Researchers observed migration of animals between the ground and *N. lutea* to fulfill habitat demands (Zbikowski et al. 2010).

A specific invertebrate community shows preference for *P. lucens.* Although leaf architecture is totally different the invertebrate coenosis of *C. demers*um shows similarity (Figure 48 and Figure 57). This pattern is confirmed by Hann (1995) who found only minor differences in faunal coenosis of *Ceratophyllum* and *Potamogeton* stocks. Qazar (2016) investigated preference of Gastropoda species for *C. demersum* and found a mutualistic relationship. A longer life span for the plant is guaranteed due to grazing of Gastropoda on periphyton.

As gramineous leaf architecture is very unique for the macrophyte mixture of *S. palustris*, *P. berchtoldii*, *P. pectinatus* and *Poaceae* Gen. sp. also invertebrate community is specific in this study (Figure 48). Similarity of faunal coenosis associated with *M. palustris* at study site 2 might be explained by occurrence of small leaves in those samples (Figure 48).

At study site 4 macrophyte samples cannot be separated according to plant species and related fauna, with exception of *N. lutea* (Figure 48). A reason therefore might be that all sampled plant species are small leaved and therefore similar in habitat characteristics. Known associations of *B. tentaculata* and *A. ephemerella* as well as *S. lacustris* and *A. ephemerella* on *P. perfoliatus* were also found in this study (Table 30) (Gross & Kornijów 2002).

Macrophyte-specific invertebrate communities in autumn

In this thesis specificity of faunal *N. lutea* coenosis can be also observed in October (Figure 49 and Figure 58). One Gastropoda species that is known to be related to *N. lutea* is *A. lacustris* – which was found on the macrophyte at study site 1 (Foeckler 1990) (Table 31). In this study *Elophila nymphaeata/rivulalis* larvae were found on aboveground parts of *N. lutea.* Furthermore the caterpillar is indicator species for the macrophyte (Table 25). Occurrence of *Elophila nymphaeata/rivulalis* on plants with floating leaves was observed by Vallenduuk & Cippen (2004).

C. demersum shows a very specific invertebrate community in this study (Figure 49 and Figure 58). One indicator species for the macrophyte species is *P. stratiotata* (Table 25). Observations by Vallenduuk & Cippen (2004) show that the caterpillar feeds mainly on *C. demersum.*

A specific invertebrate community is related to *P. lucens* (Figure 49 and Figure 58). Klein (1984) observed occurrence of *C. splendens* in Potamogeton species – what corresponds to this study as the Odonata species inhabits beside *M. palustris* also *P. lucen*s as well as *P. pectinatus* (Table 31).

Seasonal patterns of epiphytic invertebrates

A clear seasonal influence in this study is caused by faunal life cycles and life spans (Figure 52, Figure 61 and Figure 62). Invertebrates pass through diverse larval stages depending on different ecological conditions and various habitats (Ali et al. 2007).

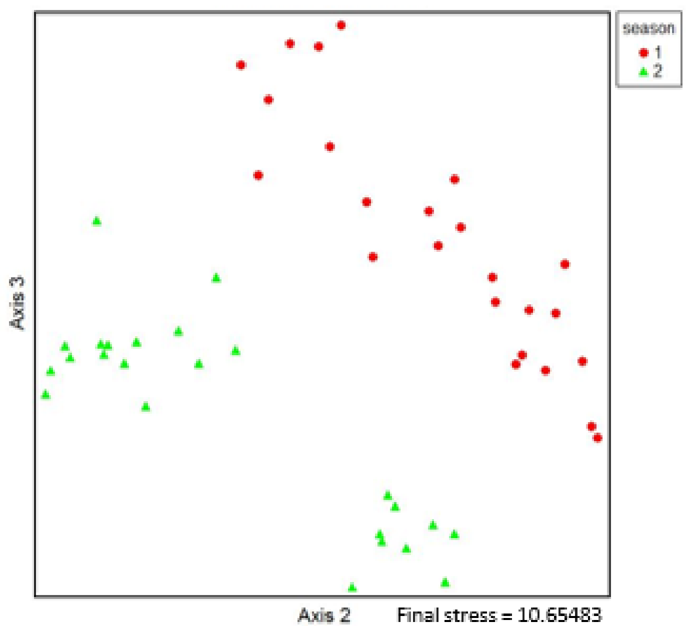

Figure 61: *NMS analysis for epiphytic invertebrates illustrating the seasonal difference. Season 1 – June, 2 – October (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

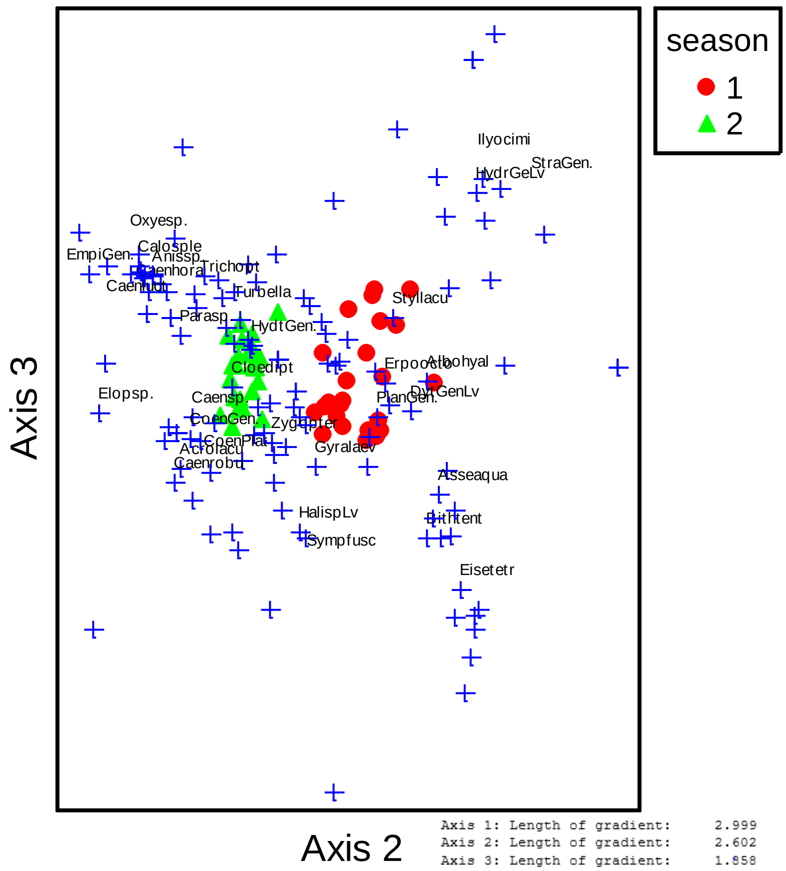

Figure 62: *DCA analysis for both seasons. Seasons: 1 – June, 2 – October. Indicator species for June and October are shown (Table 33) (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

6.3.4 Epiphytic invertebrate Index (EII)

The EII as measure for habitat complexity caused by macrophytes at water body scale shows that there is a positive linear relation between increasing plant diversity, structural complexity, density and increasing aquatic invertebrate diversity and abundance in this investigation (Figure 63, Figure 64, Figure 65 and Figure 66). Aquatic vegetation as key factor of heterogeneity at spatial scale is important for habitat complexity and known to have influence on diversity. The more complex a habitat, the higher is expected number of species (Thomaz et al. 2008). That higher macrophyte diversity results in higher invertebrate diversity was found out by Trajanovski et al. (2016). Influence of structural complexity was investigated by several authors: Already Krecker stated in 1939 that plants with dissected and fine leaves are good substrate and shelter for animal fauna. Highly branched or dissected growth forms provide more food resources and microhabitats (Walker et al. 2013). Kornijów & Gulati (1992) observed that greater fragmentation of macrophyte leaves results in higher faunal diversity and taxonomic variety of associations. Habitat complexity also affected invertebrate diversity and abundance significantly in a study by Thomaz et al. (2008). Weigelhofer et al. (2014) observed macrophyte community and density as most important factors for faunal composition. It might be expected that there is influence on results due to habitat quantification, colonization patterns or habitat use of invertebrates (Thomaz et al. 2008; Verdonschot et al. 2012).

Study site 1 has lowest habitat complexity provided by macrophytes (Table 28). This fact is supported by Riedler et al. (2013) who state that the site is poorest in macrophyte diversity within the largest water bodies in the Lower Lobau. Invertebrate abundance and diversity per sample are lowest at this study site – a deviation is observable for invertebrate abundance in summer (Table 26, Table 27, Figure 63, Figure 64, Figure 65 and Figure 66). Stability of study site 1 or low faunal abundance at study site 3 might be reasons therefore.

Habitat complexity at study site 2 is highest in both seasons (Table 28) – invertebrate community structure fits to the high structural diversity in summer (Table 26, Figure 63, Figure 64, Figure 65 and Figure 66). Gramineous leaves in combination with small leaves provide high structural complexity that is optimal habitat for faunal coenosis. Highest EII in combination with highest invertebrate abundance and diversity corresponds to longest indicator taxa list and might explain high productivity of the system in summer (Table 22). In autumn results are contradictory to Krecker (1939), Kornijów & Gulati (1992) and Walker et al. (2013): Study site 4 that is dominated by small leaved macrophytes and provides lower structural complexity has higher invertebrate abundance as well as biodiversity per sample (Table 27, Figure 63, Figure 64, Figure 65 and Figure 66).

Study sites 3 and 4 are characterized by similar habitat complexity in both seasons (Table 28). Similarities in faunal community structure only come true for invertebrate diversity per sample in summer (Table 26, Figure 63, Figure 64, Figure 65 and Figure 66): Study site 3 has lowest invertebrate abundance per sample. Probably increased abundance of predators might be reason therefore (Figure 54). Obvious is highest variation in invertebrate taxa richness and abundance at study site 4 – a pattern that is also observable for distribution of habitat values in calculation of the FI (Figure 23) and might be explained by changing hydrological conditions. In autumn occurrence of gramineous leaves in combination with small leaves might explain highest invertebrate abundance and diversity. Furthermore also list for indicator species is longest at study site 4 (Table 23). Highest faunal abundance is explainable by occurrence of r-strategist *O. flavicornis*.

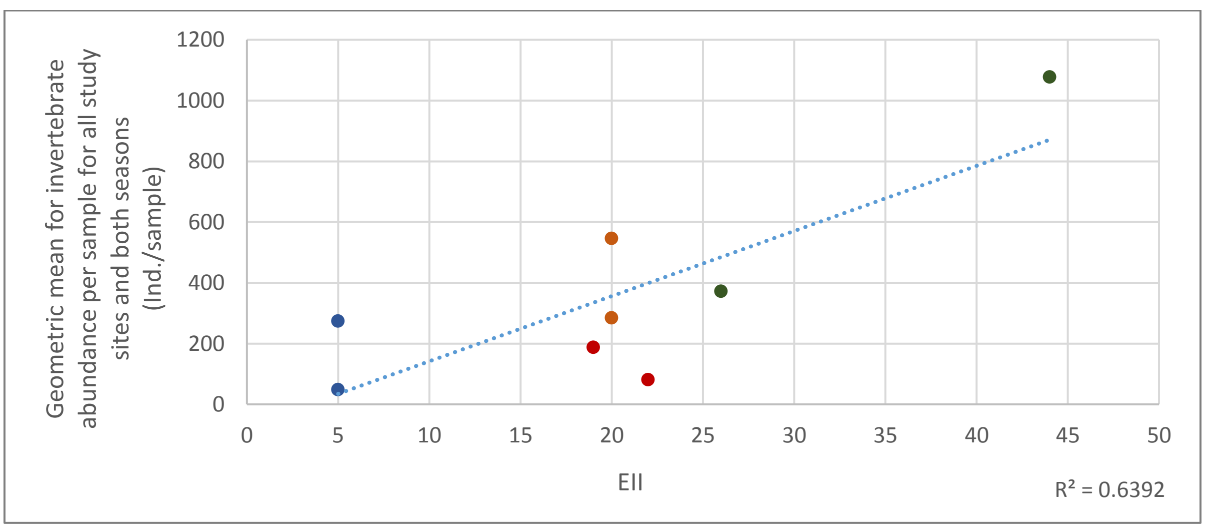

Figure 63: *Linear regression between EII and geometric mean of invertebrate abundance per sample for each study site in both seasons. Study site 1 – blue, 2 – green, 3 – red and 4 – orange (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

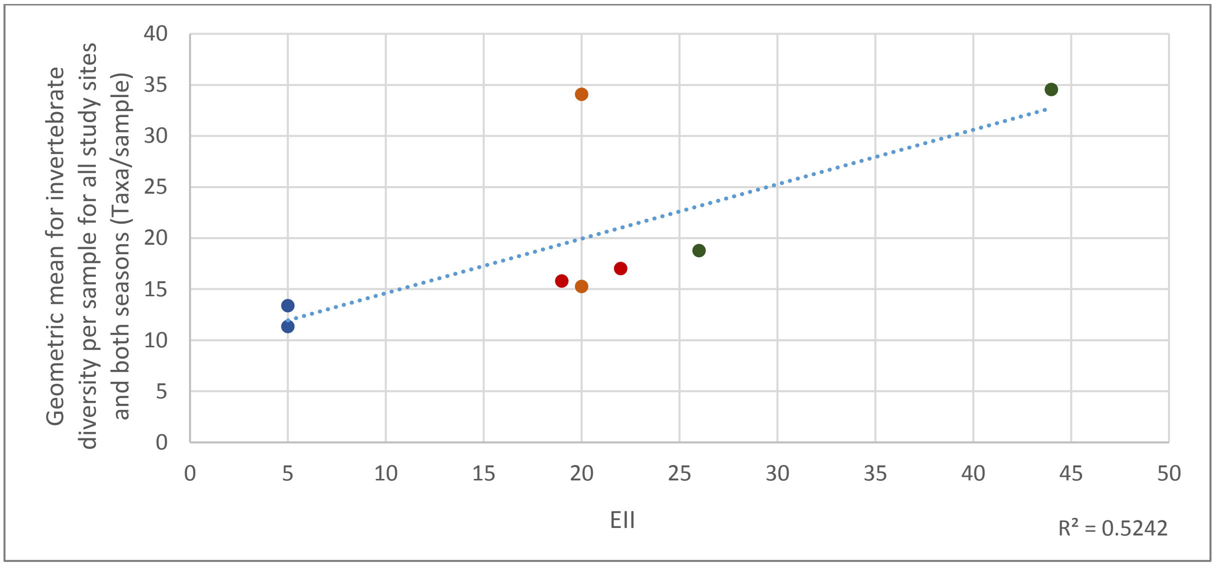

Figure 64: *Linear regression between EII and geometric mean of invertebrate diversity per sample for each study site in both seasons. Study site 1 – blue, 2 – green, 3 – red and 4 – orange (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

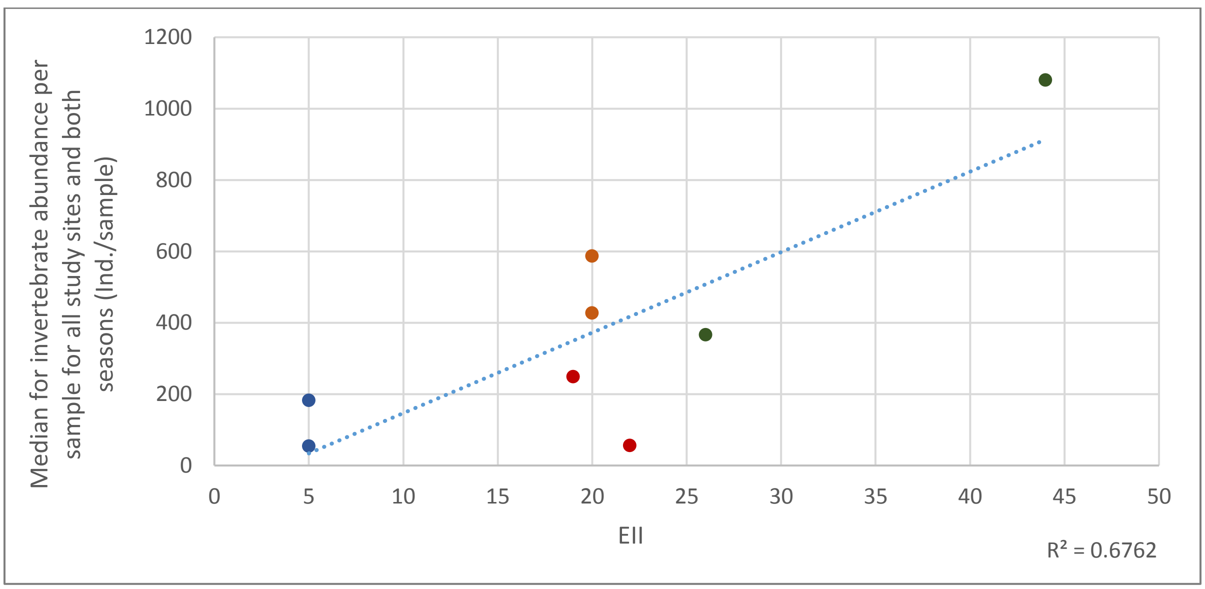

Figure 65: *Linear regression between EII and median for invertebrate abundance per sample for each study site in both seasons. Study site 1 – blue, 2 – green, 3 – red and 4 – orange (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

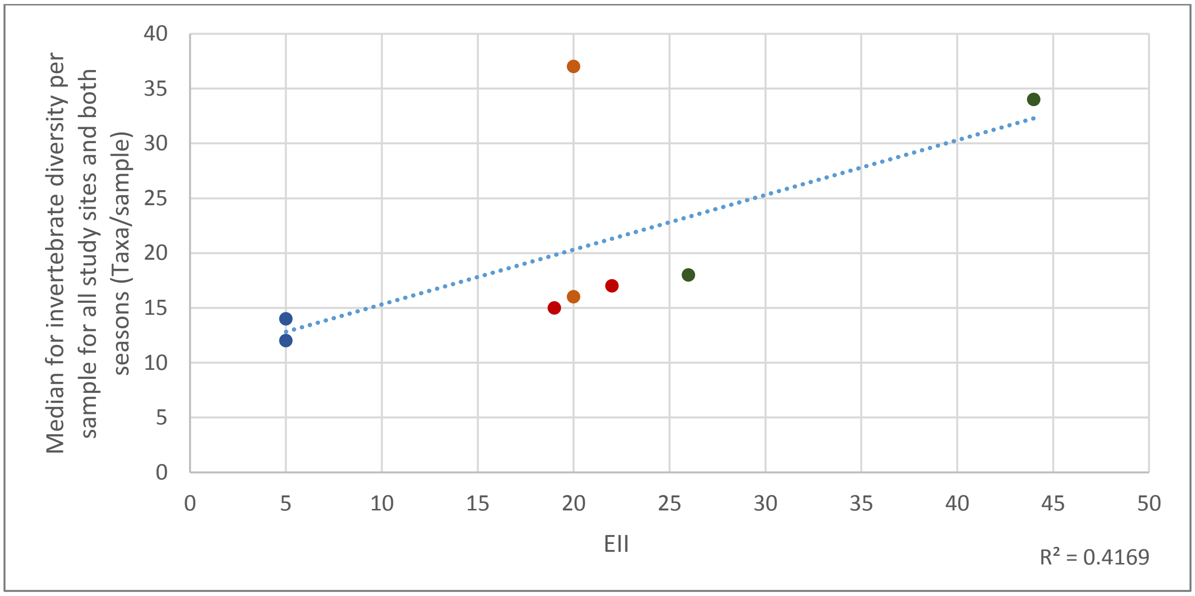

Figure 66: *Linear regression between EII and median for invertebrate diversity per sample for each study site in both seasons. Study site 1 – blue, 2 – green, 3 – red and 4 – orange (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

6.3.5 Complexity of factors and their influence on the invertebrate community structure – leaf structure, distance to the main channel and water surface area

In the Lower Lobau floodplains invertebrate biodiversity depends in a first step on leaf structure in this investigation (Figure 67 and Figure 68): Large flat leaves of *N. lutea* are a regulating factor for diversity as structure is completely different from small, pinnate and mixed leaves. Faunal diversity in small, pinnate and mixed leaves depends on the distance to the Danube and the water surface area (Figure 67 and Figure 68). The study shows that sites close to the Danube (up to 650m distance) are characterized by high biodiversity – reason therefore might be influence of the main channel. Sites that are in more than 1000m distance show also high biodiversity as productivity seems to be increased due to reduced hydrological dynamics. Sites smaller than 0,1ha are characterized by low biodiversity.

The study shows that different factors operating at various scales – from leaf structure to macrophyte species, macrophyte heterogeneity within a study site, distance to the Danube, surface area, hydrological conditions and season – influence the invertebrate community associated with aquatic vegetation within the Lower Lobau floodplain water bodies.

Almost all factors influence each other: The leaf structure depends on the established macrophyte species. Macrophyte species are regulated by the nutrient content, hydrological conditions and the degree of terrestrialization. Terrestrialization depends on hydrological dynamics. Hydrological conditions are related to the distance of the Danube and ground water fluctuations. Hydrology, seasonal die-off of vegetation, impact of floods related to the distance of the Danube and water surface area regulate the nutrient content. Those study site-specific factors impact macrophyte heterogeneity that is related to invertebrate diversity and abundance at water body scale. Faunal community within a water body is furthermore influenced by leaf structure, macrophyte species and season. Whereby invertebrates have impact on macrophytes – all those parameters build interdependences to each other.

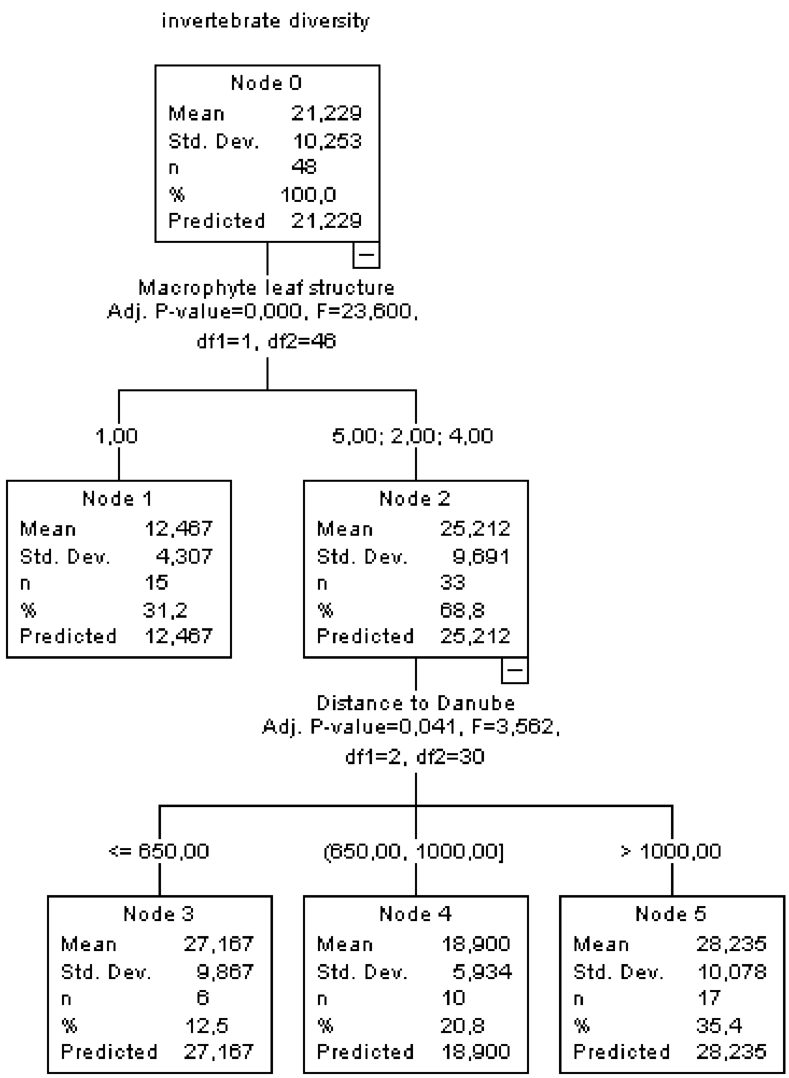

Figure 67: *Decision Tree with the dependent variable invertebrate diversity and the independent variables macrophyte leaf structure and distance to the Danube. Macrophyte leaf structure: 1 – large flat leaved, 2 – small leaved, 4 - pinnate leaved, 5 – mixed leaved. (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

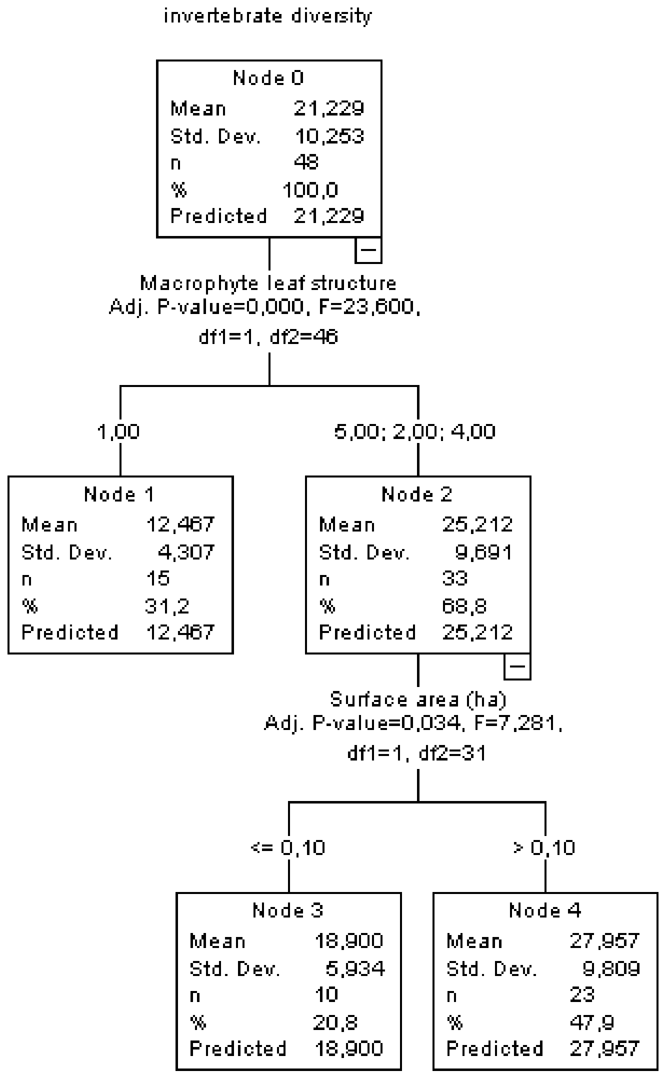

Figure 68: *Decision Tree with the dependent variable invertebrate diversity and the independent variables macrophyte leaf structure and water surface area (in ha). Macrophyte leaf structure: 1 – large flat leaved, 2 – small leaved, 4 - pinnate leaved, 5 – mixed leaved. (Samples N for each study site: June N_1=3, N_2=3, N_3=7, N_4=11; October N_1=3, N_2=3, N_3=9, N_4=9).*

6.3.6 Saprobity, feeding types and longitudinal zonation of epiphytic invertebrate community

Saprobity

As the Lower Lobau is a static system the study shows moderate to high organic pollution (Figure 53). Especially the alphamesosaprobic proportion is indicator for missing dynamics. Strong sedimentation and siltation processes are going on. Dead plant material is not washed out as there is only slow flow velocity or even standing conditions. Water bodies are getting shallower and shallower. Input of suspended sediment is one of the reasons for siltation (Baart 2016). According to Funk & Reckendorfer (2014) species typical for oligo- to polysaprobic zones are dominant in the Danube floodplains.

Saprobity gets minimally worse between June and October at study sites 1, 2 and 3 (Figure 53). The reason therefore might be summer period and increase in organic material due to terrestric input and dying of macrophytes. At study site 4 it stays more or less the same, this might be due to flow velocity washing organic matter out during flowing periods.

Functional feeding guilds

Dominance of detritivores in this investigation (Figure 54) seems appropriate as high amounts of detritus and dead organic material are available. This fact fits to saprobical valences as all study sites have a high organic load (Figure 53). Detritivors benefit from fine particular organic material accumulating below plant stocks (Soszka 1975). High morphological plant complexity leads to high detritus trapping ability and therefore to high diversity of detritivors (Taniguchi et al. 2003). *S. lacustris* which plays a role in detritivore proportion in summer in this study is according to Weigand (1994) defined as phytophilous species.

Beside detritivors grazers are another important feeding guild in this study (Figure 54). As macrophytes themselves are low quality food source growth of periphyton on plant surfaces is important for grazers (Weigand 1994). Weigand (1994) observed that the distribution of epiphytic animals can be explained by quality and quantity of periphyton. Another important fact found in literature is that *Potamogeton* species are significantly more heavily grazed than non-*Potamogeton* species (Jacobsen & Sand-Jensen 1992).

Occurrence of predators (Figure 54) might be explained by suitability of macrophytes for hunting on prey organisms. At study site 3 dominance of predators is noticeable in summer what is in contrast to other water bodies (Figure 54). Low mean abundance of invertebrates per sample might be explained by dominance of predators (Table 26). Linhart (1999) describes predators as feeding group typical for phytal macrofauna. High numbers of predators imply high numbers of prey (Walker et al. 2013; Dvořák 1969).

Study site 4 is different in feeding type distribution in autumn: It is dominated by occurrence of *O. flavicornis* which is a r-strategist and piercer (Figure 54) (Van den Brink et al. 2013; Schmidt-Kloiber & Hering 2015).

Longitudinal zonation

Littoral zonation is dominant at all sites as they are standing to slowly flowing (Figure 55). According to Funk & Reckendorfer (2014) distribution focus of fauna in the Nationalpark area is from hyporhithral to metapotamal as well as on littoral sections. This pattern fits to results in this thesis (Figure 55). Species indicating littoral zonation are typical for less dynamic water bodies (Funk & Reckendorfer 2014).

6.4 Verification/falsification of hypotheses

1) **It is expected that hydromorphological classification of floodplain habitat types is corresponding with biological responses (Trichoptera, Odonata, Mollusca and Ephemeroptera communities).**
   Hydromoprhological classification of habitat types after Hohensinner et al. (2011) corresponds to biological responses of Trichoptera, Odonata, Mollusca, Ephemeroptera and macrophytes at study sites 1, 2 and 3 – they are classified as a Plesio-/Paläopotamon. Study site 4 shows para-, plesio- and paläopotamal characteristics regarding biota and eupotamal flow and sediment properties – therefore it is defined as a Pseudopotamon. This micro-scale phenomenon is not displayed within the hydromorphological classification map of Hohensinner et al. (2011) as its resolution is too high. Hypothesis 1 is verified.

2) **a) There is a difference in invertebrate community inhabiting the different study sites, macrophyte species and leaf types.**

Study-site specific factors like the distance to the Danube, water surface area and hydrological conditions play a role for faunal community structure. For large flat, small and pinnate leaves differences and only slight similarities are observable in invertebrate community. Faunal coenosis is inherent for *N. lutea*, for *S. palustris/P. berchtoldii/Poaceae* Gen. sp., *P. lucens* and *C. demersum*. Hypothesis 2a) is verified.

b) Higher invertebrate richness as well as density is expected with an increase in macrophyte diversity, density and structural complexity at the different study sites.

The Epiphytic Invertebrate Index (EII) as measure for habitat complexity provided by macrophytes (diversity, density and structural complexity) shows a linear relation to increasing invertebrate abundance and diversity. Hypothesis 2b) is verified.

c) A seasonal influence on the faunal community is observable.

A seasonal influence is observable. Hypothesis 2c) is verified.

Summary and conclusions

Summary

Before systematic regulation works were done in the 19th century the Danube and Lower Lobau floodplains were characterized by high dynamics in hydrology as well as morphology. A dynamic equilibrium between erosion and sedimentation was generated. Regulation of the Danube and construction of a flood protection levee separated former side arms and floodplain waters from the main channel – resulting in increasing sedimentation as well as siltation processes and a change in distribution of floodplain water bodies. Former dominance of eupotamal waters was reduced - today the Plesio-/Paläopotamon makes out highest proportion. The system became a static one and is very homogenous today (Nanson & Knighton 1996; Hohensinner et al. 2008; Graf et al. 2012; Graf et al. 2013).

In this thesis three out of four study sites reflect deviation from reference situation and therefore non dynamic as well as stable conditions – study sites 1, 2 and 3 are according to biological responses (Ephemeroptera, Trichoptera, Odonata, Molluska and macrophytes) classified as a Plesio-/Paläopotamon (chapters 5.2 and 5.3). This fits to hydromorphological classification after Hohensinner et al. (2011) (Figure 4). The sites are characterized as stagnant waters with reduced hydrological dynamics, terrestrialization processes, siltation, sedimentation and establishment of macrophyte communities. Due to missing flood pulses lateral connectivity, interchange processes, succession, biogeochemistry and biotic interactions are disturbed. Ecological integration of the Danube and its relating wetland is impacted. As the water bodies in the study area are hydrologically seen very homogeneous also invertebrate coenosis is similar between the three sites (Figure 46 and Figure 47). Study site 4 shows para-, plesio- and paläopotamal characteristics regarding biota and eupotamal flow and sediment properties – therefore it is defined as a Pseudopotamon (chapters 5.2 and 5.3). This micro-scale phenomenon is not displayed within the hydromorphological classification map after Hohensinner et al. (2011) as resolution is too high. The study shows that heterogeneity in hydrological conditions results in a response of biota. As the study site is regularly impacted by hydrological dynamics and changes in habitat type no specific invertebrate community can establish on a long-term scale (Graf et al. 2012).

All study sites are inhabited by macrophytes as static conditions within the floodplain and missing hydrological dynamics cause establishment of aquatic vegetation (chapter 5.3). As the studied macrophytes are colonized by a diversity in invertebrate taxa they are habitats with various properties for the fauna, especially for Trichoptera, Gastropoda, Ephemeroptera, Odonata and Diptera, in the Lower Lobau floodplains (Figure 29). Aquatic vegetation plays an important role for animals as it provides habitat complexity, heterogeneity, shelter, breeding area and substrate for growth of periphyton and food production (Papas 2007).

The study shows that different factors operating at various scales influence the invertebrate community associated with aquatic vegetation within the Lower Lobau floodplain water bodies: The fauna shows a clear seasonality caused by faunal life cycles and life spans (Figure 52). Site-specific properties like distance to the Danube, water surface area and hydrology influence the epiphytic invertebrate community within the floodplain. The Epiphytic Invertebrate Index (EII) as measure for habitat complexity provided by macrophytes (diversity, density and structural complexity) at water body scale has a linear relation to increasing invertebrate abundance and diversity (Figure 63, Figure 64, Figure 65 and Figure 66). Leaf morphology plays a role for invertebrate colonization as well. For large flat, small and pinnate leaves differences and only slight similarities are observable in faunal coenosis (Figure 39). Furthermore an influence of single macrophyte-species on invertebrate colonization is observable: Faunal coenosis is inherent for *Nuphar lutea*, *Stachys palustris/Potamogeton berchtoldii/Poaceae* Gen. sp., *Potamogeton lucens* and *Ceratophyllum demersum* (Figure 48 and Figure 49). Almost all those parameters are linked to each other: Macrophytes are regulated by hydrology and nutrients. Nutrients are impacted by distance to the Danube, season, surface area and hydrology. Hydrology is linked to distance to the Danube and ground water fluctuations. Those study site specific factors impact macrophyte species, density and complexity – parameters that are related to the invertebrate community.

Perspective

For the future changes in macrophyte composition and densities are expected due to ongoing siltation and sedimentation processes: Since the 1970s hydrophyte community decreases. Already now species depending on permanent deep water bodies with moderate nutrient content are affected by changes. There is a small increase in floating leaf societies, in plant stocks that are freely floating and tolerate a high nutrient content, in helophytes and amphiphytes (Pall et al. 2014). These impacts on macrophyte communities are known to have consequently influence on invertebrate coenosis (Reckendorfer et al. 2012).

The study is one more puzzle piece for understanding floodplain systems in a holistic view: Anthropogenic modifications that cause changes in lateral connectivity, hydrological dynamics and flood pulses consequently have impact on macrophyte and invertebrate communities in floodplain water bodies. Although the water bodies in the Lower Lobau are hydrologically seen very homogenous the faunal biodiversity demonstrates importance of this ecosystem. As wetlands are centers of biodiversity (Tockner & Stanford 2002) the hotspot Lower Lobau is endangerd due to regulation works and the flood protection levee. Conservation and restoration are important measures to generate stronger connectivity between the Danube and the relating floodplain system. Further homogenization and fragmentation of water bodies should be prevented and hydrological dynamization generated. Conservation of floodplain water bodies and ecological quality plays an essential role for maintaining high level of species richness. Therefore restauration and conservation of wetland systems are essential aspects in modern water management. Rivers and their related surroundings are a holistic system linked via multiple components to each other.

Bibliography

Ali, M.M., Mageed, A.A. & Heikal, M., 2007. Importance of aquatic macrophyte for invertebrate diversity in large subtropical reservoir. *Limnologica*, 37, pp.155–169.

Amoros, C. et al., 1987. The reversible concept applied to the environment management of large river systems. *Environmental Management*, 11, pp.607–617.

Amoros, C. & Roux, A.L., 1988. Interaction between water bodies within the floodplains of large rivers: function and development of connectivity. *Münstersche Geographische Arbeiten*, 29, pp.125–130.

Baart, I., 2016. Die Makrophyten in den Gewässern des Wiener Teils des Nationalparks Donau-Auen. *Wissenschaftliche Reihe Nationalpark Donau-Auen*, 47, pp.1–174.

Balci, P. & Kennedy, J.H., 2003. Comparison of Chironomids and Other Macroinvertebrates Associated with Myriophyllum spicatum and Heteranthera dubia. *Journal of Freshwater Ecology*, 18(2), pp.235–247.

Barnes, L.E., 1983. The colonization of ball-clay ponds by macroinvertebrates and macrophytes. *Freshwater Biology*, 13(6), pp.561–578.

Barta, V., Schmidt-Mumm, U. & Janauer, G.A., 2009. Adapting floodplain connectivity conditions – a prerequisite for sustaining aquatic macrophyte diversity in the UNESCO Biosphere Reserve Lobau (Austria). *Ecohydrology & Hydrobiology*, 9(1), pp.73–81.

Bauernfeind, E. & Humpesch, U.H., 2001. *Die Eintagsfliegen Zentraleuropas (Insecta: Ephemeroptera): Bestimmung und Ökologie*, Wien: Verlag des Naturhistorischen Museums Wien.

Bazzanti, M., Coccia, C. & Dowgiallo, M.G., 2010. Microdistribution of macroinvertebrates in a temporary pond of Central Italy: Taxonomic and functional analyses. *Limnologica*, 40, pp.291–299.

Cattaneo, A. & Kalff, J., 1980. The relative contribution of aquatic macrophytes and their epiphytes to the production of macrophyte beds. *Limnology and Oceanography*, 25(2), pp.280–289.

Cheruvelil, K.S., Soranno, P.A. & Madsen, J.D., 2001. Epiphytic Macroinvertebrates Along a Gradient of Eurasian Watermilfoil Cover. *Journal of Aquatic Plant Management*, 39, pp.67–72.

Chovanec, A. et al., 2004. Lateral connectivity of a fragmented large river system: assessment on a macroscale by dragonfly surveys (Insecta: Odonata). *Aquatic Conservation: Marine and Freshwater Ecosystems*, 14, pp.163–178.

Chovanec, A. et al., 2005. The Floodplain Index - a new approach for assessing the ecological status of river/floodplain-systems according to the EU Water Framework Directive. *Archiv für Hydrobiologie - Supplements*, 155(1-4), pp.169–186.

Chovanec, A. & Waringer, J., 2001. Ecological integrity of river-floodplain systems - assessment by dragonfly surveys (Insecta: Odonata). *Regulated Rivers: Research & Management*, 17, pp.493–507.

Cramer, M.J. & Willig, M.R., 2005. Habitat heterogeneity, species diversity and null models. *Oikos*, 108, pp.209–218.

Cyr, H. & Downing, J.A., 1988. The abundance of phytophilous invertebrates on different species of submerged macrophytes. *Freshwater Biology*, 20, pp.365–374.

Diehl, S., 1992. Fish predation and benthic community structure - The role of omnivory and habitat complexity.

Ecology, 73, pp.1646–1661.

Downing, J.A., 1991. The effect of habitat structure on the spatial distribution of freshwater invertebrate populations. In Bell S.S., McCoy E.D., Mushinsky H.R., *Habitat Structure*. Dortrecht: Springer.

Dreyer, W. & Franke, U., 1987. *Die Libellen. Ein Bildbestimmungsschlüssel für alle Libellenarten Mitteleuropas und ihre Larven*, Hildesheim: Gerstenberg Verlag.

Dvořák, J., 1969. Horizontal Zonation of Macrovegetation, Water Properties and Macrofauna in a Littoral Stand of Glyceria aquatica (L.) Wahlb. in a Pond in South Bohemia. *Hydrobiologia*, 35, pp.17–30.

Dvořák, J. & Bestz, E.P.H., 1982. Macro-invertebrate communities associated with the macrophytes of Lake Vechten: structural and functional relationships. *Hydrobiologia*, 95(1), pp.115–126.

Eckey, H.-F., Kosfeld, R. & Türck, M., 2005. *Deskriptive Statistik*, Wiesbaden: Betriebswirtschaftlicher Verlag Dr. Th. Gabler/GWV Fachverlage GmbH.

Edinger, M., 2009. *Comparison of the water quality status of selected wetlands in the Danube river basin*. Vienna: University of Vienna.

Elliot, J. M., 1977. Some methods for the statistical analysis of samples of benthic invertebrates. *Freshwater Biological Association*, 25, pp.1-160.

Engel, J., 1997. Signifikante Schule der schlichten Statistik. Fürth: Filander Verlag GmbH.

Eiseler, B., 2010. *Taxonomie für die Praxis. Bestimmungshilfen - Makrozoobenthos (1). LANUV-Arbeitsblatt 14*, Recklinghausen: Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen.

Eiseler, B. & Hess, M., 2013. *Taxonomie für die Praxis. Bestimmungshilfen - Makrozoobenthos (2). LANUV-Arbeitsblatt 20*, Recklinghausen: Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen.

Ellenberg, H., 1996. *Vegetation Mitteleuropas mit den Alpen in ökologischer, dynamischer und historischer Sicht*, Stuttgart: Eugen Ulmer GmbH & Co.

Ervin, G.N. & Wetzel, R.G., 2003. An ecological perspective of allelochemical interference in land - water interface communities. *Plant and Soil*, 256, pp.13–28.

European Commission, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities L327*, p.72.

Foeckler, F., 1990. Charakterisierung und Bewertung von Augewässern des Donauraums Straubing durch Wassermolluskengesellschaften. *Bericht Bayrische Akademie für Naturschutz und Landschaftspflege, Bericht 7*, 7, p.154.

Funk, A. & Reckendorfer, W., 2014. *Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donau-Auen). Auen-Habitat-Index: Makrozoobenthos und Beurteilung Untere Lobau*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Geldiay, R., 1956. Studies on Local Populations of the Freshwater Limpet Ancylus fluviatilis Muller. *Journal of Animal Ecology*, 25(2), pp.389–402.

Glöer, P., 2015. *Süßwassermollusken. Ein Bestimmungsschlüssel für die Muscheln und Schnecken im Süßwasser der Bundesrepublik Deutschland* 14th ed., Göttingen: Deutscher Jugendbund für Naturbeobachtung (DJN).

Grabherr, G. & Mucina, L., 1993. *Die Pflanzengesellschaften Österreichs Teil II*, Jena: Gustav Fischer Verlag.

Grabherr, G., Mucina, L. & Ellmauer, T., 1993. *Die Pflanzengesellschaften Österreichs. Teil I*, Jena: Gustav Fischer Verlag.

Graf, W. et al., 2013. Das Makrozoobenthos als Indikatorgruppe zur Bewertung großer Flüsse unter Einbeziehung auenökologischer Aspekte. *Österreichische Wasser- und Abfallwirtschaft*, 65, pp.386–399.

Graf, W. et al., 2012. *Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donauauen). Erhebung der Trichoptera 2011*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Graf, W. et al., 2016. *Script "Ecology of benthic invertebrates - Determination keys (Screening level),"* Vienna: University of Natural Resources and Life Sciences, Institute of Hydrobiology and Aquatic Ecosystem Management.

Graf, W. & Chovanec, A., 2016. *Entwicklung eines WRRL-konformen Bewertungssystems für Auen grosser Flüsse auf Basis des Makrozoobenthos unter besonderer Berücksichtigung der Donau*, Wien: Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft.

Graf, W., Leitner, P. & Hohensinner, S., 2013. *Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donau-Auen). Erhebung der Trichoptera 2012*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Gross, E.M. & Kornijów, R., 2002. Investigations on competitors and predators of herbivorous aquatic Lepidoptera (Acentria ephemerella) on submersed macrophytes in a large prealpine lake. *Verhandlungen des Internationalen Verein Limnologie*, 28, pp.721–725.

Haidvogl, G. et al., 2009. Flusslandschaften im Wandel. In B. Egger, G., Michor, K., Muhar, S., Bednar, *Flüsse in Österreich. Lebensadern für Mensch, Natur und Wirtschaft*. Innsbruck, Wien, Bozen: StudienVerlag, pp. 32–43.

Hann, B.J., 1995. Invertebrate associations with submersed aquatic plants in a prairie wetland. *UFS (Delta Marsh) Annual Report*, 30, pp.78–84.

Hanson, J.M., 1990. Macro-invertebrate size distributions of two contrasting macrophyte communities. *Freshwater Biology*, 24, pp.481–491.

Hartung, J. & Elpelt, B., 1999. *Multivariate Statistik*, München, Wien.

Heck Jr., K.L. & Crowder, L.. B., 1991. Habitat structure and predator—prey interactions in vegetated aquatic systems. In H. Bell, S., McCoy, E., Mushinsky, *Habitat Structure*. Dordrecht: Springer, pp. 281–299.

Heidemann, H. & Seidenbusch, R., 2002. *Die Libellenlarven Deutschlands*, Keltern: Verlag Goecke & Evers.

Hein, T., 2006. Hydrochemische Voruntersuchung im Maßnahmengebiet Untere Lobau. *Wissenschaftliche Reihe Nationalpark Donau-Auen*, 16, pp.1–48.

Higler, L.W.G. & Verdonschot, P.F.M., 1989. Macroinvertebrates in the Demmerik ditches (The Netherlands): The role of environmental structure. *Hydrobiological Bulletin*, 23(2), pp.143–150.

Hill, M.O., 1973. Reciprocal averaging: an eigenvector method of ordination. *Journal of Ecology*, 61, pp.237–249.

Hill, M.O. & Gauch, H.G., 1980. Detrended correspondence analysis: an improved ordination technique. *Vegetatio*, 42, pp.47–58.

Hohensinner, S., 2008. *Rekonstruktion ursprünglicher Lebensraumverhältnisse der Fluss-Auen-Biozönose der Donau* *im Machland auf Basis der morphologischen Entwicklung von 1715 - 1991*. Wien: Universität für Bodenkultur, Institut für Hydrobiologie und Gewässermanagement.

Hohensinner, S. et al., 2011. Spatio-Temporal Habitat Dynamics In A Changing Danube River Landscape 1812–2006. *River Research & Applications*, 27(8), pp.939–955.

Hohensinner, S. et al., 2008. Type-specific reference conditions of fluvial landscapes : A search in the past by 3D-reconstruction. *Catena*, 75, pp.200–215.

Hutchinson, G.E., 1957. Concluding Remarks. *Cold Spring Harbor Symposium on Quantitative Biology*, 22, pp.415–427.

IBM Director of Licensing, IBM Corporation, 2011. *IBM SPSS Decision Trees 20*, New York.

IUCN - The World Conservation Union, 1994. *Resolutions and Recommendations*, Buenos Aires: IUCN Communication Divisons.

Jacobsen, D. & Sand-Jensen, K., 1992. Herbivory of invertebrates on submerged macrophytes from Danish freshwaters. *Freshwater Biology*, 28(3), pp.301–308.

Jäger, B., 2013. *River floodplain habitats and their aquatic macrophyte vegetation: biodiversity and conservation status defined by connectivity*. Vienna: University of Vienna.

Jäger, E.J. & Werner, K., 2005. *Rothmaler - Exkursionsflora von Deutschland, Bd. 4, Gefäßpflanzen: Kritischer Band.* 10.Auflage ed., Berlin-Heidelberg: Spektrum Akademischer Verlag.

Jeppesen, E. et al., 1998. *The structuring role of submerged macrophytes in lakes*. New York, Berlin, Heidelberg: Springer Verlag.

Jones, J.I. et al., 1999. Do submerged aquatic plants influence their periphyton to enhance the growth and reproduction of invertebrate mutualists? *Oecologia*, 120, pp.463–474.

Jorga, W. & Weise, G., 1979. Zum Bioindikationswert submerser Makrophyten und zur Rückhaltung von Wasserinhaltsstoffen durch Unterwasserpflanzen in langsam fließenden Gewässern. *Acta hydrochimica et hydrobiologica*, 7, pp.43–76.

Junk, W.J., Bayley, P.B. & Sparks, R.E., 1989. The flood pulse concept in river-floodplain systems. In P. Dodge, *Proceedings of the International Large River Symposium*. pp. 110–127.

Keast, A., 1984. The introduced aquatic macrophyte, Myriophyllum spicatum, as a habitat for fish and their invertebrate prey. *Canadian Journal of Zoology*, 62, pp.1289–1303.

Klein, R., 1984. Einfluß der Gewässergüte und der Wasservegetation von Calopteryx splendens Harris, Platycnemis pennipes Pall. und Ischnura elegans v.d.L. an sauerländischen Fließgewässern. *Libellula*, 3(3/4), pp.7–17.

Kornijów, R. & Gulati, R.D., 1992. Macrofauna and its ecology in Lake Zwemlust, after biomanipulation. II.Fauna inhabiting hydrophytes. *Archiv für Hydrobiologie*, 123(3), pp.349–359.

Krausch, H., 1996. *Farbatlas Wasser- und Uferpflanzen*, Stuttgart: Eugen Ulmer GmbH & Co.

Krecker, F.H., 1939. A Comparative Study of the Animal Population of Certain Submerged Aquatic Plants. *Ecology*, 20(4), pp.553–562.

Kruskal, J.B., 1964. Multidimensional scaling by optimizing goodness of fit to a non-metric hypothesis. *Psychometrika*, 29, pp.1–27.

Kufikowski, T., 1974. The phytophilous fauna of the dam reservoir at Goczalkowice. *Acta hydrobiologia Krakow*, 16, pp.189–207.

Lazowski, W., 1997. *Auen in Österreich. Vegetation, Landschaft und Naturschutz*, Wien: Umweltbundesamt.

Linhart, J., 1999. Phytophilous macrofauna in the Stratiotes aloides vegetation of the Lake Łukie, Poland. *Biologica*, 37, pp.67–76.

Lodge, D.M., 1991. Herbivory on freshwater macrophytes. *Aquatic Botany*, 41, pp.195–224.

MacArthur, R.H. & MacArthur, J.W., 1961. On Bird Species Diversity. *Ecology*, (3), pp.594–598.

McCune, B. & Mefford, M.J., 2006. Multivariate Analysis of Ecological Data.

Moog, O. et al., 2001. *Aquatische Ökoregionen und Fließgewässer-Bioregionen Österreichs - eine Gliederung nach geoökologischen Milieufaktoren und Makrozoobenthos-Zönosen*, Wien: Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wasserwirtschaftskataster.

Moog, O., 2002. *Fauna Aquatica Austriaca, Lieferung 2002.* Wien: Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wasserwirtschaftskataster.

Nanson, G.C. & Croke, J.C., 1992. A genetic classification of floodplains. *Geomorphology*, 4(6), pp.459–486.

Nanson, G.C. & Knighton, D.A., 1996. Anabranching rivers: their cause, character and classification. *Earth Surface Processes and Landforms*, 21, pp.217–239.

Nesemann, H., 1997. *Egel und Krebsegel Österreichs*, Rankweil: Erste Vorarlberger Malakologische Gesellschaft.

Nienhuis, P.H., 2008. *Environmental History of the Rhine-Meuse Delta: An ecological story on evolving human-environmental relations coping with climate change and sea-level rise*, Nijmengen: Springer Science + Business Media B.V..

Niklfeld, H. & Schratt-Ehrendorfer, L., 1999. Rote Liste gefährdeter Farn- und Blütenpflanzen (Pteridophyta und Spermatophyta) Österreichs. 2. Fassung. In *Rote Listen gefährdeter Pflanzen Österreichs. 2. Auflage. Grüne Reihe des Bundesministeriums für Umwelt, Jugend und Familie, Band 10.* Graz: Austria Medien Service, pp. 33–152.

Oberdorfer, E., 2001. *Pflanzensoziologische Exkursionsflora für Deutschland und angrenzende Gebiete*, Stuttgart: Eugen Ulmer GmbH & Co.

Pall, K. et al., 2013. *Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donauauen). C.8.3 Makrophyten Biomasseerhebung. Abschätzung der Makrophytenbiomasse in den Gewässern der Unteren Lobau im Jahr 2012*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Pall, K. et al., 2014. *Ökologie. Fachbericht Makrophyten*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Pall, K. & Kum, G., 2006. Die Makrophytenvegetation in der Unteren Lobau – Voruntersuchungen. *Wissenschaftliche Reihe Nationalpark Donau-Auen*, 3, pp.1–90.

Pall, K., Mayerhofer, V. & Mayerhofer, S., 2011. *Dotation Lobau. Abschnitt Untere Lobau. Beweissicherung 2010*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Papas, P., 2007. *Effect of macrophytes on aquatic invertebrates – a literature review*, Melbourne.

Phiri, C., Chakona, A. & Day, J.A., 2012. Macroinvertebrates associated with two submerged macrophytes, Lagarosiphon ilicifolius and Vallisneria aethiopica, in the Sanyati Basin, Lake Kariba, Zimbabwe: effect of plant morphological complexity. *African Journal of Aquatic Science*, 37(3), pp.277–288.

Poff, N.L., 1997a. Landscape Filters and Species Traits : Towards Mechanistic Understanding and Prediction in Stream Ecology. *North American Benthological Society*, 16(2), pp.391–409.

Poff, N.L., 1997b. Landscape filters and species traits: towards mechanistic understanding and prediction in stream ecology. *J. N. Am. Benthol. Soc.*, 16, pp.391–409.

Pühringer, C. et al., 2015. *Auenstrategie für Österreich 2020+*, Wien: Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft.

Qazar, I.A.A., 2016. The relationship between aquatic macrophytes and some gastropoda (snails) in the lower reaches of Hammar marsh. *Mesopotamio Environmental Journal*, 2(4), pp.23–32.

Rabitsch, W., 2005. *Spezialpraktikum Aquatische und Semiaquatische Heteroptera*, Wien.

Reckendorfer, W., Funk, A. & Teuffl, B., 2012. *Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donau-Auen). Erhebung des Makrozoobenthos 2011*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Rennie, M.D. & Jackson, L.J., 2005. The influence of habitat complexity on littoral invertebrate distributions : Patterns differ in shallow prairie lakes with and without fish. *Canadian Journal of Fisheries and Aquatic Sciences*, 62, pp.2088–2099.

Riedler, P. et al., 2013. *Limnologisches Monitoring Untere Lobau und Beweissicherung Dotation Lausgrund*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Rooke, J.B., 1984. The invertebrate fauna of four macrophytes in a lotic system. *Freshwater Biology*, 14(5), pp.507–513.

Sandilands, K.A. & Hann, B.J., 1996. Effect of fish and submersed macrophytes on the abundance of zooplankton in a prairie wetland. *UFS (Delta Marsh) Annual Report*, 31, pp.58–62.

Schmidt-Kloiber, A. & Hering, D., 2015. www.freshwaterecology.info - an online tool that unifies, standardises and codifies more than 20,000 European freshwater organisms and their ecological preferences. *Ecological Indicators 53*, pp.271–282.

Schöll, F. et al., 2012. Conceptual paper on large river assessment. *XGIG Large River Intercalibration*, pp.41–43.

Schönborn, W., 1992. *Fließgewässerbiologie*, Jena: Gustav Fischer Verlag.

Schulze, C.H. & Schneeweihs, S., 2013. *Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donau-Auen). Auenhabitatindex: Die Libellen (Odonata) der Unteren Lobau - Erhebungen aus dem Jahr 2012*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Schulze, C.H. & Schneeweihs, S., 2013. *Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donau-Auen). Wissenschaftliche Beweissicherung Lausgrund: Erhebung der Libellen 2012*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Secretariat of the Convention on Biological Diversity, 2017. Convention on Biological Diversity. Available at: https://www.cbd.int/secretariat/ (04.03.2018).

Smock, A. & Stoneburner, D.L., 1980. The response of macroinvertebrates to aquatic macrophyte decomposition. *Oikos*, 35, pp.397–403.

Soszka, G.J., 1975. The invertebrates on macrophytes in three Masurian lakes. *Ekologia Polska*, 23, pp.371–391.

Stark, G., 2001. *Überprüfung von Bezugsgrößen zur Quantifizierung der Makrozoobenthos-Besiedelung von Makrophyten*, Wien: Universität für Bodenkultur, Institut für Hydrobiologie und Gewässermanagement.

Stiftung Natur und Umwelt Rheinland-Pfalz, 2017. Sumpf-Vergissmeinnicht Steckbrief. *Stiftung Natur und Umwelt Rheinland-Pfalz*.

Strayer, D.L. et al., 2003. Invertebrate communities associated with a native (Vallisneria americana) and an alien (Trapa natans) macrophyte in a large river. *Freshwater Biology*, 48, pp.1938–1949.

Tachet, H. et al., 2000. *Invertébrés d'eau douce, systématique, biologie, écologie*, Paris: CNRS Éditions.

Taniguchi, H., Nakano, S. & Tokeshi, M., 2003. Influences of habitat complexity on the diversity and abundance of epiphytic invertebrates on plants. *Freshwater Biology*, 48, pp.718–728.

The Ramsar Convention Secretariat, 2017. Ramsar Convention. Available at: https://www.ramsar.org/the-ramsar-secretariat (04.03.2018).

Thomaz, S.M. et al., 2008. Influence of aquatic macrophyte habitat complexity on invertebrate abundance and richness in tropical lagoons. *Freshwater Biology*, 53, pp.358–367.

Timms, B. V, 1981. Animal communities in three Victorian lakes of different salinities. *Hydrobiologia*, 81, pp.181–193.

Tockner, K. & Stanford, J.A., 2002. Riverine Flood Plains: Present State and Future Trends. *Environmental Conservation*, 29(3), pp.308–330.

Trajanovski, S. et al., 2016. Macrophyte vegetation as a structuring factor of the macrozoobenthic communities in Lake Ohrid. *Botanica Serbica*, 40(2), pp.145–151.

Vallenduuk, H.J. & Cippen, H.M.J., 2004. The aquatic living caterpillars (Lepidoptera: Pyraloidea: Crambidae) of Central Europe. A key to the larvae and autecology. *Lauterbornia*, 49, pp.1–17.

Van den Brink, F.W.B., Van der Velde, G. & Wijnhoven, S., 2013. Diversity, occurrence and feeding traits of caddisfly larvae as indicators for ecological integrity of river-floodplain habitats along a connectivity gradient. *Ecological Indicators*, 25, pp.92–98.

Verdonschot, R.C.M., Didderen, K. & Verdonschot, P.F.M., 2012. Importance of habitat structure as a determinant of the taxonomic and functional composition of lentic macroinvertebrate assemblages. *Limnologica*, 42, pp.31–42.

Walker, P.D., Wijnhoven, S. & Van der Velde, G., 2013. Macrophyte presence and growth form influence macroinvertebrate community structure. *Aquatic Botany*, 104, pp.80–87.

Ward, J.V. & Stanford, J.A., 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. *Regulated Rivers: Research & Management*, 11, pp.105–119.

Waringer, J. et al., 2005. The Floodplain Index - habitat values and indication weights for molluscs, dragonflies, caddisflies, amphibi-ans and fish from Austrian Danube floodplain waterbodies. *Lauterbornia*, 54, pp.177–186.

Waringer, J. & Graf, W., 2011. *Atlas der mitteleuropäischen Köcherfliegenlarven/Atlas of Central European*

Trichoptera Larvae., Dinkelscherben: Erik Mauch Verlag.

Waringer, J. & Graf, W., 2002. Trichoptera communities as a tool for assessing the ecological integrity of Danubian floodplains in Lower Austria. In W. Mey, *Proceedings of the 10th International Symposium on Trichoptera*. Nova Supplementa Entomologica, pp. 617–625.

Weigand, E., 1994. Lebensraum Phytal - Zur Ökologie der Biozönose submerser Makrophytenbestände in einem Donaustauraum (Altenwörth, Österreich). *Wissenschaftliche Mitteilungen Niederösterreichisches Landesmuseum*, 8, pp.91–109.

Weigand, E., 1996. *Ökologische Studie über den Lebensraum Phytal in einem Donaustauraum (Altenwörth, Österreich) unter besonderer Berücksichtigung der epiphytischen Fauna*. Wien: Universität Wien.

Weigelhofer, G. et al., 2014. *Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donau-Auen). ÖKOLOGIE - Fachbericht Makrozoobenthos*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Weigelhofer, G., Preiner, S. & Hein, T., 2014. *Fachbericht Wasserqualität Oberflächengewässer (Lobaugewässer). Bericht zum Projekt Gewässervernetzung (Neue) Donau - Untere Lobau (Nationalpark Donau-Auen).*, Wien: Magistratsabteilung 45 - Wiener Gewässer.

Zbikowski, J., Kobak, J. & Zbikowska, E., 2010. Is Nuphar lutea (L.) Sm. a structuring factor for macrozoobenthos and selected abiotic parameters of water and bottom sediments throughout the year? *Aquatic Ecology*, 44, pp.709–721.

Zimmer, K.D., Hanson, A.M. & Butler, M.G., 2000. Herbivory on freshwater macrophytes. *Canadian Journal of Fisheries and Aquatic Science*, 57, pp.76–85.

List of figures

List of tables

Appendix

Invertebrate taxa and abundance list summer

Table 30: Invertebrate taxa and abundances in June 2016.

	Study site 1			Study site 2			Study site 3							Study site 4										
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
TURBELLARIA																								
Turbellaria Gen. sp.				5							1			22	27		1						1	
GASTROPODA																								
Acroloxus lacustris (LINNAEUS, 1758)														3	2									
Bithynia tentaculata (LINNAEUS, 1758)				40	4	27	3		13	1				65	54	59	3	7	1	33	9	1		
Potamopyrgus antipodarum (GRAY, 1843)									1															
Radix ovata/peregra	1	1	3	4	9													1			1			
Radix sp. juv. MONTFORT, 1810									1															
Stagnicola sp. JEFFREYS, 1830												1				1								
Physidae Gen. sp. FITZINGER, 1833		4	7	1							2													
Anisus sp. STUDER, 1820																		2		2				
Gyraulus crista (LINNAEUS, 1758)				14	32	3				3				5	16	8			1	3	1			

Gyraulus laevis/parvus				40	33	42	17	20	32	28		2		15	15	5	5	19	1	9	20		1	
Planorbarius corneus (LINNAEUS, 1758)															3	1								
Planorbidae Gen. sp. juv. RAFINESQUE, 1815		2	6	77	139	44	2	4	16	40	3	1	1	30	61	22	20	36		40	32	1	7	8
Planorbis carinatus O.F. MÜLLER, 1774														2	5	1	1				4			
Planorbis planorbis (LINNAEUS, 1758)			2										1		4	1								
Planorbis sp. juv. O.F. MÜLLER, 1774														2	5			5			4			
Valvatidae Gen. sp. juv. GRAY, 1840														23	105	12			1	11	4	3	1	
Valvata piscinalis spp.				67	69	56																		
BIVALVIA																								
Musculium lacustre (O.F. MÜLLER, 1774)					5	1																		
Pisidium casertanum spp.														9										
Pisidium sp. juv. PFEIFFER, 1821			1	2		2											1			7				
Pisidium subtruncatum MALM, 1855															30	2								
OLIGOCHAETA																								
Oligochaeta Gen. sp.	87	75	512	157	541	360	1		30		2	4	6	162	10	18	36	95		172	66			9
Eiseniella tetraedra (SAVIGNY, 1826)					1	2								3	19					2				
Stylaria lacustris	55	81	151	411	533	2								438	968	395	75	244	80	605	338	50	225	16

(LINNAEUS, 1767)																								
HIRUDINEA																								
Erpobdella octoculata (LINNAEUS, 1758)		1	2	31	68	41	11	4	33	16	4	3	5	2	7		6		1					
Alboglossiphonia hyalina (O.F. MÜLLER, 1774)		1	1	1			3	1	12	8	1	1												
Alboglossiphonia sp. juv.		1	1	1		1	1																	
Helobdella stagnalis (LINNAEUS, 1758)					4																			
Glossiphonia concolor (APATHY, 1883)			1		1																			
Glossiphonia sp. juv.				1						1													1	
Piscicolidae Gen. sp.					3	2																		
CRUSTACEA																								
Argulus sp.						1																		
Asellus aquaticus (LINNAEUS, 1758)				1	14	18				3	1			16	15	3			1	8	3	2		
Corophium sp. LATREILLE, 1806			2																					
Gammaridae Gen. sp. juv.																		5						
Jaera istri (VIEUILLE, 1979)													1											
Limnomysis benedeni CZERNIAWSKI, 1882		2																						
EPHEMEROPTERA																								
Baetis bucertus/nexus														1										
Baetis sp. juv.														1	2	3				2				

Centroptilum luteolum (MÜLLER, 1776)																				2	1			
Centroptilum/Cloeon sp. juv.			2										4											
Cloeon dipterum (LINNAEUS, 1761)	2	4	1	32	4	35	18	13	31	44	6	4	2		1	1								
Caenis sp. juv.				2	5	3			2	39													2	
Serratella ignita (PODA, 1761)														5	3	1				1	1			
Habrophlebia cf. fusca (CURTIS, 1834)																						1		
ODONATA																								
Zygoptera Gen. sp. juv.			1	4		6	1	1				2								2				
Coenagrionidae Gen. sp. juv.		1	1											1				1			1		1	
Aeshnidae Gen. sp. juv.					1																			
Aeshna cf. cyanea (MÜLLER, 1764)																				1				
Somatochlora metallica (VAN DER LINDEN, 1825)				1																				
Lestidae Gen. sp. juv.				8	2	7																		
Lestes virens (CHARPENTIER, 1825)																						2		
Sympecma fusca (VAN DER LINDEN, 1820)				1	1	2		1	1															
Libellulidae Gen. sp. juv.														1	1									
Sympetrum sanguineum (MÜLLER, 1764)				1						1				2	1									
HETEROPTERA																								

Corixidae Gen. sp.				48	3	34				2														
Ilyocoris cimicoides spp.	2	4	15							2	3	11	4						1			1		
Plea minutissima spp.				1			2	1	1	34	2	9	2											
COLEOPTERA																								
Chrysomelidae Gen. sp. Ad.			1																					
Dryopidae Gen. sp. Ad.											1													
Dryops sp. Lv.															2									
Dytiscidae Gen. sp. Lv.		2		24	8	21	7	8	20	19	3	2	5		1		1	2						
Haliplus sp. Ad.								1		1														
Haliplus sp. Lv.				50	9	20	2	1	5	40				1	1						2			
Peltodytes caesus Lv. (DUFTSCHMID, 1805)				1			1			2													1	
Hydraena sp. Ad.													1											
Hydrophilidae Gen. sp. Ad.											1			1										
Hydrophilidae Gen. sp. Lv.	3	2	13		1	1					1	2	6	1	2								1	
TRICHOPTERA																								
Hydropsyche angustipennis spp.														4	18	21			2	1		2		
Hydroptilidae Gen. sp. juv.														2	3			2				1	1	
Agraylea multipunctata CURTIS, 1834														1	1					5	1			
Agraylea sexmaculata CURTIS, 1834									1							1		1			1			
Hydroptila sp.														8	4	2			1					
Leptoceridae Gen. sp. juv.				4						1				1	1									
Mystacides azurea/nigra														1										

Oecetis furva (RAMBUR, 1842)				3	1	1																		
Oecetis lacustris (PICTET, 1834)					4	15																		
Oecetis sp. juv.				2	3																			
Oecetis testacea (CURTIS, 1834)				8		1																		
Triaenodes bicolor (CURTIS, 1834)										2														
DIPTERA																								
Brachycera Gen. sp.		1																					1	
Ceratopogonidae Gen. sp.	1		8	5			3			9	1		3	11	19	2	3							
Chaoborus crystallinus (DE GEER, 1776)				24	8	1	2			1														
Stratiomyidae Gen. sp.	2		3							2	2	5	12		1									
Tabanidae Gen. sp.					1																			
LEPIDOPTERA																								
Acentria ephemerella (DENIS & SCHIFFERMÜL-LER, 1775)				5	7				1								1	1						
Elophila nymphaeata/rivulalis																							1	
Parapoynx stratiotata (LINNAEUS, 1758)																	2	4	1					
ACARI																								
Hydrachnidia Gen. sp.				3	7	3	1	1	1	1	1	1		5	12	3	2	2			6			

Invertebrate taxa and abundance list autumn

Table 31: Invertebrate taxa and abundances in October 2016.

	Study site 1			Study site 2			Study site 3									Study site 4								
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
TURBELLARIA																								
Turbellaria Gen. sp.			1													124	103	117	84	87	68	17	13	15
GASTROPODA																								
Acroloxus lacustris (LINNAEUS, 1758)			3													1	2	3	4	1	4			3
Bithynia tentaculata (LINNAEUS, 1758)																2	2	3			3	1		1
Radix auricularia (LINNAEUS, 1758)				1	2																			
Radix ovata/peregra		3	1	2	3	1			1	1			2	1	1			1		2	1			
Radix sp. juv. MONTFORT, 1810				6	14																			
Physidae Gen. sp. FITZINGER, 1833	2	2	4			1					1													
Ancylus fluviatilis O.F. MÜLLER, 1774	4	4															2							
Anisus sp. STUDER, 1820																11	7	16	19	41	214	19	9	9
Gyraulus crista (LINNAEUS, 1758)					5											1		3	2	2	2			1
Gyraulus laevis/parvus					15			4	5	1	2	3				2	2	5	6	5	8	7	6	10
Planorbarius corneus (LINNAEUS, 1758)																				1				
Planorbidae Gen. sp. juv. RAFINESQUE, 1815				1	13	1				1		6				1			8	7	22	10	4	3
Planorbis carinatus O.F. MÜLLER, 1774																2	1	1	2	2	5	2		3
Planorbis planorbis																								

(LINNAEUS, 1758)																								
Segmentina nitida FLEMING, 1818																								1
Valvatidae Gen. sp. juv. GRAY, 1840																1	6		1	2	1		5
Valvata piscinalis spp.															15		6						10
BIVALVIA																								
Pisidium nitidum JENYNS, 1832															1									
Pisidium sp. juv. PFEIFFER, 1821															3	2								
Pisidium subtruncatum MALM, 1855																	13						2
OLIGOCHAETA																								
Oligochaeta Gen. sp.	3		5		142	200	68	111	8		2		2	3		25			34	17	16	34	17	13
Stylaria lacustris (LINNAEUS, 1767)	1	4	2		1											28	20	13	108	67	110	63	28	28
HIRUDINEA																								
Erpobdella octoculata (LINNAEUS, 1758)					5				2	1	2		1		1	1						3	5	1
Alboglossiphonia sp. juv.					1				1											1				
Piscicolidae Gen. sp.			1															1	6	4	1		4	4
CRUSTACEA																								
Asellus aquaticus (LINNAEUS, 1758)									2			3				3	1	1						1
Gammaridae Gen. sp. juv.																					1			
Jaera istri (VIEUILLE, 1979)																				1				
EPHEMEROPTERA																								
Baetis lutheri/vardarensis																			2	1				1
Baetis bucertus/nexus																	1						1	
Baetis sp. juv.									2		1			1		1			4	3	1	2	6	5
Centroptilum/Cloeon sp. juv.								4					5		10					10				1

Cloeon dipterum (LINNAEUS, 1761)	16	41	24	100	662	128	246	64	50	177	85	630	20	20	30	12		10	10	12	10	14	1	1
Caenis horaria (LINNAEUS, 1758)																2	2	9	6	1	18	10	2	8
Caenis luctuosa (BURMEISTER, 1839)																2	2	5	2	2	17	8		5
Caenis robusta EATON, 1884					10	1		1	85	35	5	17	1	1		2		1						
Caenis sp. juv.	1				2				145	33	3	12	1			13		21	8		18	8	2	2
Paraleoptophlebia sp.																1								
ODONATA																								
Zygoptera Gen. sp. juv.			1	1	3	1	5	7	3	46	36	77	1				2	1						
Coenagrionidae Gen. sp. juv.	3	2	4	7	63	10	4	4	14	35	24	38	4	1				5	8	2	1	1		2
Coenagri-onidae/Platycnemidae Gen. sp.				2	141	7	6	7	6	136	75	183	4	1			2	4			2	2	1	
Aeshnidae Gen. sp. juv.												1												
Aeshna cf. cyanea (MÜLLER, 1764)					1				1	1		5			1					1				
Gomphus vulgatissimus (LINNAEUS, 1758)																		3						
Corduliidae/Libellulidae Gen. sp.						1												1			1	1		
Calopteryx splendens (HARRIS, 1782)																	2	18	10	10	2	9	6	8
HETEROPTERA																								
Gerris argentatus SCHUMMEL, 1832														1										
Notonecta glauca spp.				1					1											3				
Ranatra linearis (LINNAEUS, 1758)						1																		
Corixidae Gen. sp.	3		1		1					2														
Ilyocoris cimicoides spp.							1					2												
Plea minutissima spp.											1	3		1	1									

COLEOPTERA																								
Dryops sp. Lv.																	1							
Dytiscidae Gen. sp. Ad.															1									
Dytiscidae Gen. sp. Lv.											1									1				
Platambus maculatus Ad. (LINNAEUS, 1758)																1								
Haliplus sp. Ad.						1					2													
Haliplus sp. Lv.				5	2			2	4															
Peltodytes caesus Ad. (DUFTSCHMID, 1805)						1						1												
Peltodytes caesus Lv. (DUFTSCHMID, 1805)				1															2					
Oulimnius sp. Lv.															1	2								
TRICHOPTERA																								
Trichoptera Gen. sp. juv.							1	2			36										1	3		
Hydropsyche angustipennis spp.															17	5	9	2	1		6	4	22	
Hydroptilidae Gen. sp. juv.				1	1	1		1			1				14		3			10	6	9	18	
Agraylea sexmaculata CURTIS, 1834			1	4	4		1			1										1				
Hydroptila sp.															2	1			8	5		1		
Orthotrichia sp.											1				1		1	2	1					
Oxyethira flavicornis (PICTET, 1834)								5							200	79	146	306	331	182	338	336	516	
Ecnomus tenellus (RAMBUR, 1842)																	1							
Leptoceridae Gen. sp. juv.																				14			1	
Athripsodes cinereus (CURTIS, 1834)															4		6			1	1			
Athripsodes sp. juv.															8	1		1					1	
Mystacides azurea/nigra																					4	1	1	
Mystacides sp.															1		9	1				2		

Oecetis sp. juv.					1	2			1	18		3									1			
Oecetis testacea (CURTIS, 1834)																		1		3		3		
Triaenodes bicolor (CURTIS, 1834)										1		3				17				1				
Agrypnia varia FABRICIUS, 1793									1	1		28												
Lype sp. juv.																1		1		1	1	1		
DIPTERA																								
Brachycera Gen. sp.		1					1													2				
Nematocera Gen. sp.																								1
Ceratopogonidae Gen. sp.	1		6		4			1	16	2		3	2		2	1		3		2			2	
Chaoborus crystallinus (DE GEER, 1776)				1						2														
Anopheles maculipennis MEIGEN, 1818												1							1					
Stratiomyidae Gen. sp.																								
Tabanidae Gen. sp.									1															
Dixidae Gen. sp.															1					1				
Empididae Gen. sp.																11	1	16	2	3	13	4	4	1
Limoniidae/Pediciidae Gen. sp.																	1							
Tipulidae Gen. sp.																						1		
LEPIDOPTERA																								
Acentria ephemerella (DENIS & SCHIFF-ERMÜLLER, 1775)					1	2														2	1			
Elophila nymphaeata/rivulalis	2	2	1						8				1	2	1	1				1	1			
Parapoynx stratiotata (LINNAEUS, 1758)				4	2	3	6	7	18	9	11	25	1	1			1	1	14	24	7	3	2	1
ACARI																								
Hydrachnidia Gen. sp.	1								2							8	2	12		3	3	7	6	13

Indicator species analysis

Leaf type

Table 32: *Indicator species analysis for the different leaf types in both seasons. Taxa with Indication value >20 and Significance p* <1,00 are shown. Taxa with Significance <0,05 are highlighted grey. Leaf types: 1 – large flat leaved, 2 – small leaved, 3 – pinnate leaved, 4 – mixed leaved (Samples N=48).*

Indicator species	Leaf type	Indication value	p*
HydrGeLv	1	36.3	0.054
Ilyocimi	1	35	0.069
PhysGen.	1	28	0.091
Elopsp.	1	27.2	0.165
StraGen.	1	26.1	0.115
Plancari	2	56.5	0.005
Hypsangu	2	55	0.009
ValvGen.	2	50.4	0.040
Turbella	2	50.1	0.017
Anissp.	2	47.8	0.039
Hydrachn	2	44.1	0.038
Baetsp.	2	43.8	0.021
Oxyesp.	2	43.5	0.016
Caenhora	2	39.1	0.033
EmpiGen.	2	39.1	0.030
Hydtsp.	2	39.1	0.033
HydtGen.	2	38.4	0.068
Caenluct	2	34.8	0.037
Calosple	2	34.8	0.039
Styllacu	2	30.1	0.464
Acrolacu	2	22.6	0.209
Epheigni	2	21.7	0.135
Lypesp.	2	21.7	0.184
Cloedipt	4	77.5	0.003
CoenPlat	4	77.5	0.001
Zygopter	4	71.8	0.003
CoenGen.	4	66.6	0.005
Caenrobu	4	60.9	0.004
Caensp.	4	60.2	0.028
Aeshcyan	4	52.6	0.005
Pleaminu	4	50.8	0.035
Parasp.	4	50.5	0.021
Oecesp.	4	44.8	0.019
Agryvari	4	39.7	0.016
Triabico	4	36.3	0.044

HalispAd	4	34.9	0.019
CeraGen.	4	32.2	0.220
PeltcaLv	4	24.1	0.134
Chaocrys	5	72.7	0.002
PlanGen.	5	65.4	0.006
LestGen.	5	60	0.002
Oecefurv	5	60	0.002
Valvpisc	5	58	0.001
CoriGen.	5	55.8	0.009
Oligocha	5	54.7	0.042
Sympfusc	5	54.1	0.002
Acensp.	5	51.5	0.005
Radiovat	5	49.5	0.021
HalispLv	5	48.7	0.029
Erpoocto	5	47.8	0.080
Gyracris	5	44	0.049
Musclacu	5	40	0.018
Oecelacu	5	40	0.018
Asseaqua	5	38.3	0.091
DytGenLv	5	37.1	0.083
Oecetest	5	34.2	0.034
Bithtent	5	33.1	0.215
Gyralaev	5	32.5	0.304
Pisisp.	5	22.3	0.157
PiscGen.	5	20.7	0.248

Seasons

Table 33: *Indicator species analysis for both seasons. Taxa with Indication value >20 and Significance p* <1,00 are shown. Taxa with Significance <0,05 are highlighted grey. Seasons: 1 – June, 2 – October (Samples N=48).*

Indicator species	Season	Indication value	p*
Bithtent	1	60.2	0.001
Gyracris	1	35.1	0.095
Gyralaev	1	55.9	0.022
PlanGen.	1	81.1	0.000
ValvGen.	1	30.3	0.201
Oligocha	1	61	0.051
Eisetetr	1	20.8	0.049
Styllacu	1	64.3	0.005
Erpoocto	1	62.7	0.002
Albohyal	1	37.5	0.001
Asseaqua	1	44.3	0.015

Epheigni	1	20.8	0.054
Sympfusc	1	20.8	0.049
Ilyocimi	1	35.1	0.012
Pleaminu	1	29.9	0.126
DytGenLv	1	57.4	0.000
HalispLv	1	37.9	0.031
HydrGeLv	1	45.8	0.000
CeraGen.	1	27.1	0.805
StraGen.	1	29.2	0.009
Hydrachn	1	28.9	0.733
Turbella	2	38.2	0.031
Acrolacu	2	35.5	0.010
Radiovat	2	27.1	0.493
Anissp.	2	37.1	0.004
PiscGen.	2	23.6	0.085
Baetsp.	2	31.9	0.053
Cloedipt	2	88.4	0.000
Caenhora	2	37.5	0.002
Caenluct	2	33.3	0.005
Caenrobu	2	45.8	0.000
Caensp.	2	48.7	0.022
Zygopter	2	49.6	0.027
CoenGen.	2	81.2	0.0002
CoenPlat	2	66.7	0.000
Aeshcyan	2	22.7	0.084
Calosple	2	33.3	0.004
Trichopt	2	20.8	0.048
HydtGen.	2	40.3	0.023
Orthsp.	2	20.8	0.052
Oxyesp.	2	41.7	0.002
Oecesp.	2	21	0.185
Lypesp.	2	20.8	0.0508
EmpiGen.	2	37.5	0.002
Elopsp.	2	39.7	0.003
Parasp.	2	75.4	0.000

Study sites/Distance to the Danube river

Table 34: *Indicator species analysis for the different study sites/distances to the Danube river. Taxa with Indication value >20 and Significance p* <1,00 are shown. Taxa with Significance <0,05 are highlighted grey. Study sites: 1 – 0-499m, 2 – 500-999m, 3 - 1000-1499m, 4 – 1500-1999m (Samples N=48).*

Indicator species	Study site	Indication value	p*
PhysGen.	1	71.6	0.000
HydrGeLv	1	36.6	0.046
Ilyocimi	1	34.7	0.052
Acrolacu	1	30.7	0.051
Elopsp.	1	23.4	0.161
Brachyce	1	20.4	0.162
PlanGen.	2	68	0.001
HalispLv	2	66.7	0.001
Chaocrys	2	63.2	0.002
CoriGen.	2	62.7	0.001
Cloedipt	2	59.7	0.049
Acensp.	2	59.3	0.001
Erpoocto	2	53.3	0.030
Gyracris	2	52.5	0.011
LestGen.	2	50	0.002
Oecefurv	2	50	0.002
Radiovat	2	49.4	0.013
Oligocha	2	48.9	0.066
Valvpisc	2	47.7	0.002
Sympfusc	2	42.1	0.009
Gyralaev	2	40.3	0.065
Agrasexm	2	39.7	0.015
Radiauri	2	33.3	0.031
Musclacu	2	33.3	0.026
Oecelacu	2	33.3	0.026
DytGenLv	2	32.8	0.094
Radisp.	2	32.7	0.026
Oecesp.	2	32.2	0.049
Asseaqua	2	31.4	0.141
CoenGen.	2	27.7	0.507
Oecetest	2	27	0.052
Albosp.	2	24.8	0.110
Pleaminu	3	65.7	0.001
Zygopter	3	49	0.047
Caenrobu	3	35.9	0.076
Caensp.	3	31.3	0.310
Albohyal	3	28.7	0.096

Parasp.	3	26	0.372
CoenPlat	3	25.3	0.372
HalispAd	3	25	0.064
ValvGen.	4	70	0.002
Hypsangu	4	70	0.000
Plancari	4	65	0.000
Turbella	4	63	0.002
Anissp.	4	55	0.015
Styllacu	4	48.5	0.037
HydtGen.	4	47.8	0.016
Baetsp.	4	47.1	0.006
Caenhora	4	45	0.010
Hydtsp.	4	45	0.009
EmpiGen.	4	45	0.008
Oxyesp.	4	44.9	0.009
Hydrachn	4	41.8	0.035
Caenluct	4	40	0.016
Calosple	4	40	0.009
Bithtent	4	36.5	0.120
Epheigni	4	25	0.082
Lypesp.	4	25	0.034