

Faunal composition of benthic invertebrates along the river Lafnitz - biodiversity, longitudinal zonation and habitat preferences

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ABSTRACT

In Austria, as in many parts of Europe, most rivers are strongly affected by human impacts with negative effects on habitat and species diversity. The Lafnitz is one of the last near-natural rivers in Austria with meandering stretches and a high diversity of benthic invertebrates.

In order to investigate the distribution patterns of macroinvertebrates in detail, six sampling sites were selected along the river course and per site at least ten single habitat samples were taken along cross-sectional transects. Samples were additionally taken from woody debris accumulations and relevant habitat characteristics such as flow velocity, water depth, distance from shore and substrate type were recorded for each sample. Existing macroinvertebrate data were included to analyse longitudinal zonation and to investigate the fauna associated with woody debris. The results clearly show the influence of the longitudinal gradient on the benthic community. The proportion of shredders and cold-stenotherm species was higher in the upper course, in contrast, the lower course was mainly dominated by grazers and collectors and by mostly warm-stenotherm species. Several species had distinct preferences for flow velocity, however, substrate composition appeared to be the major determinant for species distribution. The effects of increased fine sediment deposition were demonstrated by comparing an unimpacted with an impacted site, resulting in significantly lower individual densities and taxa richness at the silted site. Woody debris accumulations on the other hand contributed substantially to benthic species diversity. The results of this study underline the importance of habitat diversity in running waters as a prerequisite for a high biodiversity.

Key words: benthic macroinvertebrates, Lafnitz, faunal composition, habitat preferences, fine sediment deposition, woody debris

KURZFASSUNG

In Österreich, wie auch in vielen Teilen Europas, sind die meisten Fließgewässer stark von menschlichen Eingriffen geprägt, mit negativen Auswirkungen auf die Habitat- und Artenvielfalt. Die Lafnitz ist einer der letzten, weitgehend naturnah erhaltenen Flüsse in Österreich mit mäandrierenden Flussabschnitten und einer hohen Vielfalt an benthischen Evertebraten. Um die der Benthos-Gemeinschaft in der Lafnitz zu untersuchen, wurden insgesamt sechs Untersuchungsstellen entlang des Flusses ausgewählt und pro Abschnitt mindestens zehn Einzelproben entlang eines Transektes quer zur Fließrichtung entnommen. Zusätzlich wurde auch Totholzansammlungen beprobt und relevante Habitat-Charakteristika wie Fließgeschwindigkeit, Wassertiefe, Entfernung vom Ufer und Substratzusammensetzung erhoben. Bereits vorhandene Makrozoobenthos-Daten wurden für die Analysen der longitudinalen Zusammensetzung der Gemeinschaft, als auch für die Dokumentation der charakteristischen Totholzfauna miteinbezogen. Die Ergebnisse zeigten deutlich den Einfluss des longitudinalen Gradienten auf die benthische Lebensgemeinschaft. Der Anteil an Zerkleinerern und kalt-stenothermen Arten ist im Oberlauf deutlich höher, während im Unterlauf neben Weidegängern vor allem Sammler und zunehmend warm-stenotherme Arten zu finden waren. Einige Arten zeigten klare Fließgeschwindigkeitspräferenzen, jedoch scheint insbesondere die Substratzusammensetzung großen Einfluss auf die Besiedelung durch Evertebraten zu haben. Die Auswirkungen erhöhter Feinsedimentablagerungen konnten anhand des merklichen Rückgangs der Individuendichte und Taxavielfalt in einem beeinträchtigten Flussabschnitt im Vergleich zum nahegelegenen unbeeinträchtigten Abschnitt gezeigt werden. Totholzansammlungen hingegen tragen wesentlich zur Artenvielfalt des Makrozoobenthos in Gewässern bei. Die Resultate dieser Arbeit unterstreichen die Bedeutung der Habitatvielfalt in Fließgewässern als Voraussetzung für eine hohe Biodiversität.

Schlüsselwörter: Makrozoobenthos, Lafnitz, Artenzusammensetzung, Habitatpräferenzen, Feinsedimentablagerungen, Totholz

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1 INTRODUCTION

Freshwater ecosystems cover only around **0.8 % of the Earth's surface**, but support almost 6 % of all described species worldwide, and this combination makes them hotspots for global biodiversity. The disproportionate high diversity is the reason why the declines in species richness, due to human modifications, are considerably higher in inland waters than in terrestrial counterparts (DUDGEON et al., 2006).

Human impacts on surface fresh waters, especially rivers and streams, are diverse and can be divided into: overexploitation, water pollution, flow regulation, destruction or degradation of habitats and invasion by exotic species. Moreover, rivers are open, directional systems, hence downstream assemblages are also affected by upstream processes, including human interventions. The loss of species may heavily affect the functioning of ecosystems, and the goods and services they provide for human societies (e.g. clean water). Fresh water is an essential resource for human livelihood and the conservation of freshwater biodiversity should be an overriding global objective. Benthic invertebrates, for example, are fundamental components of ecosystem integrity and have substantial influence on nutrient cycling, primary production, decomposition and material transport (WALLACE & WEBSTER, 1996; COVICH et al., 2004; DUDGEON et al., 2006 and references therein; DUDGEON, 2012).

The identification of benthic invertebrates and their spatial distribution have long been main targets of stream ecology, starting with observational studies on presence and absence of macroinvertebrates with different oxygen demands at the beginning of the 20th century. Nowadays macroinvertebrates are widely used to assess a variety of environmental pressures and, following the EU Water Framework Directive (WFD), to determine the ecological status of running waters. The benthic community consists of many different species with various morphological adaptations and a broad range of behaviour patterns, reacting in manifold ways to environmental changes, and therefore suitable biological indicators for human degradation of rivers and lakes (CAIRNS & PRATT, 1993; POFF et al., 1997; USSEGLIO-POLATERA et al., 2000; HERING et al., 2003; FINN & POFF, 2005).

The River Continuum Concept (RCC) by VANNOTE et al. (1980) is a well-known, general framework to explain longitudinal alterations in structure and function of the benthic community and related habitat variables in rivers. Shifts in community composition reflect different adaptations along the downstream gradient of e.g. available food resources, water temperature and dominant substrate type. Food particle size decreases downstream from coarse (CPOM) to fine particulate organic matter (FPOM) and correspondingly, the proportion of the four main feeding types (shredders, grazers, collectors and predators) changes. Shredders utilize coarse particles and therefore are most abundant in headwaters,

whereas collectors are dominating in the downstream sections as they feed on smaller food particles.

Water temperature is closely related to the amount of dissolved oxygen and another important habitat characteristic with great influence on the distribution of aquatic organisms due to species-specific environmental tolerances (VANNOTE et al., 1980; QUINN & HICKEY, 1990; DUDGEON et al., 2006; HAIDEKKER & HERING, 2008; DOHET et al., 2014).

The physical habitat structure is mainly determined by the movement of water and sediments, within the channel itself and between the channel and floodplain. Flow and the resulting downstream forces are a great challenge for organisms living in aquatic habitats. On the one hand, flowing water ensures e.g. food and oxygen supply, but on the other hand, the animals have to resist the downstream forces to prevent drifting away from suitable habitats. Macroinvertebrate species are also known to have preferences for different substrate types, but mainly determined by their feeding habits and current tolerance (STATZNER, 1980; POFF et al., 1997; SCHRÖDER et al., 2013).

Human impacts disrupt the natural dynamic equilibrium between hydrologic and morphologic processes within rivers, with affecting the availability and diversity of habitat features, which in turn are limiting distribution and abundance of aquatic species. Most Austrian rivers are hydro-morphologically altered due to human activities, and near-natural river stretches with undisturbed species assemblages are rare (POFF et al., 1997; MUHAR et al., 2000; DOLÉDEC et al., 2007).

Hence, the river Lafnitz in Eastern Austria was chosen, as natural and semi-natural stretches are making up the major part of its course, to investigate faunal composition, longitudinal as well as transectional benthic species distribution and habitat preferences.

1.1 PROJECT BACKGROUND

This master thesis is part of the project “**BIO_CLIC**” for the exploration of the impact of climate change on European river systems and potential mitigation effects of the riparian vegetation. Abiotic and biotic data are collected at different sites along two different Austrian rivers of the Pannonian lowlands (Lafnitz and Pinka). This project aims to develop different climate scenarios for this region, to investigate the influence of the surrounding vegetation on water temperature and to create habitat utilization curves for fish, macroinvertebrates and plants. The results are used to develop tools and guidelines for sustainable river management in terms of climate change and ecosystem services.

1.2 RESEARCH QUESTIONS AND HYPOTHESES

- Does the distribution and abundance of benthic invertebrates change along the longitudinal gradient?

H1: From source to mouth the benthic community changes in structure and function following the downstream shifts in habitat characteristics.

H2: Distinct longitudinal distribution patterns can especially be observed at species level, in contrast to the almost stable community composition at higher taxonomic levels (e.g. family, genus) along the river.

- Are there differences in species composition and abundance within the river cross-section?

H3: Species composition and abundance changes in lateral direction due to different habitat conditions within the river cross-section.

- Are there significant differences in the colonisation of habitats depending on flow velocity and substrate type?

H4: Benthic species have specific preferences for flow velocity and substrate type.

2 METHODS

2.1 STUDY AREA

The river Lafnitz is located in South-Eastern Austria (see figure 1), with its origin in the Eastern Alps near Wenigzell (Styria) and continues as border between Styria and Southern Burgenland before it discharges into the river Rába near Szentgotthárd (Hungary). The altitudinal difference between the source (980 m AMSL) and the mouth (215 m AMSL) is 765 m over a length of approximately 114 km and the catchment size is of almost 2000 km². Numerous natural and near-natural stretches exist along its course, especially between the villages of Neustift and Fürstenfeld, where it is a meandering river. However, this river also exhibits sections influenced by human activities as flood protection measures, small electric power plants and agriculture.

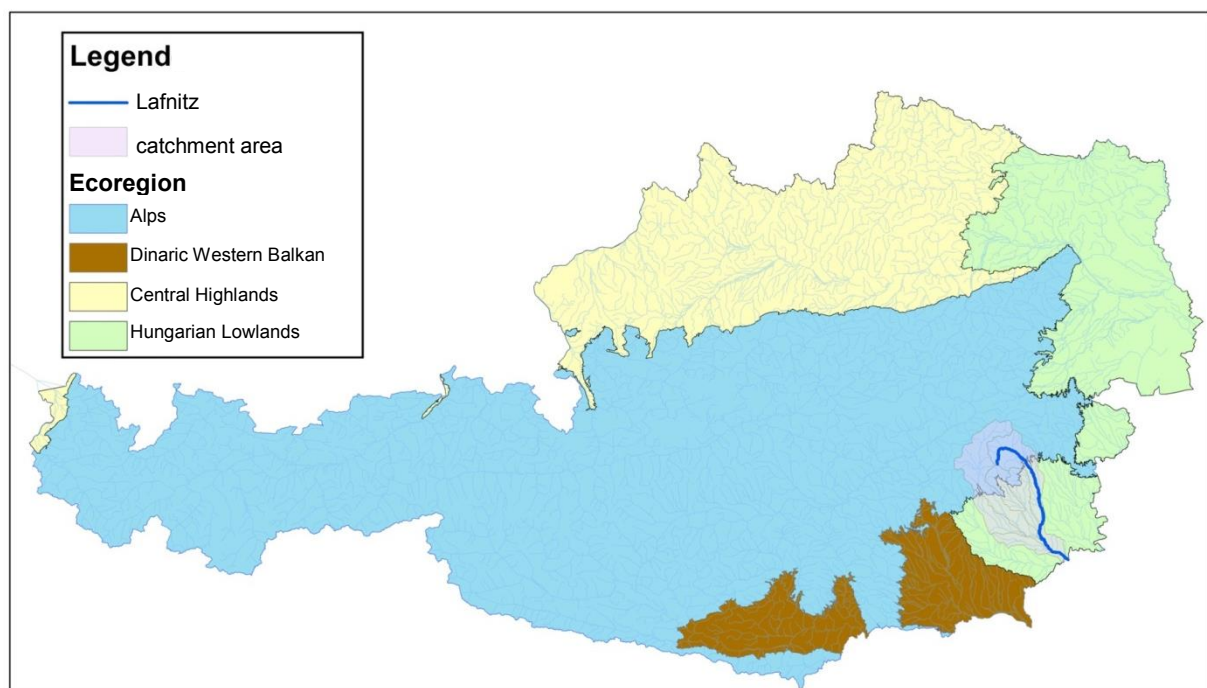


Figure 1: Geographical location of the river Lafnitz and ecoregions of Austria (according to ILLIES, 1978)

The Lafnitz serves as an important landscape structure for the entire Lafnitz valley, which is a substantial area for nature conservation. Main parts are Natura 2000 sites, both under the “Birds Directive” (79/409/EEC) and “Habitats Directive” (92/43/EEC), and protected by the Ramsar Convention as well (RAMSAR CONVENTION BUREAU, 2002; CEJKA et al., 2005).

2.1.1. TYPOLOGY

From source to mouth, the river Lafnitz crosses two different ecoregions (according to ILLIES, 1978) and bioregions (according to MOOG et al., 2001) respectively. The upper course is situated in **bioregion 3 “Ridges and Foothills of the Crystalline Alps” within the ecoregion “Alps”** and the hydrological regime is typically nival. Downstream the village Rohrbach it is located in **bioregion 13 “Eastern Ridges and Lowlands” within the ecoregion “Hungarian Lowlands”**, where the hydrological regime is mainly influenced by precipitation and therefore described as pluvial (MOOG et al., 2001; WIMMER et al., 2012).

The catchment area of the river Lafnitz is influenced by two different climate zones, the cold Alpine and the continental Mediterranean climate. Therefore, this region is among the warmest and driest parts of Austria. On the other hand, a high number of days with thunderstorms and heavy rainfalls (especially in summer, see figure 2) are recorded, which in turn cause many sudden flood events (HORNICH & SEIBERT, 1996). Figure 3 shows the average daily discharge around Dobersdorf in the year 2012 indicating the highly variable hydrological regime of this river.

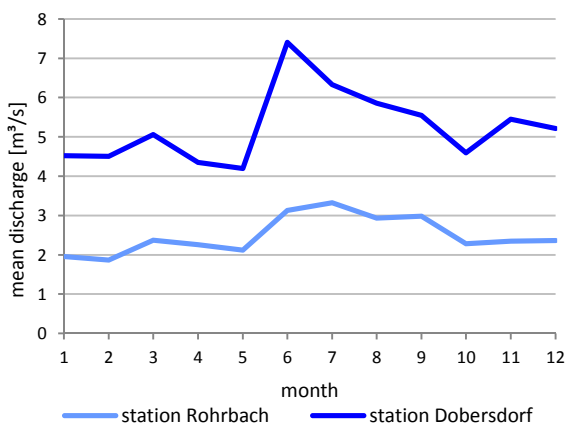


Figure 2: Mean discharge per month at Rohrbach (419 m AMSL) and Dobersdorf (234 m AMSL) between 2003 and 2012 (data source: BMLFUW, 2014)

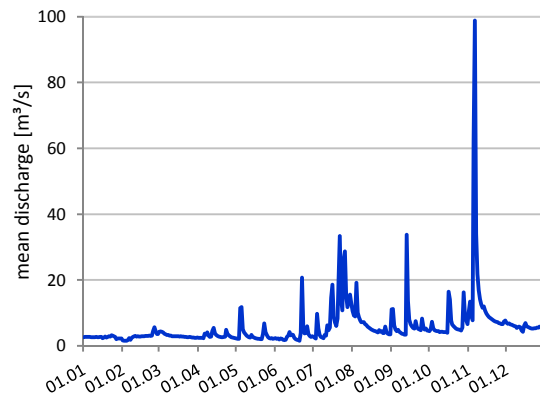


Figure 3: Daily discharge from 2012 at Dobersdorf (data source: BMLFUW, 2014)

2.2 SAMPLING DESIGN AND DATA AVAILABILITY

Macroinvertebrate samples were collected from 12th to 14th March 2014, at six sampling sites along the river Lafnitz. At each site, at least ten Single Habitat Samples (SHS) were taken from the river bottom. Number of samples and positions in the river cross-section were fixed after visual assessment of existing hydraulics and substrate characteristics, at each sampling site individually (see table 1).

Table 1: Longitudinal location and number of Single Habitat Samples (SHS) per site (March 2014)

site	altitude [m AMSL]	no of SHS
Wenigzell	794	10
Bruck	524	10 *
Rohrbach	438	10
Neustift_b section A	384	15
Neustift_b section B	384	16
Dobersdorf	234	20
Königsdorf	220	29

*and 20 additional habitat samples of *Allogamus auricollis*

To investigate small-scale habitat characteristics and lateral community differences, sample positions were arranged in cross-sectional transects, from one bank to the other (see figure 6). Flow velocity, water depth, distance to bank and substrate type were recorded for each single microhabitat. Samples were also collected from woody structures, if present, and put into individually labelled sample containers as well.

Already existing macroinvertebrate data of the river Lafnitz from previous samplings were incorporated for several analyses as well (see table 2), including Multi-Habitat Sampling (MHS), Single Habitat Samples (SHS) and occasionally adult catches by sweeping nets or light traps.

Table 2: Overview of analytical approaches, data source, sampling method (no. of samples) and total number of samples

Analyses	Data source	sampling method	sample size
Longitudinal distribution *	Dossi (2014) DHONJU (2013) own data (2014)	MHS (24), SHS (16) SHS (124) SHS (103)	269
Species distribution	Graf (unpubl. 1991-2005) Dossi (2014) DHONJU (2013) own data (2014)	sweeping net/ light traps (11) MHS (24), SHS (114) SHS (124) SHS (110)	383
Transectional distribution	own data (2014)	SHS	88
Habitat preferences	own data (2014)	SHS	110
Effects of siltation	own data (2014)	SHS	30
Wood-associated fauna	Dossi (2014) own data (2014)	MHS (24), SHS (52) SHS (110)	186

* with exception of woody debris

Data were available for additional seven sampling sites along the river and table 3 gives an overview of all sampling sites between 2012 and 2014, their position along the river course, the year of sampling and sampling season.

Table 3: Sampling sites (2012-2014), longitudinal position, year of sampling and sampling season

site	site	distance from source [km]	year of sampling	sampling season
Quelle	1_QU	0.3	2012	summer
Wenigzell	1a_WZ	5.7	2014	spring
Mayerhofer	2_MM	8.7	2012	summer, autumn
Bruck	3_BR	18.2	2012 2014	summer spring
Rohrbach	4_RB	26.1	2012 2014	summer, autumn spring
Neustift	5_NS	32.4	2012	summer
Neustift_a	5a_NS	34.8	2012	summer
Neustift_b	5b_NS	35.4	2012 2014	autumn spring
Wolfau	6_WA	52.1	2012	summer, autumn
Neudau	7_ND	67.1	2012	summer
Deutsch-Kaltenbrunn	8_DK	87.0	2012	summer
Dobersdorf	9_DD	100.4	2012 2014	summer, autumn spring
Königsdorf	9a_KD	104.0	2014	spring

2.2.1 WATER CHEMISTRY AND HABITAT CHARACTERISTICS

Water chemistry was measured at each sampling site using a portable HACH® Multi-Parameter Meter including pH, conductivity, oxygen content and saturation. Measured physico-chemical values for each site are given below (table 4).

Table 4: Physico-chemical parameters at the sampling sites between 12th and 14th March 2014

site	conductivity [$\mu\text{S cm}^{-1}$]	oxygen content [mg l^{-1}]	oxygen saturation [%]	pH
Wenigzell	107	10.6	94.1	8.80
Bruck	127.8	11.05	95.8	9.29
Rohrbach	151.9	11.17	95.1	8.89
Neustift	159.5	12.13	97.5	8.95
Dobersdorf	235	11.08	96.8	7.60
Königsdorf	235	11.08	96.8	7.60

Flow velocity [ms^{-1}] was measured with a flow meter (FLO-MATE TM Modell 2000 and a top-setting-wading rod) at 40 % of the total water depth (v40) for all 110 SHS. Additionally water depth, distance to shore and substrate type were recorded. Substrate types were defined by substrate particle size following the European standard procedure according to the WFD (see table 5).

Table 5: Substrate types and definition (according to MOOG et al., 1999)

Mineral substrates	particle size class	description
megalithal	> 40 cm	large cobbles, boulders and blocks, bedrock
macrolithal	> 20 to 40 cm	coarse blocks, head-sized cobbles, with a variable percentage of cobble, gravel and sand
mesolithal	> 6 to 20 cm	fist to hand-sized cobbles with a variable percentage of gravel and sand
microlithal	> 2 to 6 cm	coarse gravel with variable percentages of medium to fine gravel
akal	> 0,2 to 2 cm	fine to medium-sized gravel
psammal	> 6 μm to 2 mm	sand and mud
pelal	< 0.0063	mud and sludge
Organic substrates	description	
xylal*	tree trunks (dead wood), branches, roots	
CPOM	deposits of coarse particulate organic matter (e.g. leaves)	
FPOM	deposits of fine particulate organic matter	
debris	organic and inorganic matter deposited within the splash zone area by wave motion and changing water levels, e.g. mussel shells, snail shells	
submerged macrophytes	macrophytes, including moss and Characeae	
emergent macrophytes	e.g. Thypha, Carex, Phragmites	
living parts of terrestrial plants	fine roots, floating riparian vegetation	

* or large woody debris (LWD)

2.3 SAMPLING SITES

Macroinvertebrate sampling for this master thesis project was done at six different sites along the Lafnitz, including Wenigzell (WZ) near source, Bruck (BR), Rohrbach (RB), Neustift (NS), Dobersdorf (DD) and more than 100 km downstream at Königsdorf (KD). The sites were consecutively numbered from source to mouth and integrated into the existing coding system of the BIO_CLIC Project data set of the river Lafnitz. Figure 4 shows the positions of all sampling sites along the river (including sites from previous samplings in 2012).

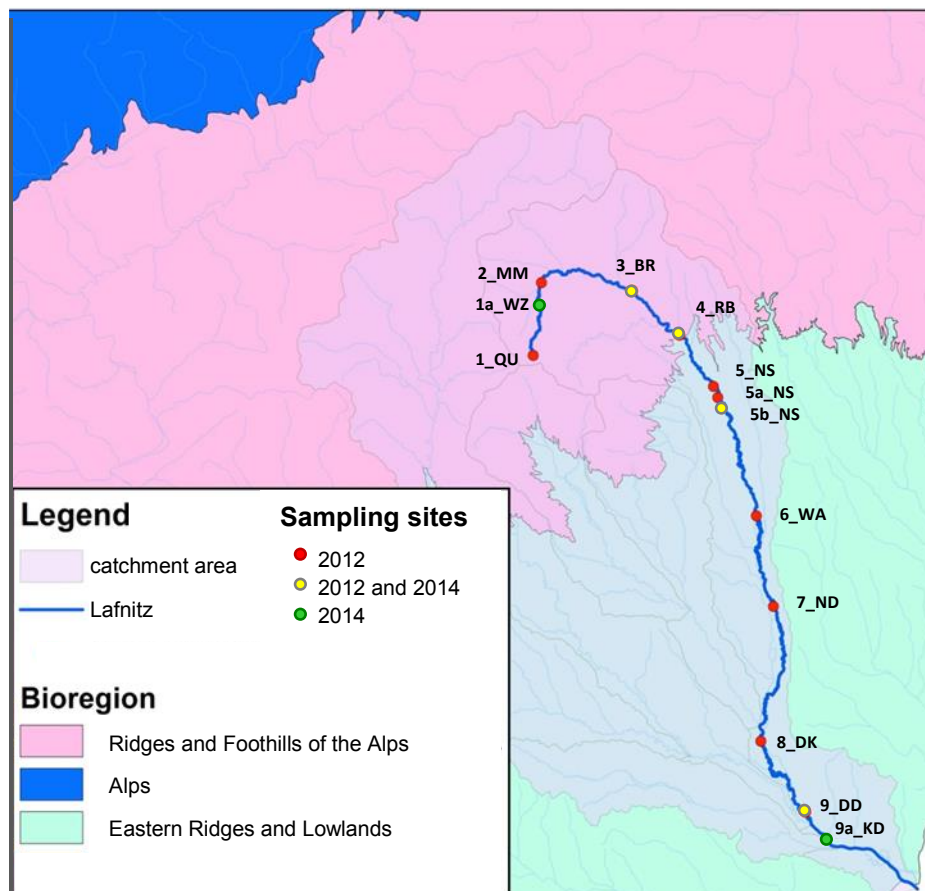


Figure 4: Position of sampling sites along the river Lafnitz between 2012 and 2014

Estimated substrate composition, distance from source and to mouth, maximum and minimum flow velocity as well as water depth is given below for all sites sampled in March 2014 (see figure 5). At the site 5b_Neustift samples were taken from two completely different sections (A and B) in terms of flow velocity and substrate composition. Therefore the most important habitat characteristics, based on the single habitat samples from March 2014, are shown for both sections.

1a_Wenigzell

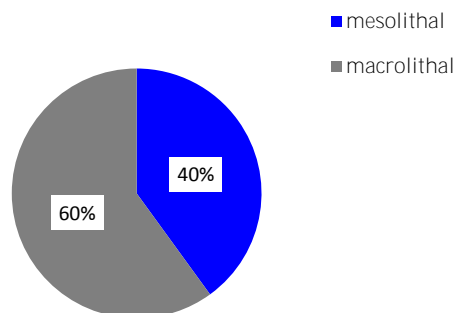
sampling date: 13.03. 2014

distance from source 5.7 km

flow velocity max 0.90 m/s
min 0.05 m/s

distance to mouth 108.3 km

water depth max 19 cm
min 11 cm



3_Bruck

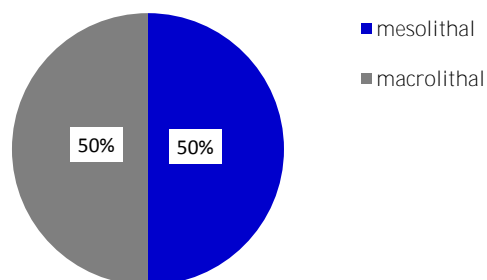
sampling date: 13.03. 2014

distance from source 18.2 km

flow velocity max 1.05 m/s
min 0.05 m/s

distance to mouth 94.7 km

water depth max 32 cm
min 5 cm



4_Rohrbach

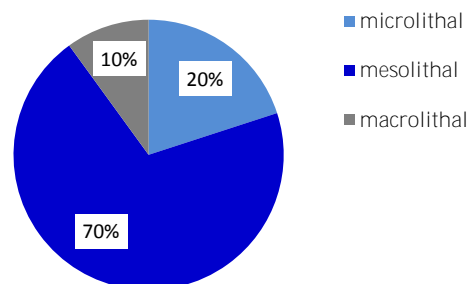
sampling date: 13.03. 2014

distance from source 26.1 km

flow velocity max 1.05 m/s
min 0.36 m/s

distance to mouth 87.1 km

water depth max 38 cm
min 13 cm



5b_Neustift section A

sampling date: 14.03. 2014

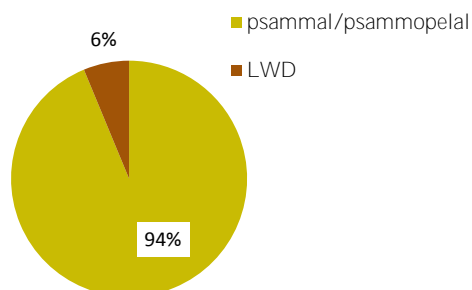
distance from source 35.4 km

flow velocity max 0,38 m/s
min 0 m/s



distance to mouth 78.6 km

water depth max 38 cm
min 5 cm



5b_Neustift section B

sampling date: 14.03. 2014

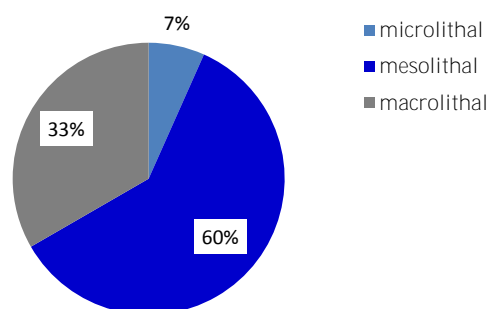
distance from source 35.5 km

flow velocity max 0.78 m/s
min 0.32 m/s



distance to mouth 78.5 km

water depth max 20 cm
min 5 cm



9_Dobersdorf

sampling date: 12.03. 2014

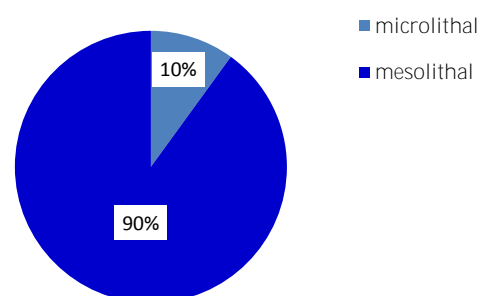
distance from source 100.4 km

flow velocity max 1.19 m/s
min 0.39 m/s



distance to mouth 13.6 km

water depth max 66 cm
min 16 cm



9a_Königsdorf

sampling date: 12.03. 2014

distance from source 104 km

flow velocity max 1.07 m/s
min 0.05 m/s

distance to mouth 10 km

water depth max 75 cm
min 28 cm

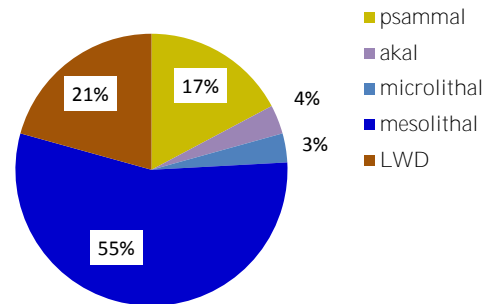


Figure 5: Physio-geographical characteristics and substrate composition per sampling site (March 2014)

2.4. MACROINVERTEBRATE SAMPLING AND PROCESSING

Macroinvertebrate samples were taken with a WFD-compliant MHS hand net (frame size: 0.25 x 0.25 m, mesh size: 500 µm) at low flow conditions and arranged in cross-sectional transects in wadeable areas (see figure 6). Measuring of hydraulic habitat characteristics was done before positioning the hand net vertically on the river bottom, with the frame at right angles to the current. The substrate in an area of 0.25 x 0.25 m in front of the net was disturbed and the surface of larger stones was brushed into the net. Large sediments were removed by rinsing the sample for at least three times (if necessary), before they were transferred into the sample container (according to OFENBÖCK et al., 2010).

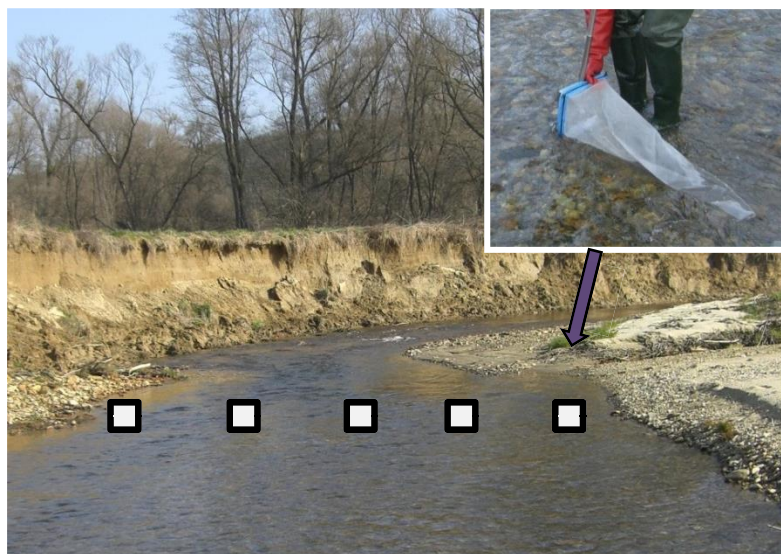


Figure 6: Cross-sectional transect at Neustift and sampling device (MHS hand net)

Each sample was put in a labelled container with information to sampling site, date, transect and sample number. Macroinvertebrates from woody structures were collected at two sampling sites (Neustift and Königsdorf) by brushing them into the hand net.

At the sampling site Bruck, in total 20 habitats of *Allogamus auricollis* were examined directly in the field, by counting the animals and measuring flow velocity at the habitats, due to the high abundance of this Trichoptera species at this river stretch.

All Single Habitat Samples were fixed with formalin immediately after collection (final concentration 4 %), to prevent carnivores from eating other organisms and were transported into the lab. After a fixation time of three weeks, macroinvertebrate samples were further processed in the lab. At first the complete sample was rinsed through a set of sieves (five sieves from 2 cm to 500 µm), to get rid of the preservative liquid and to separate the material in different fractions. All fractions were completely sorted and the organisms were mostly determined to species or genus level, with the exception of most Diptera (family level, species in exceptional cases), Oligochaeta (mixed level of order, species) and Hydrachnidia.

The identification process was done with the help of the binocular and several determination keys (Ephemeroptera: BAUERNFEIND & HUMPESCH, 2001; Plecoptera: GRAF & SCHMIDT-KLOIBER, 2008; Trichoptera: WARINGER & GRAF, 2011; all other: MOOG et al., 2008; screening level). For some taxa, especially the whole Trichoptera-family of Limnephilidae and the Ephemeroptera-genus *Baetis* the assistance of experts (Dr. Wolfram Graf, DI Dr. Patrick Leitner, DI Thomas Huber and DI Florian Dossi) was needed, due to determination uncertainties.

Animals were counted and weighed in defined groups (Bivalvia; Crustacea; Coleoptera; Diptera: Chironomidae, Simuliidae and other; Gastropoda; Heteroptera; Hirudinea; Hydrachnidia; Odonata; Oligochaeta; Plecoptera: Systellognatha, Euholognatha; Trichoptera: Annulipalpia, Intergripalpia; Turbellaria), before storing them in 70 % ethanol.

2.5. ECOLOGICAL CLASSIFICATION OF MACROINVERTEBRATES

Ecological information about benthic species was gathered from the Austrian online database freshwaterecology.info or the Austrian classification catalogue of benthic invertebrates “Fauna Aquatica Austriaca” (MOOG, 2002).

According to the RCC by VANNOTE et al. (1980), feeding types were grouped into four functional feeding groups: shredder, grazer, collector and predator (see table 6).

Table 6: Macroinvertebrate feeding types and definitions (from MOOG, 2002)

Functional Feeding group	Feeding type	Sources of food
Shredder	Shredders	Fallen leaves, plant tissue, CPOM
Grazer	Grazers	Epilithic algal tissues, biofilm, partially POM
	Scrapers, rasps	Endo- & epilithic algal tissue, partially tissues of living plants
Collector	Filtering collectors	Suspended FPOM, CPOM
	<ul style="list-style-type: none"> ○ active ○ passive 	
	Detritus feeders	Sedimented FPOM
Predator	Predators	prey

Data on species-specific water temperature range preferences were exclusively collected from freshwaterecology.info and correspondingly the species were classified into cold stenotherm, warm stenotherm and eurytherm.

2.6. DATA ANALYSIS

Distribution analyses of EPT and Coleoptera (family, genus and species level), based on presence/absence data, was done with the following assumption: if one species was present at two sites but absent in-between, this region was also considered as a potential distribution area. Correlations and other statistical procedures (Kruskal-Wallis-test, Mann-Whitney-U-test) were done with SPSS Statistics version 21. PCORD 5.33 was used to create ordination plots by non-metric multidimensional scaling (NMS) to analyse community patterns regarding various habitat variables. Therefore abundance data were logarithmically ($\log + 1$) transformed whereas Soerensen (Bray-Curtis) distance measure was used. Indicator Species Analysis (ISA) for large woody debris accumulation was also performed with PCORD, which uses mean abundances to remove any effect of different sample sizes between substrate groups. Habitat utilization curves were only created for selected species with $N > 20$ individuals, in the form of frequency distributions. For flow velocity intervals with highest abundance a Suitability Index (SUI) of 1.0 was assigned and used to evaluate the utilization intensity of less frequently colonised intervals. When drawing the curves, only the maximum values along the gradient were considered. Lower values in between were omitted, based on the assumption that individuals inhabiting velocities of e.g. 0.2 and 0.5 ms^{-1} hardly avoid velocities of 0.3 ms^{-1} .

Community differences between the silted and non-silted river section at the sampling site Neustift were analysed with two different similarity measures, the Jaccard Index based on

presence/absence data and the Renkonen Index (or percentage similarity) which also includes abundances. The corresponding formulas were used:

Jaccard Index (JACCARD, 1912)

$$S_j = \frac{a}{a + b + c}$$

a = Number of species in sample A and sample B

b = Number of species in sample B but not in sample A

c = Number of species in sample A but not in sample B

For comparison purposes with the Renkonen Index (ranging from 0 to 100 percentage similarity) the Jaccard Index was multiplied with 100.

Renkonen Index (RENKONEN, 1938)

$$P = \sum_i \text{minimum } (p_{1i}, p_{2i})$$

P = percentage similarity between sample 1 and 2

p₁ = Percentage of species *i* in community sample 1

p₂ = Percentage of species *i* in community sample 2

3. RESULTS

3.1. LONGITUDINAL DISTRIBUTION

For comparison purposes, only samples from mineral substrates were considered for longitudinal community composition analyses, because woody debris was not found in each sampled river stretch ($n = 269$ samples).

3.1.1. ABUNDANCE AND BIOMASS

Highest numbers of individuals per square metres (mean of all samples per site between 2012 and 2014) were shown at site 5b_Neustift with 6623.7 individuals/m² and at site 1a_Wenigzell with 5292.8 individuals/m² (see figure 7). High densities of macroinvertebrates were also found at the sampling sites 5_Neustift and 3_Bruck with 4435.7 and 4458.4 ind/m². Mean abundance was lower at site 5a_Neustift with 2700.8 ind/m², 6_Wolfau with 2489.4 ind/m² and 2_Mayerhofer with 2319.8 ind/m². All other sites had macroinvertebrate densities between 1324.4 and 1644.9 individuals/m² on average. The lowest number of individuals was recorded near mouth at 9a_Königsdorf with 1238.3 ind/m².

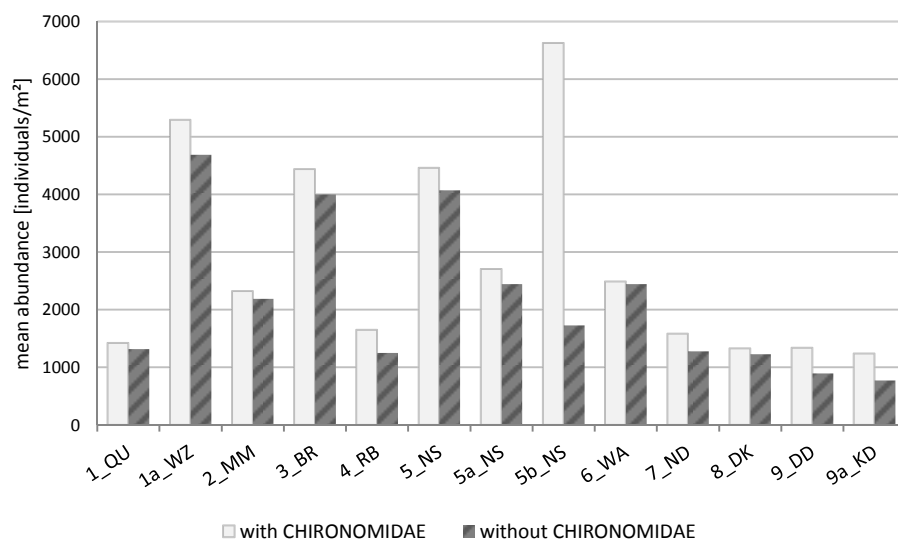


Figure 7: Mean abundance per site with and without Chironomidae ($n = 269$ samples)

Excluding the dipteran family Chironomidae (dark grey bars with diagonal stripes, figure 7), the abundances only slightly decreased, except for 5b_Neustift, where the individual density strongly declined by nearly 5000 ind/m² (to 1725.8 individuals/m²).

Considered separately according to seasons, although not all sites were sampled at each season, some differences regarding abundance were obvious (see figure 8). Highest densities were observed in spring (light grey bars) at in the upper course, including site 5a_Neustift, compared to summer (grey bars) and autumn (black bars). At 9_Dobersdorf highest numbers of individuals were found in summer, but also in autumn there were more macroinvertebrates in the samples than in spring. Individual-densities in summer were throughout lower than in spring, but higher than in autumn, with the exception of site 6_Wolfau.

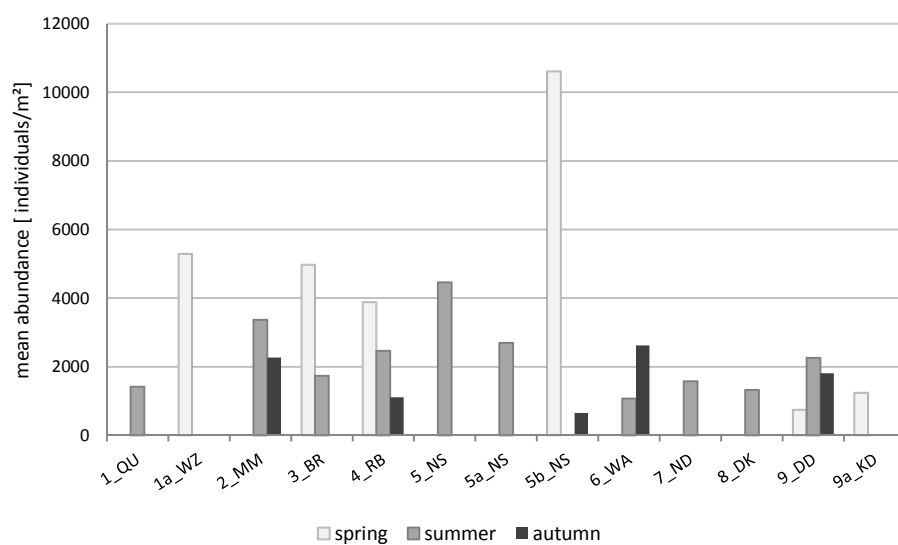


Figure 8: Mean abundance per site and season (n = 269 samples)

In autumn, the lowest numbers of individuals were detected except for site 6_Wolfau, where on average in autumn more than twice as many benthic invertebrates were in the samples compared with summer.

Figure 9 shows mean macroinvertebrate biomass and including all individuals (light grey bars with black spots), mean biomass per sample was highest at site 5b_NS with 24.8 g/m². The samples at 1a_Wenigzell and 5a_Neustift had also biomasses clearly above 20 g/m² with 23.6 respectively 23.3 g/m² on average.

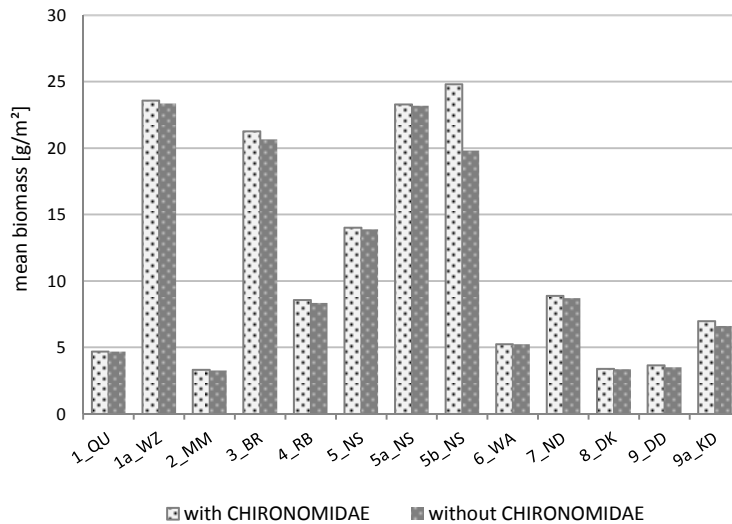


Figure 9: Mean biomass per site with and without Chironomidae (n = 269 samples)

More than 20 g/m² were found at 3_Bruck (21.3 g/m²) and less than 15 g/m² were found at 5_Neustift. Mean biomass between 7 and 9 g/m² were measured at 4_Rohrbach, 7_Neudau and 9a_Königsdorf. At all other sites a biomass of around 5 g/m² or lower was ascertained. Without consideration of the large family of Chironomidae (dark grey bars with bright spots), only at 5b_Neustift the biomass was clearly reduced by 5 g/m² to 19.8 g/m², at all other sites the mean biomass did not change substantially. Therefore mean fresh weight was highest at 1a_Wenigzell and 5a_Neustift with 23.4 respectively 23.2 g/m².

Separated by seasons (see figure 10), highest mean biomass per sampling site was found in spring (light grey bars with dark spots), except for site 9_Dobersdorf and maximum biomass was documented at 5b_Neustift.

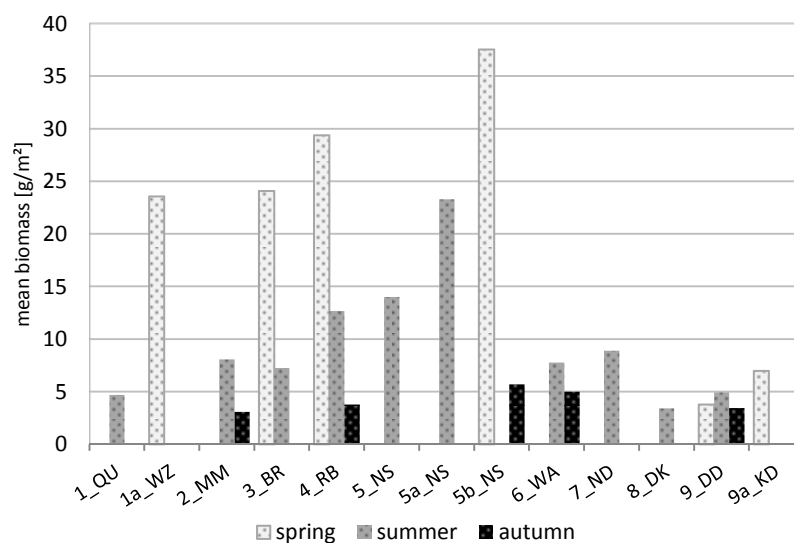


Figure 10: Mean biomass per site and season (n = 269 samples)

During summer (grey bars with dark spots) macroinvertebrate samples showed the highest biomass at site 5a_Neustift with 23.3 g/m² on average, and the lowest at 8_Deutsch-Kaltenbrunn with 3.4 g/m². Compared to spring and summer, samples taken in autumn (black bars with light spots) had lowest biomasses at each sampling site.

3.1.2. FAUNAL COMPOSITION

The proportional shares of different macroinvertebrate orders (individuals/m²) per sampling site are shown in figure 11. The term “other” refers to a mixed group of Bivalvia, Gastropoda, Heteroptera, Hirudinea, Hydrachnidia, Hymenoptera, Nematoda, Oligochaeta and Turbellaria, whereas the subphylum Crustacea only consisted of one species (*Gammarus fossarum*).

Individuals of Coleoptera were collected at each site, but abundances were higher in the upper course. The subphylum Crustacea was only represented by one species (*Gammarus fossarum*) and most abundant in the area of origin, with a share of more than 74 % of total number of individuals at this site. Below 1_Quelle there was a strong decline recorded, and only at 5a_Neustift, 6_Wolfau and 7_Neudau again higher abundances were observed.

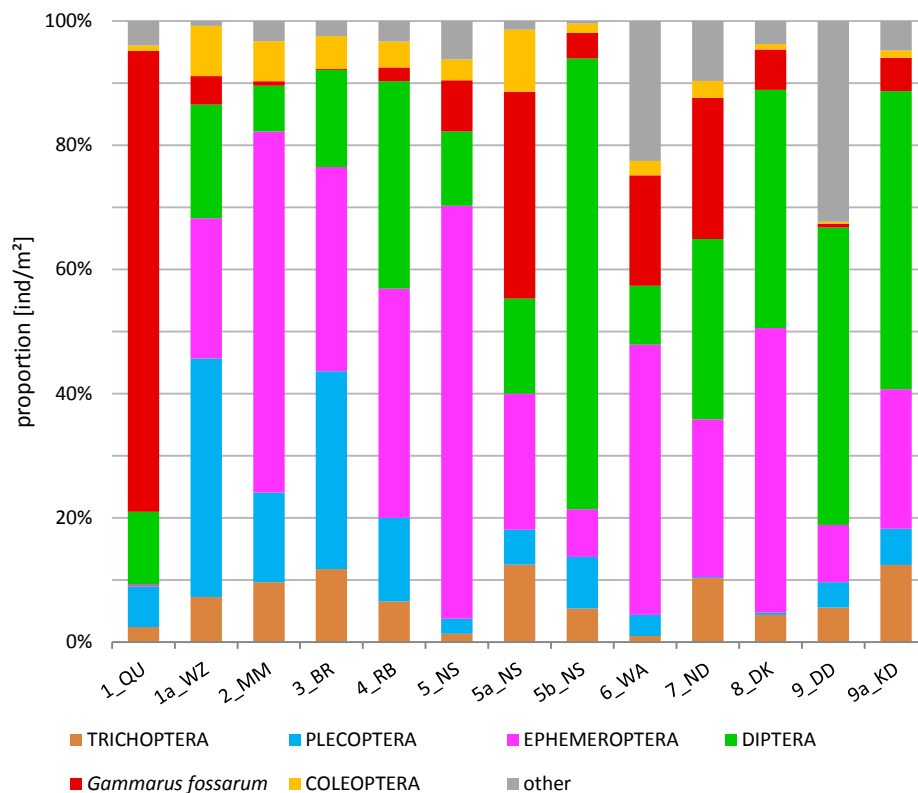


Figure 11: Community composition per site and orders based on abundance data (n = 269)

Individuals of Diptera were present at each site, but most numerous at 5b_Neustift, where they accounted for over 72 % of total individuals present. With the exception of site 6_Wolfau, the share of Diptera increased again downstream, but not in that extent. Near the origin, only a few individuals of Ephemeroptera were counted, but some kilometres downstream at 1a_Wenigzell, the share was almost a quarter of total individuals and at 2_Mayerhofer nearly 60 %. The highest number of individuals of this order was documented at 5_Neustift (more than 65 % of collected individuals). Except for 1_Quelle, 1a_Wenigzell and 5b_Neustift, the group of Ephemeroptera was representing the majority of the individuals of EPT-taxa. Plecoptera were more abundant in the upper course, especially at site 1a_Wenigzell (38.4 %) and 3_Bruck (31.8 %). More downstream, the number of individuals in this group decreased and lowest abundances were detected at 7_Neudau and 8_Deutsch-Kaltenbrunn (below 0.01 %). Individuals of Trichoptera were also found at each site, with highest shares (around 12 % of the community) at 3_Bruck, 5a_Neustift and 9a_Königsdorf and lowest at 5_Neustift and 6_Wolfau (below 0.01 %). Considering EPT (Ephemeroptera, Plecoptera and Trichoptera)-taxa, the results showed that at site 1_Quelle, they were very rare but a few kilometres downstream, they were making up more than 80 % of total individuals. At 2_Mayerhofer and up to site 5_Neustift, they represented clearly more than half of the macroinvertebrate community. At most sites Ephemeroptera were more abundant than Plecoptera and Trichoptera.

The same analysis was done separately for Ephemeroptera, Plecoptera and Trichoptera on genus level and based on relative abundances on mineral substrates. Genera with very low **overall abundances per site were summed up to “other”**. The proportional shares of Ephemeroptera genera per site are shown in figure 12. The genera *Baetis* and *Rhithrogena* were present at each site in comparatively high quantities, individuals of *Ephemerellaa* were also collected at each site but with clearly lower abundances. The genus *Epeorus* was only found in the upper and middle course and the genus *Electrogena* even exclusively at the uppermost site near source. By contrast, the genus *Heptagenia* was only documented in the lower course.

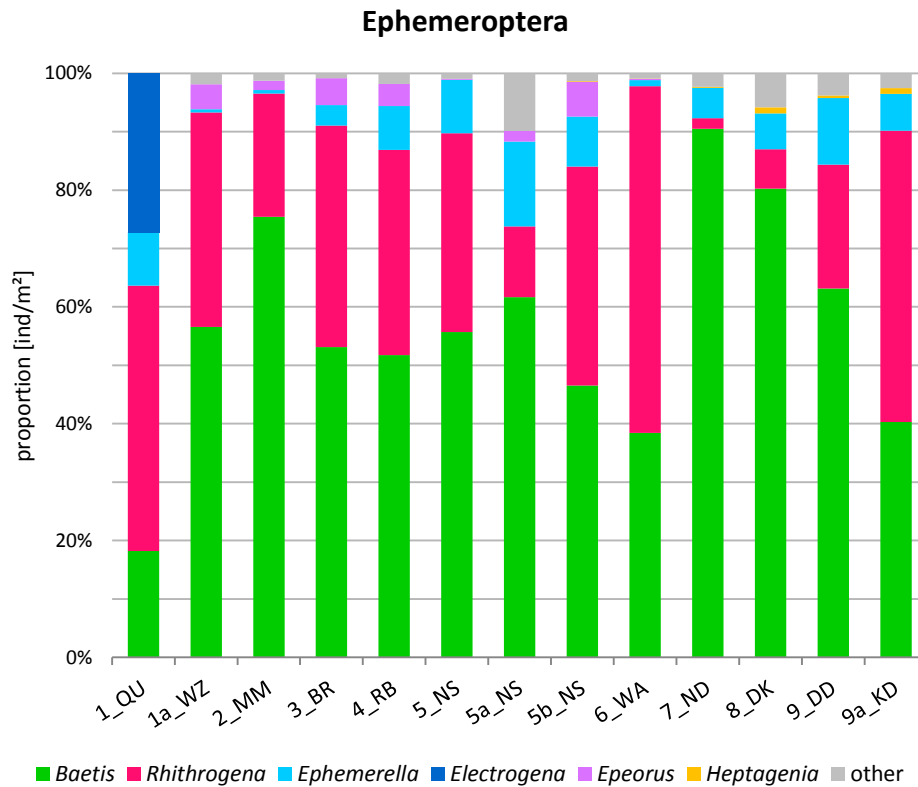


Figure 12: Composition of Ephemeroptera on genus level per site (based on abundance, $n = 269$)

Considering the group of Plecoptera, the genus *Isoperla* was documented at each sampling site and also individuals of *Leuctra* were present nearly everywhere (see figure 13). The genus *Brachyptera* was found from near source to mouth, but missing at those sites where samples were taken only during summer. The sites 1_Quelle, 5_Neustift, 5a_Neustift, 7_Neudau and 8_Deutsch-Kaltenbrunn were never sampled neither in spring nor autumn, and therefore have to be interpreted with caution. Individuals of *Protonemura* were more frequently found in the upper course and only a few individuals in the lower course, whereas the genus *Amphinemura* showed the exact opposite distribution and abundance pattern. Highest abundances of *Perla* were found in the middle course, but individuals were present at nearly all sites, in contrast to *Dinocras* which was restricted to the middle course.

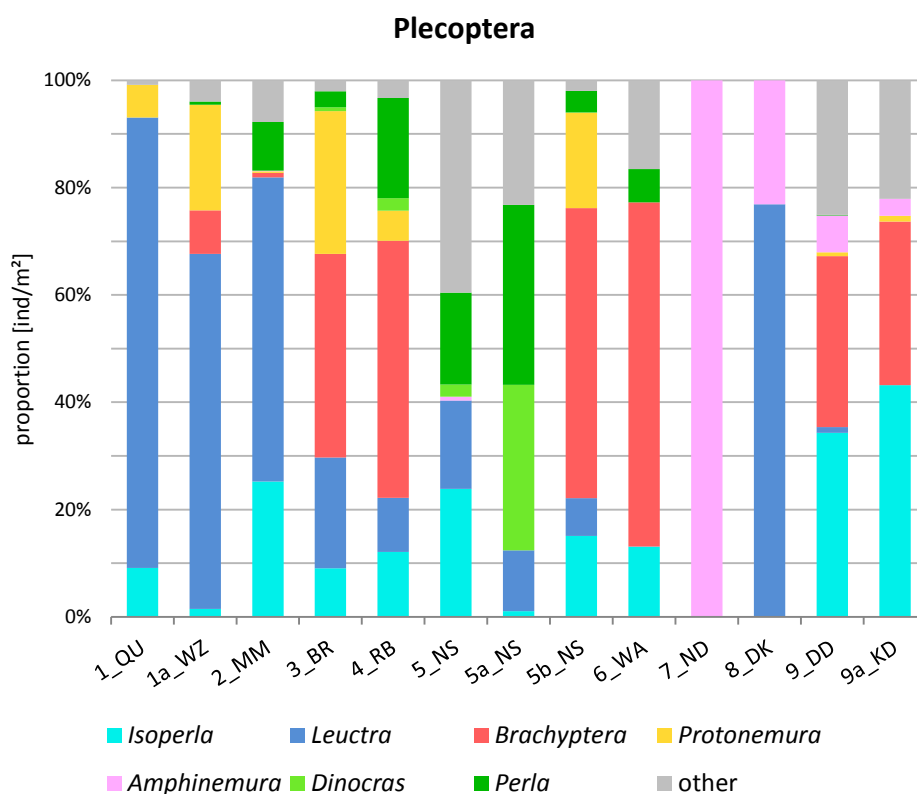


Figure 13: Composition of Plecoptera on genus level per site (based on abundance, $n = 269$)

Figure 14 shows the proportional shares of Trichoptera on genus level per sampling site. The genus *Rhyacophila* was present everywhere along the Lafnitz but with varying proportions, whereas *Hydropsyche* was quite numerous everywhere, but missing close to mouth. In contrast to *Psychomyia* and *Cheumatopsyche*, with highest shares in the lower course, the genus *Odontocerum* was more frequently registered in the upper course. The share of “other” genera was quite high at some sites, as there were many genera present but with very low individual densities.

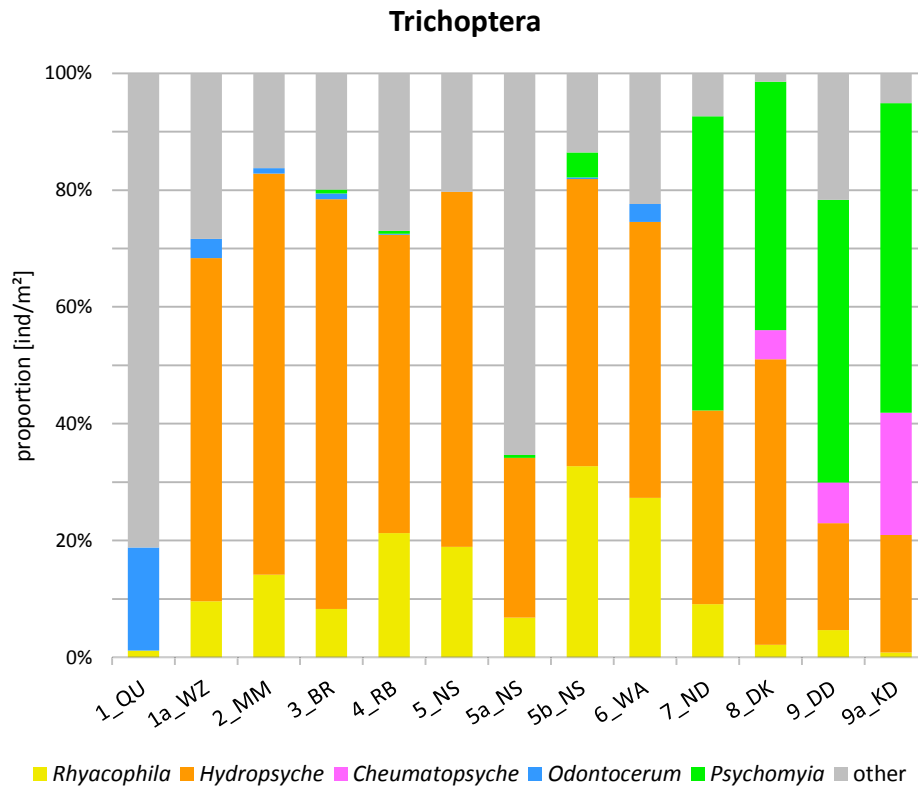


Figure 14: Composition of Trichoptera on genus level per site (based on abundance, $n = 269$)

3.1.3. FUNCTIONAL FEEDING GROUPS

Longitudinal distribution analyses of different feeding groups were performed in two different ways (presence/absence and abundance data), based on all taxa (family, genus and species level) for which data of functional feeding type were available (161 taxa). Relative proportions of different feeding groups (shredder, grazer, collector and predator) per site regarding taxa presence and absence data are shown in figure 15.

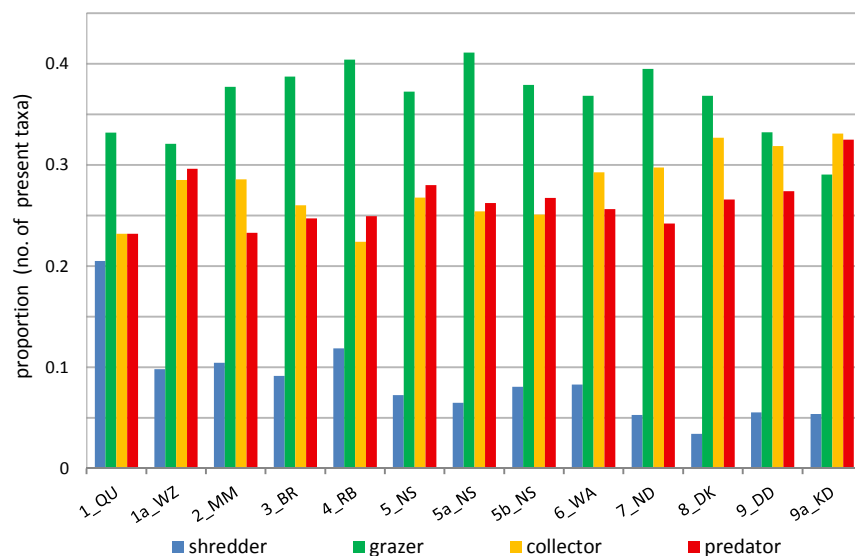


Figure 15 Proportion of feeding groups per site based on presence/absence data ($n = 161$ taxa)

Highest proportion of taxa classified into shredders (blue bars) was found near source at 1_Quelle with 21 % and decreased further downstream. At each sampling site shredders were representing the smallest number of collected taxa. The share of grazing taxa (green bars) increased from near origin up to more than 40 % at 5a_Neustift, then again followed by a slight decline. Grazers had the highest shares of taxa composition at each site (over 30 %), with the exception of site 9a_Königsdorf, where more collectors (orange bars) and predators (red bars) were present. Taxa of the feeding type collector were fewest at site 4_Rohrbach, with a proportion of 22 % and had maximum shares at 8_Deutsch-Kaltenbrunn and 9a_Königsdorf with 33 %. At site 9a_Königsdorf most taxa were classified as collectors, followed by predators. Predatory taxa had relatively high proportion at each site, ranging between 23 % (at 1_Quelle and 2_Mayerhofer) and 33 % at 9a_Königsdorf.

Considering the number of individuals per taxa respectively feeding group at each sampling site (see figure 16), by far the most shredders were collected at 1_Quelle representing a share of 60 %, followed by a strong decline at 1a_Wenigzell to less than 5 %.

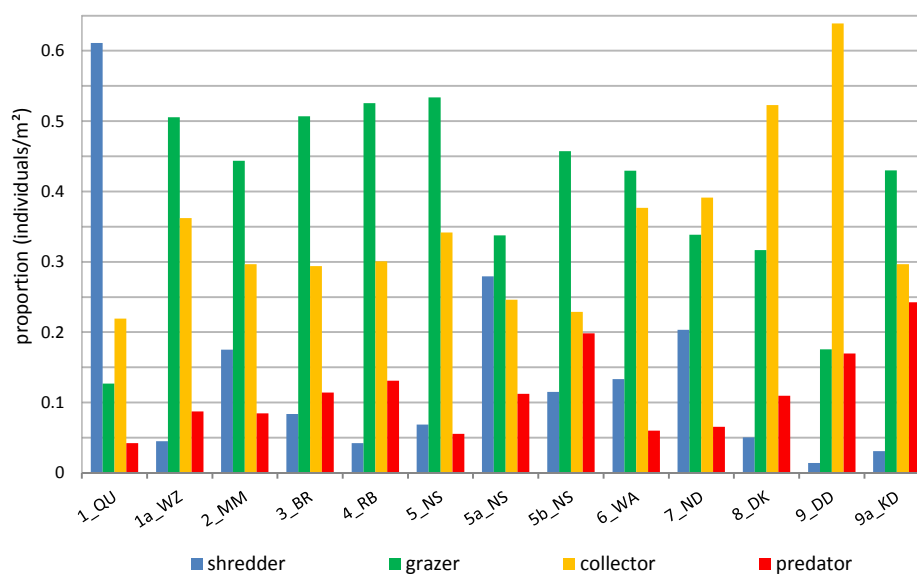


Figure 16: Proportion of feeding groups per site based on abundance (n = 161 taxa)

Further downstream the share increased up to 25 % at 5a_Neustift, before decreasing again with lowest share at 9_Dobersdorf. Grazing individuals had lowest share at 1_Quelle and clearly higher shares below, with the maximum of 53 % at site 5_Neustift. Up to site 6_Wolfau, most individuals were classified as grazers, with the exception of 1_Quelle. Collectors had second highest shares at most sampling sites and below 6_Wolfau, this feeding guild was even representing the highest shares of total number of individuals, except for 9a_Königsdorf where again more grazers were found. Predatory individuals were not very

abundant comparatively, only shredders were less abundant at some sites. Predators were most numerous at 9a_Königsdorf with a share of 24 % and at 5b_Neustift with almost 20 %, and only a few were collected near the origin at 1a_Wenigzell.

3.2. TRANSECTIONAL DISTRIBUTION

Differences in community structure depending on the position on the river bottom were analysed based on 88 out of 110 samples taken in March 2014. Woody debris was only present at the shoreline and therefore not considered, as well as samples from areas of fine sediment accumulation at Neustift, due to very homogenous hydraulic conditions within the river cross-section.

3.2.1. HABITAT VARIABLES

First the relation between distance from shore and different habitat variables (flow velocity, water depth and substrate type) was examined. **The results of Spearman's rank** correlation showed a slight, but significant positive correlation between distance from shore and flow velocity ($r_s = 0.315$, $p < 0.01$), but no correlation with water depth ($r_s = 0.193$, $p > 0.05$).

Before Kruskal-Wallis test was performed, the substrate type akal was removed from analysis because it was only sampled once. According to that, the test was based on SHS and four different mineral substrate type, showing that there were significant differences in substrate composition depending on distance from shore ($H = 24.51$, $df = 3$, $p < 0.01$).

3.2.2. MACROINVERTEBRATE DISTRIBUTION

The measured distance from shore was converted into relative distance from nearest shoreline, ranging from 0 to 50 % of the river width and summarized in steps of 10 % to get similar high sample sizes. Based on 88 SHS, collected from akal, micro-, meso- and macrolithal, the number of individuals did not differ significantly according to the position on the river bottom (see figure 17). There were also no clear differences concerning macroinvertebrate biomass and distance from shoreline (see figure 18) obvious.

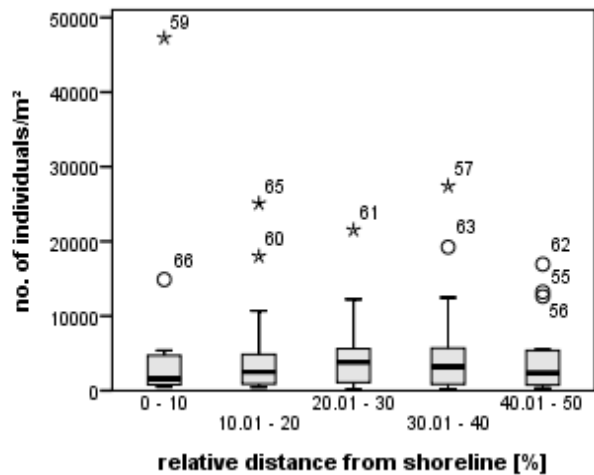


Figure 17: Abundance at different positions on the river bottom ($n = 88$ samples)

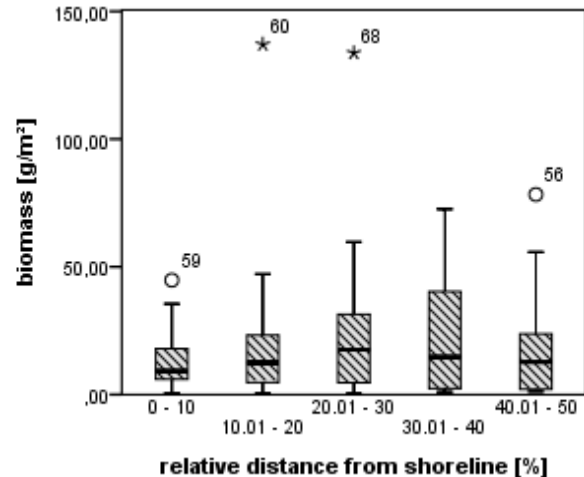


Figure 18: Biomass at different positions on the river bottom ($n = 88$ samples)

3.3. CURRENT AND SUBSTRATE PREFERENCES

3.3.1. FLOW VELOCITY

The measured flow velocities, for a total of 110 SHS samples (from March 2014), ranged between 0 and 1.19 m s^{-1} . According to that, macroinvertebrate samples were divided in three flow velocity classes (low, moderate and high) from minimum to maximum velocity in intervals of 0.4 ms^{-1} and to have approximately equal samples size per class (see table 7).

In total 102 taxa were identified, 85 taxa of those were found in habitats where flow velocity was relatively low and 79 taxa within moderate and high flow velocities.

Table 7: Overview of Flow velocity classes including flow velocity range, samples size and taxa richness per class

Class	Flow velocity [ms^{-1}]	Sample size	Taxa richness
low	0-0.39	39	85
moderate	0.4-0.79	38	79
high	0.8-1.19	33	79
total	0-1.19	110	102

Mean abundance and biomass comparison between different flow velocity classes showed, that mean individual density was lowest in samples from habitats (see figure 19), where flow velocity was relatively high. Macroinvertebrates were more abundant in low-flow areas and highest in the samples taken from habitats of moderate velocities. Mean biomass was also lowest in samples from high flow velocities and highest within moderate velocities (see figure 20).

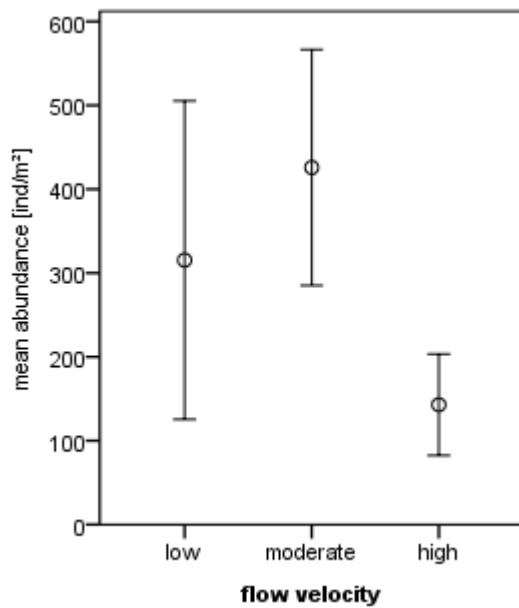


Figure 19: Mean abundance per flow velocity class and error bars with 95 % confidence intervals (n = 110 samples)

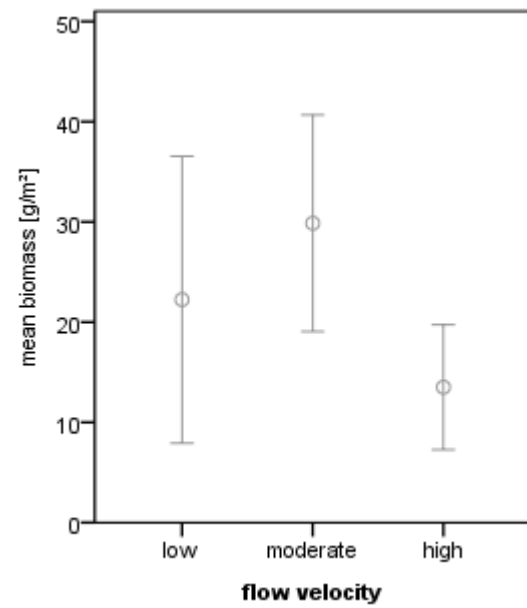


Figure 20: Mean biomass per flow velocity class and error bars with 95 % confidence intervals (n = 110 samples)

3.3.2. SUBSTRATE TYPE

Macroinvertebrate samples of March 2014 were collected from six different substrate types (see table 8), including psammal, akal, micro-, meso-, macrolithal and large woody debris (LWD).

Table 8: Number of Single Habitat Samples (SHS) per substrate type

substrate type	no. of SHS
psammal	20
akal	1
microlithal	6
mesolithal	59
macrolithal	17
large woody debris	7
total	110

Spearman's rank correlation coefficient r_s was used to test for relations between all recorded hydraulic habitat variables (flow velocity, water depth and substrate particle size), based on pooled data from all sampled river stretches. Akal was excluded for this analysis because it was only sampled once, and also LWD was not considered here. The results indicated significant positive correlations ($p < 0.01$) between flow velocity and water depth ($r_s = 0.435$) as well as between flow velocity and substrate size ($r_s = 0.442$). No significant correlation could be detected between water depth and substrate particle size.

Mean abundance was clearly highest on macrolithal, with an average number of 8453.6 ind/m² (see figure 21) followed by mesolithal and microlithal with 4599.6 and 4120 ind/m², respectively. Lowest mean individual densities were detected on psammal with 3097.6 ind/m². Akal was only sampled once, thus not representative, and only shown for the sake of completeness.

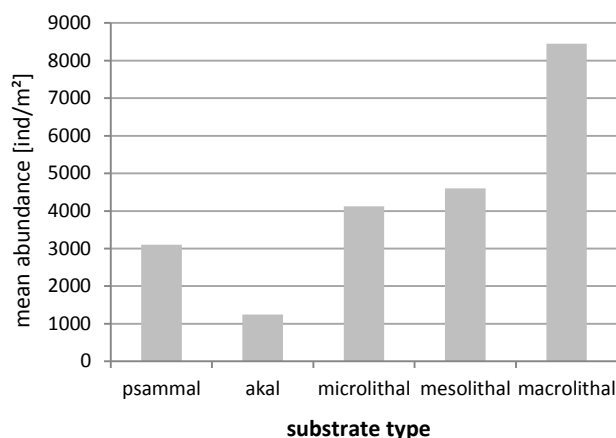


Figure 21: Mean abundance (ind/m²) per substrate type (n = 103 samples)

Figure 22 shows mean biomass per substrate type, which was highest on macrolithal with an average of 45.8 g/m². A considerably lower biomass was recorded for psammal (15.7 g/m²) and mesolithal (15.6 g/m²). With the exception of akal (for the reason mentioned above), lowest biomass was collected from microlithal (14.1 g/m²).

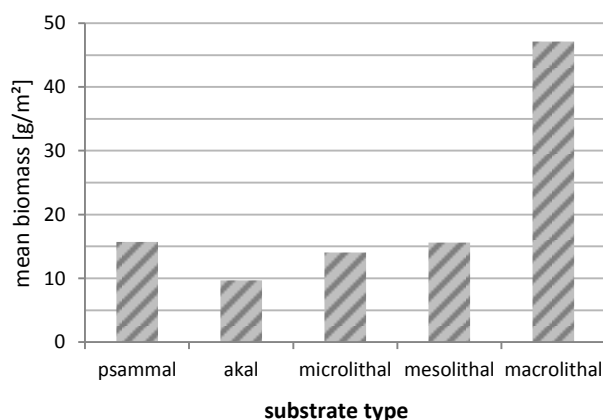


Figure 22: Mean biomass (g/m²) per substrate type (n = 103 samples)

Taxa richness was highest in the samples from mesolithal followed by macrolithal and microlithal (see figure 23), regarding EPT-taxa as well as other taxa present in March 2014. Lowest species diversity, except for akal, was recorded within the samples taken from psammal, but again EPT-taxa made up the majority of present taxa like on every substrate type sampled in spring 2014.

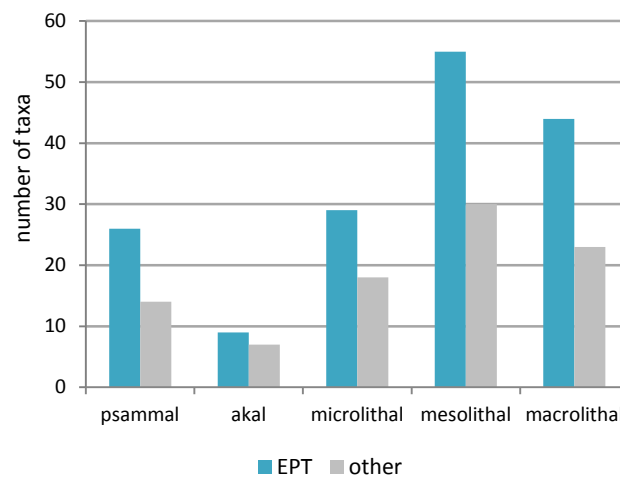


Figure 23: Number of EPT and other taxa per substrate type (n = 103 samples)

3.3.2.1. EFFECTS OF FINE SEDIMENT DEPOSITION

In total 30 macroinvertebrate samples were taken at the sampling site 5b_Neustift, from two completely different sections regarding substrate composition and hydraulic conditions. Substrate composition was dominated by psammal in section A and correspondingly mean flow velocity was also clearly lower there, compared to section B where larger sediments were present (see table 9).

Table 9: Abiotic characteristics of section A (silted) and B (non-silted) at sampling site 5b_Neustift including substrate composition (no. of SHS), mean flow velocity and mean depth out of 30 samples

section	substrate type (no. of SHS)	mean velocity [m s ⁻¹]	mean depth [cm]
A	psammal (15)	0.26	22.93
B	microlithal (1), mesolithal (9), macrolithal (5)	0.55	11.46

The performed Mann-Whitney U-test indicated significant differences between both sections, regarding macroinvertebrate abundance (U = 16.00, p < 0.01) and biomass (U = 20.00, p < 0.01). Macroinvertebrate samples of section A had clearly lower individual densities and

also biomass per sample was clearly lower there compared to section B (see figure 24 and 25). Only sample 21 from section A represented an exception, as the number of individuals as well as biomass were quite high due to high abundance of Chironomids in this sample.

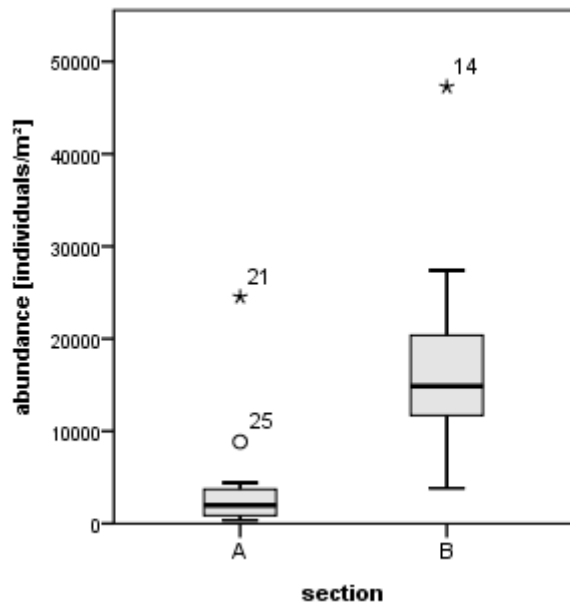


Figure 24: Abundance comparison between section A (silted) and B (non-silted) at Neustift (n = 15 samples)

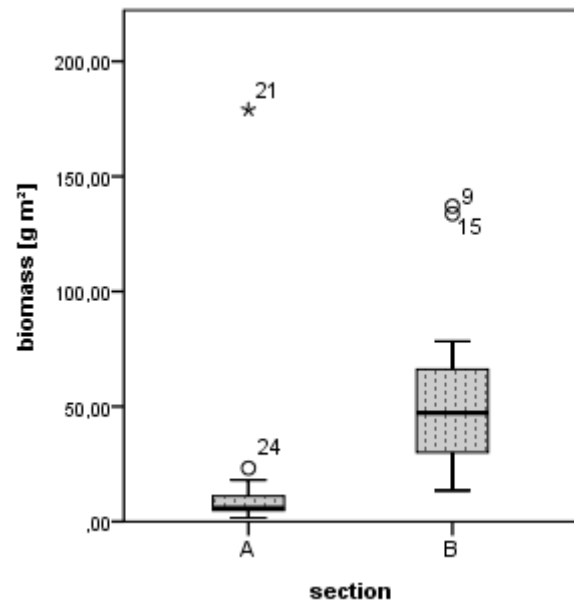


Figure 25: Biomass comparison between section A (silted) and B (non-silted) at Neustift (n = 15 samples)

The proportional shares of different orders are shown in figure 26, based on relative abundance per section. Chironomids showed the largest share of the benthic community in both sections with 87.1 % in section A and almost 75 % in section B. Other Diptera only made up 6.1 % of the community in section A and 1.6 % in section B. The biggest difference was observed for EPT-taxa which accounted for just 1.6 % in section A and 21.1 % in section B. The order Crustacea was only represented by *G. fossarum*, and had a share of 2.9 % in section A and 1.1 % in the other section. Oligochaeta were more numerous in section A with 1.8 % and less than 0.01 % of the whole community in section B. The share of Coleoptera was below 0.01 % in section A and above 1.6 % in section B. Bivalvia, Gastropoda and Hydrachnidia were also found in the samples and summarized to one group (other) as they were rarely found in the samples (less than 0.01 %). But in contrast to the documented individuals of Bivalvia, which were only present in section A, the individuals of Gastropoda and Hydrachnidia were only documented in section B.

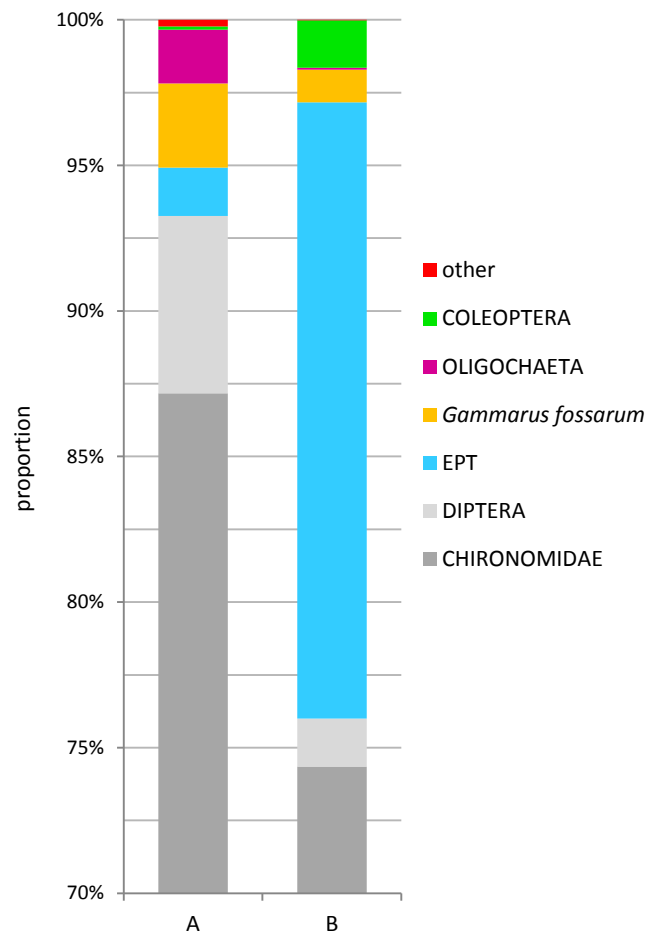


Figure 26: Proportions of macroinvertebrate orders in section A (silted) and section B (non-silted) based on abundance (individuals/m²), n = 30 samples

In total 59 taxa (34 families) were identified in both sections, 27 taxa (18 families) were present in section A (see table 10), and 52 taxa (32 families) in section B (see table 11). Five taxa were only documented in section A, and 30 taxa were exclusively found in section B.

Table 10: Taxa list of section A (27 taxa) at site 5b_Neustift (exclusive taxa marked with *) and mean abundance/m² (n = 15 samples)

section A (silted)			
order	family	taxa	mean ind/m ²
BIVALVIA	SPHAERIIDAE	* <i>Pisidium</i> sp.	7.47
BIVALVIA	SPHAERIIDAE	* <i>Sphaerium</i> sp.	1.07
COLEOPTERA	ELMIDAE	<i>Elmis</i> sp.	1.07
COLEOPTERA	ELMIDAE	<i>Limnius</i> sp.	3.20
CRUSTACEA	GAMMARIDAE	<i>Gammarus fossarum</i>	112.00
DIPTERA	CERATOPOGONIDAE	* CERATOPOGONIDAE Gen. sp.	1.07
DIPTERA	CHIRONOMIDAE	CHIRONOMIDAE Gen. sp.	3369.60
DIPTERA	LIMONIIDAE	<i>Hexatoma</i> sp.	220.80
DIPTERA	LIMONIIDAE	LIMONIIDAE Gen. sp.	11.73
DIPTERA	SIMULIIDAE	<i>Simulium</i> sp.	2.13
EPEMEROPTERA	BAETIDAE	<i>Baetis juvenil</i>	1.07
EPEMEROPTERA	BAETIDAE	<i>Baetis rhodani</i>	14.93
EPEMEROPTERA	BAETIDAE	* <i>Cloeon dipterum</i>	2.13
EPEMEROPTERA	EPEMERELLIDAE	<i>Ephemerella mucronata</i>	17.07
EPEMEROPTERA	EPEMERIDAE	<i>Ephemera danica</i>	3.20
EPEMEROPTERA	HEPTAGENIIDAE	<i>Ecdyonurus</i> sp.	1.07
EPEMEROPTERA	HEPTAGENIIDAE	<i>Rhithrogena</i> sp.	5.33
OLIGOCHAETA	OLIGOCHAETA	OLIGOCHAETA Gen. sp.	71.47
PLECOPTERA	NEMOURIDAE	<i>Protonemura</i> sp.	3.20
PLECOPTERA	PERLODIDAE	<i>Isoperla</i> sp.	2.13
PLECOPTERA	TAENIOPTERYGIDAE	<i>Brachyptera juvenil</i>	1.07
PLECOPTERA	TAENIOPTERYGIDAE	<i>Brachyptera risi</i>	2.13
TRICHOPTERA	HYDROPSYCHIDAE	<i>Hydropsyche juvenil</i>	3.20
TRICHOPTERA	LIMNEPHILIDAE	* <i>Allogamus auricollis</i>	1.07
TRICHOPTERA	LIMNEPHILIDAE	<i>Halesus</i> sp.	1.07
TRICHOPTERA	LIMNEPHILIDAE	LIMNEPHILIDAE Gen. sp.	3.20
TRICHOPTERA	SERICOSTOMATIDAE	<i>Sericostoma</i> sp.	2.13

Table 11: Taxa list of section B (52 taxa) at site 5b_Neustift (exclusive taxa marked with *) and mean abundance/m² (n = 15 samples)

section B (non-silted)			
order	family	taxa	mean ind/m ²
COLEOPTERA	ELMIDAE	<i>Elmis</i> sp.	172.80
COLEOPTERA	ELMIDAE	* <i>Esolus</i> sp.	19.20
COLEOPTERA	ELMIDAE	<i>Limnius</i> sp.	80.00
COLEOPTERA	GYRINIDAE	* <i>Orectochilus villosus</i>	2.13
COLEOPTERA	HYDRAENIDAE	* <i>Hydraena</i> sp.	7.47
CRUSTACEA	GAMMARIDAE	<i>Gammarus fossarum</i>	194.13
DIPTERA	ATHERICIDAE	* <i>Atherix ibis</i>	3.20
DIPTERA	CHIRONOMIDAE	CHIRONOMIDAE Gen. sp.	12890.67
DIPTERA	EMPIDIDAE	* EMPIDIDAE Gen. sp.	35.20
DIPTERA	LIMONIIDAE	* <i>Antocha</i> sp.	2.13
DIPTERA	LIMONIIDAE	<i>Hexatoma</i> sp.	154.67
DIPTERA	PEDICIIDAE	* <i>Dicranota</i> sp.	64.00
DIPTERA	PSYCHODIDAE	* PSYCHODIDAE Gen. sp.	1.07
DIPTERA	SIMULIIDAE	* <i>Prosimulium</i> sp.	3.20
DIPTERA	SIMULIIDAE	<i>Simulium</i> sp.	23.47
EPHEMEROPTERA	BAETIDAE	* <i>Baetis alpinus</i>	263.47
EPHEMEROPTERA	BAETIDAE	<i>Baetis juvenil</i>	165.33
EPHEMEROPTERA	BAETIDAE	<i>Baetis rhodani</i>	309.33
EPHEMEROPTERA	EPHEMERELLIDAE	<i>Ephemerella mucronata</i>	114.13
EPHEMEROPTERA	EPHEMERIDAE	<i>Ephemera danica</i>	4.27
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Ecdyonurus</i> sp.	5.33
EPHEMEROPTERA	HEPTAGENIIDAE	* <i>Epeorus assimilis</i>	100.27
EPHEMEROPTERA	HEPTAGENIIDAE	HEPTAGENIIDAE Gen. sp.	1.07
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Rhithrogena</i> sp.	517.33
GASTROPODA	PLANORBIDAE	* <i>Ancylus fluviatilis</i>	1.07
HYDRACHNIDIA	HYDRACHNIDIA	* HYDRACHNIDIA Gen. sp.	2.13
OLIGOCHAETA	OLIGOCHAETA	OLIGOCHAETA Gen. sp.	11.73
PLECOPTERA	LEUCTRIDAE	* <i>Leuctra</i> sp.	137.60
PLECOPTERA	NEMOURIDAE	* <i>Nemoura/Nemurella</i> sp.	5.33
PLECOPTERA	NEMOURIDAE	<i>Protonemura</i> sp.	343.47
PLECOPTERA	PERLIDAE	* <i>Dinocras cephalotes</i>	1.07
PLECOPTERA	PERLIDAE	* <i>Perla marginata</i>	56.53
PLECOPTERA	PERLIDAE	PERLIDAE Gen. sp.	1.07
PLECOPTERA	PERLODIDAE	<i>Isoperla</i> sp.	276.27
PLECOPTERA	PERLODIDAE	* <i>Perlodes</i> sp.	25.60
PLECOPTERA	TAENIOPTERYGIDAE	<i>Brachyptera juvenil</i>	99.20

Table 11 (continued)

PLECOPTERA	TAENIOPTERYGIDAE	<i>Brachyptera risi</i>	804.27
PLECOPTERA	TAENIOPTERYGIDAE	* <i>Brachyptera seticornis</i>	100.27
TRICHOPTERA	BRACHYCENTRIDAE	* <i>Micrasema minimum</i>	1.07
TRICHOPTERA	GLOSSOSOMATIDAE	* <i>Glossosoma boltoni</i>	3.20
TRICHOPTERA	GOERIDAE	* <i>Silo pallipes</i>	4.27
TRICHOPTERA	HYDROPSYCHIDAE	* <i>Hydropsyche dinarica</i>	2.13
TRICHOPTERA	HYDROPSYCHIDAE	* <i>Hydropsyche instabilis</i>	3.20
TRICHOPTERA	HYDROPSYCHIDAE	<i>Hydropsyche juvenil</i>	185.60
TRICHOPTERA	LIMNEPHILIDAE	* <i>Ecclisopteryx guttulata</i>	1.07
TRICHOPTERA	LIMNEPHILIDAE	<i>Halesus</i> sp.	1.07
TRICHOPTERA	LIMNEPHILIDAE	* <i>Potamophylax</i> sp.	1.07
TRICHOPTERA	ODONTOCERIDAE	* <i>Odontocerum albicorne</i>	1.07
TRICHOPTERA	PSYCHOMYIIDAE	* <i>Psychomyia pusilla</i>	17.07
TRICHOPTERA	RHYACOPHILIDAE	* <i>Rhyacophila</i> s. str. sp.	109.87
TRICHOPTERA	RHYACOPHILIDAE	* <i>Rhyacophila tristis</i>	2.13
TRICHOPTERA	SERICOSTOMATIDAE	<i>Sericostoma</i> sp.	6.40

3.3.2.2. MACROINVERTEBRATE FAUNA ASSOCIATED WITH WOODY DEBRIS

The analyses of community differences between mineral substrates (including psammal, akal, micro-, meso- and megalithal) and large woody debris (LWD) were performed with additional macroinvertebrate samples from Dossi, 2014, including 24 MHS from mineral substrates and 52 SHS from woody debris ($n = 186$ samples). For some samples no biomass data were available and therefore excluded, so that the calculations of mean abundance and biomass per sample were based on 182 samples. Mean abundance was clearly higher in the samples from mineral substrates with 4370.3 individuals/m², compared to 2044 individuals/m² collected from large woody debris (see figure 27). By contrast, mean biomass (see figure 28) was lower on mineral substrates (18.39 g/m²) than on large woody debris (27.89 g/m²).

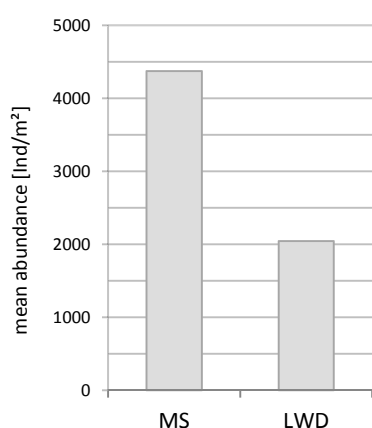


Figure 27: Mean abundance on mineral substrates (MS) and large woody debris (LWD), $n = 182$ samples

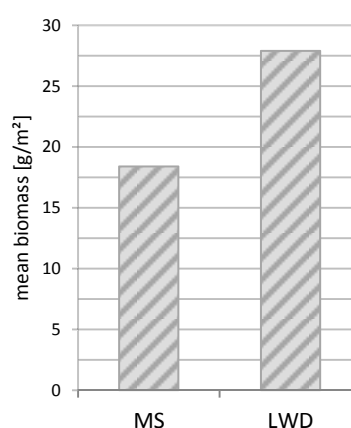


Figure 28: Mean biomass on mineral substrates (MS) and large woody debris (LWD), $n = 182$ samples

In total 173 taxa (69 families) were recorded, 158 taxa (66 families) out of them on mineral substrates and 101 taxa (49 families) were collected from woody debris. Indicator Species Analysis (ISA) was performed to find out the most characteristic species for large woody debris accumulations (based on 186 samples). Ten taxa showed indicator values (IV) beyond 25 and p-values below 0.01 for woody debris (see table 12). Highest indicator values were found for *G. fossarum*, but *Halesus* sp., *Hydropsyche* sp. (juvenile), *Ephemerella ignita*, *Heptagenia flava* and *Heptagenia longicauda* received values clearly above the selected threshold level (suggested by DUFRENE & LEGENDRE, 1997) as well. *Ecdyonurus* sp., *Macronychus quadrituberculatus*, *Orectochilus villosus* and *Lepidostoma basale* also seemed to be characteristic wood-associated species.

Table 12: Results of Indicator Species Analysis for large woody debris (IV > 25 and $p < 0.01$); $n = 186$ samples

taxa	IV	Mean	SD	p-value
<i>Gammarus fossarum</i>	78.9	42.6	5.56	0.0002
<i>Halesus</i> sp.	47.8	14.5	3.01	0.0002
<i>Hydropsyche</i> sp. (juvenile)	45.6	18.9	3.27	0.0002
<i>Ephemerella ignita</i>	44.1	16.1	3.09	0.0002
<i>Heptagenia flava</i>	39.1	9.5	2.32	0.0002
<i>Heptagenia longicauda</i>	34.5	8.4	2.28	0.0002
<i>Ecdyonorus</i> sp.	34.5	21	3.87	0.0044
<i>Macronychus quadrituberculatus</i>	29.3	6.9	2.01	0.0002
<i>Orectochilus villosus</i>	28.3	9.4	2.48	0.0002
<i>Lepidostoma basale</i>	27.3	10.7	2.72	0.0002

Most taxa of Coleoptera did not get high indicator values, due to small numbers of individuals, except for *M. quadrituberculatus* and *O. villosus*. In total, twelve different taxa of water beetles were identified, and eleven of them at least once associated with woody debris. *Dryops* sp., *P. substriatus*, *Oreodytes* sp., *M. quadrituberculatus* and *Pomatinus* sp. were only found on wood and absent on mineral substrates. Six beetle taxa were collected from both substrates (*Elmis* sp., *Esolus* sp., *Limnius* sp., *Hydraena* sp., *P. maculatus*, *O. villosus*, Scirtidae Gen. sp.) and *Riolus* sp. was exclusively found on mineral substrates.

4. DISCUSSION

4.1. LONGITUDINAL DISTRIBUTION

Rivers are open systems and exhibit a longitudinal gradient of several physical and chemical variables, resulting in a series of different habitat conditions from the source to the mouth. Habitat variables like discharge, water temperature, dominant substrate type, organic loading, channel size and food resources are changing along the course of a river and affecting the distribution of species (ALLAN, 1975; VANNOTE et al. 1980).

Therefore macroinvertebrate samples from in total 13 sampling sites along the river Lafnitz between 2012 and 2014 were taken into consideration for faunal composition and longitudinal distribution analyses. Mean abundance and biomass varied quite strongly, especially in the upper third of the river course, and almost continuously decreased downstream. Considered separately according to seasons, mean abundance as well as biomass were substantially higher in spring samples compared to those from summer, and by far the lowest values were found in autumn.

Seasonal variation in the benthic community is a known phenomenon, as species have different life cycles and therefore more or less well represented depending on season (LINKE et al., 1999).

Several Plecoptera have an indirect development involving an egg diapause, for example *Brachyptera risi* and *Brachyptera seticornis*. Both species are hatching in autumn after an obligatory egg diapause of 80-110 days during summer (WAGNER et al. 2011) and therefore well-represented in spring, but missing in samples taken in summer.

Faunal composition analysis showed that EPT-taxa were highly abundant, particularly in the upper third of the river and dominated by Ephemeroptera. Plecoptera are known to prefer high current and tolerate only minor water temperature fluctuations (QUINN & HICKEY, 1990 and references therein; GRAF & SCHMIDT-KLOIBER, 2008), and accordingly the share more or less continuously decreased from the source to the mouth. The share of Trichoptera was relatively low along the entire river course.

Considering Ephemeroptera, Plecoptera and Trichoptera separately based on genus level, it is obvious, that within each group some genera were found along the entire river course and others were less widespread. Ephemeroptera were dominated by *Baetis* and *Rhithrogena*, which together made up over 80 % at nearly all sampling sites, but *Baetis* had highest abundances at most sites. In contrast to that, individuals of *Electrogena* were only collected near source, and *Heptagenia* was restricted to the lower course. Seasonal variation in community structure was most obvious within the group of Plecoptera, as individuals of *Brachyptera* were only missing at sites, where macroinvertebrate samples had only been taken during summer. *Isoperla* as well as *Leuctra* were present everywhere. Other genera

showed more narrow distribution patterns like *Dinocras*, which was restricted to the middle course. Some Trichoptera were also present along the entire river course, such as individuals of the genera *Rhyacophila* and *Hydropsyche*, whereas others were less widespread like *Psychomyia* and *Cheumatopsyche* and were only part of the benthic community in the lower course.

Macroinvertebrates were classified into shredders, collectors, grazers and predators, to test the predictions of the RCC about longitudinal distribution of the four functional feeding groups (see VANNOTE et al., 1980). Based on relative abundances, shredders made up the majority in the headwater-region, but strongly declining further downstream (see figure 29).

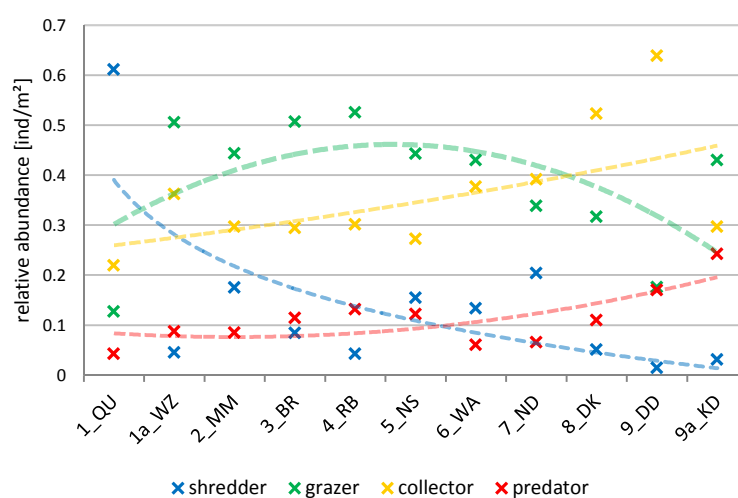


Figure 29: Proportional share of functional feeding groups along the longitudinal gradient and best-fitting trend lines (shredder: logarithmic, grazer and predator: polynomial, collector: exponential)

Downstream from source until two thirds of the river length, most individuals were grazers and replaced by collectors in the lower course. The share of predators only accounted for a small proportion of the benthic community and slightly increased with increasing distance from source.

Although abundance was used instead of biomass, the distribution of functional feeding groups was broadly consistent with the expectations of the RCC, even though this concept was developed for North American streams. Shredders had the highest share of total number of individuals in the headwater section, more downstream most individuals were grazers and in the lower course the community mainly consisted of collectors. According to the RCC, the proportional share of predators was relatively low along the entire river course.

VANNOTE et al. (1980) also emphasize the importance of temperature parameters on distribution patterns of the benthic community, due to species specific temperature

tolerances. Water temperature is a crucial factor in aquatic habitats and sets clear limits on the distribution of species, as shown in several other studies (QUINN & HICKEY, 1990; HAIDEKKER & HERING, 2008; POFF et al., 2010; DOHET et al., 2014).

Presence/absence data from all species, for which information about temperature preference were available, were used to investigate the influence of the longitudinal thermal regime on the distribution of species in the Lafnitz. Data about temperature range preferences originate from the online database freshwaterecology.com, but were only given for about one third of all taxa present in the river Lafnitz. As expected, cold stenotherm taxa were more frequently documented in the upper course and warm stenotherm species were almost restricted to the lower course (see figure 30). Eurytherm species were present along the entire river course and made up the majority at nearly all sites.

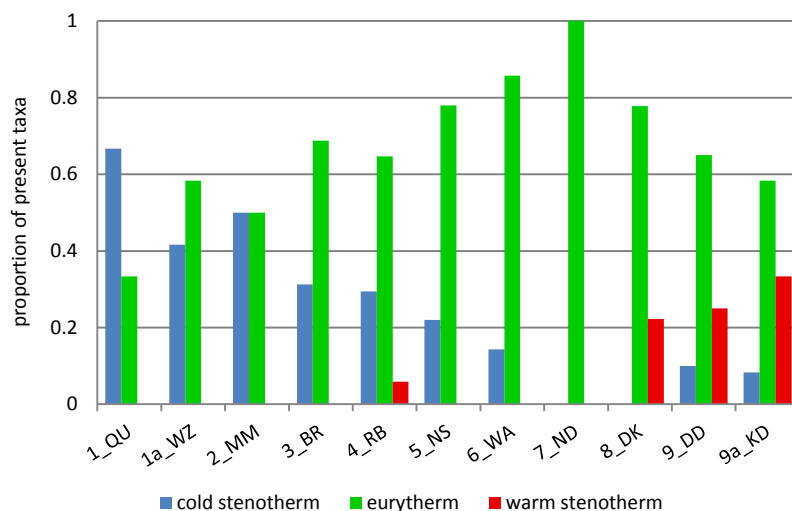


Figure 30: Proportion of taxa with different temperature range preferences based on presence/absence data (n = 41 taxa)

Life cycle characteristics of macroinvertebrates like egg development, growth rate, emergence, metabolism, etc. are mainly determined by water temperature resulting in a variety of biological strategies and adaptations along the temperature gradient of a river. Cold-water adapted species (cold stenotherm) are limited to springs and headwaters, where water temperature is low and large thermal fluctuations are missing. In contrast, eurytherm species tolerate a wide range of different temperatures and therefore typically occurring in the middle and downstream sections, whereas warm-stenothermic species are restricted to the lowest, usually warmest, river section.

Thus, climate change is a great threat to the benthic community, as thermal conditions might shift, especially at higher altitudes, and cold-adapted species are progressively replaced by

eurythermic species. Global warming favours the dispersal of more generalist species in terms of temperature tolerance, in contrast to highly specialized cold-water species, resulting in species losses which may affect ecosystem function. (HAIDEKKER & HERING, 2008; DOHET et al., 2014; POFF et al., 2010)

Macroinvertebrate species respond differently to the same environmental pressures and although the identification to species level is time consuming and needs a lot of experience, it is crucial for ecological interpretation. An exact knowledge of species inventory and community structure is a basic prerequisite for river assessment, combined with the comparison to previous findings or relevant reference conditions.

The river Lafnitz is a representative example for minor disturbed sites and therefore can be considered as a reference site for rivers of analogous typology and within the same biogeographical region. Longitudinal distribution Of Ephemeroptera, Plecoptera, Trichoptera and Coleoptera was analysed in detail, and the resulting taxa list may provide a basis for defining reference conditions. The results are shown in figure 31 – 36 on family (bold line), genus (continuous line) and species level (broken line or short broken line for species which were the only representative of their genus), based on all individuals, including larval and adult stages, collected along the river between 1991 and 2014.

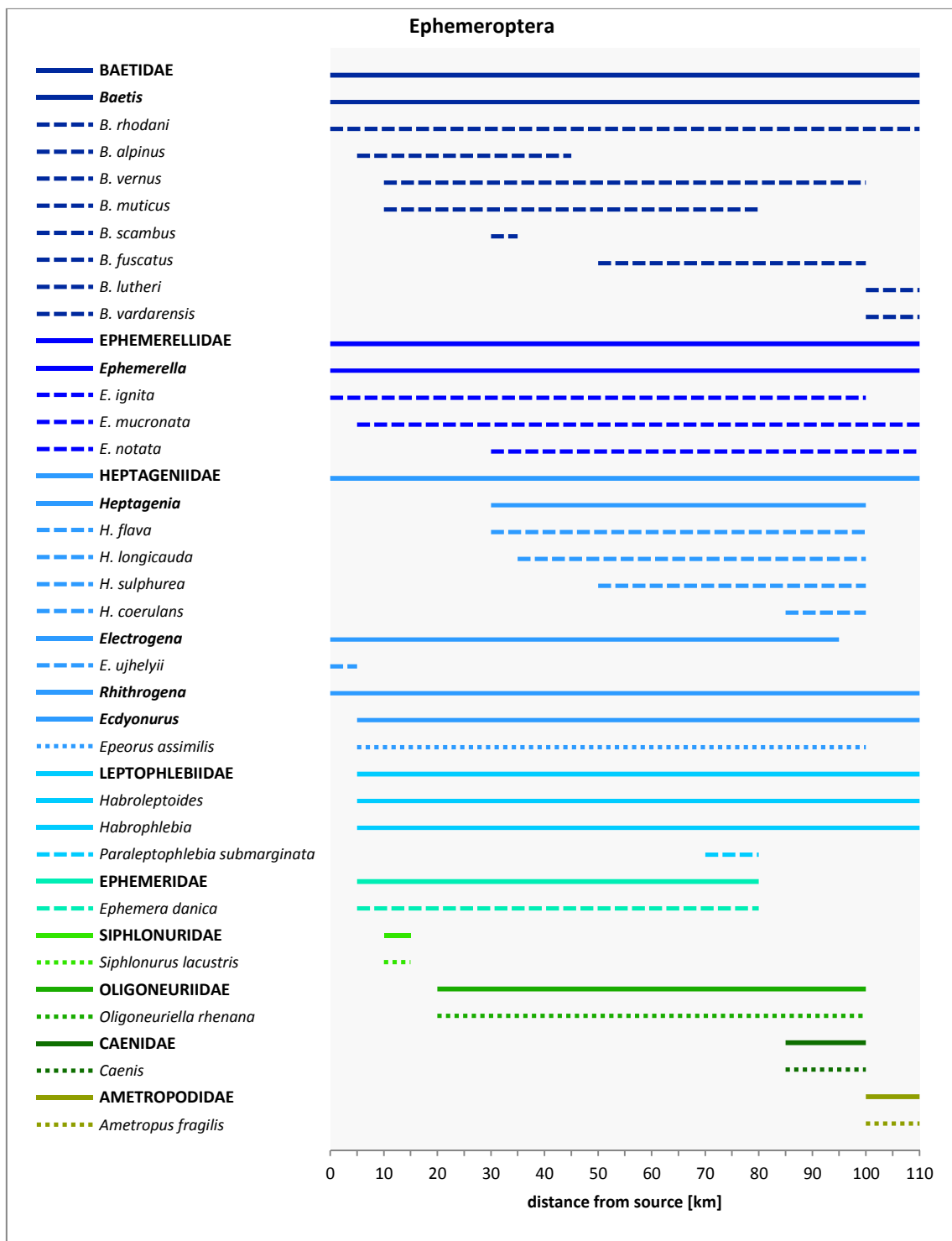


Figure 31: Longitudinal distribution of Ephemeroptera families (bold line), genera (continuous line) and species (broken or short broken line) in the river Lafnitz

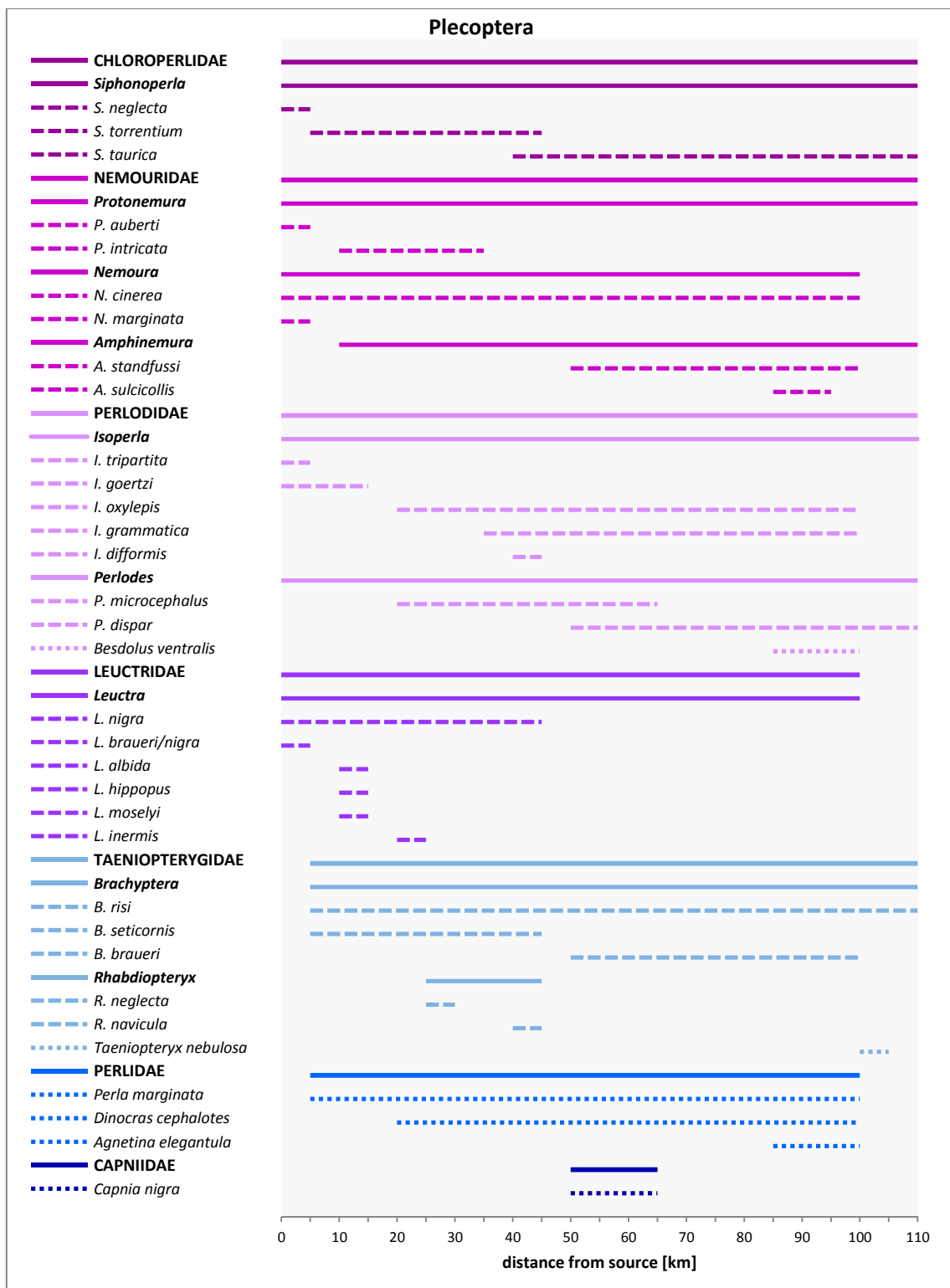


Figure 32: Longitudinal distribution of Plecoptera families (bold line), genera (continuous line) and species (broken or short broken line) in the river Lafnitz

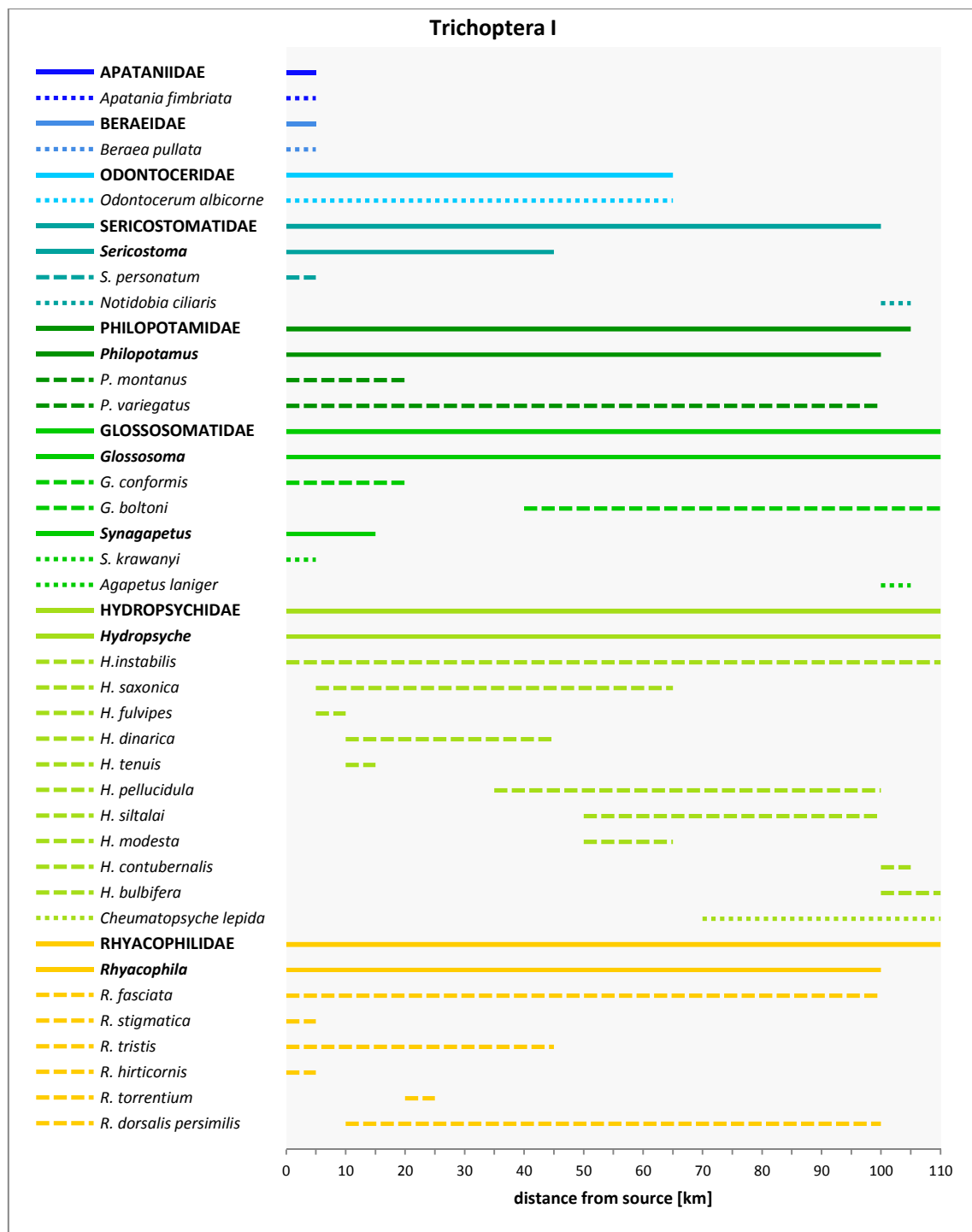


Figure 33: Longitudinal distribution of Trichoptera families (bold line), genera (continuous line) and species (broken or short broken line) in the river Lafnitz

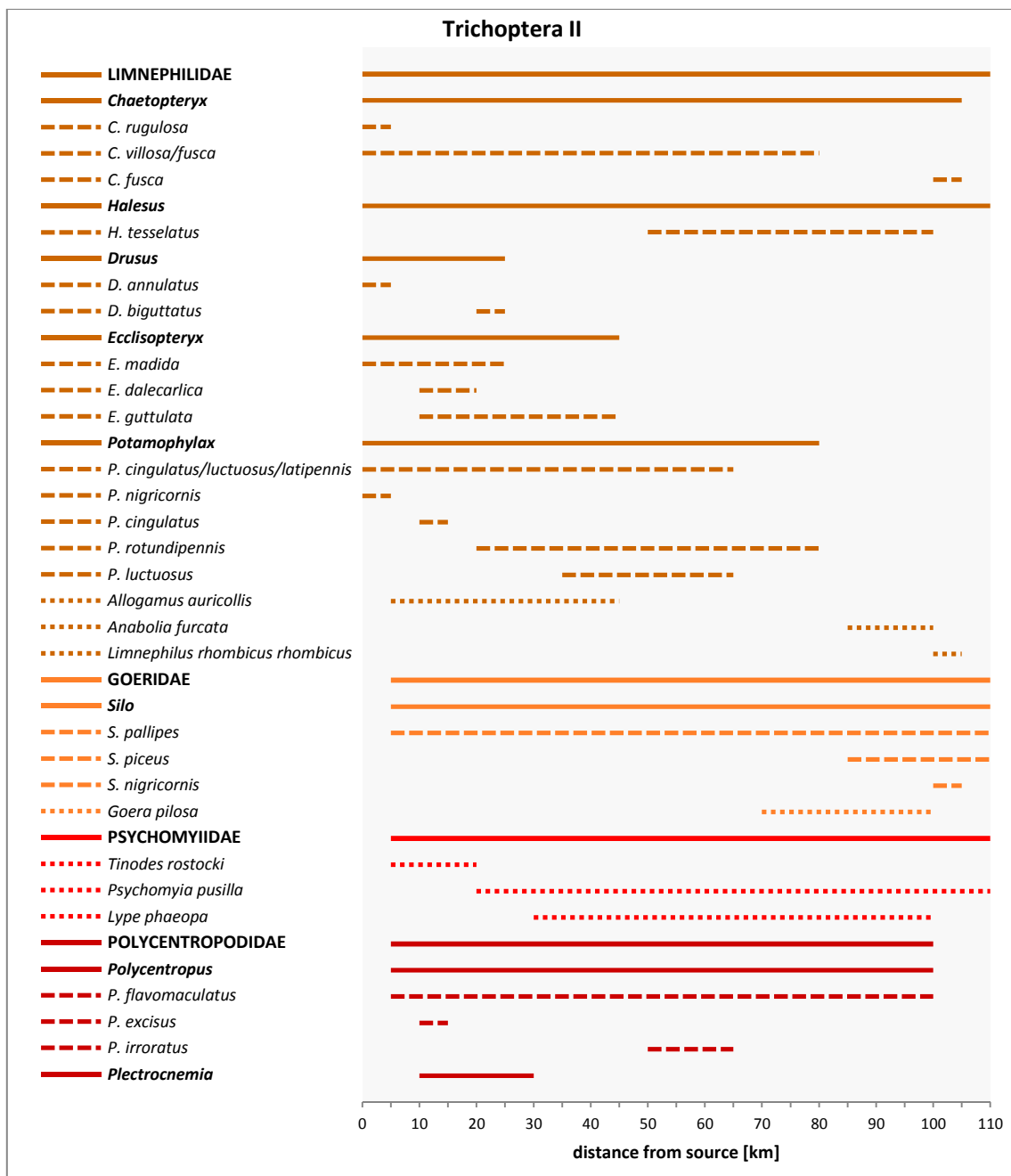


Figure 34: Longitudinal distribution of Trichoptera families (bold line), genera (continuous line) and species (broken or short broken line) in the river Lafnitz

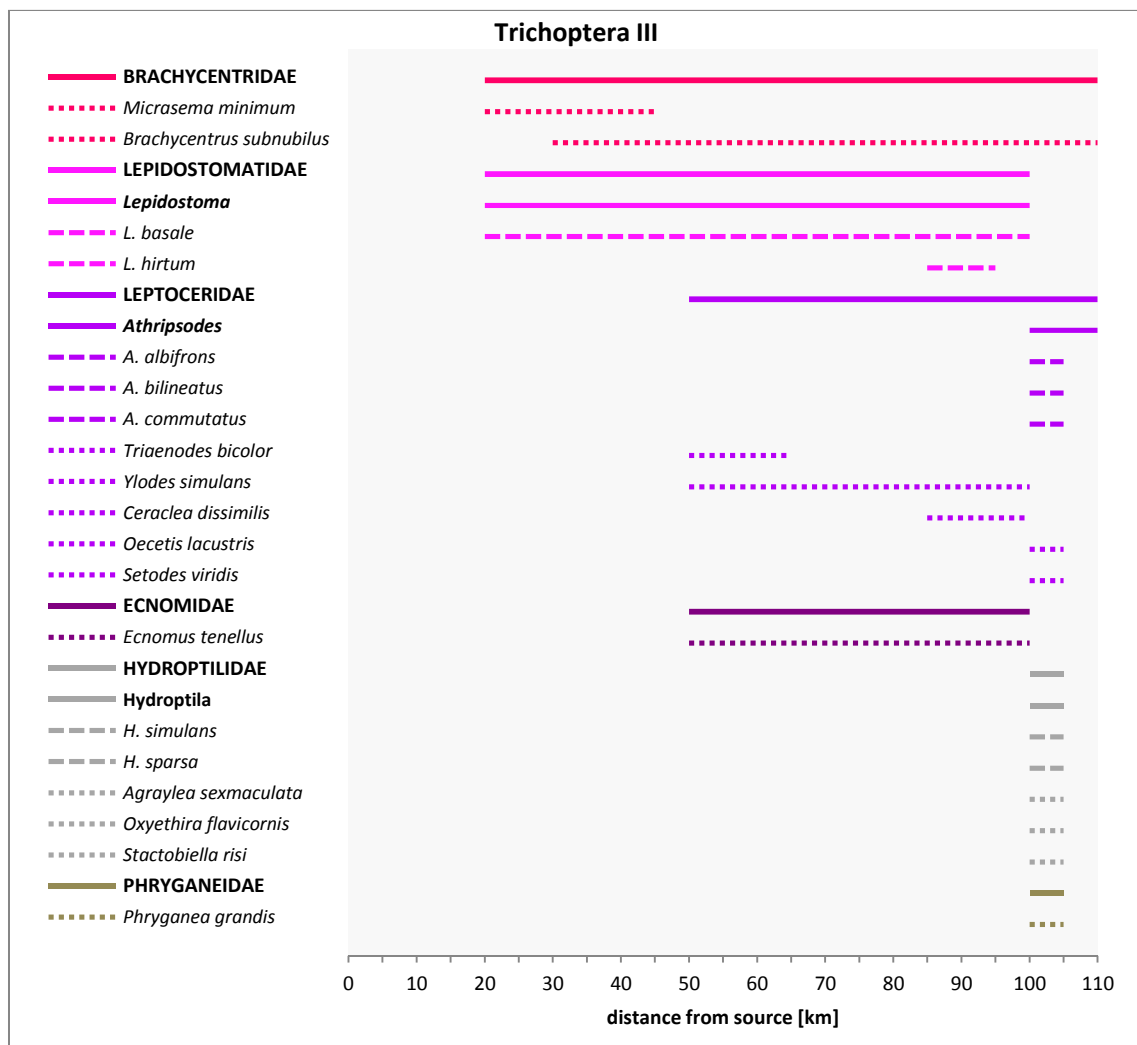


Figure 35: Longitudinal distribution of Trichoptera families (bold line), genera (continuous line) and species (broken or short broken line) in the river Lafnitz

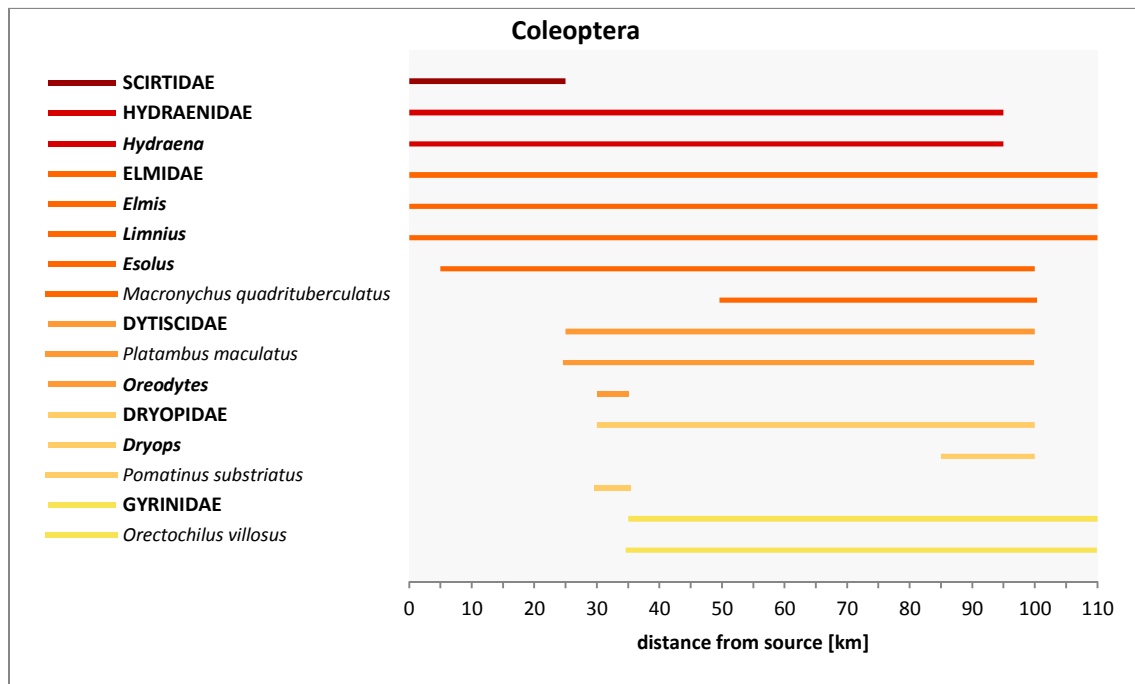


Figure 36: Longitudinal distribution of Coleoptera families (bold line), genera (continuous line) and species (broken or short broken line) in the river Lafnitz

The resulting graphs indicated, that macroinvertebrate distribution analyses on family level have only little explanatory value, especially for those which are very widespread and consisting of several genera and species. Only a further subdivision into lower taxonomic units allows a detailed insight into community composition and changes within the longitudinal sequence of species. Moreover, rare species cannot be detected by using family level, but especially those are substantial for management measures and conservation issues (LENAT, 1988; CUNNINGHAM & LINDENMAYER, 2005).

For example, *Brachyptera braueri* was registered at the Lafnitz, a species which is known to be heavily endangered in Central European large rivers, such as the Danube (GRAF & KOVÁCS, 2002), as well as *Ametropus fragilis*, another rare and threatened macroinvertebrate species (KOVÁCS et al., 2002).

Furthermore, ecological information is mainly available for species level and the basis of various biological metrics, as sensitivity of benthic macroinvertebrates to sedimentation, habitat degradation, organic and chemical pollution varies between species (GUEROLD, 2000; BAUERNFEIND & MOOG, 2000; BUFAGNI et al. 2001; LENAT & RESH, 2001; AQEM CONSORTIUM; 2002; HERING et al., 2004).

On the one hand, macroinvertebrates are relatively easy to collect, but on the other hand, determination to lower taxonomic levels (genus and especially species) needs a lot of time and mostly impossible without specialists. Nevertheless, the information provided on species level is essential for ecological studies as well as biological river assessment.

4.2. TRANSECTIONAL DISTRIBUTION

Macroinvertebrate sampling in March 2014 was done along cross-sectional transects at each sampling site, based on the idea that habitat conditions as well as macroinvertebrate distribution also vary laterally. Samples from woody debris were excluded, as they were all collected directly next to the shoreline, and also the samples from the silted section at Neustift were not taken into consideration, due to the homogenous hydraulic conditions there. For the remaining samples the measured distance from shoreline was converted into distance to the nearest shoreline in relation to total river width for each transect.

The comparison of macroinvertebrate abundance and biomass did not show any significant differences depending on the distance from shoreline. NMS analysis was performed based on the same selection of samples, to find out if community structure changes depending on position on the river bottom. The resulting ordination plot is given in figure 37 and indicated no similarities between macroinvertebrate assemblages depending on the relative distance from shore. The symbols, representing macroinvertebrate samples based on faunal composition and abundance (coloured according to relative distance from shoreline) were very widespread and there was no pattern obvious.

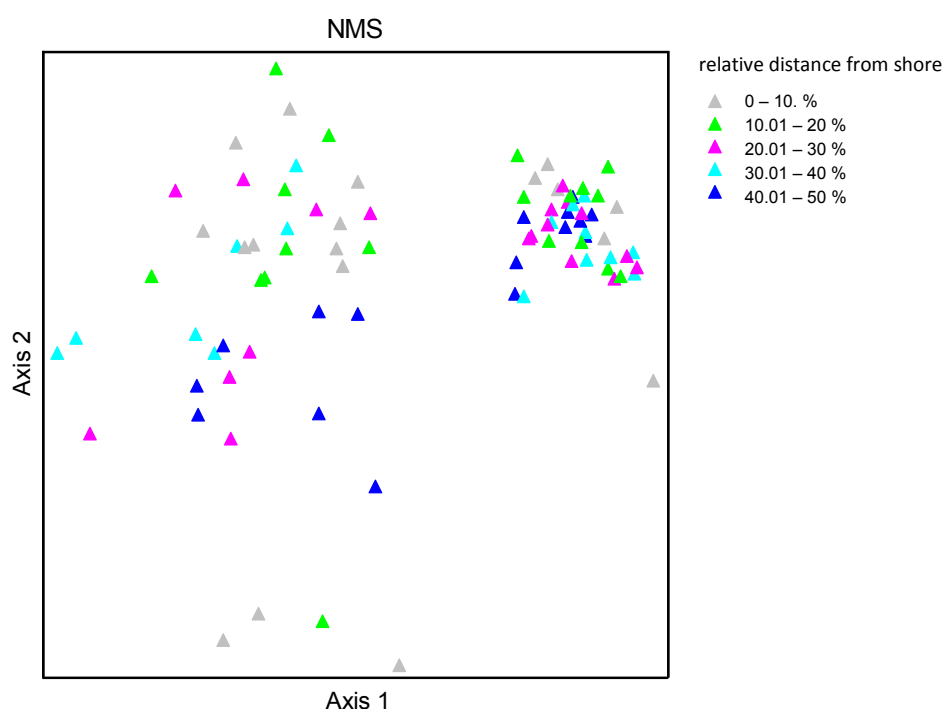


Figure 37: Similarity/Dissimilarity between macroinvertebrate samples (symbols) in relation to relative distance from shore (colours); NMS scatterplot using $\log(n+1)$ transformed abundance data (14.00964 = final stress for 2-dimesional solution; 0.00000 = final stress, 105 = number of iterations; (n = 88 SHS)

There are only a few studies on such a fine scale available such as the one from Li et al. (2001), which also showed that transect position had little explanatory value for within-stream variance of species distribution.

One explanation might be the small gradient of habitat variables from shoreline to the middle of the channel. Flow velocity tends to increase with increasing distance from shore, but highly variable (see figure 38).

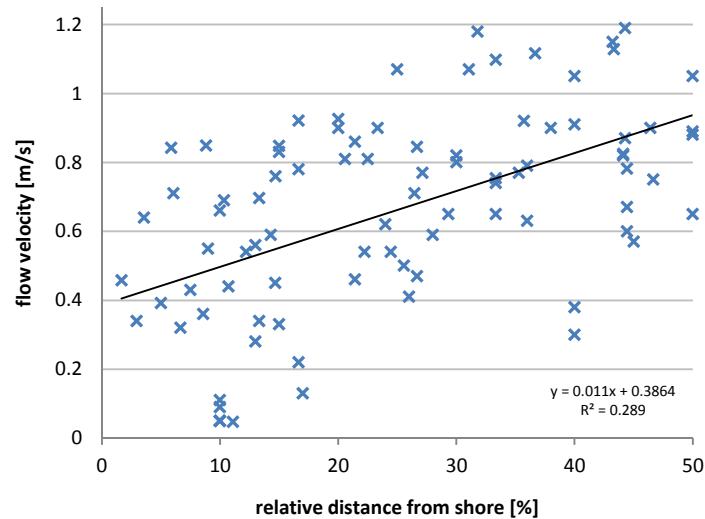


Figure 38: Linear regression between flow velocity and relative distance from shore ($n = 88$ SHS)

There was also evidence that substrate composition closely connected to transect position, however, figure 39 shows that small particle sizes were restricted close to the shoreline, and larger sizes were found more often in the middle of the channel, but meso- and macrolithal also present next to the shoreline.

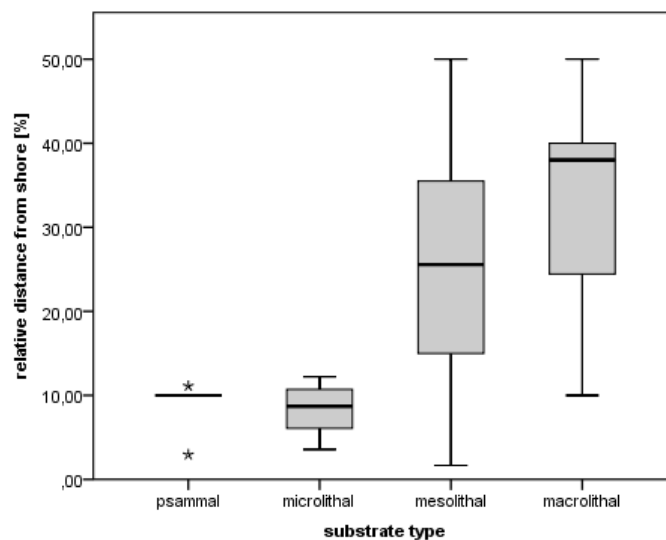


Figure 39: Relative distance from shore and substrate size ($n = 87$ SHS)

Hydraulic conditions can change very small-scale, like in front or behind a stone, and therefore may require sampling techniques which capture the high spatial variability on the river more accurate. Spatial distribution may also vary within species, due to ontogenetic habitat shifts, therefore the distinction between different larval stages, at least between early and latest instars, is recommended.

4.3. HABITAT PREFERENCES

Many studies about the relative importance of different environmental factors on benthic community structure exist, demonstrating that the complex interactions between habitat characteristics make a distinction of individual effects on benthic organisms very difficult (REMPEL et al., 2000).

Hydraulic and substrate conditions have been identified to affect within-stream species distribution and abundance (STATZNER et al., 1988; QUINN & HICKEY, 1994; JOWETT, 2003; BEAUGER et al., 2006; SCHRÖDER et al., 2013), but other factors such as temperature (VANNOTE et al., 1980; QUINN & HICKEY, 1990; HAIDEKKER & HERING, 2008), food availability (VANNOTE et al., 1980; BEAUGER et al., 2006), water chemistry and light (REMPEL et al., 2000 and references therein) have an influence on habitat selection as well.

NMS analysis was performed including all 110 SHS samples taken in March 2014 and the resulting ordination plot is displayed with overlay of flow velocity (see figure 40), substrate type (see figure 42) and sampling site (see figure 43).

Although the division of macroinvertebrates into three different flow velocity classes in steps of 0.4 ms^{-1} was a bit arbitrary, this classification could be confirmed by the NMS-scatterplot with overlay of flow velocity classes (see figure 40) to a certain extent. Starting with 12 flow velocity classes in steps of 0.1 ms^{-1} , grouping of macroinvertebrate samples was best possible by using these three classes in steps of 0.4 ms^{-1} , although still no real clustering was obvious. The samples of flow velocity class 1 (dark blue symbols) and class 3 (pink symbols) were well-separated with only a few overlaps, whereas those of flow velocity class 2 were located somewhere in-between. The NMS ordination was performed for a second time, but with exception of psammal and large woody debris (see figure 41), to get rid of samples from habitats where conditions for macroinvertebrates are expected to be mainly influenced by substrate type. Again, the remaining samples were scattered widely and there was no clear separation between macroinvertebrate assemblages regarding low, moderate or high flow velocity possible.

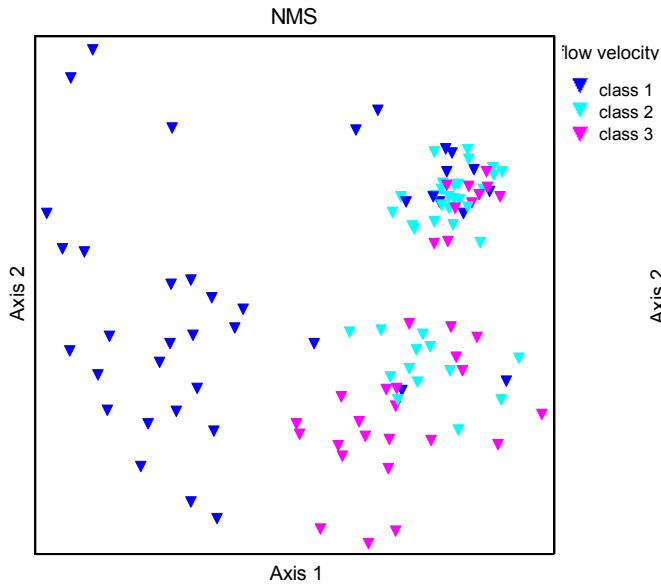


Figure 40: Similarity/Dissimilarity between macroinvertebrate samples (symbols) in relation to flow velocity classes (colours); NMS scatterplot using $\log(n+1)$ transformed abundance data (15.96154 = final stress for 2-dimensional solution, 0.00964 = final instability, 205 = number of iterations), $n = 110$ SHS

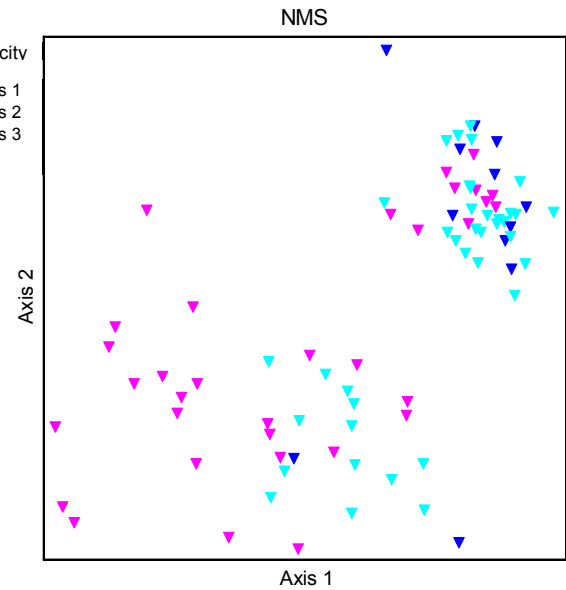


Figure 41: Similarity/Dissimilarity between macroinvertebrate samples (symbols) in relation to flow velocity classes (colours); NMS scatterplot using $\log(n+1)$ transformed abundance data (12.74929 = final stress for 2-dimensional solution, 0.00000 = final instability, 74 = number of iterations); $n = 83$ SHS (with exception of psammal and LWD)

Figure 42 shows the same NMS-scatterplot as figure 40, but with overlay of six different substrate types.

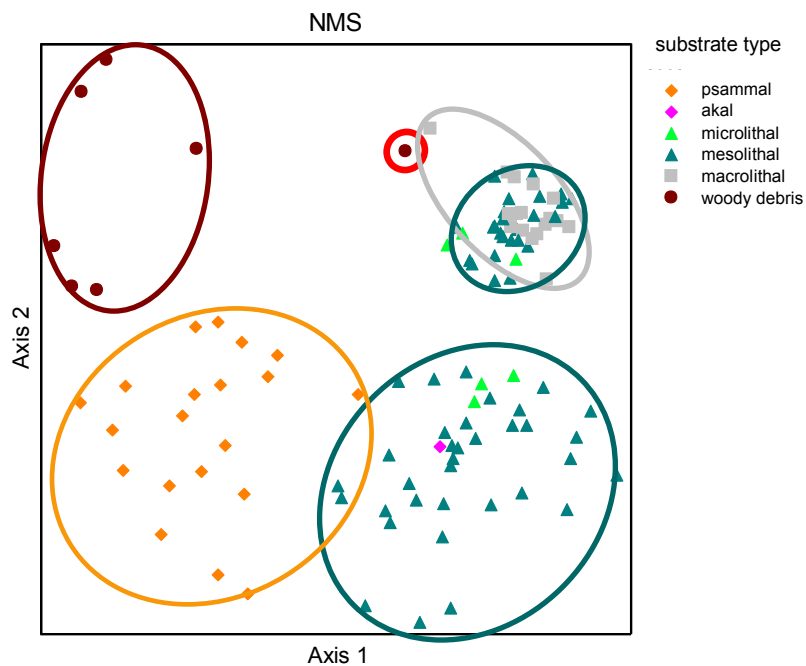


Figure 42: Similarity/Dissimilarity between macroinvertebrate samples (symbols) in relation to substrate type (colours); NMS scatterplot using $\log(n+1)$ transformed abundance data (15.96154 = final stress for 2-dimensional solution, 0.00964 = final instability, 250 = number of iterations); $n = 110$ SHS; continuous outlines = samples with high similarity from the same substrate type (brown = woody debris, orange = psammal, blue-green = mesolithal, grey = macrolithal), red line = outlier

Similarity was highest between macroinvertebrate assemblages from fine substrates (psammal, orange outline) and large woody debris (brown outline). Samples from both substrates formed each an isolated cluster, well-separated from macroinvertebrate samples of other substrate types. One sample from large woody debris differed considerably from the others (red line), and was located close to the samples from large mineral substrates. Macrolithal samples were arranged in a tight cluster (grey outline), but overlapping with samples taken from mesolithal which were more divers and formed two distinct clusters (blue-green outline). One cluster nearly completely overlapped with the samples from macrolithal, but the samples were close together, whereas the other part of the mesolithal samples was spread more widely. Akal and microlithal were rarely sampled and somewhere in between the samples from mesolithal, with a certain distance to those taken from smaller substrates.

The NMS-scatterplot, but this time with overlay of sampling sites, is given in figure 43, to analyse community differences along the longitudinal gradient.

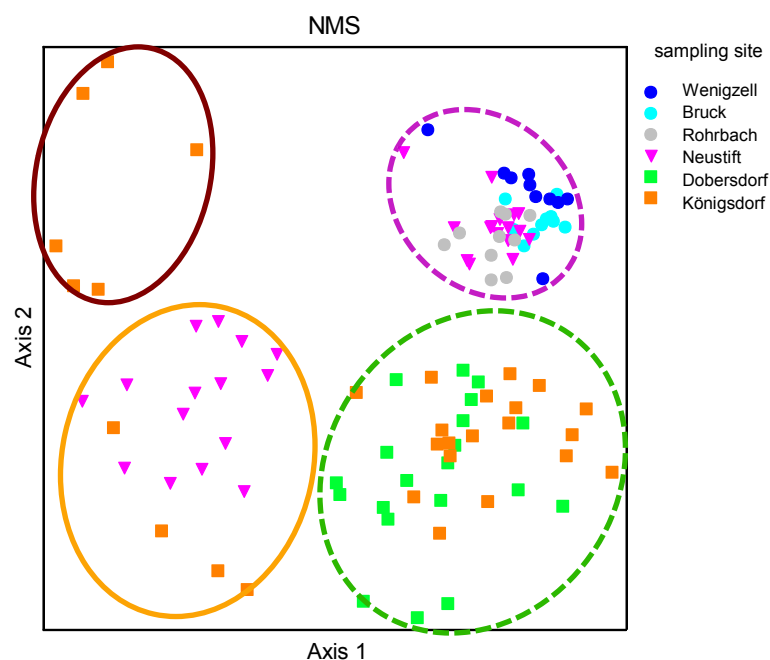


Figure 43: Similarity/Dissimilarity between macroinvertebrate samples (symbols) in relation to sampling site (colours); NMS scatterplot using $\log(n+1)$ transformed abundance data (15.96154 = final stress for 2-dimensional solution, 0.00964 = final instability, 250 = number of iterations); $n = 110$ SHS; continuous outline = samples from the same substrate type (purple = woddy debris, orange = psammal); broken outline = samples of high similarity depending on longitudinal location (blue = Wenigzell, Bruck, Rohrbach and Neustift; green = Dobersdorf and Königsdorf)

Macroinvertebrate samples from the upper three sites (Wenigzell, Bruck and Rohrbach) seemed to be quite similar, forming a tight cluster clearly detached from those taken from the other sites (blue broken outline). Macroinvertebrate samples taken from Neustift (pink symbols) were split up into two different clusters. One of them was completely overlapping with samples taken more upstream, whereas the other was more or less isolated (orange outline, with only a few overlaps with samples further downstream at Königsdorf (orange symbols). Some samples from Königsdorf formed another well-separated cluster (brown outline), but the majority of samples taken from this site were quite similar to those from the site above around Dobersdorf (green broken line).

By comparing the NMS plots with overlay of substrate type and site, it can be seen that the samples within this solitary cluster from Königsdorf were collected from large woody debris (see figure 42 and figure 43 brown outline). The one sample from woody debris, which appeared to be a bit different from the others (figure 42 red broken line), was the one taken from more upstream at Neustift. Macroinvertebrate samples from psammal taken at Neustift and at Königsdorf formed a well-separated cluster (see figure 42 and figure 43 orange outline), indicating a specific community structure on this type of substrate. Samples from mesolithal were arranged in two detached clusters (see figure 42 blue-green outlines). The comparison with overlay of sampling site revealed that, the samples concentrated within the tighter cluster and completely overlapping with those from macrolithal, were those from the upper third of the river course (see figure 43 purple broken line). Furthermore, it became apparent that the other cluster only consisted of macroinvertebrate samples from the lower course (figure 43 green broken outline).

These results clearly indicate longitudinal shifts in community structure (see figure 43 purple and green broken outline), and that fine substrates as well as woody debris are inhabited by a specific fauna (see figure 42 and 43 orange and brown outline). Moreover, there were also longitudinal changes in macroinvertebrate assemblages on woody structures obvious, as samples taken from upper and lower course clearly differed from each other.

NMS analysis was again performed only including macroinvertebrate within the small cluster from the upper course, to find out which habitat variable are crucial for benthic community structure there. Similarities between samples could only be observed using the variable **“sampling site”** (see figure 44), indicating that other environmental factors, for example water temperature or food availability are major determinants for benthic species distribution as well. Macroinvertebrate samples from Wenigzell can be clearly separated from the samples taken more downstream, which are all more or less overlapping.

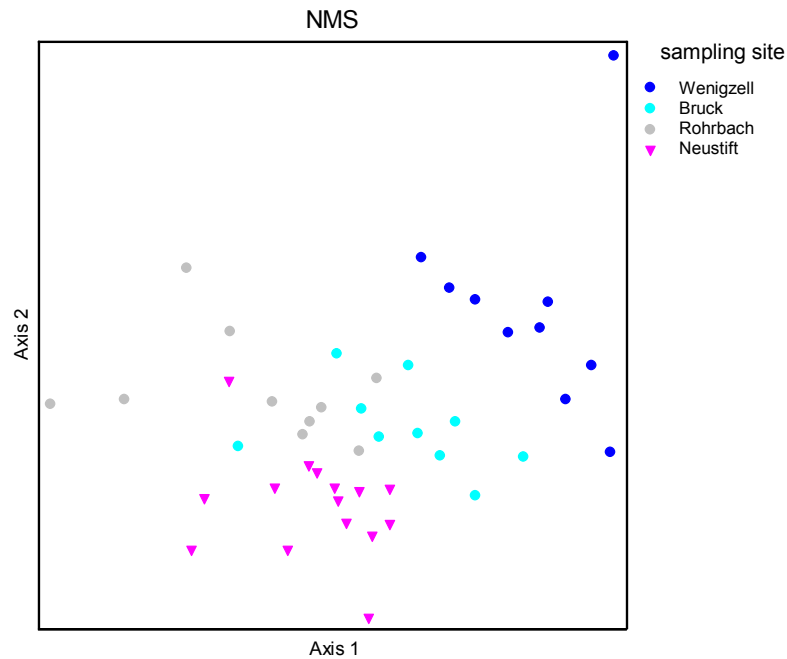


Figure 44: Similarity/Dissimilarity between macroinvertebrate samples (symbols) in relation to sampling sites (colours) NMS scatterplot using $\log(n+1)$ transformed abundance data (19.53107 = final stress for 2-dimensional solution, 0.00000 = final instability, 71 = number of iterations); $n = 45$ SHS

Numerous habitat variables are crucial for habitat selection of benthic species and the results of this study reflect the high complexity of physical habitat variables and their influence on the distribution of macroinvertebrates. Substrate characteristics seemed to be more important for explaining spatial distribution patterns compared to flow velocity, but as both are interrelated with each other, it is difficult to distinguish between their individual effects on community structure.

Flow velocity is a challenging factor in aquatic environments and benthic species have specific adaptations and preferences for different flow velocities (AMBÜHL, 1957; STATZNER et al., 1988; JOWETT et al., 1991; BUNN & ARTHINGTON, 2002; MÉRIGOUX et al. 2009).

Habitat utilization curves based on frequency distributions at different flow velocities from March 2014 were drawn to analyse hydraulic preferences for selected species of the river Lafnitz. Only EPT species which are known to live on the surface of the bottom substrates, directly exposed to the flow were considered, and of which more than 20 individuals were collected. According to that, suitability graphs were generated for in total 15 species and compared with existing data about current preferences from the Austrian database freshwaterecology.info (SCHMIDT-KLOIBER & HERING, 2012: www.freshwaterecology.info), unless otherwise specified.

The resulting graphs for Ephemeroptera are shown in figure 45. All three species of the genus *Baetis* are classified as rheophilic, but in contrast to *B. alpinus* and *B. lutheri*, most

individuals of *B. rhodani* were collected from relatively low velocities. Several studies report preferences of this species for strong current (SCHMEDTJE, 1995), but others for moderate velocities (FJELLHEIM, 1996 and references therein). Intraspecific differences are not surprising, as individuals of the whole genus *Baetis* are known to undergo ontogenetic habitat shifts. During growth their preferences change from high to lower velocities (STATZNER, 2008), and the high share of late larval stages may be the reason for the high densities of *B. rhodani* and *B. alpinus* at relatively low flow velocities. Other Ephemeroptera species such as *E. mucronata* and *E. notata* were most frequently found at relatively low flow velocities, but seemed to tolerate higher flow velocities as well, and both are classified as rheo- to limnophil. SCHMEDTJE (1995) reported preferences of *E. notata* for slow flowing water especially in spring, but in autumn this species was also frequently found at high flow velocities, indicating habitat shifts within this species during development. The dorsoventrally flattened mayfly *E. assimilis* is well-adapted to high current and distributed over a wide range of flow velocities in quite similar densities in the samples from the river Lafnitz.

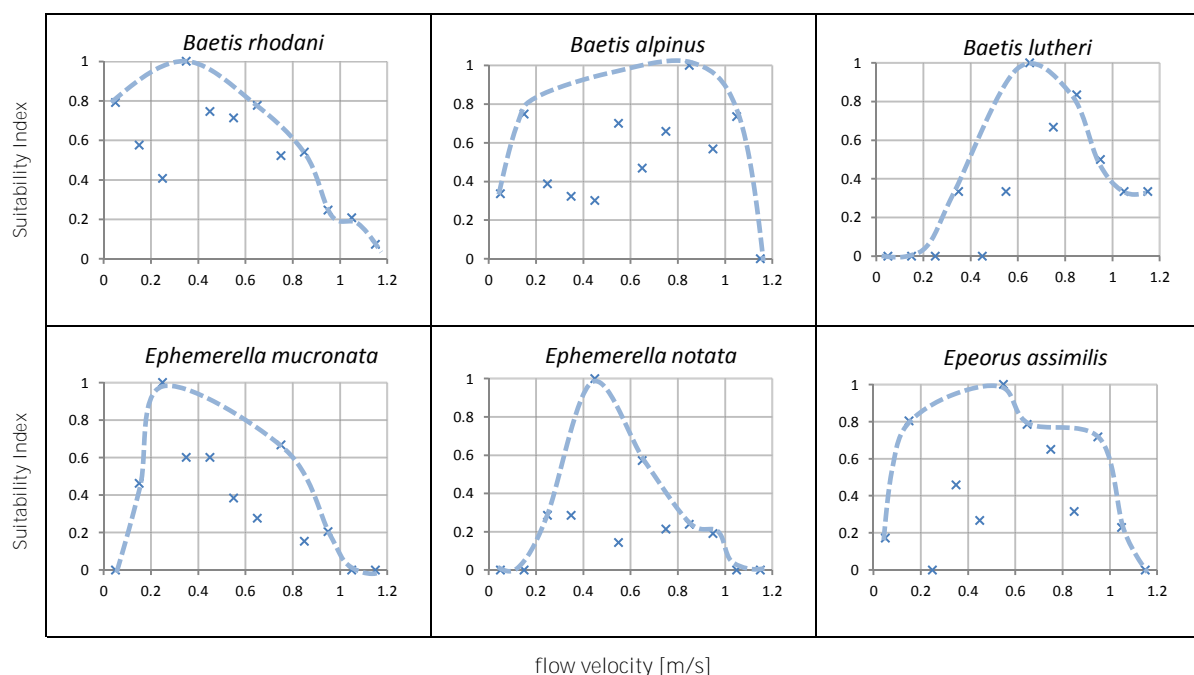


Figure 45: Habitat utilization curves of Ephemeroptera

Plecoptera are characteristic inhabitants of mountain streams and prefer high current. Consistent with the existing knowledge, *B. risi*, *B. seticornis* as well as *P. marginata* showed highest individual densities especially at high flow velocities (see figure 46).

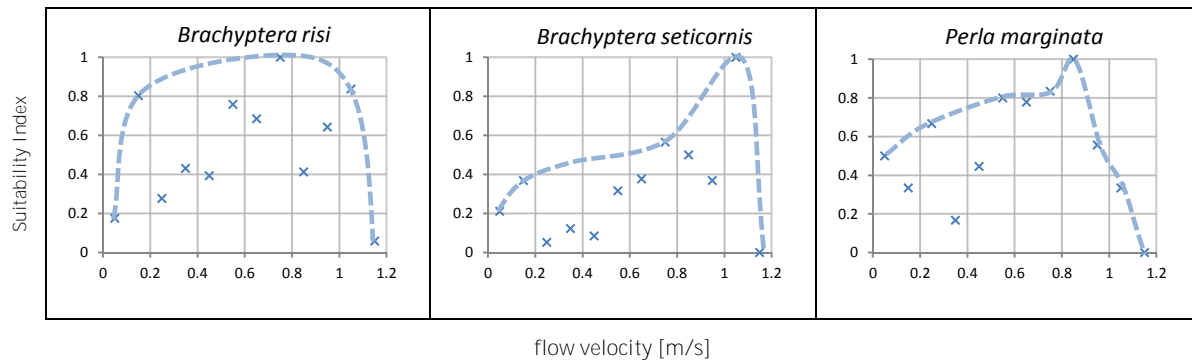


Figure 46: Habitat utilization curves of Plecoptera

The cased Trichoptera species *A. auricollis*, was restricted to low-flow areas (see figure 47), supporting the observations of GRAF et al. (1992), SCHMEDTJE (1995) and SCHMUTZ et al. (2013). This species seems to be quite sensitive to high velocities, and may be a good indicator for alterations of the natural flow regime, e.g. flow acceleration due to river straightening and hydro-peaking. Individuals of *E. guttulata* are living down to a sediment depth of 1 metre (WARINGER, 1987), and the measurement of flow velocity in the water column is only a very rough estimation of near-bed hydraulics. However, according to the Austrian database and the study by SCHMEDTJE (1995), this species prefers areas of fast flowing water. The results of this study showed that *E. guttulata* mostly occupied habitats within moderate velocities, but was also collected at velocities above 1 ms⁻¹. *E. madida* is also classified as rheophilic, and was widely distributed over a broad range of flow velocities, but most individuals were present at moderate to high velocities. *S. pallipes* is another rheophilic species and was frequently found over a quite broad range of flow velocities. The two caseless species *P. pusilla* and *C. lepida* showed highest abundances at relatively high flow velocities and both are known to have preferences particularly for higher velocities (for *P. pusilla* see also SCHMEDTJE, 1995).

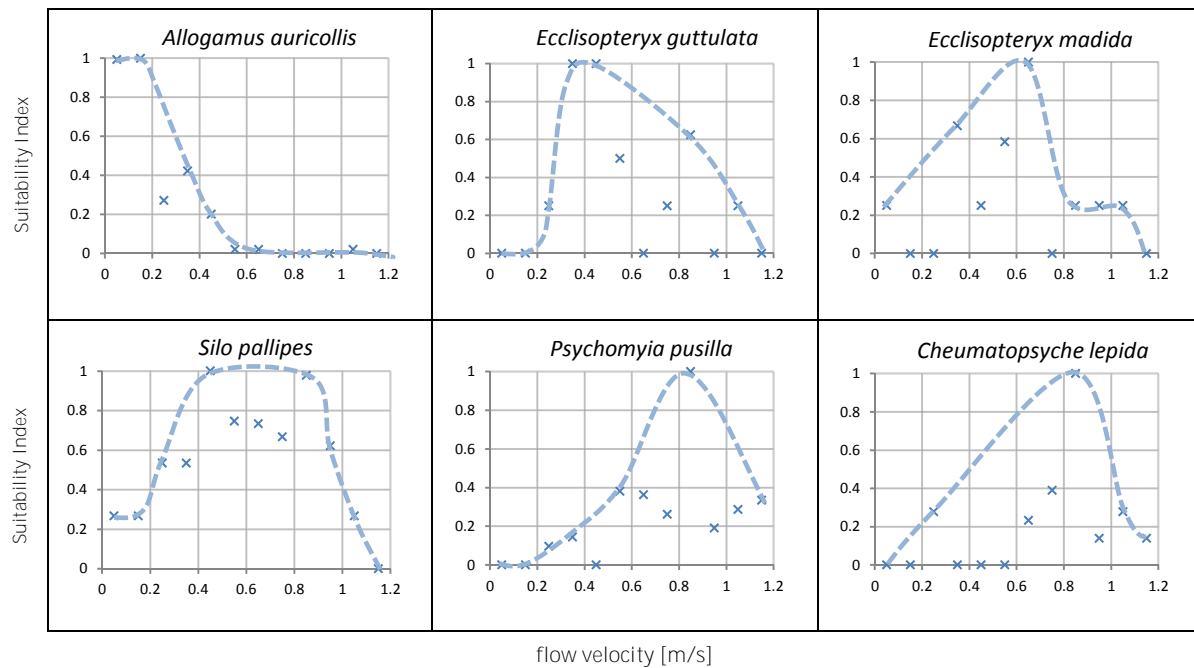


Figure 47: Habitat utilization curves of Trichoptera

Discrepancies with previous studies on hydraulic preferences of benthic invertebrates were not surprising, as no differentiation between early and late larval instars was made. Smaller individuals of several species well-adapted to high current are expected to be less numerous in fast flowing areas, as morphological adaptations e.g. anal claws of larger individuals of the same species are more effective (SAGNES et al., 2008). On the other hand, late larval stages of freely moving species, for example the genus *Baetis*, may be found more frequently within low-flow areas, as they shift their preferences during growth from high to low current (STATZNER, 2008).

Due to seasonal variability of habitat conditions within running waters, the quantification of habitat preferences of benthic invertebrates should be based on seasonally replicated samples of several river systems (SAGNES et al., 2008). Furthermore, habitat preferences of macroinvertebrates are changing depending on larval development and especially short-living species occupy several different habitats within relatively short time. The presence and individual densities of species also varies between seasons, depending on species-specific life cycles and environmental conditions.

For this master thesis project only samples from one season and one river were considered, and this may be another reason for inconsistencies with existing data about current preferences of benthic species. Habitat utilization curves were used to roughly assess hydraulic preferences of selected species, in order to highlight the importance of flow variability for habitat and species diversity.

However, studies on species-specific hydraulic preferences are important tools for flow management and the increased emphasis on conservation of multiple species, as measures for a few target species may affect habitat availability for other species (GORE et al., 2001).

4.3.1. EFFECTS OF INCREASED FINE SEDIMENT DEPOSITION

Increasing anthropogenic induced siltation has great effects on river systems and riverine species. The impacts of fine sediment deposition on aquatic systems are numerous, ranging from reduced primary production, through increased turbidity and limited light penetration, to habitat loss, through altered substrate conditions and filling up of the interstices (WOOD & ARMITAGE, 1997; EXTENCE et al., 2011).

According to WOOD & ARMITAGE (1997), increased fine sediment deposition affects the benthic community by 1) modifying substrate conditions and therefore altering habitat suitability for some taxa, 2) increasing drift because of sedimentation or substrate instability, 3) limiting respiration due to deposition of fine sediments on respiration organs or low oxygen concentrations and 4) deteriorating feeding conditions for filtering organisms due to high concentration of suspended solids as well as a general reduction of available prey items. The accumulation of fine sediments together with low flow velocity creates extreme habitats, where only specialists are adapted to and therefore favours some taxa at the expense of others.

The comparison between macroinvertebrate assemblages from different substrate types along the entire river course showed, that substrate conditions have great influence on benthic species distribution. Especially fine substrates seemed to provide habitats only suitable for a specific community, apart from large woody debris. To demonstrate the impacts of fine sediment accumulation on the community structure, macroinvertebrate samples from an impacted and a non-impacted river section around Neustift were compared, based on abundance, biomass and community composition.

Tolerance against different environmental conditions varies between species, therefore total macroinvertebrate density may be not useful for identification of impacted and unimpacted sites (LINKE et al., 1999; RELYEA et al., 2000). Some groups of macroinvertebrates have the potential to significantly increase in abundance in areas of fine sediment deposition (Ephemeroptera: *Baetis* and *Paraleptophlebia*, Diptera: Chironomidae, Bivalvia: Sphaeriidae, Oligochaeta), whereas most EPT taxa are clearly less abundant in impacted habitats (WOOD & ARMITAGE, 1997, RELYEA et al., 2000; LARSEN et al., 2009).

Nevertheless, significant differences between abundance and biomass were detected, which were much lower in the silted section, supporting the observations documented by e.g. BENKE

et al. (1994); ANGRADI (1999), SUREN & JOWETT (2001), SUREN (2005) and CONOLLY & PEARSON (2007). Mean abundance was reduced by almost 80 %, and mean biomass by around 65 % at the impacted section (see table 13). Habitat loss and lower macroinvertebrate densities in silted areas can be e.g. caused by filling up the interstitial through high sediment loads and reducing habitat availability of many taxa resulting in lowered overall macroinvertebrate density and diversity (WOOD & ARMITAGE, 1997; ANGRADI, 1999 and references therein).

Table 13: Mean abundance, mean biomass and taxa (family) richness per section at Neustift

section	mean abundance [ind/m²]	mean biomass [g/m²]	taxa richness
A (silted)	3866.7	19.77	27 (18)
B (non-silted)	17337.6	55.32	52 (32)

Correspondingly, taxa richness was substantially lower in the silted section as well, demonstrating again the tremendous effects of fine sediment accumulation on the benthic fauna. In those areas almost half as many taxa were documented as in the unaffected river section. Greatest discrepancies were observed for taxa richness of Plecoptera and Trichoptera, which was reduced by almost two thirds each. Several experiments in artificial channels as well as many case studies (see review by JONES et al, 2011) have reported noticeable reductions of total taxa richness and EPT-taxa richness.

Higher amounts of fine sediments favour some taxa at the expense of others, based on different life strategies (e.g. feeding type, reproduction) and resulting distinct tolerances for environmental conditions. Shifts in community structure were most obvious by comparing mean biomass per sample of Chironomidae and EPT-taxa, between the silted and the non-silted river section (see figure 48). EPT biomass was comparatively variable, but quite high in the non-silted section and almost negligible within samples from the silted section. In contrast to that, mean biomass of Chironomidae varied greatly between samples from the silted section, but clearly higher there than in the non-silted section.

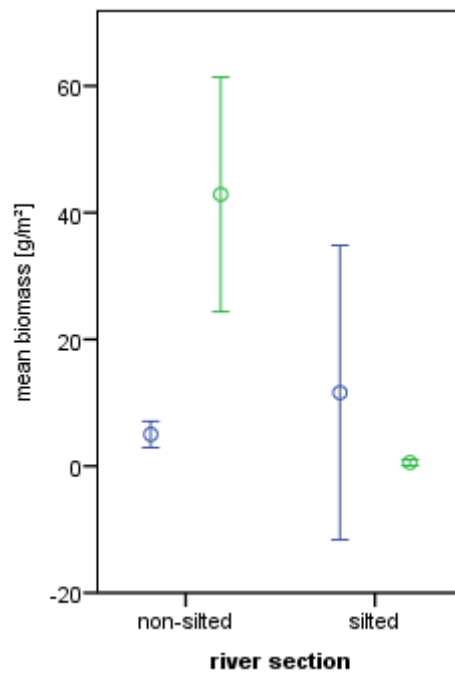


Figure 48: Mean biomass of EPT-taxa (green) and Chironomidae (blue) and 95 % confidence interval per section (non-silted, silted) out of 30 samples

Individuals of Chironomidae utilize sandy substrates for the construction of cases and tubes and therefore potentially increasing in areas of fine sediment accumulation, in contrast to many EPT-taxa which need coarser substrates and higher flow velocities for e.g. respiration, feeding and movement (WOOD & ARMITAGE, 1997, SCHRÖDER et al., 2013).

Increased loads of fine sediments and turbidity can reduce primary production via photosynthesis, enhance physical abrasion of algae and prevent the attachment of periphyton to substrate surfaces. Grazers are known to be quite sensitive to accumulations of fine sediments as they mainly feed on periphyton attached to the substrates on the river bottom. The comparison of feeding type distribution was based on 53 out of 60 taxa, as little knowledge exists about feeding habits of some water beetles, and for some Diptera families (including Chironomidae) no classification on family level was available.

However, consistent with other studies (REMPEL et al., 2000; RELYEA et al., 2000; EXTENCE et al., 2011; JONES et al, 2011), the share of grazing considerably declined in the silted section (see figure 49). The community changed from a grazer dominated community in the unimpacted section, to a community that mainly consisted of predatory individuals at the impaired section. Prey availability and predation efficiency might be higher in the silted section as areas where fine sediments accumulate do not provide sufficient hiding places for prey items.

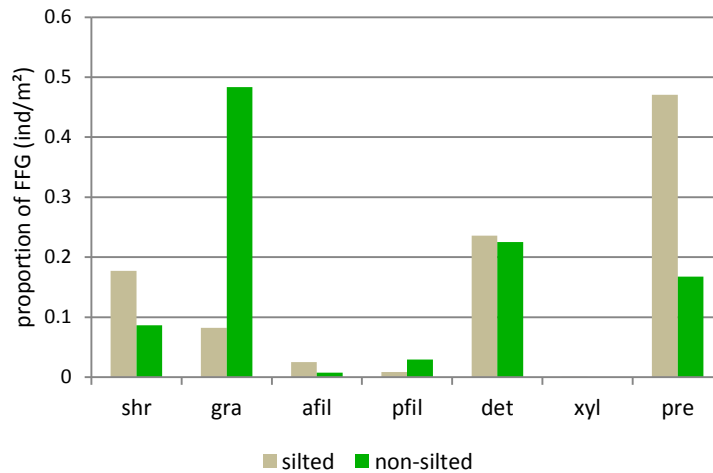


Figure 49: Proportion of feeding types based on abundance data (n = 53 taxa)

Increased amounts of fine sediments have various direct and indirect impacts on the benthic community such as abrasion, burial, clogging and reduced oxygen, habitat and food availability. Furthermore, the homogenous substrate conditions at silted sites only provide suitable habitats for some taxa and the input of fine sediments strongly increases invertebrate drift (ALLAN, 1975; SUREN & JOWETT, 2001; JONES et al., 2011).

The results of the present study impressively demonstrate the negative effects of increasing proportions of fine substrates on the river bottom for the benthic fauna. Although the two sampled river sections were just 100 metres away from each other, a fundamental change in macroinvertebrate assemblages was evident.

Similarity indices such as the Jaccard Index or Renkonen Index are common tools to detect differences between benthic communities. The Jaccard Index is based on taxa composition and only gives information about species similarity, whereas the Renkonen Index also takes relative abundances into account. Both indices (see table 14) underline the great impact of increased amount of fine sediments within rivers on the benthic fauna. Species similarity was only around 34 %, indicating that only a small proportion of species was present at both sections. Due to the high abundance of Chironomidae in both sections, this Diptera family was excluded for the calculation of the Renkonen Index. After that, the degree of similarity between the impacted and non-impacted section strongly declined from almost 80 % to less than 20 %.

Table 14: Similarity Indices (* including individuals of Chironomidae)

Index	based on	type	percentage
Jaccard	presence/absence	species similarity	33.89
Renkonen	abundance	dominance similarity	19.01 (77.89*)

The results of the present study demonstrate the negative effects of human induced siltation on the benthic fauna of the river Lafnitz. This river, is one of the last examples of meandering rivers in Austria, and mainly consists of natural or near-natural stretches, but is also influenced by human activities such as e.g. agriculture, removal of bankside vegetation, river straightening and hydropower plants causing increased input and deposition of fine sediments in rivers. The deposition of sediments occurs in areas of slow flowing water, comparable with the situation at the impacted site, where flow velocity declined and substrate was dominated by fine sediments. Rivers are open, directional systems and therefore human modifications may not only affect local conditions, but also the habitat conditions further downstream.

4.3.2. WOOD-ASSOCIATED FAUNA

Woody debris plays a central role in riverine systems, influencing the abiotic environment as well as biotic components. Wood and accumulations of woody debris in rivers provide e.g. low-flow areas up to current-protective sites and serves as habitat, refuge and food source for macroinvertebrates and able to mitigate the effects of increased hydraulic stress. Moreover, floods and the resulting transport of floating wood are important for the dispersal of benthic species (BORCHARDT, 1993; HOFFMANN & HERING, 2000).

Based on cumulative macroinvertebrate data from 2012-2014 of the river Lafnitz, mean macroinvertebrate biomass was higher in the samples from woody debris, indicating that woody structures are an important food resource for benthic invertebrates. Although mean individual densities was higher on mineral substrates, it is evident that woody structures significantly contribute to macroinvertebrate density and biomass in riverine systems, supported by the findings of BENKE et al. (1994).

Woody debris was colonized by characteristic species assemblages, clearly differing from those collected directly from the river bottom, and Indicator Species Analyses was performed to find out which species present in the river Lafnitz are characteristic for this substrate type. In total ten taxa were identified to be indicators for woody debris accumulations, including taxa of Ephemeroptera (*Ecdyonurus* sp., *Ephemerella ignita*, *Heptagenia flava*, *Heptagenia longicauda*), Trichoptera (*Hydropsyche* sp., *Halesus* sp., *Lepidostoma basale*) Coleoptera (*Macronychus quadrituberculatus*, *Orectochilus villosus*) and Amphipoda (*Gammarus fossarum*).

G. fossarum, *Halesus* sp. and *L. basale* are known to use wood as a food resource, while *E. ignita* and *H. flava* are classified as non-xylophagous species, but closely associated with wood. *H. longicauda* also uses woody structures as a habitat to a certain extent as well as *Ecdyonurus* sp. (BORCHARDT, 1993; HOFFMANN & HERING, 2000; SCHRÖDER et al., 2013; freshwaterecology.info).

Filter-feeders like the genus *Hydropsyche* are reliant on solid substrates in the highly variable hydraulic environment and a sufficient food supply. Larvae of Hydropsychidae were very abundant in the samples from wood, and are known to build large cavities into woody structures with the help of their strong mouth parts and use it as a retreat (HOFFMANN & HERING, 2000).

Several species had low indicator values due to low individual densities, but are also known to be part of the wood-associated benthic fauna in Central Europe streams. Table 14 shows all benthic species present in the river Lafnitz and their classification by HOFFMANN & HERING (2000) according to the degree of association to woody substrates.

Table 15: Wood-associated species present in the river Lafnitz (species with high indicator values according to ISA marked with *) and classified corresponding to HOFFMANN & HERING (2000) into non-xylophagous, wood-associated species (1), facultative xylophagous wood-associated species (1), facultative xylophagous species (2), obligate xylophagous species (3) and species which are probably xylophagous (4)

Species	Order	Family	class
<i>Gammarus fossarum</i> *	Amphipoda	Gammaridae	4
<i>Macronychus quadrituberculatus</i> *	Coleoptera	Elmidae	3
<i>Orectochilus villosus</i> *	Coleoptera	Gyrinidae	1
<i>Atherix ibis</i>	Diptera	Athericidae	4
<i>Ibisia marginata</i>	Diptera	Athericidae	4
<i>Ephemerella ignita</i> *	Ephemeroptera	Ephemerellidae	1
<i>Heptagenia flava</i> *	Ephemeroptera	Heptageniidae	1
<i>Heptagenia sulphurea</i>	Ephemeroptera	Heptageniidae	1
<i>Paraleptophlebia submarginata</i>	Ephemeroptera	Leptophlebiidae	1
<i>Aphelocheirus aestivalis</i>	Heteroptera	Aphelocheiridae	1
<i>Asellus aquaticus</i>	Isopoda	Asellidae	2
<i>Calopteryx virgo</i>	Odonata	Calopterygidae	1
<i>Nemoura cinerea</i>	Plecoptera	Nemouridae	4
<i>Protonemura intricata</i>	Plecoptera	Nemouridae	2
<i>Agnetina elegantula</i>	Plecoptera	Perlidae	1
<i>Beraea pullata</i>	Trichoptera	Beraeidae	2
<i>Brachycentrus subnubilus</i>	Trichoptera	Brachycentridae	1
<i>Hydropsyche pellucidula</i>	Trichoptera	Hydropsychidae	1
<i>Hydropsyche saxonica</i>	Trichoptera	Hydropsychidae	1
<i>Hydropsyche siltalai</i>	Trichoptera	Hydropsychidae	1
<i>Lepidostoma basale</i> *	Trichoptera	Lepidostomatidae	2
<i>Lepidostoma hirtum</i>	Trichoptera	Lepidostomatidae	2
<i>Anabolia furcata</i>	Trichoptera	Limnephilidae	2
<i>Limnephilus rhombicus</i>	Trichoptera	Limnephilidae	2
<i>Potamophylax cingulatus</i>	Trichoptera	Limnephilidae	2
<i>Potamophylax nigricornis</i>	Trichoptera	Limnephilidae	2
<i>Philopotamus montanus</i>	Trichoptera	Philopotamidae	1
<i>Lype phaeopa</i>	Trichoptera	Psychomyiidae	3
<i>Rhyacophila tristis</i>	Trichoptera	Rhyacophilidae	1
<i>Sericostoma personatum</i>	Trichoptera	Sericostomatidae	2

Most taxa of Coleoptera were not very abundant, and did not get significant Indicator values, except for *M. quadrituberculatus* and *O. villosus*, both typically wood-inhabiting species. *O. villosus* does not feed on wood, but closely associated with this habitat type, by contrast, larval stages of *M. quadrituberculatus* live and feed on submerged wood and also the adults are bound to this specific habitat type (HOFFMANN & HERING, 2000).

Nevertheless, it was obvious that woody debris provides an important habitat for water beetles, as all documented taxa of this group were at least once collected from woody debris, except for individuals of the genus *Riolus*. Moreover, five taxa (*Dryops* sp., *Pomatinus substriatus*, *Oreodytes* sp., *M. quadrituberculatus*, and *Pomatinus* sp.) were only found on wood and completely absent on mineral substrates.

Woody debris accumulations in rivers and streams function as hot spots for macroinvertebrates and provide a structurally highly complex habitat (O'CONNOR, 1991; WEIGELHOFER & WARINGER, 1999; HOFFMANN & HERING, 2000). BENKE et al. (1994) compared macroinvertebrate densities and diversity on wood with the sandy benthos in the main channel. They found considerably lower densities on the sandy substrates and also benthic community composition was less diverse there and dominated by chironomids and oligochaetes.

Due to the presence of woody debris accumulations within the silted section at Neustift, one additional sample was taken from woody debris. According to the findings of BENKE et al. (1994), macroinvertebrate diversity was much greater there, with 29 different taxa in one sample compared to between two and twelve taxa in the 15 samples from fine substrates.

Woody structures serve an important habitat for macroinvertebrates in aquatic systems, rich in taxa and abundance (BENKE et al., 1984; BORCHARDT, 1993; WEIGELHOFER & WARINGER, 1999; ELLIOT, 2008; SCHRÖDER et al., 2013), as shown with the example of the river Lafnitz.

Especially xylophagous species depend on the presence of wood within the channel and the riparian zones, and play an important role in the degradation process of wood.

Moreover, woody debris accumulations provide suitable habitats for many aquatic species, direct or indirect, by modifying habitat variables such as flow velocity, sedimentation and retention of organic and inorganic matter (BORCHARDT, 1993; WEIGELHOFER & WARINGER, 1999; HOFFMANN & HERING, 2000).

The presence of woody structures greatly enhances habitat heterogeneity and biodiversity within rivers and the removal of bankside vegetation or woody debris accumulations may have severe effects, not only on macroinvertebrates, but also on fish and other aquatic species.

5. SUMMARY

Most rivers in Austria are hydro-morphologically altered due to a variety of human modifications, hence minimally disturbed river habitats and unaffected species assemblages are increasingly scarce. Human impacts such as channel straightening, riverbank stabilisation, levees, removal of riparian vegetation, etc. have multiple effects on running waters like flow velocity acceleration, increased fine sediment input, loss of riparian habitats and reduced import of wood into river systems (BROOKER, 1985; STATZNER et al., 1988; POFF et al., 1997; WOOD & ARMITAGE, 1997; MUHAR et al., 2000).

The Lafnitz is an example of a near-natural river, including free-meandering stretches, hosting many rare and endangered benthic species (GRAF & KOVÁCS, 2002) and therefore ideal for studies on community composition and species distribution.

At least ten single habitat samples were taken at six sampling sites along the entire river course, from near source to close to the mouth, and arranged in cross-sectional transects, based on the idea that environmental conditions also vary laterally, from one bank to the other. In addition to that, macroinvertebrates were collected from woody debris accumulations, if present, and flow velocity, substrate composition, water depth and transect position were recorded for each single sample. Existing macroinvertebrate data of this river (1991 – 2005, Graf unpubl.; DHONJU, 2013; DOSSI, 2014) were also included for several analyses.

Longitudinal changes in benthic community structure and function indicated that food availability and water temperature are major determinants for macroinvertebrate distribution. The identification of macroinvertebrates to low taxonomic levels (genus and species) is quite difficult and requires specific determination keys, but fundamental for the detection of structural as well as functional changes within the community, and the basis for autecological research. Selected species showed distinct flow velocity preferences and there was a strong association between macroinvertebrate assemblages and substrate composition obvious and as well. The effects of increased amounts of fine sediments on the river bottom were demonstrated by comparing an impacted and a non-impacted section. Individual density, biomass as well as taxa richness were significantly lower in the silted-section. In contrast to that, a great variety of macroinvertebrates was collected from wood, supporting the existing knowledge that woody debris accumulations serves as an important habitat for macroinvertebrates and is crucial for structural and species diversity within running waters. The influence of the cross-sectional gradient remains unclear, as macroinvertebrate assemblages did not significantly differ depending on the position on the river bottom. On the one hand, the variation in physical habitat characteristics could only partly explained by transect position, and on the other hand, there was no differentiation made between early

and late larval stages. Macroinvertebrate species are known to use different habitats during development, therefore the distinction between early and late larval instars within a species is recommended for further research on lateral distribution differences.

The results of this study clearly demonstrate that numerous physical habitat variables play a substantial role for macroinvertebrate distribution and individual effects are sometimes difficult to distinguish. But summarising, it can be concluded that habitat heterogeneity, also in terms of food availability, is a key factor for biodiversity within river systems.

Together, the naturally highly variable hydrological regime and the near-pristine river course of the river Lafnitz provide a great variety of habitats suitable for many benthic species, including several rare and endangered species, underlining the importance of the Lafnitz and the whole surrounding area for nature conservation purposes.

6. LITERATURE

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9. ANNEX

Table 16: Macroinvertebrate taxa list and abundance (ind/m²) per site of the river Lafnitz (March 2014)

order	family	genus	species	1a_WZ	3_BR	4_RB	5b_NS	9_DD	9a_KD
BIVALVIA	SPHAERIIDAE	<i>Pisidium</i>	sp.	0	0	0	112	0	0
BIVALVIA	SPHAERIIDAE	<i>Sphaerium</i>	sp.	0	0	0	16	0	0
COLEOPTERA	ELMIDAE	<i>Elmis</i>	sp.	0	128	96	2880	32	144
COLEOPTERA	ELMIDAE	<i>Esolus</i>	sp.	16	80	96	288	0	0
COLEOPTERA	ELMIDAE	<i>Limnius</i>	sp.	3424	2064	512	1264	0	16
COLEOPTERA	GYRINIDAE	<i>Orectochilus</i>	<i>villosus</i>	0	0	0	160	0	64
COLEOPTERA	HYDRAENIDAE	<i>Hydraena</i>	sp.	832	288	192	128	0	0
CRUSTACEA	ASSELIDAE	<i>Asellus</i>	<i>aquaticus</i>	0	0	0	0	0	16
CRUSTACEA	GAMMARIDAE	<i>Gammarus</i>	<i>fossarum</i>	2448	64	432	10832	64	1728
DIPTERA	ATHERICIDAE	<i>Atherix</i>	ibis	0	0	0	48	0	48
DIPTERA	ATHERICIDAE	<i>Ibisia</i>	<i>marginata</i>	240	128	16	0	0	0
DIPTERA	BLEPHARICERIDAE	<i>Liponeura</i>	sp.	0	0	16	0	0	0
DIPTERA	CERATOPOGONIDAE	<i>Gen.</i>	sp.	304	32	64	16	16	256
DIPTERA	CHIRONOMIDAE	<i>Gen.</i>	sp.	6064	4992	3104	246240	3584	11920
DIPTERA	EMPIDIDAE	<i>Gen.</i>	sp.	208	176	288	544	96	448
DIPTERA	LIMONIIDAE	<i>Antocha</i>	sp.	0	16	0	32	32	688
DIPTERA	LIMONIIDAE	<i>Gen.</i>	sp.	0	0	0	176	0	0
DIPTERA	LIMONIIDAE	<i>Hexatoma</i>	sp.	80	288	1232	5648	736	688
DIPTERA	PEDICIIDAE	<i>Dicranota</i>	sp.	1168	864	1312	976	432	928
DIPTERA	PEDICIIDAE	<i>Pedicia</i>	sp.	32	0	0	0	0	0
DIPTERA	PSYCHODIDAE	<i>Gen.</i>	sp.	16	96	16	16	0	0

DIPTERA	RHAGIONIDAE	Gen.	sp.	0	0	0	0	0	16
DIPTERA	SIMULIIDAE	Prosimulium	sp.	592	112	0	48	16	16
DIPTERA	SIMULIIDAE	Simulium	sp.	880	544	128	384	1600	544
DIPTERA	TABANIDAE	Gen.	sp.						16
DIPTERA	TIPULIDAE	Gen.	sp.	64	0	48	0	80	96
EPHEMEROPTERA	AMETROPODIDAE	<i>Ametropus</i>	<i>fragilis</i>	0	0	0	0	0	16
EPHEMEROPTERA	BAETIDAE	<i>Baetis</i>	<i>alpinus</i>	3904	4544	2768	3952	0	0
EPHEMEROPTERA	BAETIDAE	<i>Baetis</i>	<i>juvenil</i>	880	1712	1600	2544	416	336
EPHEMEROPTERA	BAETIDAE	<i>Baetis</i>	<i>lutheri</i>	0	0	0	0	192	352
EPHEMEROPTERA	BAETIDAE	<i>Baetis</i>	<i>muticus</i>	0	16	0	16	0	0
EPHEMEROPTERA	BAETIDAE	<i>Baetis</i>	<i>rhodani</i>	1968	2048	3088	5168	1056	1824
EPHEMEROPTERA	BAETIDAE	<i>Baetis</i>	<i>vardarensis</i>	0	0	0	0	16	48
EPHEMEROPTERA	BAETIDAE	<i>Baetis</i>	<i>vernus</i>	0	0	0	0	16	0
EPHEMEROPTERA	BAETIDAE	<i>Cloeon</i>	<i>dipterum</i>	0	0	0	32	0	0
EPHEMEROPTERA	EPHEMERELLIDAE	<i>Ephemerella</i>	<i>mucronata</i>	64	592	704	2416	16	48
EPHEMEROPTERA	EPHEMERELLIDAE	<i>Ephemerella</i>	<i>notata</i>	0	0	0	0	480	400
EPHEMEROPTERA	EPHEMERIDAE	<i>Ephemera</i>	<i>danica</i>	16	16	16	112	0	0
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Ecdyonurus</i>	<i>sp.</i>	16	64	16	576	0	208
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Epeorus</i>	<i>assimilis</i>	512	752	304	1504	0	0
EPHEMEROPTERA	HEPTAGENIIDAE	Gen.	<i>sp.</i>	16	160	0	16	64	144
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Heptagenia</i>	<i>longicauda</i>	0	0	0	32	0	0
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Heptagenia</i>	<i>sp.</i>	0	0	0	0	0	544
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Rhithrogena</i>	<i>juvenil</i>	0	0	0	608	0	0
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Rhithrogena</i>	<i>picteti</i>	0	0	0	32	0	0
EPHEMEROPTERA	HEPTAGENIIDAE	<i>Rhithrogena</i>	<i>semicolorata</i>	0	0	0	128	0	0

EPHEMEROPTERA	HEPTAGENIIDAE	<i>Rhithrogena</i>	sp.	4384	6000	8384	7072	640	3168
EPHEMEROPTERA	LEPTOPHLEBIIDAE	Gen.	sp.	32	0	0	0	0	0
EPHEMEROPTERA	LEPTOPHLEBIIDAE	<i>Habroleptoides</i>	sp.	48	32	0	16	0	224
EPHEMEROPTERA	LEPTOPHLEBIIDAE	<i>Habrophlebia</i>	sp.	112	0	0	0	0	16
GASTROPODA	HYDROBIIDAE	<i>Potamopyrgus</i>	<i>antipodarum</i>	0	0	0	0	16	0
GASTROPODA	PLANOBORIDAE	<i>Ancylus</i>	<i>fluviatilis</i>	64	0	48	16	32	448
HETEROPTERA	APHELOCHEIRIDAE	<i>Aphelocheirus</i>	<i>aestivalis</i>	0	0	0	0	48	160
HIRUDINEA	(Leer)	Gen.	sp.	0	0	16	0	0	0
HYDRACHNIDIA	HYDRACHNIDIA	Gen.	sp.	16	112	112	32	32	176
HYMENOPTERA	AGRIOTYPIDAE	<i>Agriotypus</i>	<i>armatus</i>	0	48	0	0	0	0
ODONATA	CALOPTERYGIDAE	<i>Calopteryx</i>	sp.	0	0	0	0	0	16
ODONATA	GOMPHIDAE	<i>Gomphus</i>	<i>vulgatissimus</i>	0	0	0	0	0	64
ODONATA	GOMPHIDAE	<i>Ophiogomphus</i>	<i>cecilia</i>	0	0	0	0	0	32
OLIGOCHAETA	LUMBRICIDAE	<i>Eiseniella</i>	<i>tetraedra</i>	48	16	0	0	16	32
OLIGOCHAETA	Oligochaeta	Gen.	sp.	272	1040	384	1264	1920	624
PLECOPTERA	CHLOROPERLIDAE	<i>Siphonoperla</i>	<i>taurica</i>	0	0	0	0	352	480
PLECOPTERA	CHLOROPERLIDAE	<i>Siphonoperla</i>	<i>torrentium</i>	624	0	0	0	0	0
PLECOPTERA	LEUCTRIDAE	<i>Leuctra</i>	sp.	13440	3392	720	2096	0	0
PLECOPTERA	NEMOURIDAE	<i>Amphinemura</i>	sp.	0	0	0	0	160	48
PLECOPTERA	NEMOURIDAE	<i>Nemoura/Nemurella</i>	sp.	128	208	32	80	0	0
PLECOPTERA	NEMOURIDAE	<i>Protonemura</i>	sp.	4000	4496	944	5232	0	16
PLECOPTERA	PERLIDAE	<i>Dinocras</i>	<i>cephalotes</i>	0	112	64	32	0	0
PLECOPTERA	PERLIDAE	Gen.	sp.	0	0	0	16	0	0
PLECOPTERA	PERLIDAE	<i>Perla</i>	<i>marginata</i>	128	464	448	880	0	0
PLECOPTERA	PERLODIDAE	<i>Isoperla</i>	sp.	304	1520	1184	4448	768	720

PLECOPTERA	PERLODIDAE	<i>Perlodes</i>	sp.	48	48	48	384	16	176
PLECOPTERA	TAENIOPTERYGIDAE	<i>Brachyptera</i>	<i>juvenil</i>	160	864	512	1504	112	160
PLECOPTERA	TAENIOPTERYGIDAE	<i>Brachyptera</i>	<i>risi</i>	992	3744	6880	12128	448	304
PLECOPTERA	TAENIOPTERYGIDAE	<i>Brachyptera</i>	<i>seticornis</i>	496	1824	528	1504	0	0
PLECOPTERA	TAENIOPTERYGIDAE	<i>Rhabdiopteryx</i>	<i>neglecta</i>	0	0	32	0	0	0
TRICHOPTERA	BRACHYCENTRIDAE	<i>Brachycentrus</i>	<i>subnubilus</i>	0	0	0	0	0	80
TRICHOPTERA	BRACHYCENTRIDAE	<i>Micrasema</i>	<i>minimum</i>	0	192	32	16	0	0
TRICHOPTERA	GLOSSOSOMATIDAE	<i>Glossosoma</i>	<i>boltoni</i>	0	0	0	48	48	32
TRICHOPTERA	GLOSSOSOMATIDAE	<i>Glossosoma</i>	<i>conformis</i>	48	112	0	0	0	0
TRICHOPTERA	GOERIDAE	<i>Silo</i>	<i>pallipes</i>	352	368	432	64	0	16
TRICHOPTERA	GOERIDAE	<i>Silo</i>	<i>piceus</i>	0	0	0	0	16	32
TRICHOPTERA	HYDROPSYCHIDAE	<i>Cheumatopsyche</i>	<i>lepida</i>	0	0	0	0	208	784
TRICHOPTERA	HYDROPSYCHIDAE	<i>Hydropsyche</i>	<i>bulbifera</i>	0	0	0	0	32	16
TRICHOPTERA	HYDROPSYCHIDAE	<i>Hydropsyche</i>	<i>dinarica</i>	0	176	0	32	0	0
TRICHOPTERA	HYDROPSYCHIDAE	<i>Hydropsyche</i>	<i>fulvipes</i>	64	0	0	0	0	0
TRICHOPTERA	HYDROPSYCHIDAE	<i>Hydropsyche</i>	<i>instabilis</i>	0	0	0	192	0	144
TRICHOPTERA	HYDROPSYCHIDAE	<i>Hydropsyche</i>	<i>juvenil</i>	2176	4144	672	3216	208	672
TRICHOPTERA	HYDROPSYCHIDAE	<i>Hydropsyche</i>	<i>saxonica</i>	16	0	0	0	0	0
TRICHOPTERA	LEPIDOSTOMATIDAE	<i>Lepidostoma</i>	<i>basale</i>	0	0	0	12400	0	0
TRICHOPTERA	LEPTOCERIDAE	<i>Athripsodes</i>	sp.	0	0	0	0	0	32
TRICHOPTERA	LIMNEPHILIDAE	<i>Allogamus</i>	<i>auricollis</i>	32	80	512	80	0	0
TRICHOPTERA	LIMNEPHILIDAE	<i>Drusus</i>	<i>biguttatus</i>	0	16	0	0	0	0
TRICHOPTERA	LIMNEPHILIDAE	<i>Ecclisopteryx</i>	<i>guttulata</i>	0	80	336	16	0	0
TRICHOPTERA	LIMNEPHILIDAE	<i>Ecclisopteryx</i>	<i>madida</i>	336	32	16	0	0	0
TRICHOPTERA	LIMNEPHILIDAE	Gen.	sp.	0	0	0	48	0	0

TRICHOPTERA	LIMNEPHILIDAE	<i>Halesus</i>	sp.	0	0	0	64	16	192
TRICHOPTERA	LIMNEPHILIDAE	<i>Limnephilinae</i>	sp.	112	32	0	0	0	16
TRICHOPTERA	LIMNEPHILIDAE	<i>Potamophylax</i>	sp.	112	96	16	208	0	0
TRICHOPTERA	ODONTOCERIDAE	<i>Odontocerum</i>	<i>albicorne</i>	128	64	16	16	0	0
TRICHOPTERA	PHILOPOTAMIDAE	<i>Philopotamus</i>	<i>variegatus</i>	0	16	0	0	0	0
TRICHOPTERA	POLYCENTROPODIDAE	<i>Polycentropus</i>	<i>excisus</i>	16	0	0	0	0	0
TRICHOPTERA	PSYCHOMYIIDAE	<i>Psychomyia</i>	<i>pusilla</i>	0	32	16	256	768	2000
TRICHOPTERA	PSYCHOMYIIDAE	<i>Tinodes</i>	<i>rostocki</i>	16	0	0	0	0	0
TRICHOPTERA	RHYACOPHILIDAE	<i>Rhyacophila</i>	s. str. sp.	336	384	256	1648	144	32
TRICHOPTERA	RHYACOPHILIDAE	<i>Rhyacophila</i>	<i>tristis</i>	32	112	32	32	0	0
TRICHOPTERA	SERICOSTOMATIDAE	<i>Sericostoma</i>	sp.	64	128	48	128	0	0

Statutory declaration

I hereby declare that the submitted master thesis was in all parts exclusively written on my own, and that no other resources or outside support, except for the quoted literature and other sources mentioned in the text, were utilized. The present master thesis was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.

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