universität wien

MASTERARBEIT

Titel der Masterarbeit

„Net structure and species inventory of the Hydropsychidae species (Trichoptera) of the Große Tulln catchment (Lower Austria)“

verfasst von

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angestrebter akademischer Grad

Master of Science (MSc)

Wien, 2015

Studienkennzahl lt. Studienblatt:	A 066 833
Studienrichtung lt. Studienblatt:	Masterstudium Ökologie
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Acknowledgements

Foremost I thank my advisor Prof. Johann Waringer for enabling this thesis by awaking my interest in river ecology during my master studies. His great knowledge and his patience were the best possible support for accomplishing this thesis.

I thank Hubert Kraill and Simon Vitecek for their support in lab work and introduction in microscopical software.

I further thank my student colleague Cornelia Bauer for helpful advices, and for fieldwork assistance.

Last but not least I would like to thank my parents, my sister, and my friends for mentally supporting me throughout the last year.

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1 Introduction

Caddisflies (Trichoptera) inhabit freshwater habitats on every continent except Antarctica (de MOOR & IVANOV 2008). More than 14000 species (DIJKSTRA et al. 2014) and 49 families (HOLZENTHAL et al. 2007) are identified worldwide. In central Europe (Germany, Austria, Switzerland) around 400 species and 21 families are recorded (WARINGER & GRAF 2011). Caddisflies are holometabolic insects, which split from their sister taxon Lepidoptera in the late Permian (WIGGINS 2004, MALM et al. 2013). Trichoptera and Lepidoptera share their spinning ability, wing morphology and the fact that females are heterogametic. While butterflies have scales on their wings, the Trichoptera mostly have fine hairs (MALICKY 1977).

Like most running water insects, caddisfly species are specially adapted for inhabiting distinct sections within a river continuum (HILDREW & EDINGTON 1979, ALSTAD 1987 a, TACHET et al. 1992, ROUX et al. 1992, GUINAND et al. 1994, STATZNER & DOLEDEC 2011, CILIAK et al. 2014). A sequence of macroinvertebrate species assemblages from headwaters to potamal stream sections can often be found (ILLIES 1961). According to the River Continuum Concept (RCC), factors like temperature, dissolved oxygen concentration, flow velocity, POM size/concentration, epilithic algal growth and saprobity change continuously from upstream to downstream (VANNOTE et al. 1980), and implicate different adaptations of caddisfly species depending on the section they inhabit (GOMBEER et al. 2011, STATZNER & DOLEDEC 2011). Species of middle reaches often display broad ecological tolerances and therefore a widespread occurrence along rivers (SAVIC et al. 2013). Headwaters are special habitats with unique physical conditions, often inhabited by highly specialized macroinvertebrate communities (STATZNER & DOLEDEC 2011).

Among caddisfly larvae the main feeding groups are scrapers, shredders, grazers, passive filter feeders and predators (GRAF et al. 2002). Common for all Trichoptera are biting or scraping mandibles (MALICKY 1977).

Hydropsychidae belong to the suborder of Annulipalpia. They are retreat-building caddisflies, which construct filtering nets (passive filter feeders). They undergo 5 larval stages before pupation. The species-specific length of a complete life cycle varies between 0.5 years and 2 years (PETERSEN 1981). In central Europe Hydropsychidae species inhabit running water habitats from krenal to mesopotamal (CILIAK et al. 2014, GRAF et al. 2002, GOMBEER et al. 2011). The larvae graze their filtration net periodically to feed from captured organic parti-

cles and discard indigestible particles like sediment (KAISER 1965). Hydropsychidae are omnivore (HELLMANN et al. 2013) and feed on organic particles captured in the net. Diet specialization exists according to species, instar, season and net location (PETERSEN 1981). If sufficiently available, the preferred diet of most species is of animal origin, e.g. small insect larvae (BENKE & WALLACE 1997). The capture net has to be understood to a large extent as predation device (ALSTAD 1987 b). The gut content of 2nd and 3rd instars of *H. contubernalis* and *H. pellucidula* consist almost exclusively of animal material. These species perform a shift to omnivorous feeding during the 4th instar (SIEGLSTETTER et al. 1997). For other *Hydropsyche* species the opposite, a shift from a plant-based to an animal-based diet during the larval period, has been observed (PETERSEN 1981). The larvae are not completely dependent on the filtering net for feeding. They are capable of grazing sedimentary surfaces and prey on other insect larvae (WIGGINS 2004). During winter their net spinning activity decreases and instead they feed more frequently by grazing (PHILIPSON 1969). Fauna Aquatica Austriaca (FAA) classifies the Austrian species of Hydropsychidae as 50% passive filter feeders, 30% predator and 20% grazer (GRAF et al. 2002).

A new retreat is built after each larval moult, not including disturbances that force the larva to leave its retreat (WILLIAMS & HYNES 1973). Capture nets are constructed more often (KAISER 1965), since the nets get clogged by sediments or are destroyed by the current. The construction of a capture net can be completed in 8 minutes (SATTLER 1958).

Hydropsychidae filter large amounts of POM (GEORGIAN & WALLACE 1981). Thereby they contribute to retention and nutrient spiraling (MINSHALL et al. 1983) of the seston particles. Dense populations are capable of filtering 1% of the seston that passes them in the water column (McCULLOUGH & MINSHALL 1979). The use of sediment and organic material for retreat construction increases the erosion resistance of the benthic sediment (JOHNSON et al. 2009, CARDINALE et al. 2004).

Spinning activity is associated with building retreats, and for installing and repairing the capture nets (KAISER 1965). The net consists of two hemispheres which converge in the transitional zone, the symmetric center of the net (Figure 27). The meshes of the capture nets are rectangular. At the periphery of the net the mesh size increases and the meshes are not precisely rectangular (KAISER 1965, GEORGIAN & WALLACE 1981). During net construction the larva constantly performs figure eight-shaped loops with its head while releasing a silk strand (PETERSEN 1981). Stones are mostly chosen as the net's frame and as component of the re-

treat (Figure 1). It is between two stones that the larva is capable of spinning a silk frame for the net (SATTLER 1958). The retreat consists mainly of small glued stones or plant material (Figure 1). The net surface is angled to the current which is a compromise as this both reduces the shear stress and also preserves sufficient filtering. Sensillae located at the head perceive direction and strength of the current (KAISER 1965).

Among the filter feeding Annulipalpia, the Hydropsychidae are categorized as “high-speed filtrators” (WARINGER & GRAF 2011). Compared to the families of Polycentropodidae and Philopotamidae the Hydropsychidae prefer to install their retreats and nets in habitats with high current velocities (EDINGTON 1968). TACHET et al. (1992) document preferences of up to 0.8 m s^{-1} for *H. pellucidula*.

Figure 1: Retreat of *Hydropsyche sp.* with capture net.

The mesh size of the capture nets is species- and instar-specific (KAISER 1965). Different species of Hydropsychidae produce meshes of significantly different sizes (WALLACE & MALAS 1976). Mouthpart morphology is the limiting factor for mesh length and -width (KAISER 1965). The distances between the two maxillary palps, and between silk gland

opening and submentum, are the defining factors for length and width of the meshes (KAISER 1965). These distances increase with larval instars, and hence the mesh sizes.

The construction of species-specific capture nets is assumed to be a consequence of niche diversification within the longitudinal zonation of a river system (ALSTAD 1987 a, HILDREW & EDINGTON 1979). The mesh size can be understood to be an adaptation to the conditions of a river section (LOUDON & ALSTAD 1990). According to the river continuum concept (RCC), flow velocity and POM size decrease from upstream to downstream (VANNOTE et al. 1980). Both of these parameters are discussed as affecting species composition of river sections via specific mesh sizes (EDINGTON 1968, WALLACE 1975, GORDON & WALLACE 1975, WALLACE & MERRITT 1980, ALSTAD 1987 a). Headwaters with riparian forests have high flow velocities and large POM sizes, favorable for *Hydropsyche* species with large mesh sizes. Shear stress at high flow velocities is reduced when the meshes are larger, and capture rates are still sufficient because of large particle size.
Downstream the shear stress for the nets is smaller. For ensuring high capture rates when POM size decreases, the capture net mesh sizes of *Hydropsyche* species that inhabit downstream habitats are assumed to be smaller.

The coexistence of *Hydropsyche* species with significantly different mesh sizes within one river section points out that species are not strictly split along the river continuum according to their mesh size (HILDREW & EDINGTON 1979, TACHET et al. 1987). Moreover one species has five larval stages with different mesh sizes that co-occur at each river section (MUOTKA 1990). The case of co-existing capture nets different in mesh sizes suggests that flow conditions of benthic microhabitats play also a role in the habitat selection and competition of species and instars within one river section (MALAS & WALLACE 1977, ALSTAD 1982, OSBORNE & HERRICKS 1987, MUOTKA 1990, LOUDON & ALSTAD 1990, VOELZ & WARD 1996). The species-specific mesh sizes are understood to be a consequence of niche segregation in evolutionary competition for space and food in benthic microhabitats (THORP 1984). A heterogenous streambed providing a wide spectrum of benthic microhabitats enables the co-existence of species and instars with different mesh sizes. Within the microhabitats, flow velocity and POM size/concentration are assumed to be key parameters (LOUDON & ALSTAD 1990), since flow velocity in such microhabitats is not a function of the river continuum (ALSTAD 1982). In headwaters there are microhabitats under stones with

reduced flow velocities while high velocities exist on stone surfaces in riffle regions of downstream reaches.

A broad range of capture net mesh sizes are found among specimens of the same species and instar (WILLIAMS & HYNES 1973), which presents the question of whether or not they are able to individually adapt their mesh length and -width to current microhabitat flow conditions (ALSTAD 1982). The fact that the meshes at the periphery of *Hydropsyche* capture nets are always larger than those in the middle suggests that to a small extent individual adaptation of mesh sizes is possible (KAISER 1965). When flow conditions in the microhabitat change, building a new net with different mesh sizes is a more efficient approach in terms of energy saving, than seeking new microhabitats for a new retreat.

The aim of my study was on the one hand to compare the present Hydropsychidae species inventory of the Große Tulln catchment with the situation in 1982 (SCHEIBLREITER 1982). The other major goal was to test the hypotheses of inter- and intraspecific mesh size decrease along the river continuum as consequence of decreasing POM size and decreasing flow velocity.

2 Study area

2.1 Geology, Geography and Topography of the Große Tulln catchment

The catchment of the Große Tulln (Figure 2) is located in the Wienerwald and the Tullner Feld in Lower Austria, west of Vienna and south of the Danube river. The total area of the catchment is 202.3 km^2 (SCHEIBLREITER 1982). The springs of the Große Tulln are located in the Wienerwald, the eastern branch of the Alps. The springs with the highest elevation (618 m a.s.l.) are located at Klammhöhe, near the Schöpfl (893 m a.s.l.), the highest peak of the Wienerwald. Three main tributaries within the Wienerwald are the Laabenbach and the Lengbach, joining at Außerfurth, and the Anzbach, which joins the Laabenbach at the city of Neulengbach. From Neulengbach on, the river is called “Große Tulln”. The section of the stream system within the steep areas of the Wienerwald consists of high gradient, 1-2 m wide brooks. In the central section the profile levels off and stream widths increase to 5m. The city of Neulengbach is located at the border between the Wienerwald and Tullnerfeld, where the

Große Tulln transforms into a low-gradient stream up to 10 m width and with low current velocities. After 40 km of stream length, the stream system discharges into the Danube at the city of Tulln, at an elevation about 430 m lower than its spring areas.

Whereas the upper catchment of the Große Tulln consists mainly of deciduous forests, the lower catchment (Tullnerfeld, deforested lower areas of the Wienerwald) is highly affected by agriculture. With respect to geology, the upper catchment is situated in the sandstone area of the Wienerwald (Flysch), whereas the lower catchment is located in the Molasse. The sandstone area consists mainly of various marine sediments (lime marl, lime sandstone, clay marl) from Cretaceous to Lower Tertiary (BÖGEL & SCHMIDT 1976). Lime is an abundant component of the minerals of Flysch, but never dominating when compared to the limestone section of the Wienerwald in the south. The Molasse of the Tullner Feld consists of tertiary deposits, originating from erosions of the Alps (DEL-NEGRO 1977). Molasse is mainly a sediment transported from the alpine regions by fluvial processes. Due to these fluvial transport and sedimentation dynamics, the geology of the Molasse is very diverse, consisting mainly of conglomerate, gravel, sandstone, marl limestone and clay marl (DEL-NEGRO 1977). As in Flysch, limestone is always a component of the sediments but never dominant.

2.2 Sampling sites

2.2.1 Overview

Six sampling sites were selected in the catchment (Figure 2), which are part of a much larger series of sites studied by SCHEIBLREITER (1982). This selection enabled a comparison of the status quo situation of the Hydropsychidae fauna of the Große Tulln with the situation back in 1982.

Two sampling sites (Klamm and Prinzbach) were located close to springs in the Wienerwald area. The sampling site at Laaben was located shortly downstream of the village, where slope levels off, and the character of the river slowly transforms from steep to low gradient. The sampling site at Altlengbach is situated at the central section of the stream system, and located in the Lengbach within an urbanized area. From the sampling site at Neulengbach downstream, the river enters the Tullner Feld, characterized by the transition of the river from its central to its lower reach. The sampling site at Langenrohr represents the lower reach of the Große Tulln, close to its discharge into the Danube at the city of Tulln.

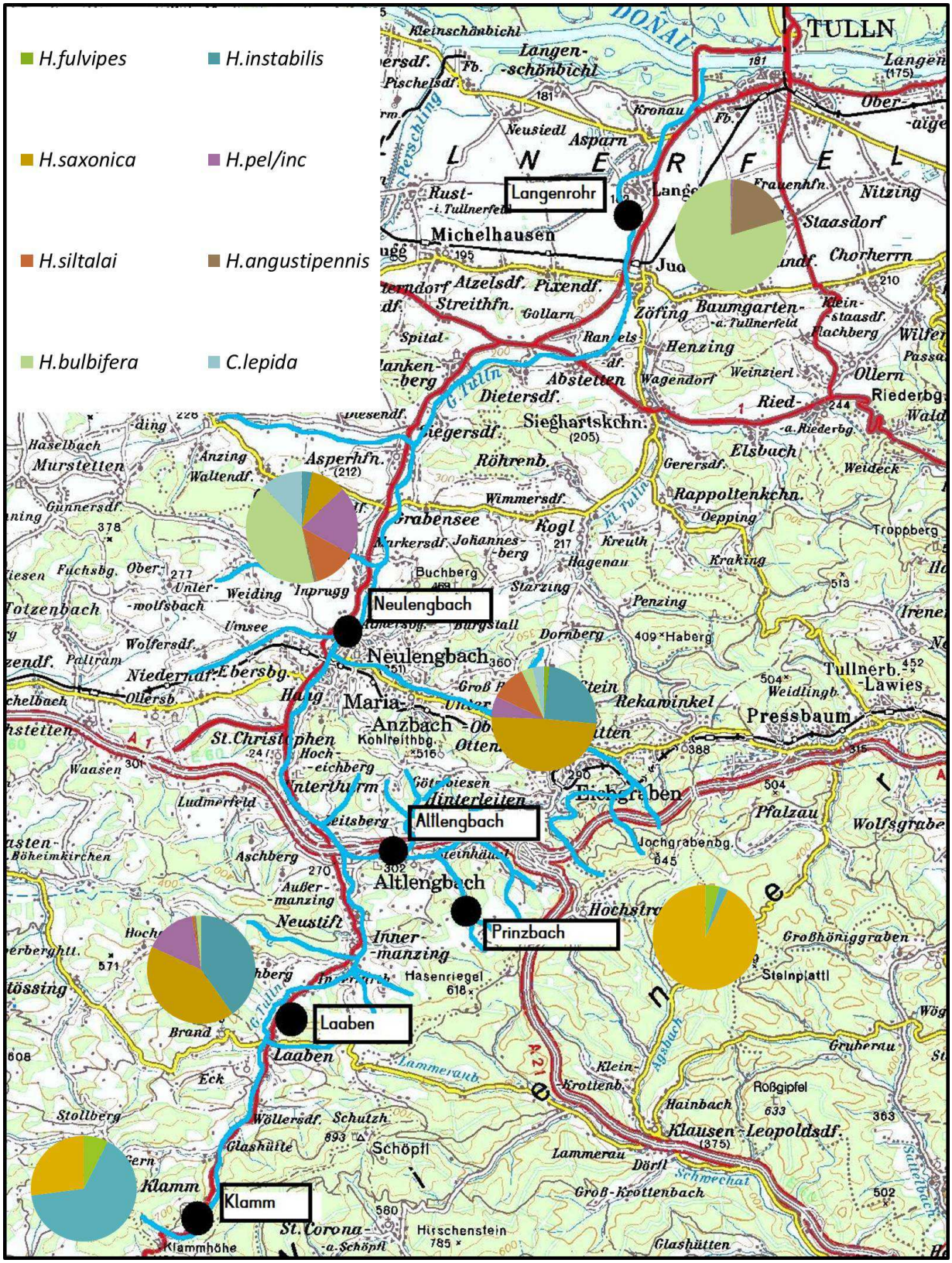

Figure 2: Catchment of the Große Tulln (Bundesamt für Eich- und Vermessungswesen, Austrian MAP Version 1.0). The sampling sites are indicated by black dots. The pie charts represent the species inventories of the sampling sites.

2.2.2 Sampling site Klamm

The sampling site Klamm (Figure 3) is located within the upper reaches of the Laabenbach. The distance to the spring at Klammhöhe is 2.3 km and the brook is enclosed in a small ravine. With its low discharge (0.03 m^3s^{-1}) and Strahler number (2) it represents a typical spring brook of the Wienerwald area. Inclination is up to 47 ‰, the steepest among the six sampling sites.

Table 1: Geographical and physical data of the Klamm sampling site

General parameters	
Elevation	535 m a.s.l.
Spring distance	1.8 km
Geographical position	48° 4´ 06.295´´ N, 15° 51´ 29.389´´ E
Strahler stream order	2
Mean discharge	0.03 $m^3 s^{-1}$
Slope	47 ‰
Chemical Index (CI)	65
Site insolation	30 %

Figure 3: Sampling site Klamm; line of sight: southwest.

Stream width at base discharge is 1 – 2 m, with cobbles braking up the water surface.
Due to the dense deciduous forest of the riparian zone, large parts (up to 70%) of the water surface are constantly shaded during the grow season.

Table 2: Distribution of choriotopes after BRAUKMANN (1987) at the Klamm sampling site.

Choriotope	Area percentage
Macrolithal	30 %
Mesolithal	30 %
Akal	25 %
Macropelal	10 %
Xylal	5 %

Large stones (macrolithal, mesolithal) dominate the sediment surface of this sampling site, with gravel in between and along the banks (akal). The area percentage of coarse particulate organic matter (detritus, branches and leaves) is high at this site when compared with other sampling sites. The mineral substrate elements are almost completely uncovered, free of autotrophic biofilms and epilithic algae (Table 2).

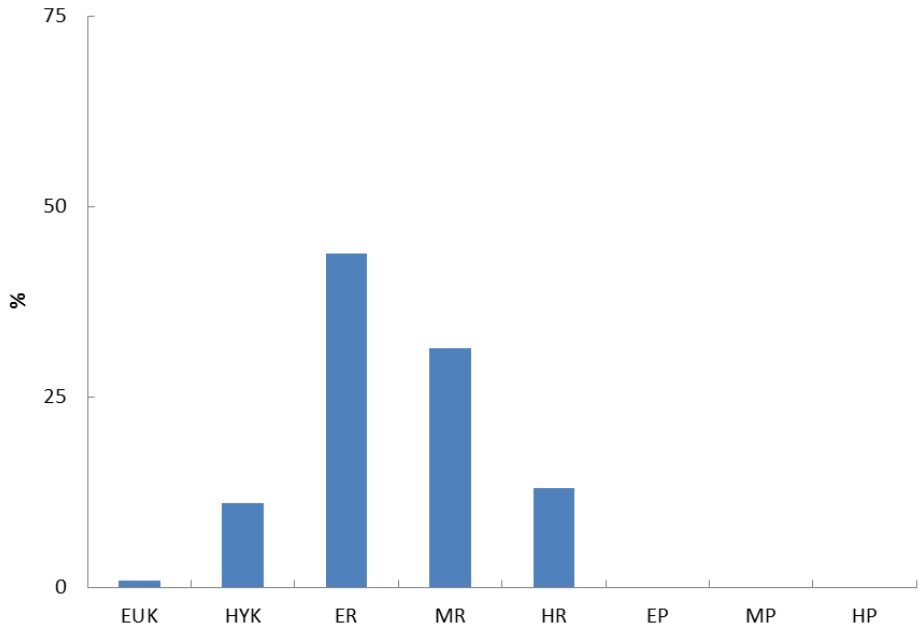

Figure 4: Valency point distribution of longitudinal stream zonation categories (GRAF et al. 2002) for the *Hydropsyche* species of the Klamm sampling site.

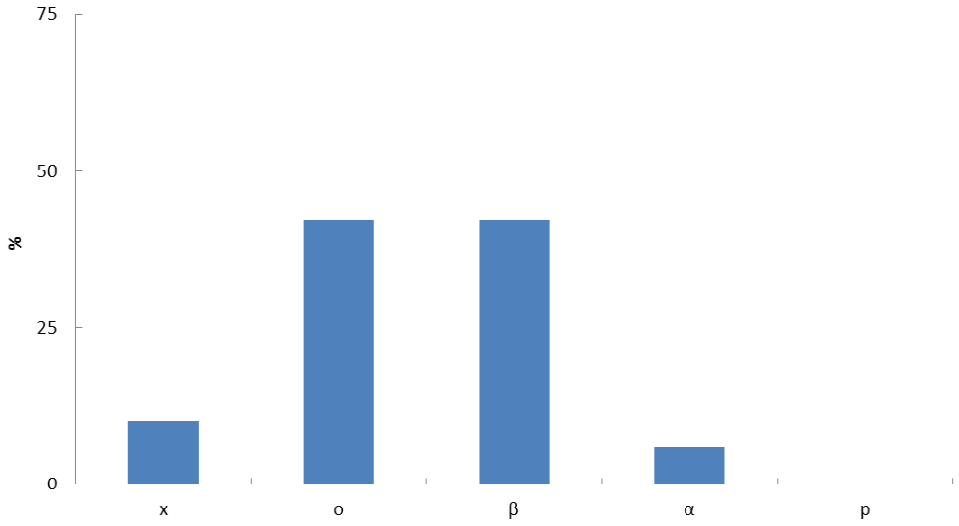

Figure 5: Distribution of saprobic valencies (GRAF et al. 2002) for the *Hydropsyche* species of the Klamm sampling site.

According to the distribution of valency points for longitudinal stream zonation and saprobity of Hydropsychidae (GRAF et al. 2002), the sampling site at Klamm is categorized as epirhitral (Figure 4), and oligosaprobic - β-mesosaprobic (Figure 5).

Table 3: Limnochemical parameters at the Klamm sampling site; showing the mean (and range) of two measurements taken at 1 June 2014 and 12 August 2014.

CI Parameters	
ph	8.2 (8.1 – 8.3)
Conductivity (µS cm^{-1})	318 (310 – 326)
Water temperature (°C)	12.9 (-)
PO_4^{3-} (mg l^{-1})	0.025 (0 – 0.05)
NO_3^- (mg l^{-1})	0
NH_4^+ (mg l^{-1})	0.015 (0 – 0.03)
O_2 (%)	94 (89 – 99)
BSB_5	8.8 (7.7 – 9.9)

The long time water temperature data over the sampling season are not available for this site, because the data logger was lost in the field; however, the temperature is assumed to be slightly lower as at the Prinzbach sampling site, which is also a spring brook, but at lower altitude. Table 3 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

2.2.3 Sampling site Prinzbach

Prinzbach is a spring brook discharging into the Lengbach between the villages Altlengbach and Steinhäusl. The spring distance of the sampling site (Figure 6) is 2.7 km. The geophysical stream parameters (Table 4) are similar to Klamm, apart from the lower elevation (335 m a.s.l.).

Table 4: Geographical and physical data of the Prinzbach sampling site

General parameters	
Elevation	335 m a.s.l.
Spring distance	2.7 km
Geographical position	48° 8´ 48.494´´ N, 15° 56´ 44.251´´ E
Strahler stream order	2
Mean discharge	0.04 $m^3 s^{-1}$
Slope	40 ‰
Chemical Index (CI)	69
Site insolation	30 %

Figure 6: Sampling site Prinzbach; line of sight: north

Stream width at base discharge is 2.5 m. The riparian forest and average site insolation (30%) resemble sampling site Klamm. With a slope of 40 ‰ the inclination is less steep compared to Klamm.

Table 5: Distribution of choriotopes after BRAUKMANN (1987) at the Prinzbach sampling site.

Choriotope	Area percentage
Macrolithal	20 %
Mesolithal	30 %
Akal	10 %
Psammal	20 %
Macropelal	15 %
Xylal	5 %

Mesolithal is dominating the sediments of the streambed, with large cobbles (macrolithal) and sand aggregations (psammal) in between (Table 5). Coarse organic matter (macropelal and xylal) represent 20 % of the sediment surface. Epilithic algal biofilms or higher plants were lacking.

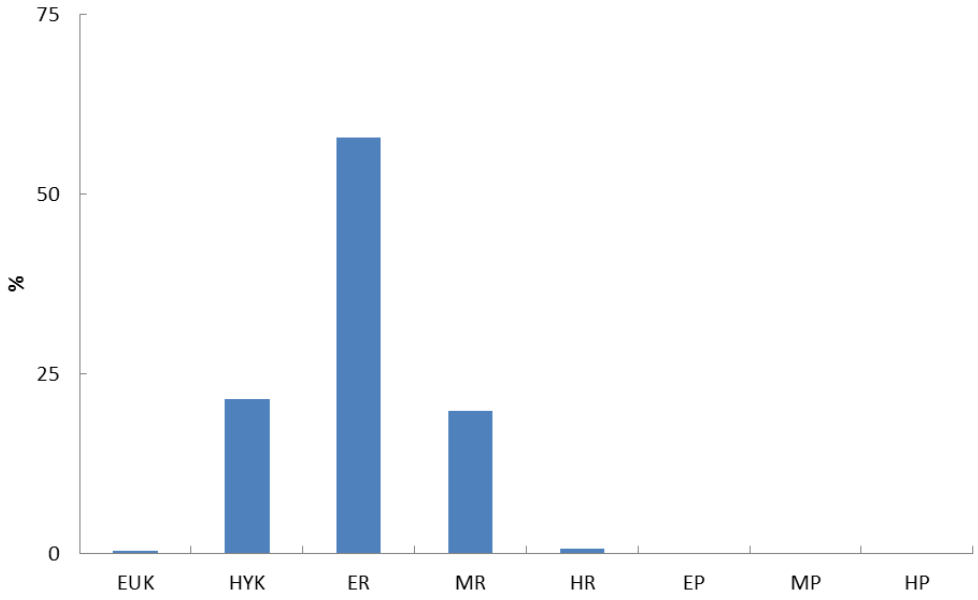

Figure 7: Valency point distribution of longitudinal stream zonation categories (GRAF et al. 2002) for the *Hydropsyche* species of the Prinzbach sampling site.

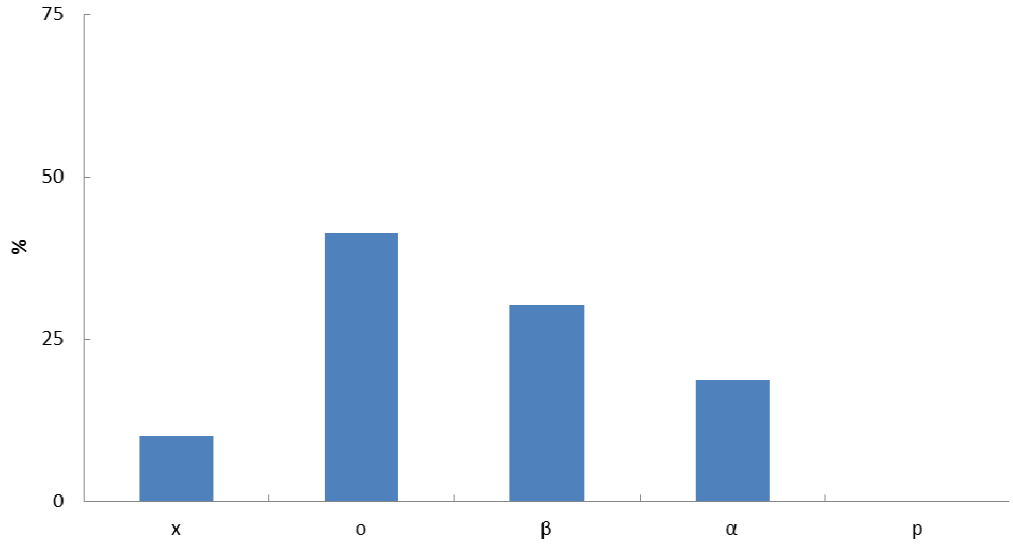

Figure 8: Distribution of saprobic valencies (GRAF et al. 2002) for the *Hydropsyche* species of the Prinzbach sampling site.

According to the distribution of valency points for longitudinal stream zonation and saprobity of Hydropsychidae (GRAF et al. 2002), the sampling site at Prinzbach is categorized as epirhitral (Figure 7), and oligosaprobic (Figure 8). Both classifications are in accordance with sampling site Klamm.

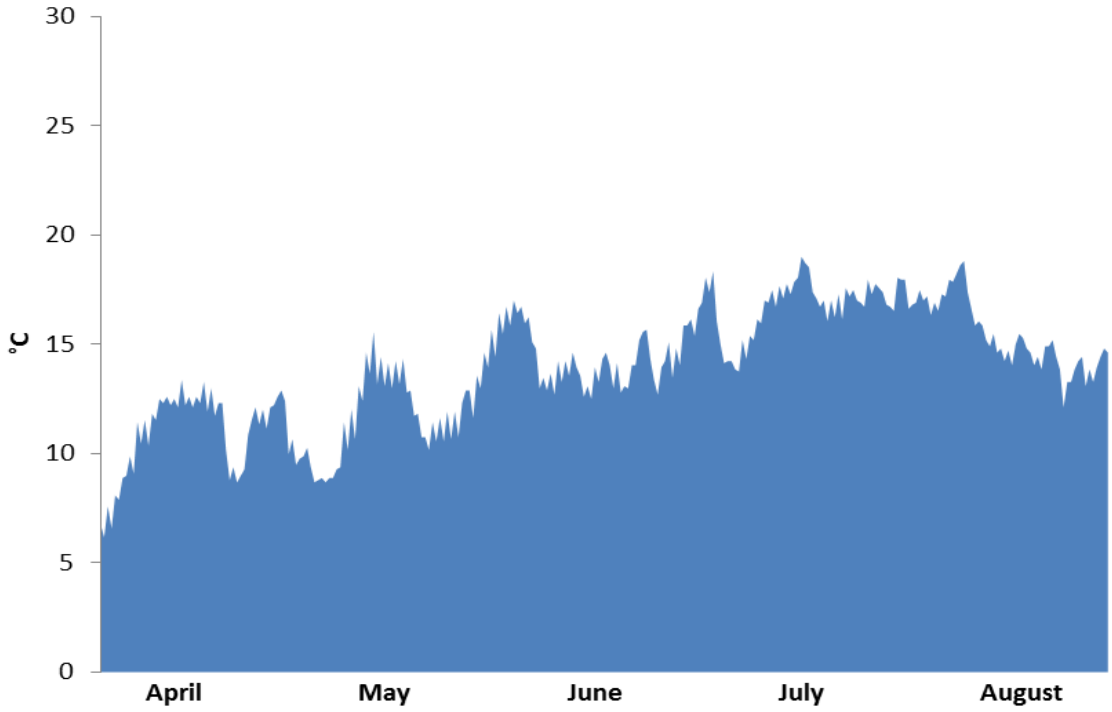

Figure 9: Long-time water temperature data from April to August 2014 at the Prinzbach sampling site.

The minimum water temperature during the sampling period from April to August was 6.1 °C in April, whereas the maximum was 18.9 °C in July (Figure 9). The mean water temperature during the sampling season was 13.9°C.

Table 6 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

Table 6: Limnochemical parameters at the Prinzbach sampling site; showing the mean (and range) of two measurements taken at 1 June 2014 and 12 August 2014.

CI Parameters	
ph	8.2 (8.1 – 8.3)
Conductivity (µS cm^{-1})	375 (-)
Water temperature (°C)	13.2 (-)
PO_4^{3-} (mg l^{-1})	0 (-)
NO_3^- (mg l^{-1})	0 (-)
NH_4^+ (mg l^{-1})	0.025 (0 – 0.05)
O_2 (%)	77 (70 – 84)
BSB_5	7.1 (7.1 – 7.1)

2.2.4 Sampling site Altlengbach

This sampling site is located in the village of Altlengbach, within a straight section of the Lengbach tributary, with cobbles at the bank (Figure 10). The spring distance is 5.2 km. In this section the river transforms from a spring brook to a middle reach stream. Stream width is 4 m and the mean discharge is 0.16 $m^3 s^{-1}$.

Table 7: Geographical and physical data of the Altlengbach sampling site

General parameters	
Elevation	283 m a.s.l.
Spring distance	5.2 km
Geographical position	48° 9´ 10.655´´ N, 15° 55´ 02.747´´ E
Strahler stream order	4
Mean discharge	0.16 $m^3 s^{-1}$
Slope	9.5 ‰
Chemical Index (CI)	64
Site insolation	50 %

Figure 10: Sampling site Altlengbach; line of sight: west

The inclination of 9.5 ‰ is considerably lower compared to the spring brook sampling sites Klamm and Prinzbach. The mean site insolation is 50%, because a riparian forest is located at the hydrological left side of the stream.

Table 8: Distribution of choriotopes after BRAUKMANN (1987) at the Altlengbach sampling site.

Choriotope	Area percentage
Macrolithal	30 %
Mesolithal	30 %
Akal	5 %
Psammal	5 %
Macropelal	5 %
Micropelal	5 %
Lithophytal	20 %

As a consequence of heterogeneity loss due to straightening, little sediment accumulation zones and pool-riffle sequences are present in the riverbed. The flow velocity is constant over a long distance, causing homogenous sediment size (Table 8). Macro- and mesolithal dominate the sediments, with little mud, detritus or deadwood. Stones are partially covered by epilithic algae (20 %).

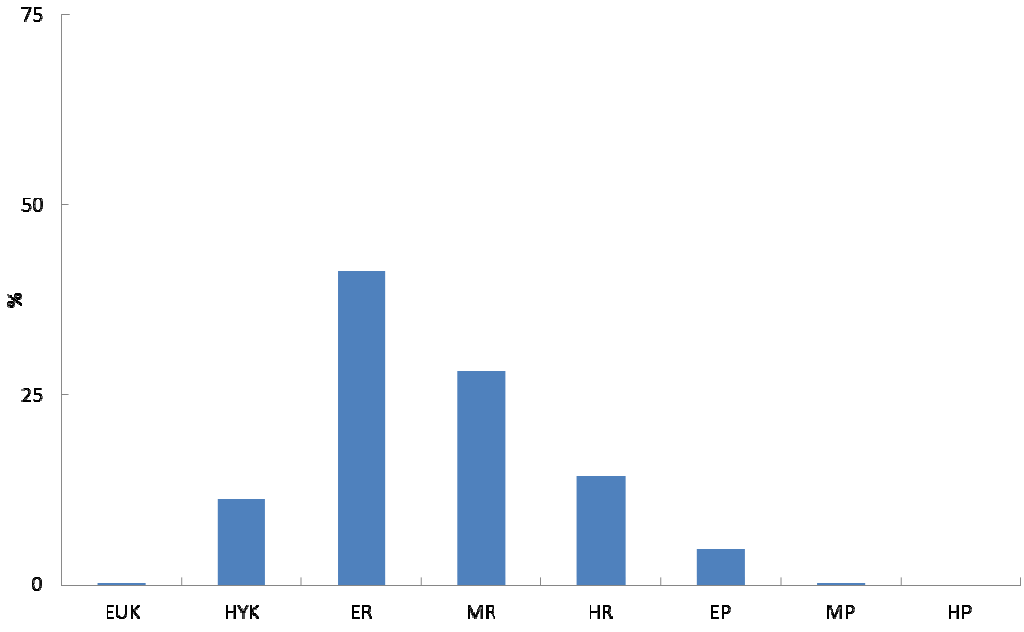

Figure 11: Valency point distribution of longitudinal stream zonation categories (GRAF et al. 2002) for the *Hydropsyche* species of the Altlengbach sampling site.

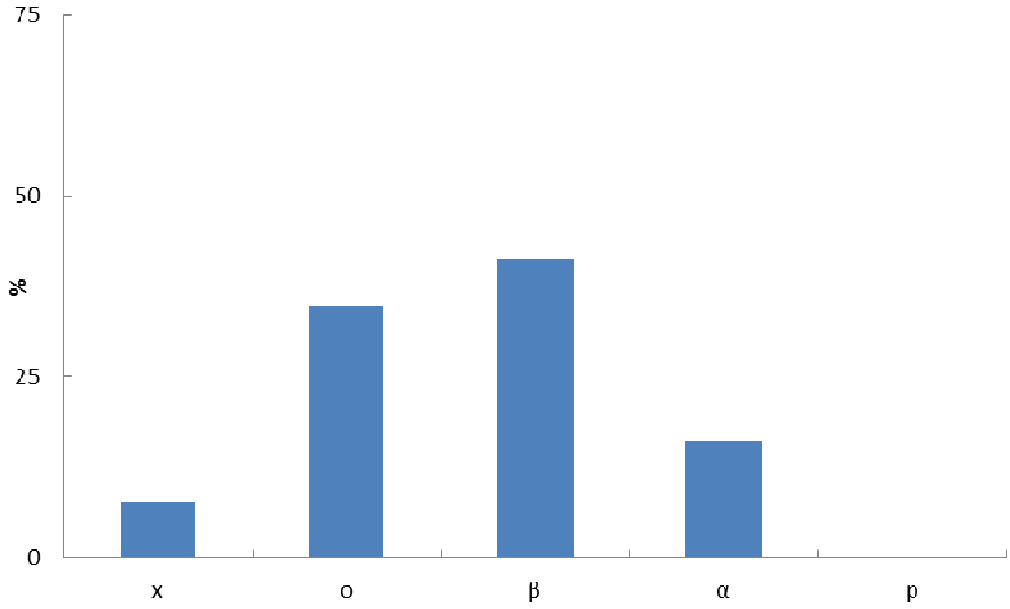

Figure 12: Distribution of saprobic valencies (GRAF et al. 2002) for the *Hydropsyche* species of the Altlengbach sampling site.

According to the distribution of valency points for longitudinal stream zonation and saprobity of Hydropsychidae (GRAF et al. 2002), the sampling site at Altlengbach is categorized as epirhitral - mesorhitral (Figure 11), and oligosaprobic - β-mesosaprobic (Figure 12).

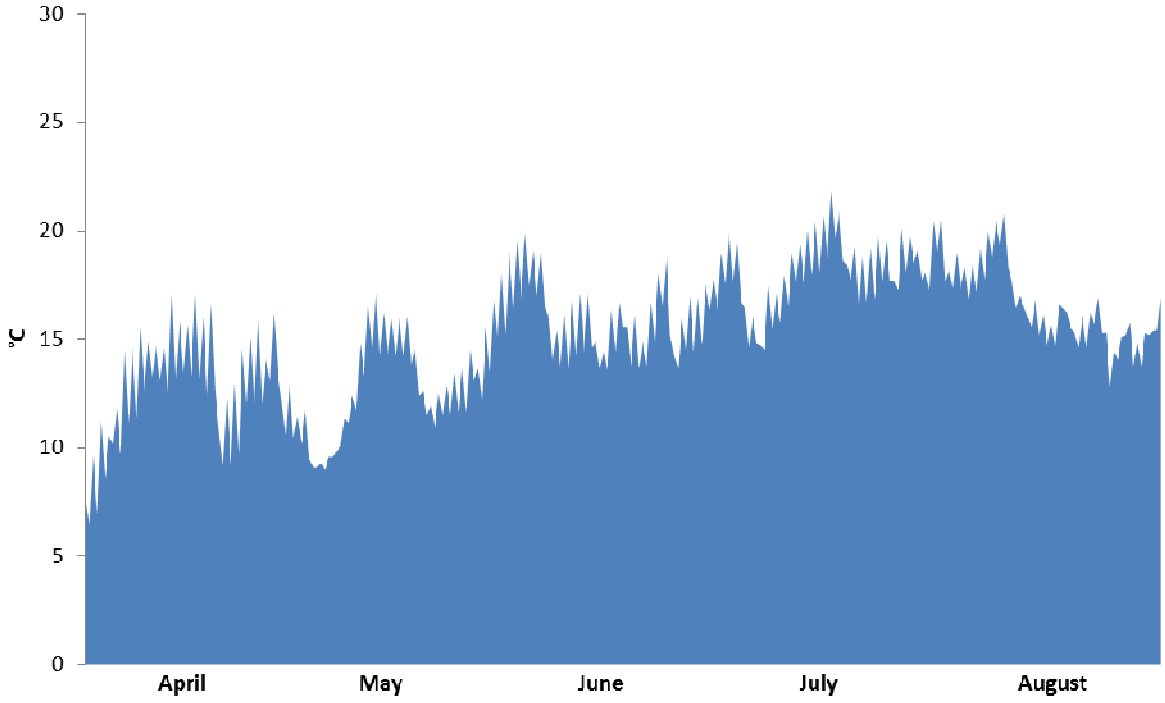

Figure 13: Long-time water temperature data from April to August 2014 at the Altlengbach sampling site.

The minimum water temperature during the sampling time from April to August was 6.5 °C in April, whereas the maximum was 21.8 °C in July (Figure 13). The mean water temperature during the sampling season was 14.3°C.

Table 9 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

Table 9: Limnochemical parameters at the Altlengbach sampling site; showing the mean (and range) of two measurements taken at 1 June 2014 and 12 August 2014.

CI Parameters	
ph	8.3 (8.3 – 8.3)
Conductivity (µS cm^{-1})	581 (-)
Water temperature (°C)	14.3 (-)
PO_4^{3-} (mg l^{-1})	0 (-)
NO_3^- (mg l^{-1})	2.5 (0 - 5)
NH_4^+ (mg l^{-1})	0.015 (0 – 0.03)
O_2 (%)	86 (76 – 96)
BSB_5	7.9 (7.4 – 8.4)

2.2.5 Sampling site Laaben

Sampling site Laaben (Figure 14) is located 1 km downstream of the village of Laaben, where the Laabenbach is in transition from spring brook to middle-reach stream. The spring distance is 7.8 km. The character of the stream resembles sampling site Altlengbach, apart from steeper inclination (22 ‰) and a more heterogenous stream bed.

Table 10: Geographical and physical data of the Laaben sampling site

General parameters	
Elevation	344 m a.s.l.
Spring distance	7.8 km
Geographical position	48° 6´ 42.251´´ N, 15° 52´ 58.108´´ E
Strahler stream order	5
Mean discharge	0.21 $m^3 s^{-1}$
Slope	22 ‰
Chemical Index (CI)	65
Site insolation	10 %

Figure 14: Sampling site Laaben; line of sight: north

The mean discharge is 0.21 $m^3 s^{-1}$ and the stream width 5 m. A dense riparian forest reduces site insolation to 10%. The streambed morphology is diverse and characterized by riffle-pool sequences and accretion zones at the banks.

Table 11: Distribution of choriotopes after BRAUKMANN (1987) at the Laaben sampling site.

Choriotope	Area percentage
Macrolithal	10 %
Mesolithal	35 %
Akal	20 %
Psammal	10 %
Macropelal	10 %
Micropelal	5 %
Xylal	5 %
Lithophytal	5%

Sediments from sand to cobbles are present in the streambed with mesolithal dominating (Table 11). At the banks mud (micropelal), coarse detritus (macropelal) and deadwood (xylal) is deposited. Cobbles are covered by epilithic algae (lithophythal) to a small extent.

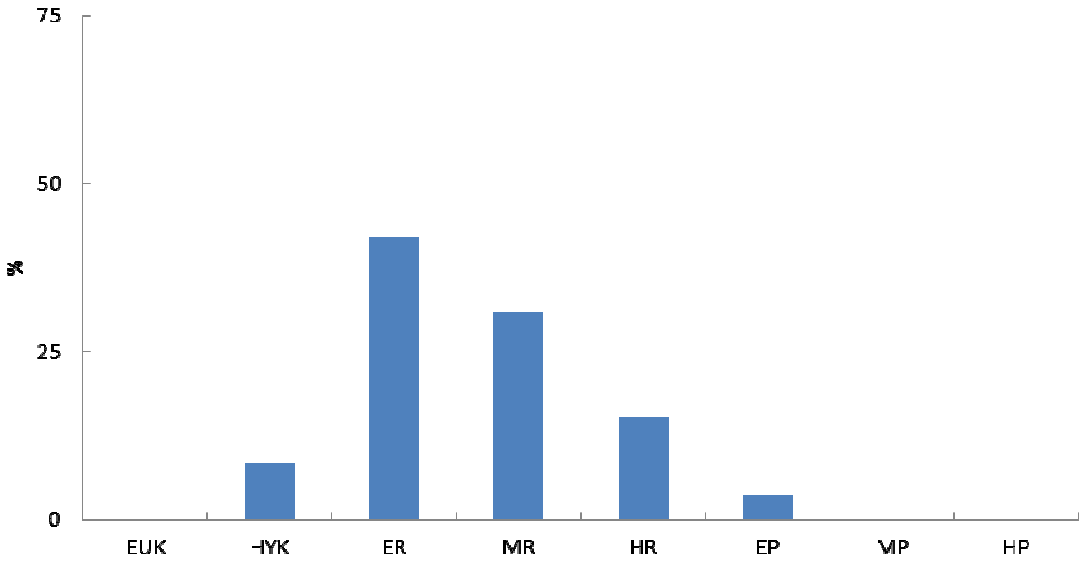

Figure 15: Valency point distribution of longitudinal stream zonation categories (GRAF et al. 2002) for the *Hydropsyche* species of the Laaben sampling site.

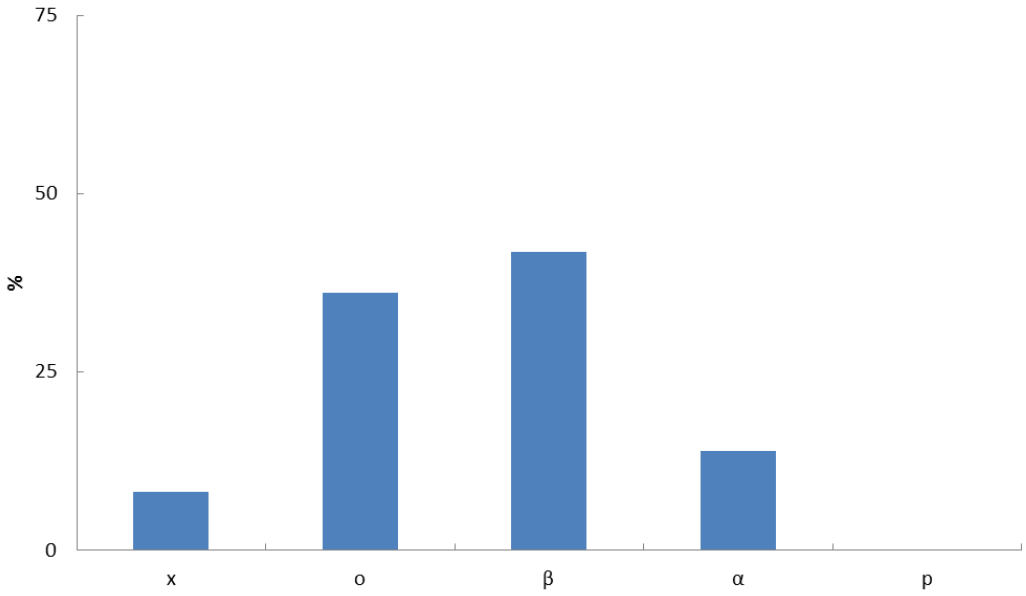

Figure 16: Distribution of saprobic valencies (GRAF et al. 2002) for the *Hydropsyche* species of the Laaben sampling site.

According to the distribution of valency points for longitudinal stream zonation and saprobity of Hydropsychidae (GRAF et al. 2002), the sampling site at Laaben is categorized as epirhitral - mesorhitral (Figure 15), and oligosaprobic - β-mesosaprobic (Figure 16).

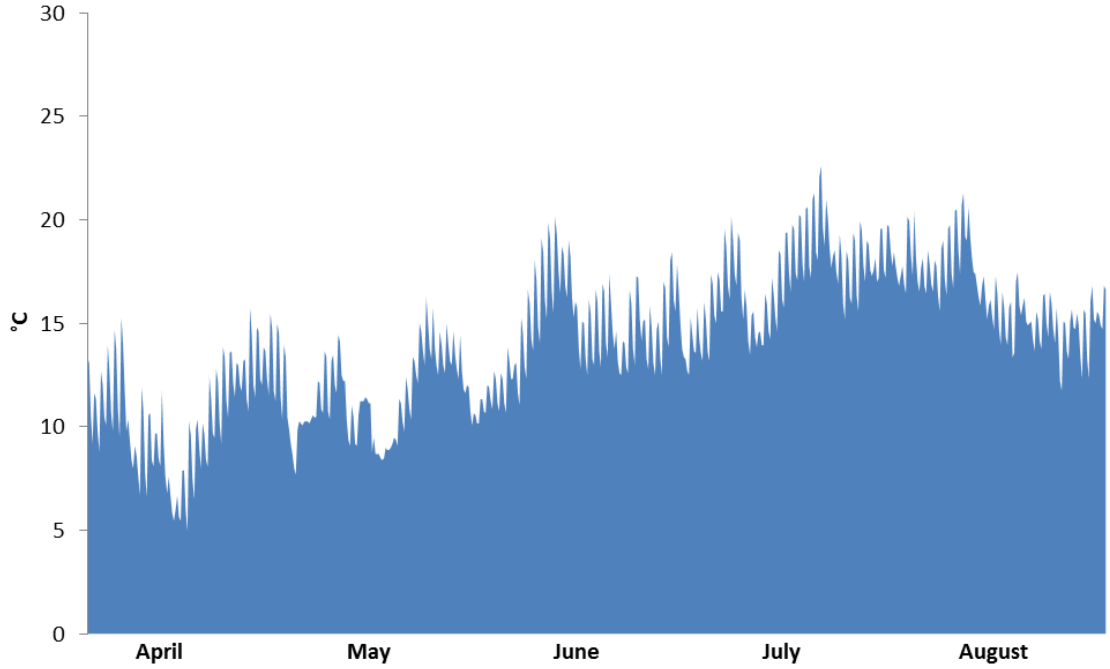

Figure 17: Long-time water temperature data from April to August 2014 at the Laaben sampling site.

The minimum water temperature during the sampling time from April to August was 4.9 °C in April, whereas the maximum was 22.6 °C in July (Figure 17). The mean water temperature during the sampling season was 14.1°C.

Table 12 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

Table 12: Limnochemical parameters at the Laaben sampling site; showing the mean (and range) of two measurements taken at 1 June 2014 and 12 August 2014.

CI Parameters	
ph	8.3 (8.3 – 8.3)
Conductivity (µS cm^{-1})	330 (-)
Water temperature (°C)	13.5 (-)
PO_4^{3-} (mg l^{-1})	0.025 (0 – 0.05)
NO_3^- (mg l^{-1})	2.5 (0 - 5)
NH_4^+ (mg l^{-1})	0.04 (0.03 – 0.05)
O_2 (%)	85 (78 – 92)
BSB_5	7.9 (7.7 – 8.1)

2.2.6 Sampling site Neulengbach

This sampling site (Figure 18) is located 1 km downstream of the city Neulengbach. From Neulengbach on the Große Tulln enters the Tullner Feld and has low reach character, meaning less inclination (3.9 ‰), less canopy closure by riparian forests (80 % site insolation) and higher discharge (0.27 m^3s^{-1}).

Table 13: Geographical and physical data of the Neulengbach sampling site

General parameters	
Elevation	217 m a.s.l.
Spring distance	19.2 km
Geographical position	48° 12´ 16.218´´ N, 15° 54´ 39.341´´ E
Strahler stream order	5
Mean discharge	0.27 $m^3 s^{-1}$
Slope	3.9 ‰
Chemical Index (CI)	65
Site insolation	80 %

Figure 18: Sampling site Neulengbach; line of sight: north

The width of the stream is 6 m at Neulengbach and the spring distance is 19.2 km. The Große Tulln was straightened at Neulengbach, causing heterogeneity loss of the streambed and constant riffle conditions with high flow velocities.

Table 14: Distribution of choriotopes after BRAUKMANN (1987) at the Neulengbach sampling site.

Choriotope	Area percentage
Macrolithal	15 %
Mesolithal	40 %
Akal	5 %
Psammal	5 %
Micropelal	5 %
Lithophytal	30 %

The sediments at Neulengbach are homogenous (Table 14), dominated by mesolithal (40%) and macrolithal (15%). Epilithic algae (lithophythal) cover parts of the sediments (30 %).

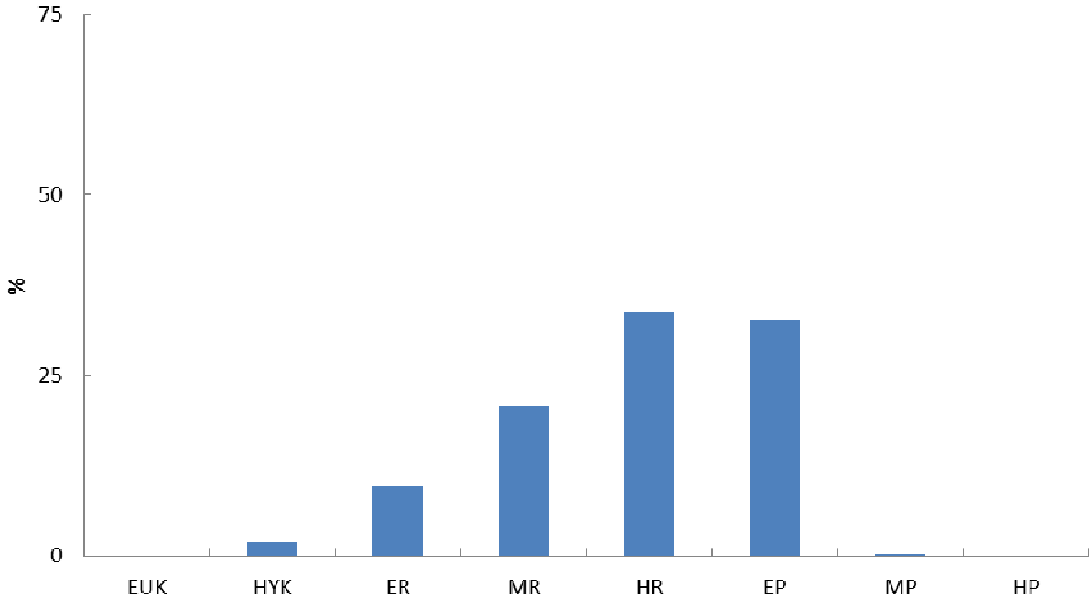

Figure 19: Valency point distribution of longitudinal stream zonation categories (GRAF et al. 2002) for the *Hydropsyche* species of the Neulengbach sampling site.

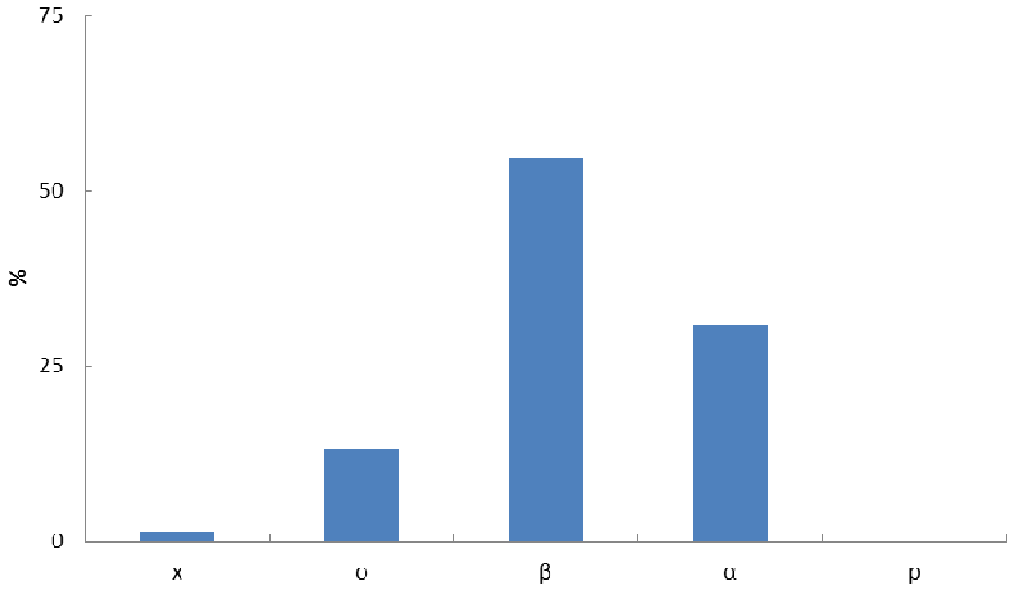

Figure 20: Distribution of saprobic valencies (GRAF et al. 2002) for the *Hydropsyche* species of the Neulengbach sampling site.

According to the distribution of valency points for longitudinal stream zonation and saprobity of Hydropsychidae (GRAF et al. 2002), the sampling site at Neulengbach is categorized as hyporhitral - epipotamal (Figure 19), and β-mesosaprobic (Figure 20).

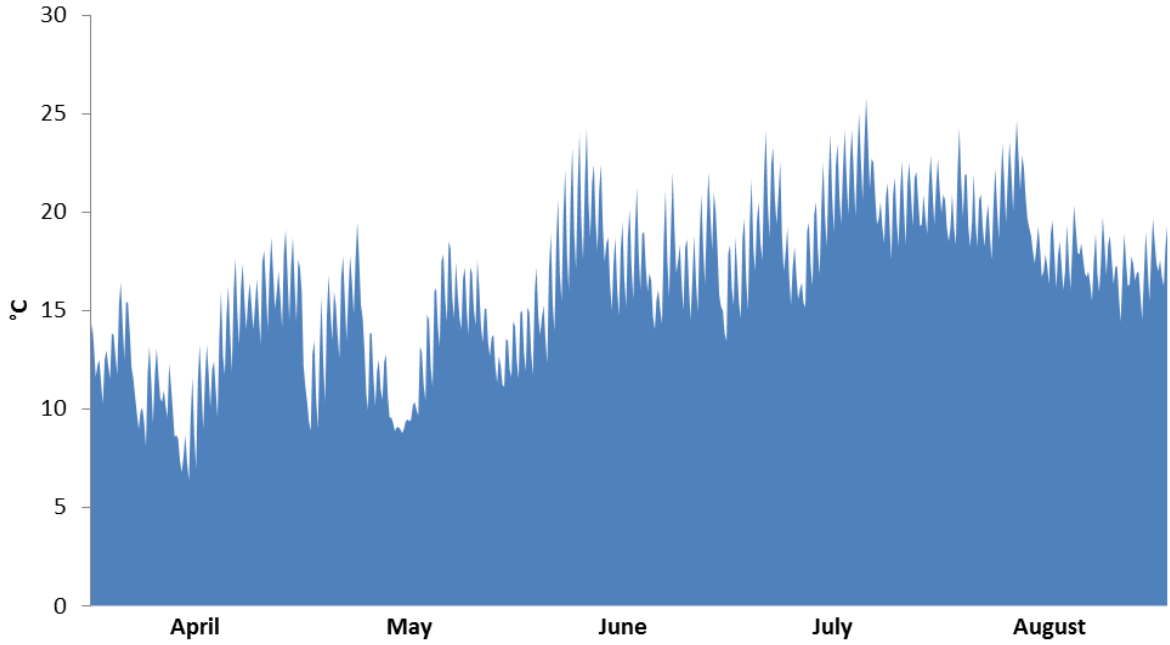

Figure 21: Long-time water temperature data from April to August 2014 at the Neulengbach sampling site.

The minimum water temperature during the sampling time from April to August was 6.4 °C in April, whereas the maximum was 25.8 °C in July (Figure 21). Mean water temperature during the sampling season was 16.5°C.
Table 15 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

Table 15: Limnochemical parameters at the Neulengbach sampling site; showing the mean (and range) of two measurements taken at 1 June 2014 and 12 August 2014.

CI Parameters	
ph	8.1 (8.0 – 8.2)
Conductivity (µS cm^{-1})	592 (-)
Water temperature (°C)	15.4 (-)
PO_4^{3-} (mg l^{-1})	0.025 (0 – 0.05)
NO_3^- (mg l^{-1})	4 (3 - 5)
NH_4^+ (mg l^{-1})	0.05 (0 – 0.1)
O_2 (%)	80 (74 – 86)
BSB_5	7.4 (7.2 – 7.6)

2.2.7 Sampling site Langenrohr

This sampling site (Figure 22) is a former horse passage across the river, located in the Tullner Feld 1 km upstream of the village of Langenrohr in 35.1 km spring distance. It represents the low reach potamal character of the river. The inclination of 0.9 ‰ is the least steep among the six sampling sites in the catchment. The width of the river is 10 m, and the site insolation is 100 %. The Große Tulln is heavily modified by dams on both banks.

Table 16: Geographical and physical data of the Langenrohr sampling site

General parameters	
Elevation	177 m a.s.l.
Spring distance	35.1 km
Geographical position	48° 18´ 19.565´´ N, 16° 0´ 07.875´´ E
Strahler stream order	5
Mean discharge	0.35 $m^3 s^{-1}$
Slope	0.9 ‰
Chemical Index (CI)	64
Site insolation	100 %

Figure 22: Sampling site Langenrohr; line of sight: north

The sampling site is a riffle, banked up with gravel. As a consequence the flow velocity in the shallow water is atypically fast for this river in the potamal section. The mean discharge is 0.35 $m^3 s^{-1}$, the highest among the sampling sites.

Table 17: Distribution of choriotopes after BRAUKMANN (1987) at the Langenrohr sampling site. The area percentage of Lithophytal is treated separately.

Choriotope	Area percentage
Macrolithal	20 %
Mesolithal	60 %
Psammal	10 %
Micropelal	10 %
Lithophytal	95 %

Gravel of up to 10 cm size (mesolithal) is the dominating sediments, with cobbles (macrolithal) in between (Table 17). At the banks muddy sediment (micropelal) is deposited. All stones are densely covered by epilithic algae (lithophythal). This sediment arrangement is true for the riffle sampling site at the horse passage, but not for the up- and downstream sections of the site. Here small stones, sand, and organic mud are predominant.

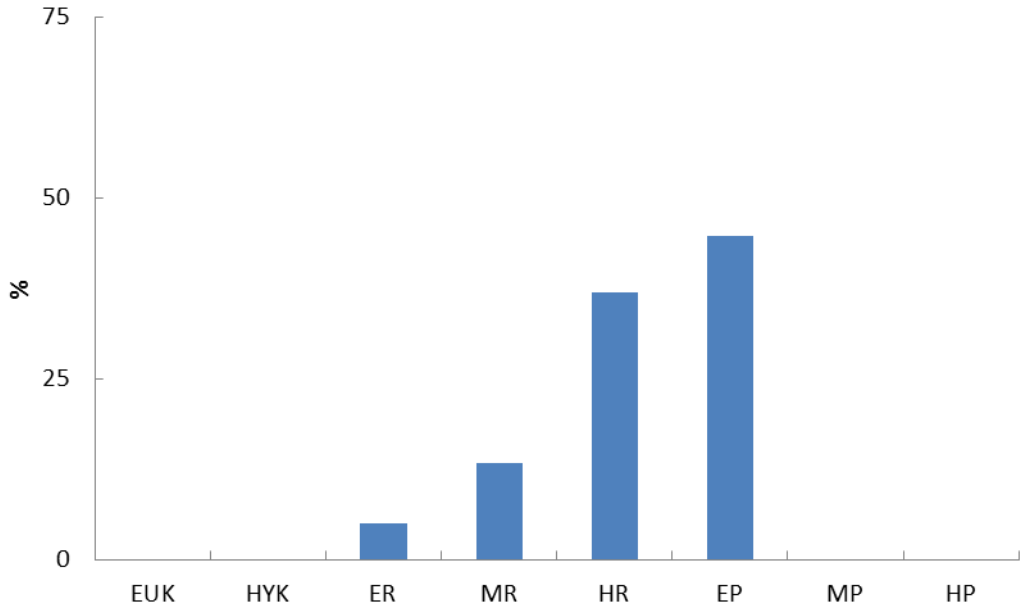

Figure 23: Valency point distribution of longitudinal stream zonation categories (GRAF et al. 2002) for the *Hydropsyche* species of the Langenrohr sampling site.

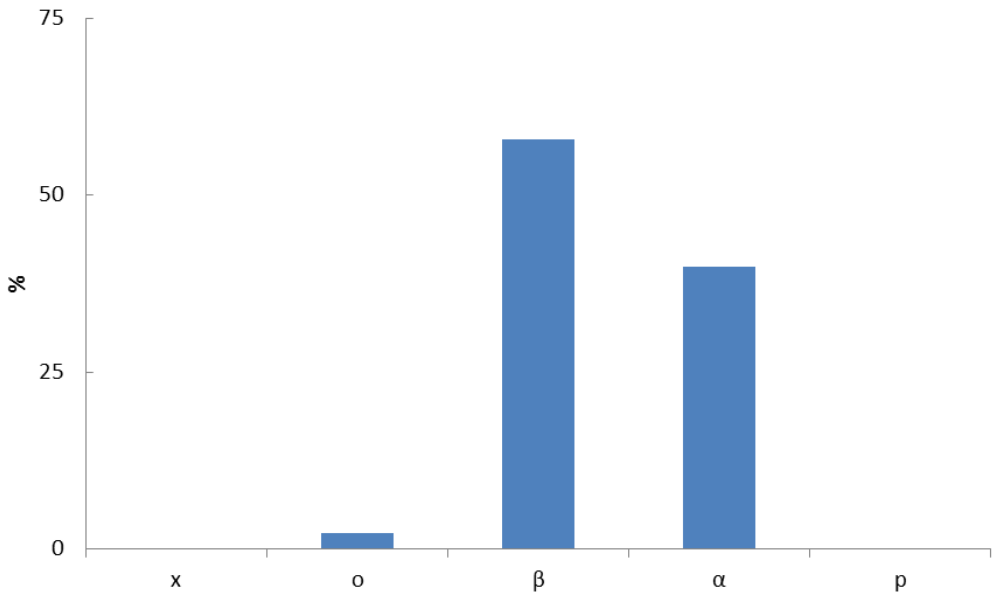

Figure 24: Distribution of saprobic valencies (GRAF et al. 2002) for the *Hydropsyche* species of the Langenrohr sampling site.

According to the distribution of valency points for longitudinal stream zonation and saprobity of Hydropsychidae (GRAF et al. 2002), the sampling site at Langenrohr is categorized as epipotamal (Figure 23), and β-mesosaprobic - α-mesosaprobic (Figure 24).

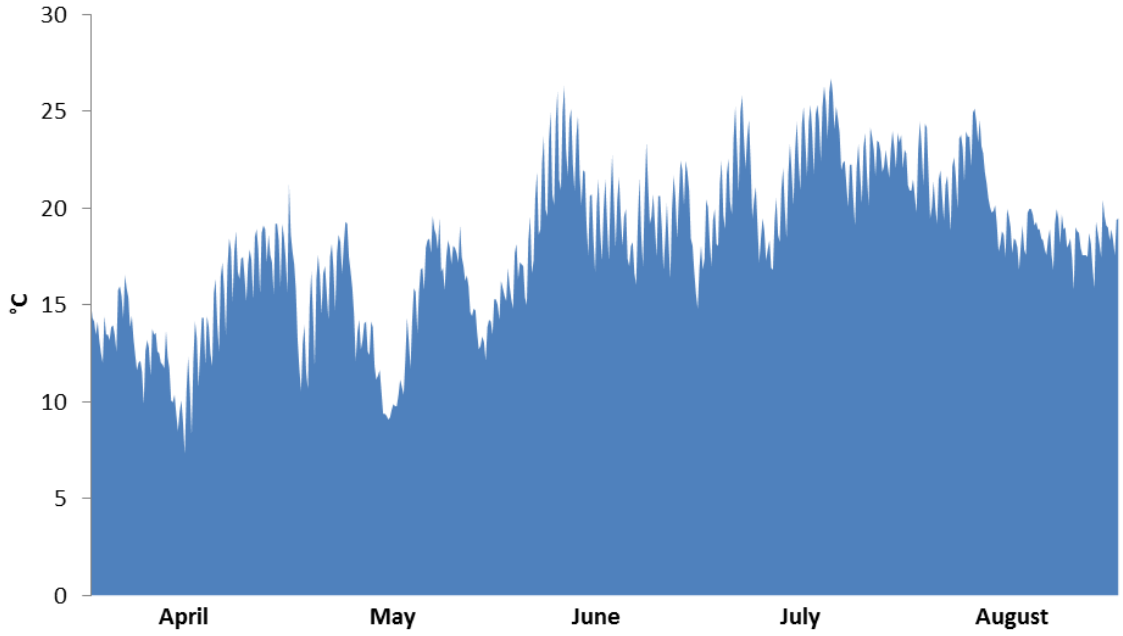

Figure 25: Long-time water temperature data from April to August 2014 at the Langenrohr sampling site.

The minimum water temperature during the sampling time from April to August was 7.3 °C in April, whereas the maximum was 26.7 °C in July (Figure 25). Mean water temperature during the sampling season was 18.1°C. Table 18 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

Table 18: Limnochemical parameters at the Langenrohr sampling site; showing the mean (and range) of two measurements taken at 1 June 2014 and 12 August 2014.

CI Parameters	
ph	8.0 (7.8 – 8.2)
Conductivity (µS cm^{-1})	658 (-)
Water temperature (°C)	16.7 (-)
PO_4^{3-} (mg l^{-1})	0.045 (0 – 0.09)
NO_3^- (mg l^{-1})	7.5 (5 - 10)
NH_4^+ (mg l^{-1})	0.05 (0 – 0.1)
O_2 (%)	65 (56 – 74)
BSB_5	6.0 (5.6 – 6.4)

3 Material and Methods

3.1 Field work

Six sampling sites (Figure 2) covering spring distances from 2.1 to 35 km were selected. From 10 March 2014 to 31 August 2014 the sampling sites were visited frequently (5 visits per sampling site) to conduct the analyses. Only 4th and 5th instars of Hydropsychidae were sampled for identification to species level using the key of WARINGER & GRAF (2011).

3.1.1 Catch per unit effort (CPUE) capture net sampling

CPUE sampling was performed at each sampling site for 45 minutes. 4th and 5th instar Hydropsychidae larvae were located and sampled including their retreats and nets. The retreat was sampled because in many cases the capture net is closely associated with the retreat when removed from the water. The depth of the capture net below water surface was measured with a ruler. Before removing the retreats, the flow velocity directly at the level of the net location was measured with a propeller meter (Ott C2; propeller diameter = 30 mm). Then the retreat (mostly attached to a large stone) with associated net and larva was removed with tweezers and preserved in 70% ethanol. This procedure allowed to associate each net with its larva and ambient depth and flow velocity.

3.1.2 CPUE species inventory sampling

In order to obtain information on species inventories at the sampling sites, Hydropsychidae larvae were sampled by CPUE: during 30 minutes, larvae (4th and 5th instars) were sampled and preserved in 70% ethanol. Thus it was possible to quantitatively compare the species inventories of the sampling sites, and to compare them with the inventories of 1982, analyzed by SCHEIBLREITER (1982).

3.1.3 Choriotopes, chemical index (CI), physical parameters

The canopy closure was assessed at each sampling date by estimating the percentage shading at the water surface. The composition of the streambed sediments was characterised once for each sampling site by estimating the percentage distribution of the choriotopes (BRAUKMANN 1987).

The eight parameters used for the Chemical Index (CI) were measured twice during the sampling period at each sampling site. O_2 saturation, NH_4^+, NO_3^-, and PO_4^{3-} concentrations, pH and electrical conductivity were measured on site. PH and electrical conductivity were measured with a WTW pH 330 pH meter and a WTW LF 330 conductivity meter, and O_2 saturation, NH_4^+, NO_3^- and PO_4^{3-} concentrations with Merck Aquaquant limnoanalytical packages. Biological Oxygen Demand (BOD-5) was measured after incubating river water in a closed sampling tube for five days at 20°C in the darkness. Then oxygen concentration was measured with the same methods as for O_2 saturation on site. The oxygen demand after 5 days of microbial respiration represents the BOD-5.

Water temperature was monitored continuously during the sampling season using Hobo data loggers. The data loggers were attatched underwater to stones and secured to trunks or a roots with a string. After the sampling season the data loggers were removed and read in the laboratory. The site-specific mean water temperature throughout the sampling season was used as CI parameter.

3.2 Identification and biometry

After each CPUE sampling, larvae were identified to species level using the identification key of WARINGER & GRAF (2011). Maximal head capsule width and body length (Figure 26) were measured using the length measurement application of Stereo Lumar V12 binocular software (ZEN 2011, Zeiss). Instars were split based on maximum head capsule widths.
Retreats with adherent nets were placed in a Petri dish in 70% ethanol using tweezers. Under a binocular microscope the nets were detached from the retreats by using dissecting needles and a lancet. Following this procedure, the net structure does not disrupt and the net could be tranfered to a microscope slide in a drop ethanol (70%). After this process the net was unfolded below the binocular microscope by using dissecting needles. The flattened net on the slide (Figure 27) was covered by a cover glass in order to keep its shape.
Average mesh length and -width for each net were measured using the binocular Stereo Lumar V12 software (ZEN 2011, Zeiss) length measurement application. The transitional zone between the two net hemispheres was used as reference line. The initial point for the measurement was given by the centrer mesh of each hemisphere. From this mesh on, the width of seven meshes was measured (Figure 27). The fourth mesh was then used as initial point for measuring the length of those seven meshes at right angles to the previous measurement. Data were used to calculate arithmetic means of mesh length and width for each net. Finally 4th and 5th instar larvae obtained from the CPUE samplings were identified to species level.

Figure 26: *Hydropsyche sp*. Measurement of body length and head capsule width.

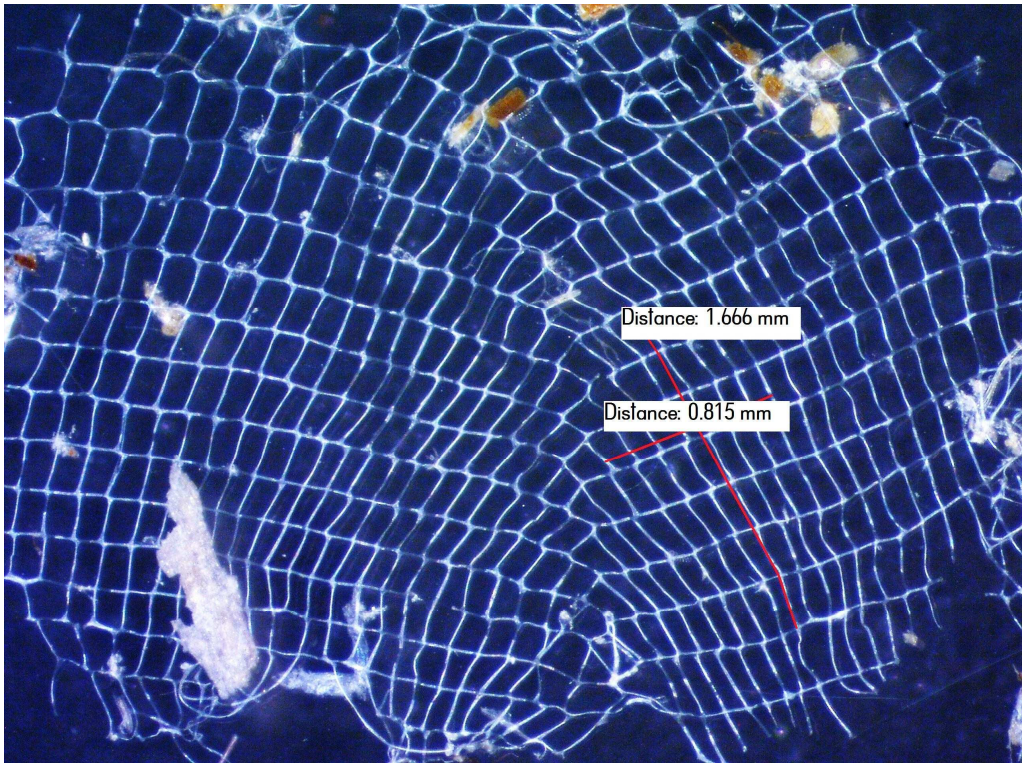

Figure 27: Capture net of *Hydropsyche sp*. Measurement of mesh length and width.

3.3 Statistical analysis

Species-specific frequency histograms of head capsule widths of 4th and 5th instars were created with STATGRAPHICS CENTURION XVI.II software.

Regression analyses for head capsule widths versus body lengths, head capsule widths versus mesh areas, mesh areas versus flow velocities at net level and *H. saxonica* instar versus head capsule widths were performed using R statistics (RSTUDIO TEAM, 2012).

Species-specific differences in mesh area for 4th and 5th instars were tested using a Kruskal-Wallis post-hoc Nemenyi test (POHLERT 2014).

Congruence curves for Hydropsychidae species distribution in the catchment, phenology of Hydropsychidae species, site-specific mesh areas of capture nets, and site-specific flow velocities were plotted using R statistics (RSTUDIO TEAM, 2012).

4 Results

4.1 Species inventory

During the whole sampling season from March to August 2014 a total of 950 specimens of Hydropsychidae (*Hydropsyche sp*. and *Cheumatopsyche sp*.) were sampled at six sampling sites in the catchment of the Große Tulln and identified to species level. Eight species of Hydropsychidae were detected in the catchment. Table 19 summarizes the species inventories (4th and 5th instars) of the six sampling sites, and compares them to the species inventory detected by SCHEIBLREITER (1982). *H. pellucidula* and *H. incognita* were pooled, because it is not possible to securely separate them morphologically. Hydropsychidae diversity was highest at the midstream sampling sites Altlengbach, Laaben, and Neulengbach. Upstream (Klamm and Prinzbach) and downstream (Langenrohr) the diversity decreased (Table19).

The upstream sites Klamm and Prinzbach were strictly dominated by either *H. instabilis* (Klamm) or *H. saxonica* (Prinzbach), whereas near the mouth at Langenrohr *H. bulbifera* was most abundant. The middle reaches (Altlengbach and Laaben) were dominated by *H. instabils* and *H. saxonica*, with five other sympatric Hydropsychidae species. Neulengbach, the most downstream site of the central section of the catchment, was dominated by *H. bulbifera*, together with six more rare Hydropsychidae species.

Table 19: *Hydropsyche* species sampled at six sampling sites within the catchment of the Große Tulln. Data are based on CPUE samplings over 45 minutes each, from 13 March 2014 to 30 August 2014 ; showing the number (and percentage) of individuals from the present study (numbers left of slash) and from SCHEIBLREITER 1982 (8-39 kick samplings per site; numbers right of slash). The chemical index (CI) is shown for each sampling site. Species are ranked according to their longitudinal distribution from upstream to downstream.

Species	**Sampling site (CI)**					
	Klamm (65)	Prinzbach (69)	Altlengbach (64)	Laaben (65)	Neulengbach (65)	Langenrohr (64)
H . fulvipes (CURTIS 1834)	8 (8)/ 1 (0)	8 (4)/-	3 (2)/-	-	-	-
H. instabilis (CURTIS 1834)	70 (65)/ 685 (66)	5 (3)/ 25 (32)	43 (25)/ 673 (74)	53 (40)/ 2384 (96)	6 (3)/ 45 (1)	-
H. saxonica McLACHAN 1884	29 (27)/ 351 (34)	169 (93)/ 53 (68)	85 (49)/ 166 (18)	55 (42)/ 62 (3)	20 (10)/-	-
H. pellucidula (CURTIS 1834)*/incognita* (PITSCH 1993)	-	-	11 (7)/ 69 (8)	20 (15)/-	39 (20)/-	1 (1)/-
H. siltalai DÖHLER 1963	-	-	19 (11)/-	1 (1)/-	25 (13)/ 16 (0)	-/9 (1)
C. lepida (PICTET 1834)	-	-	6 (3)/-	-/32 (1)	24 (12)/ 93 (2)	-
H. angustipennis (CURTIS 1834)	-	-	-	1 (1)/-	2 (1)/ 4 (0)	29 (20)/ 423 (19)
H. bulbifera McLACHLAN 1878	-	-	6 (3)/-	2 (1)/ 1 (0)	83 (41)/ 4691 (97)	117 (79)/ 1728 (80)

When comparing the samples from 2014 with the species inventory of SCHEIBLREITER (1982), *H. fulvipes*, *H. saxonica* and *H. pellucidula/incognita* have moved further downstream, whereas the reverse is true for *H.siltalai*, *C. lepida*, *H. angustipennis* and *H. bulbifera*

(Table 19). A total of 325 specimens (ultimate and penultimate instars) were measured (head capsule width, body length) and used for filtering net analyses (Table 20).

Table 20: *Hydropsyche* species used for filtering net analyses, sampled at six sampling sites within the catchment of the Große Tulln. Data are based on CPUE samplings over 45 minutes each, from 13 March 2014 to 30 August 2014; showing the number of 4th/5th instar larvae. The chemical index (CI) is shown for each sampling site. Species are ranked according to their longitudinal distribution from upstream to downstream.

Species	**Sampling site (CI)**					
	Klamm (65)	Prinzbach (69)	Altlengbach (64)	Laaben (65)	Neulengbach (65)	Langenrohr (64)
H . fulvipes (CURTIS 1834)	3/-	1/1	3/-	-	-	-
H. instabilis (CURTIS 1834)	1/25	-/3	-/15	1/23	-/4	-
H. saxonica McLACHAN 1884	3/3	31/38	8/31	7/6	-/3	-
H. pellucidula (CURTIS 1834) */incognita* (PITSCH 1993)	-	-	2/3	1/4	3/11	-
H. siltalai DÖHLER 1963	-	-	3/3	-	4/5	-
C. lepida (PICTET 1834)	-	-	-/2	-	-/5	-
H. angustipennis (CURTIS 1834)	-	-	-	-	-/1	1/7
H. bulbifera McLACHLAN 1878	-	-	2/1	1/1	9/14	15/17

The chemical index (CI) of all sampling sites is between 64 and 69 (Tables 19, 20), which is indicative of water quality II.

In the catchment of the Große Tulln three river sections with different species associations of

Hydropsychidae could be distinguished. Congruence curves split the species inventory into an upstream, midstream and downstream association (Figure 28).

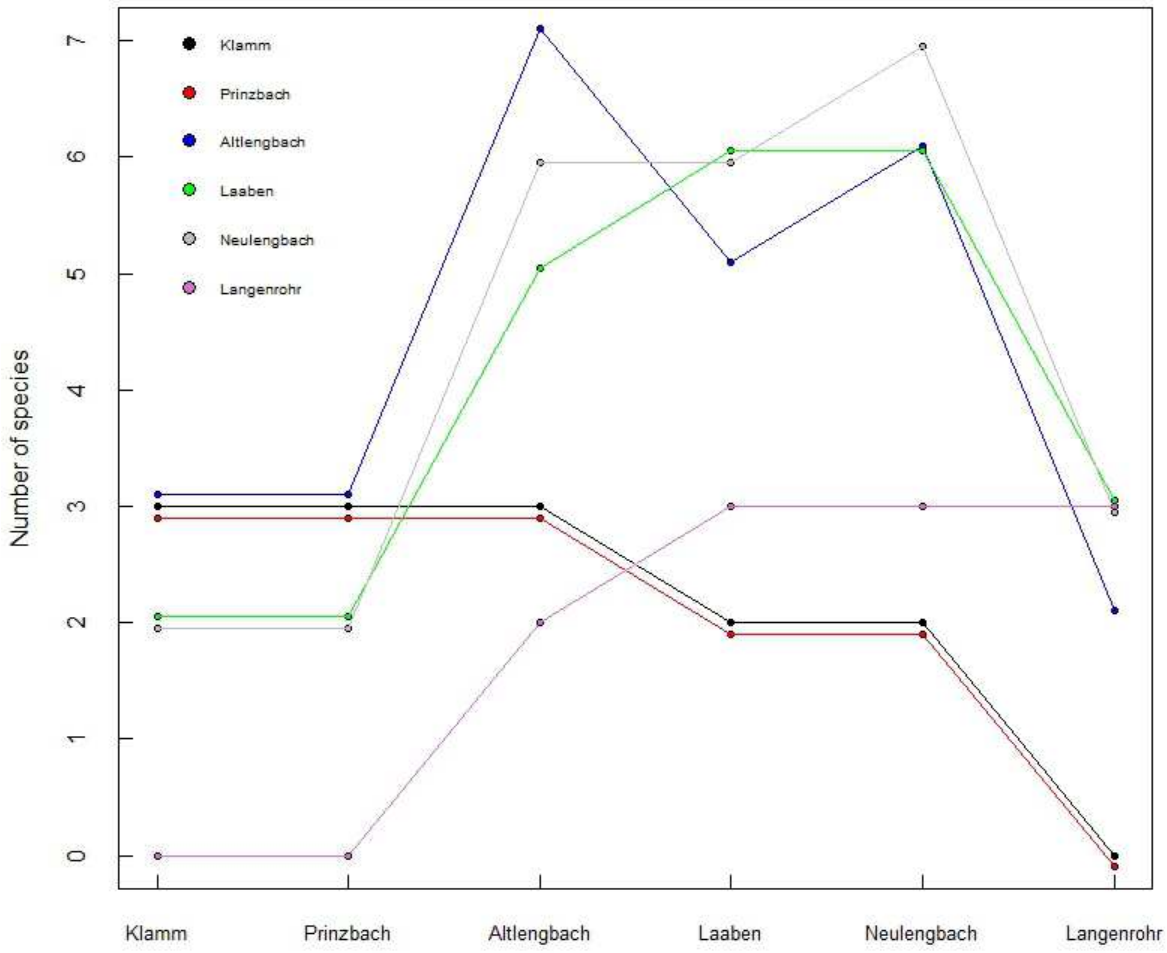

Figure 28: Congruence curves of Hydropsychidae species at six sampling sites in the Große Tulln catchment; showing the species number at each sampling site, which are colour-coded. Data are based on CPUE samplings over 45 minutes each from 10 March 2014 to 31 August 2014.

The sampling sites Prinzbach and Klamm belong to the upstream section, where *H. instabilis* and *H. saxonica* are dominant. The midstream association is characterized by 7 sympatric *Hydropsyche* species, where *H. saxonica*, *H. instabilis* or *H. bulbifera* are most abundant. This species set was recorded at sampling sites Altlengbach, Laaben, and Neulengbach. The downstream association, with *H. bulbifera*, and *H. angustipennis* as dominating species, was recorded at Langenrohr (Figure 28).

4.2 Biometry

The relationship between body length and maximum head capsule width of all specimens (4th and 5th instars) is well described by a linear regression (Figure 29).

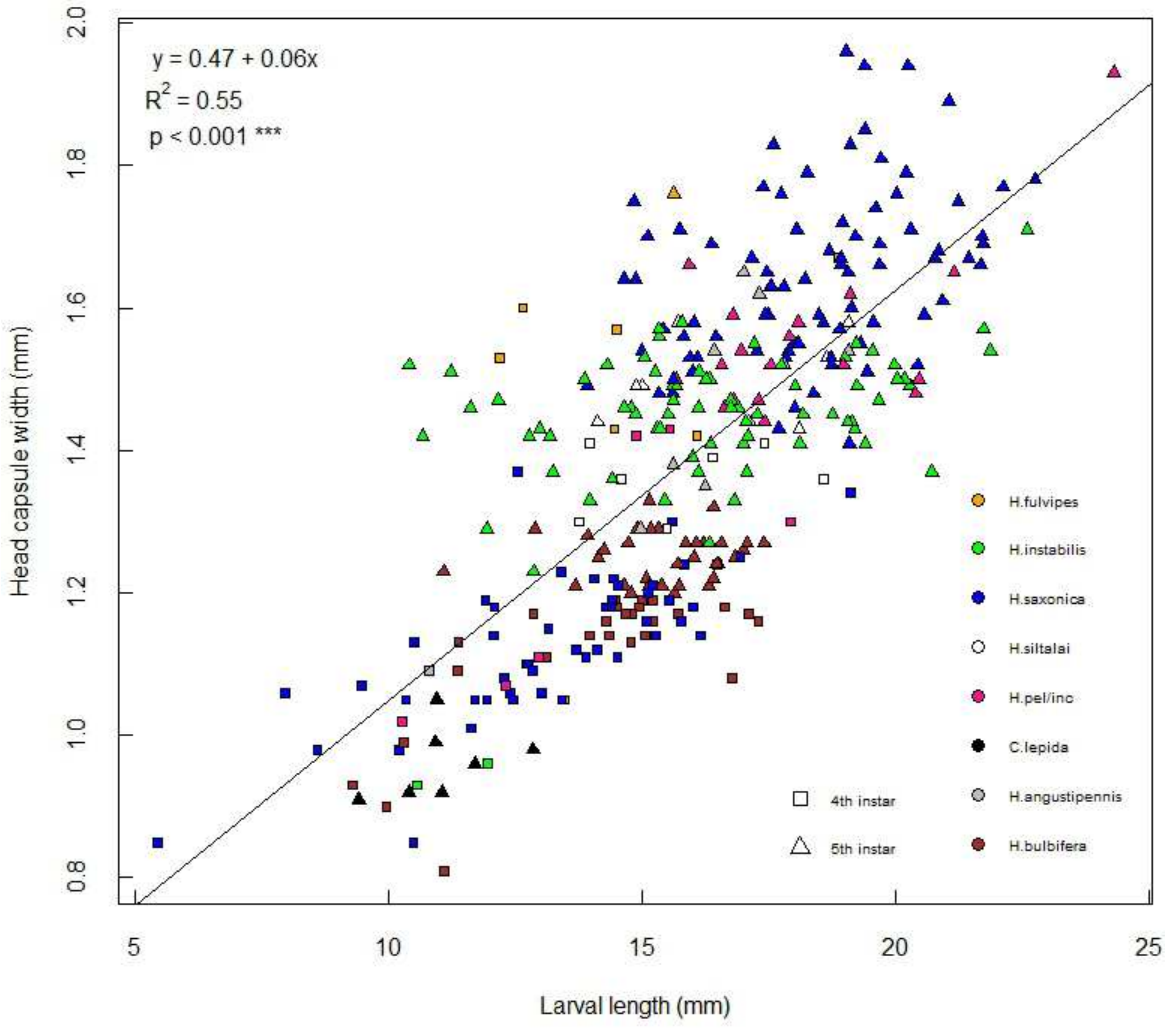

Figure 29: Regression of larval length (mm) versus maximum head capsule width (mm) of *Hydropsyche* species of the Große Tulln catchment; species and instars are indicated by colored symbols. Data are based on CPUE samplings over 45 minute each from 10 March 2014 to 31 August 2014.

Minimum length of penultimate instars were observed in *H. bulbifera* (mean head capsule width = 1.16 mm) and maximum length in *H. fulvipes* (mean head capsule width = 1.53 mm). Minimum length of ultimate instars were observed in *C. lepida* (mean head capsule width = 0.96 mm) and maximum length in *H. saxonica* (mean head capsule width = 1.64 mm).

Table 21 summarizes median and range of maximum head capsule widths of 4th and 5th in-

stars of the eight *Hydropsyche* species of the Große Tulln catchment. In *C. lepida* only 5th instar larvae were sampled. Based on median head capsule width *H. fulvipes* (penultimate instar = 1.53 mm, ultimate instar = 1.76 mm) is the largest *Hydropsyche* species in the study area, whereas *C. lepida* (ultimate instar = 0.96 mm) is the smallest one.

Table 21: Maximum head capsule widths of 4th and 5th instars of *Hydropsyche* species of the Große Tulln catchment; showing the median and the range. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 31 August 2014. Species are ranked according to their longitudinal distribution from upstream to downstream.

Species	Head capsule width (median and range; mm)	
	4th instar	5th instar
H . fulvipes (CURTIS 1834)	1.53 (1.05 – 1.67)	1.76 (-)
H. instabilis (CURTIS 1834)	0.95 (0.93 – 0.96)	1.46 (1.23 – 1.71)
H. saxonica McLACHAN 1884	1.14 (0.85 – 1.37)	1.64 (1.41 – 1.96)
H. pellucidula (CURTIS 1834) */incognita* (PITSCH 1993)	1.21 (1.02 – 1.43)	1.52 (1.44 – 1.93)
H. siltalai DÖHLER 1963	1.36 (1.29 – 1.41)	1.49 (1.43 – 1.58)
C. lepida (PICTET 1834)	-	0.96 (0.91 – 1.05)
H. angustipennis (CURTIS 1834)	1.09 (-)	1.53 (1.29 – 1.65)
H. bulbifera McLACHLAN 1878	1.16 (0.81 – 1.19)	1.26 (1.20 – 1.40)

Frequency distributions of species-specific head capsule widths are shown in Figures 30-37. In the most abundant species of the catchment, *H. saxonica*, 4th and 5th instars were well defined in the histogram (Figure 32); this split was less obvious in species where only few penultimate instars were collected.

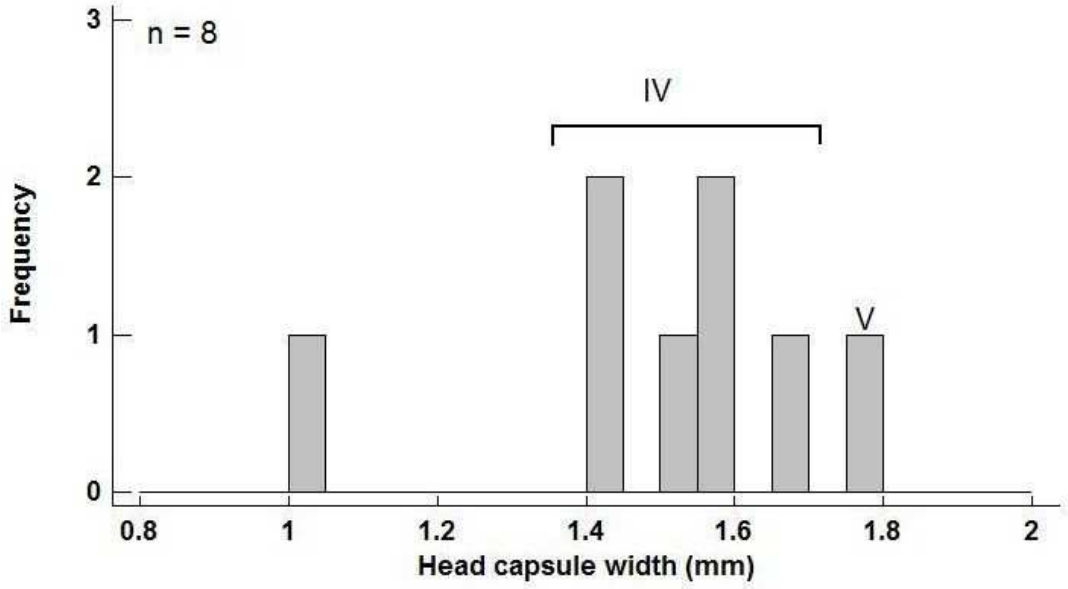

Figure 30: Size-frequency histogram of maximum head capsule widths of *H. fulvipes*. Ultimate and penultimate instars are indicated by roman numerals. Data are based on CPUE samplings over 45 minutes each, from 21 May 2014 to 09 July 2014.

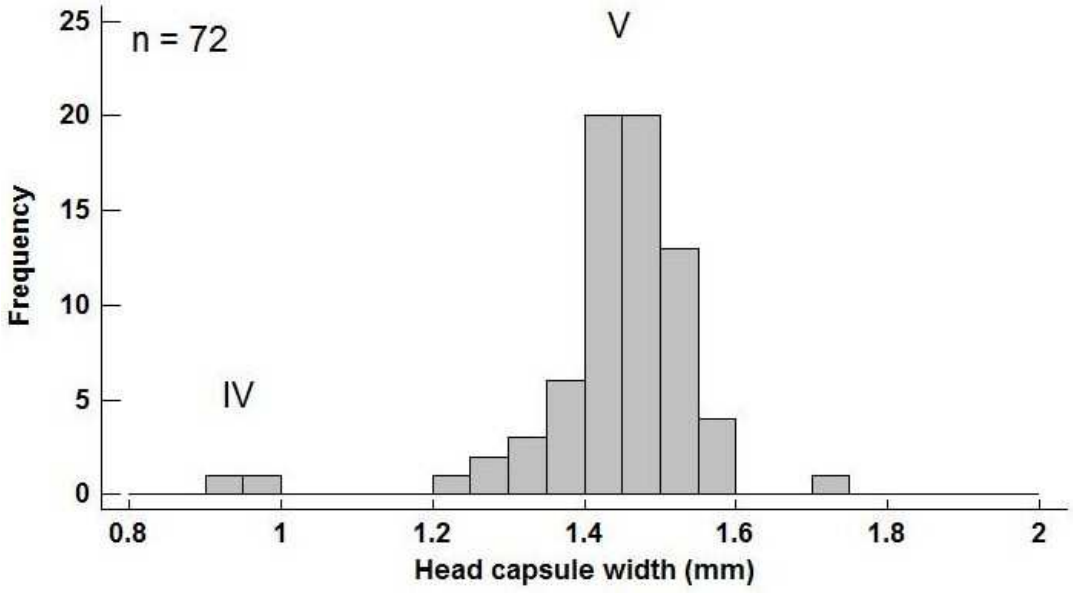

Figure 31: Size-frequency histogram of maximum head capsule widths of *H. instabilis*. Ultimate and penultimate instars are indicated by roman numerals. Data are based on CPUE samplings over 45 minutes each, from 21 March 2014 to 14 August 2014.

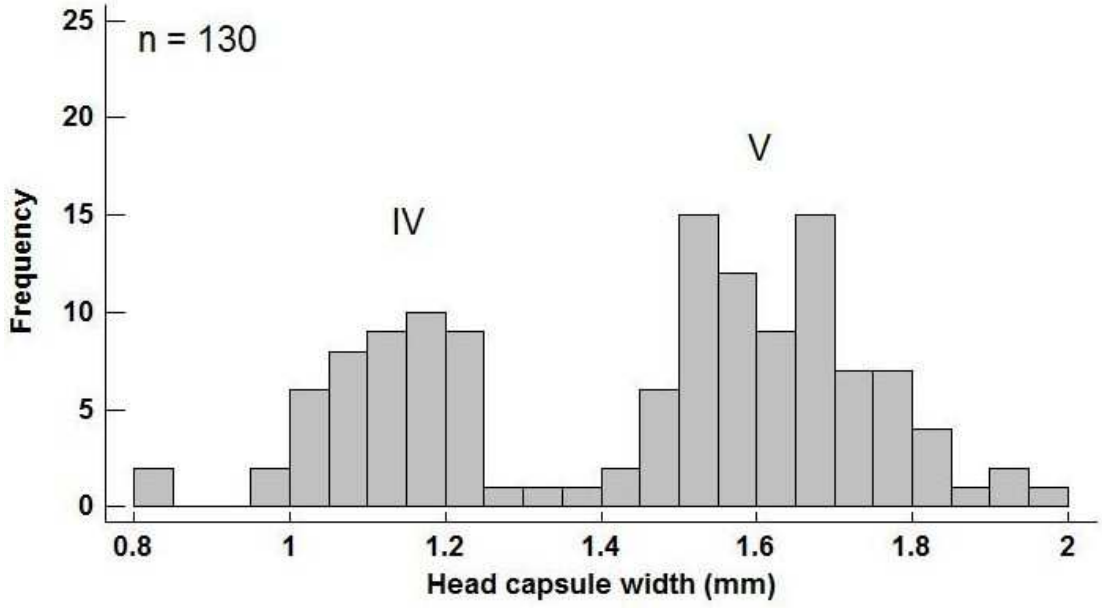

Figure 32: Size-frequency histogram of maximum head capsule widths of *H. saxonica*. Ultimate and penultimate instars are indicated by roman numerals. Data are based on CPUE samplings over 45 minutes each, from 13 March 2014 to 31 August 2014.

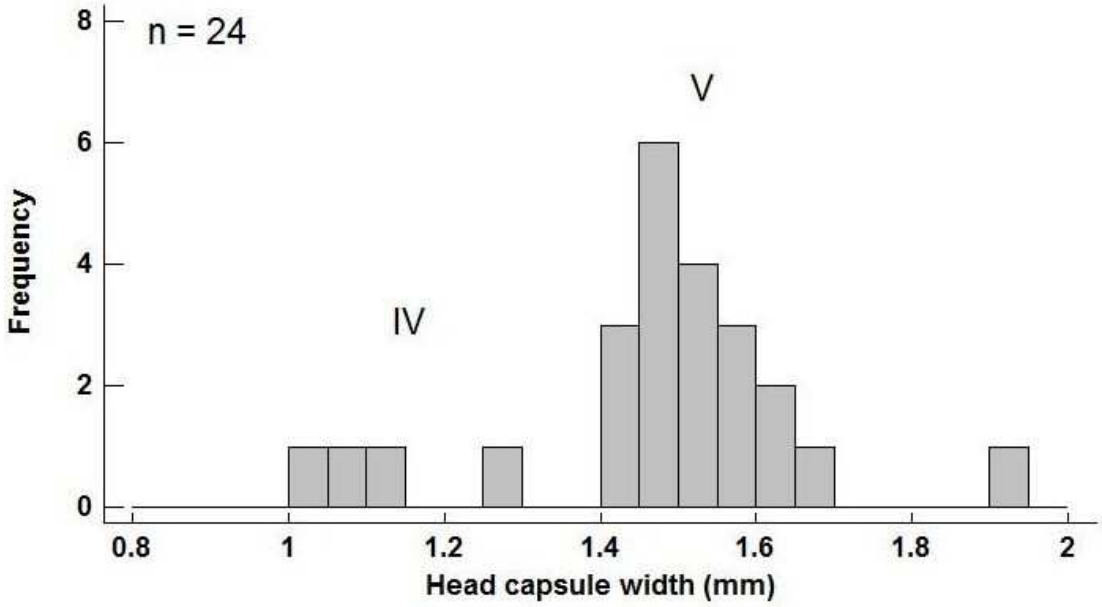

Figure 33: Size-frequency histogram of maximum head capsule widths of *H. pellucidula/incognita*. Ultimate and penultimate instars are indicated by roman numerals. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 7 August 2014.

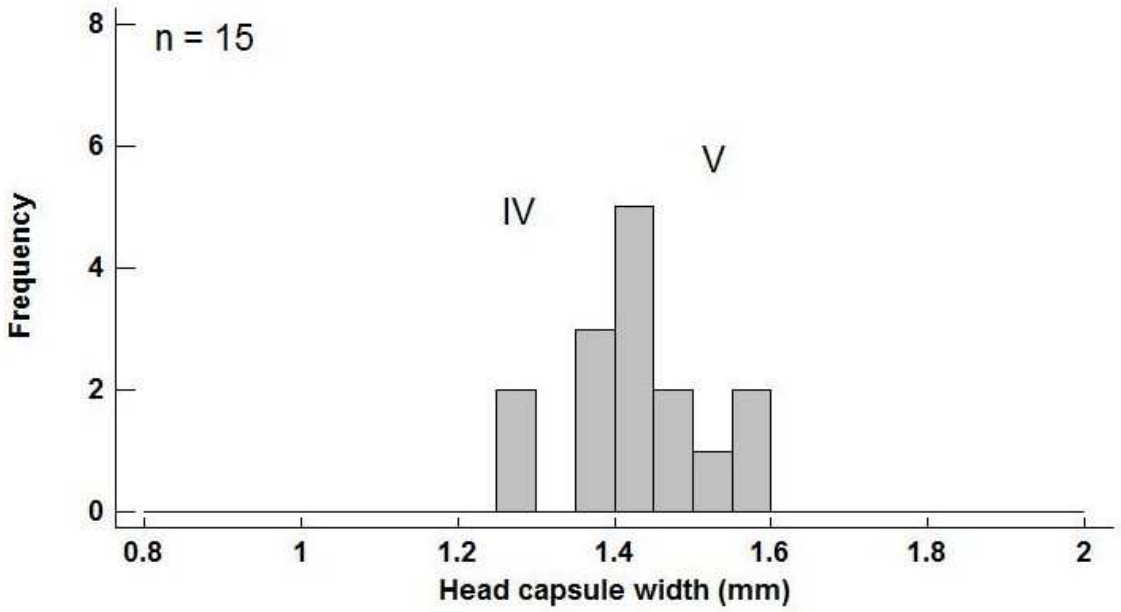

Figure 34: Size-frequency histogram of maximum head capsule widths of *H. siltalai*. Ultimate and penultimate instars are indicated by roman numerals. Data are based on CPUE samplings over 45 minutes each, from 14 May 2014 to 19 June 2014.

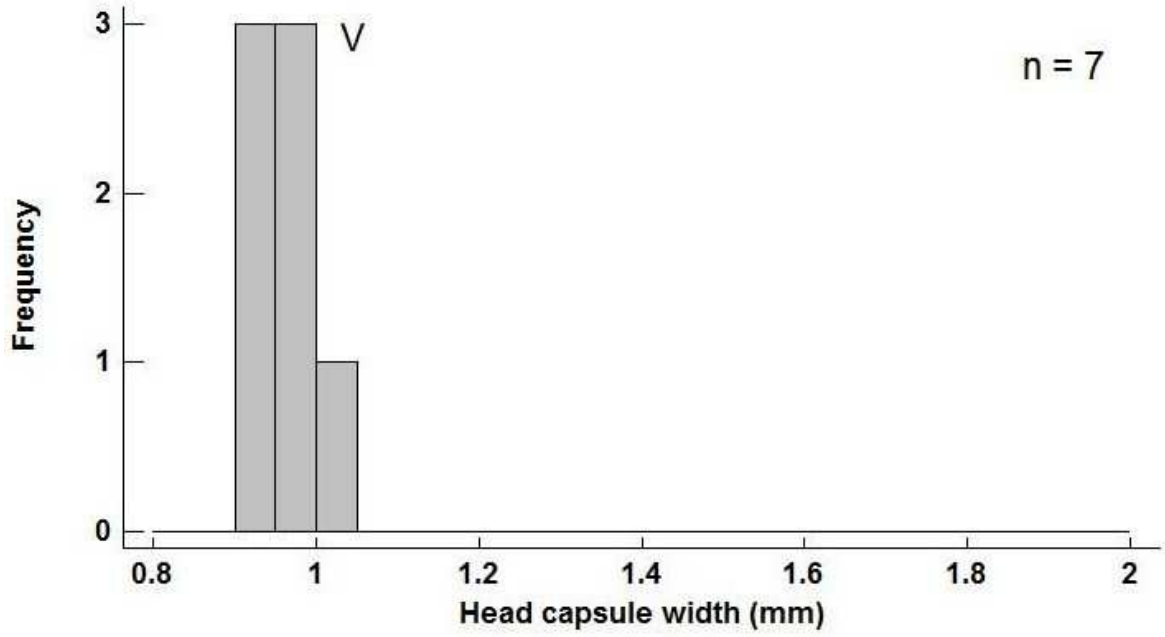

Figure 35: Size-frequency histogram of maximum head capsule widths of *C. lepida*. Ultimate and penultimate instars are indicated by roman numerals. Data are based on CPUE samplings over 45 minutes each, from 14 May 2014 to 19 June 2014.

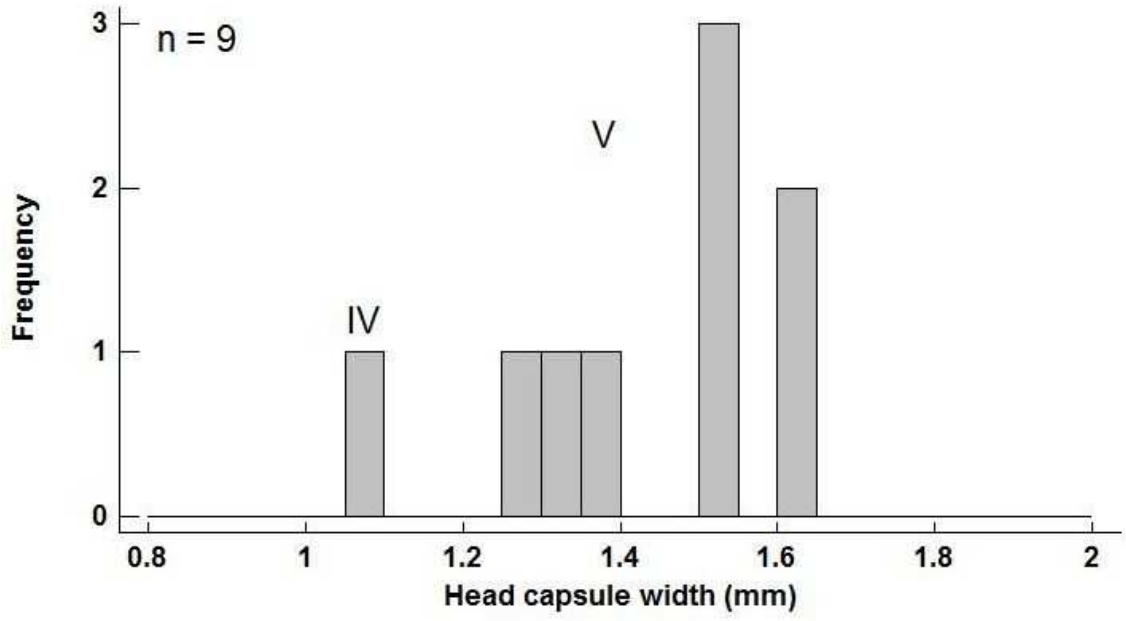

Figure 36: Size-frequency histogram of maximum head capsule widths of *H. angustipennis*. Ultimate and penultimate instars are indicated by roman numerals. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 19 August 2014.

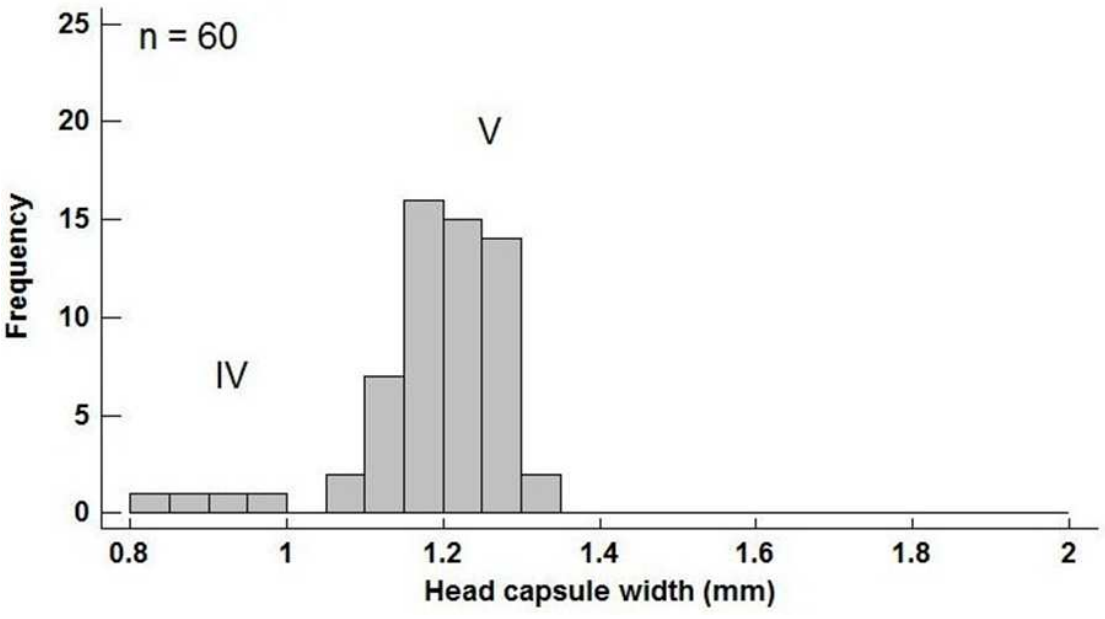

Figure 37: Size-frequency histogram of maximum head capsule widths of *H. bulbifera*. Ultimate and penultimate instars are indicated by roman numerals. Data are based on CPUE samplings over 45 minutes each, from 13 March 2014 to 19 August 2014.

When the instar number of *H. saxonica*, the most abundant species of the catchment, was plotted against head capsule width, a linear regression line was obtained on a semi-logarithmic

scale (Dyar´s rule). Therefore the relationship between head capsule width (mm) and instar number was exponential, and head capsule widths of younger instars could be extrapolated, using the semilog regression equation (Figure 38).

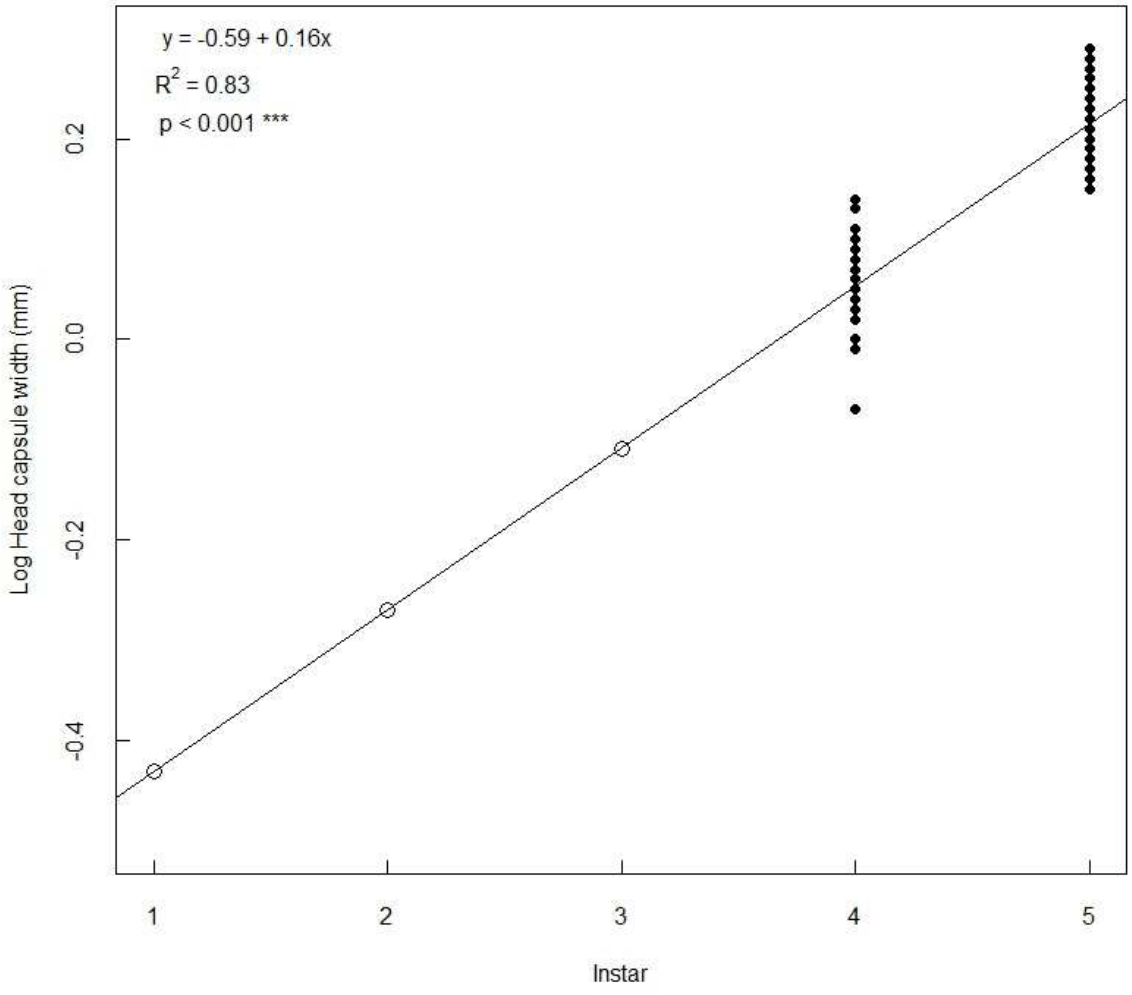

Figure 38: Regression of instar versus head capsule width (log mm) of *H. saxonica* of the Große Tulln catchment. Data (4th and 5th instars) are based on CPUE samplings over 45 minutes each from 10 March 2014 to 31 August 2014. Full circles = measured; open circles = extrapolated data for the younger instars.

4.3 Phenology

The relative frequencies of penultimate and ultimate instars of the Hydropsychidae species of the Große Tulln catchment, based on monthly samples, are shown in Figure 39. All species are univoltine.

Fourth and fifth instars larvae of *H. saxonica*, *H. pellucidula/incognita*, *H. angustipennis* and *H. bulbifera* were already recorded in March, the remaining species not before May. In *H.saxonica* and *H .bulbifera* larvae were sampled during the whole sampling season (in April, only two samplings took place at the sites Altlengbach and Prinzbach). *H. instabilis*, *H. fulvipes*, *H. siltalai* and *C. lepida* (4th and 5th instars) were sampled only during the summer months between May and July. *H. angustipennis* and *H. pellucidula/incognita* were collected at the beginning, the middle and the end of the sampling season, and lacked in the April, June and July samples. Flight periods start between April (*H. angustipennis*) and July (*H. instabilis*).

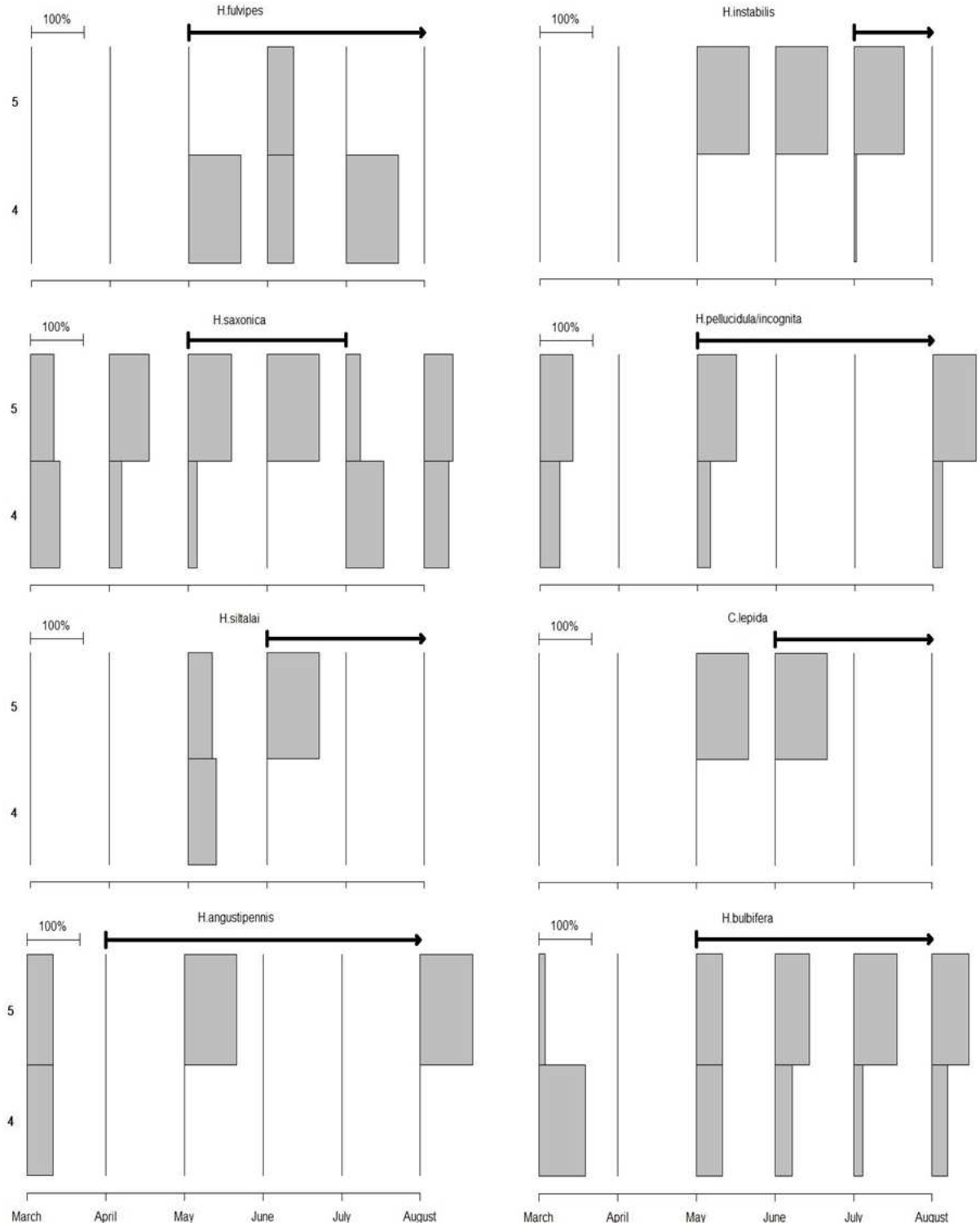

Figure 39: Phenology of *Hydropsyche* species in the Große Tulln catchment; showing the percentage of ultimate and penultimate instars for each month. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 31 August 2014. The flight periods (WARINGER & GRAF 2011) are indicated by black bars.

4.4 Biometry of the capture net meshes

In four Hydropsychidae species (*H. instabilis*, *H. saxonica*, *H. angustipennis*, *H. bulbifera*) of the Große Tulln catchment the relationship between maximum head capsule width (mm) and mesh area (mm^2) of the filtering nets could be significantly described by a linear regression (Figure 40). Larval moultings from the penultimate to the ultimate instar created significantly larger species-specific mesh areas.

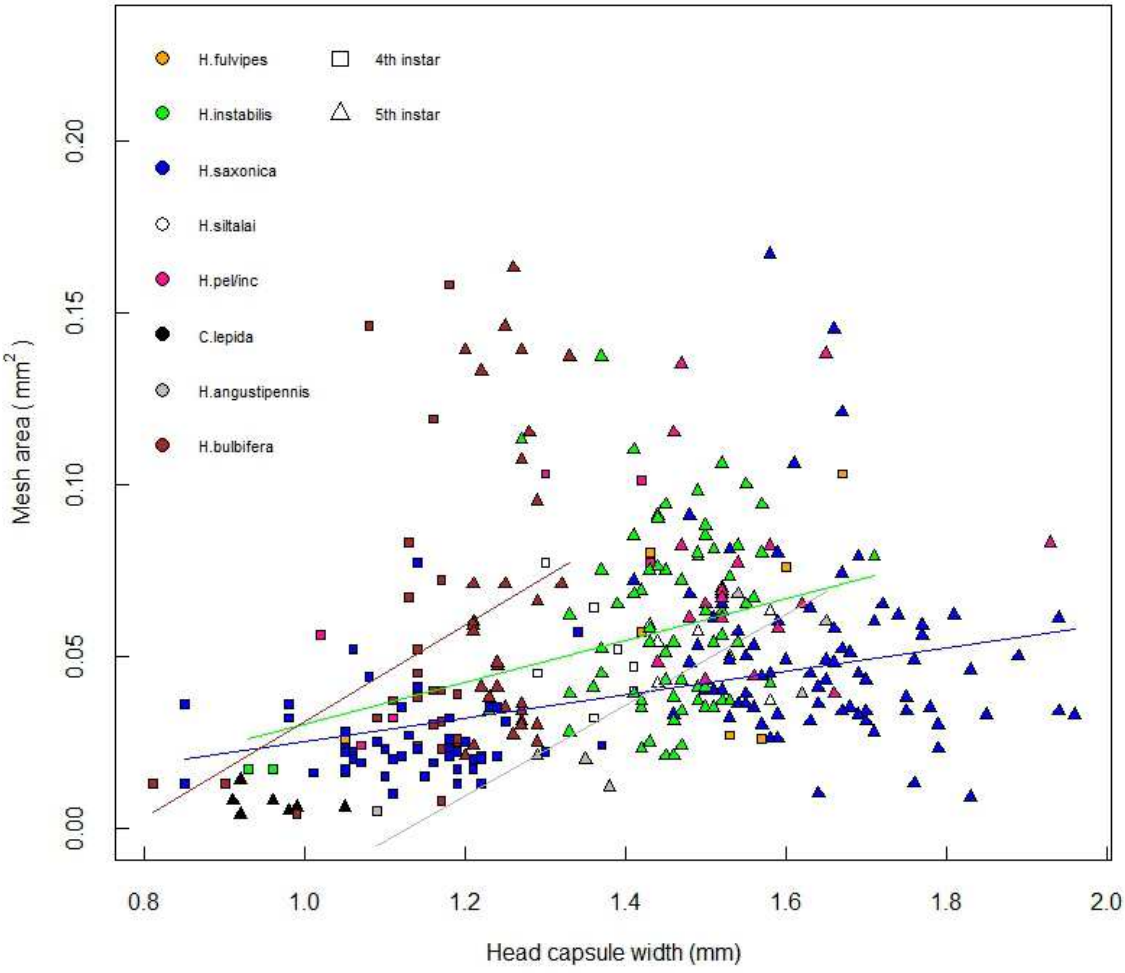

Figure 40: Regressions of maximum head capsule width (mm) versus mesh area (mm^2) of *Hydropsyche* species of the Große Tulln catchment; species and instars are indicated by colored symbols; significant regressions are shown by colored lines. Data are based on CPUE samplings over 45 minutes each from 10 March 2014 to 31 August 2014. Regression parameters: *H. instabilis* (4th and 5th instars): y = -0.031 + 0.061x; R^2 = 0.07; p < 0.05 *; *H. saxonica* (4th and 5th instars): y = -0.009 + 0.034x; R^2 = 0.14; p < 0.001 *; *H. angustipennis* (4th and 5th instars): y = -0.149 + 0.132x; R^2 = 0.64; p < 0.05 *; *H. bulbifera* (4th and 5th instars): y = -0.109 + 0.140x; R^2 = 0.10; p < 0.05 ***

Mesh areas ranged from 0.005 mm^2 (*H. angustipennis*) in fourth instar larvae to 0.074 mm^2 (*H. pellucidula/incognita*) in fifth instar larvae (Table 22).

Table 22: Mesh area of filtering nets of *Hydropsyche* species of the Große Tulln catchment. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 31 August 2014; showing the means, standard deviations, ranges, and numbers of capture nets measured (n) of ultimate and penultimate instars.

Species/Instars		**Mesh area (mm^2)**		
		Mean ± SD (mm^2)	Range (mm^2)	n
H.fulvipes	4	0.056 ± 0.031	0.026 – 0.103	7
	5	0.048 ± 0.000	-	1
H.instabilis	4	0.018 ± 0.001	0.017 – 0.019	2
	5	0.060 ± 0.024	0.021 – 0.106	70
H.saxonica	4	0.026 ± 0.012	0.010 – 0.077	49
	5	0.050 ± 0.026	0.009 – 0.167	81
H.siltalai	4	0.051 ± 0.015	0.032 – 0.077	7
	5	0.052 ± 0.009	0.037 – 0.063	8
H.pellucidula/incognita	4	0.065 ± 0.034	0.024 – 0.103	6
	5	0.074 ± 0.029	0.039 – 0.138	18
C.lepida	5	0.007 ± 0.003	0.004 – 0.014	7
H.angustipennis	4	0.005 ± 0.000	-	1
	5	0.047 ± 0.027	0.012 – 0.082	8
H.bulbifera	4	0.045 ± 0.040	0.004 – 0.158	27
	5	0.067 ± 0.043	0.021 – 0.163	33

In penultimate instars, the mesh area of *H. saxonica* (0.026 ± 0.012 mm^2) was significantly ($p < 0.05$) smaller than in all other species except *H. bulbifera* and *H. instabilis* (Table 23). The largest meshes were observed in *H. pellucidula/incognita*, *H. siltalai* and *H. instabilis* (0.051 - 0.065 mm^2; Table 22). In ultimate instars the smallest meshes were detected in *C .lepida* (0.007 ± 0.003 mm^2). They are significantly ($p < 0.05$) smaller than in all other species except *H. angustipennis* (Table 24). The largest meshes were present in *H. pellucidula/incognita* (0.074 ± 0.029 mm^2) and *H. bulbifera* (0.067 ± 0.043; Table 22).

Table 23: Tests for significant differences of mesh areas in 4th instar *Hydropsyche* species of the Große Tulln catchment; showing the probability values of post hoc Nemenyi – tests following the Tukey-method (n.s: not significant; * p < 0.05; ** p < 0.01).

	H.fulvipes	*H.instabilis*	*H.saxonica*	*H.siltalai*	*H.pel/inc*	*H.bulbifera*
H.fulvipes	-	0.178 n.s	0.039 *	1.000 n.s	1.000 n.s	0.826 n.s
H.instabilis		-	0.941 n.s	0.113 n.s	0.928 n.s	0.485 n.s
H.saxonica			-	0.014 *	0.020 *	0.095 n.s
H.siltalai				-	1.000 n.s	0.646 n.s
H.pel/inc					-	0.640 n.s
H.bulbifera						-

Table 24: Tests for significant differences of mesh areas in 5th instar *Hydropsyche* species of the Große Tulln catchment; showing the probability values of post hoc Nemenyi – tests following the Tukey-method (n.s: not significant; * p < 0.05; ** p < 0.01).

	H.instabilis	*H.saxonica*	*H.siltalai*	*H.pel/inc*	*C.lepida*	*H.angust.*	*H.bulbifera*
H.instabilis	-	0.262 n.s	0.999 n.s	0.540 n.s	8.2e-5 **	0.949 n.s	0.999 n.s
H.saxonica		-	0.997 n.s	0.015 *	0.005 **	1.000 n.s	0.797 n.s
H.siltalai			-	0.821 n.s	0.019 *	0.999 n.s	1.000 n.s
H.pel /inc				-	3.4e-6 **	0.369 n.s	0.505 n.s
C.lepida					-	0.103 ns	0.001 **
H.angust.						-	0.988 n.s
H.bulbifera							-

There was no correlation between spring distance of sampling stations and capture net mesh size (Figures 41, 42).

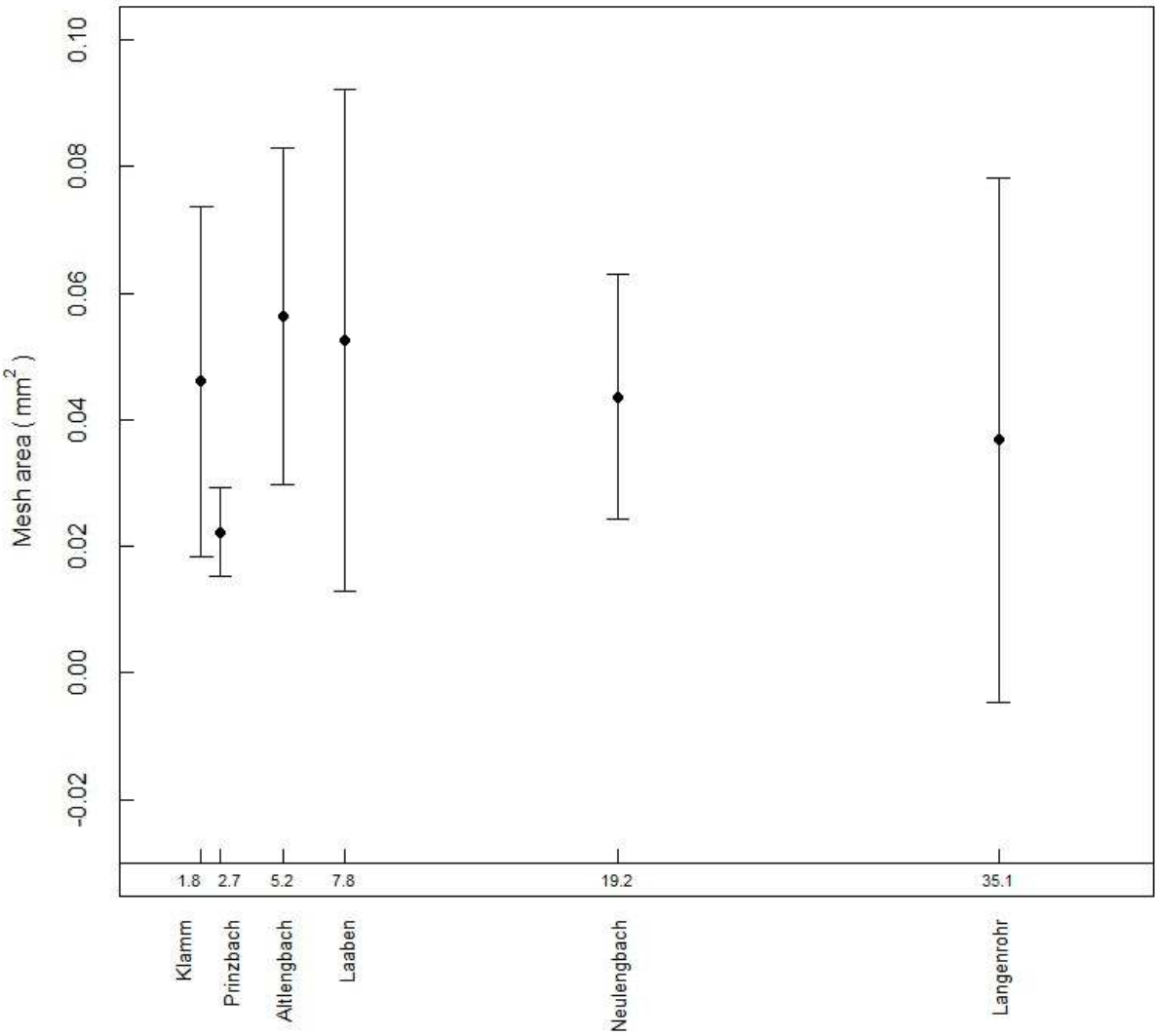

Figure 41: Mesh area of capture nets of 4th instar *Hydropsyche* species of the Große Tulln catchment. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 31 August 2014; showing the arithmetic means and standard deviations of all measured velocities at each sampling site. The sampling sites are ranked according to their spring distance (km).

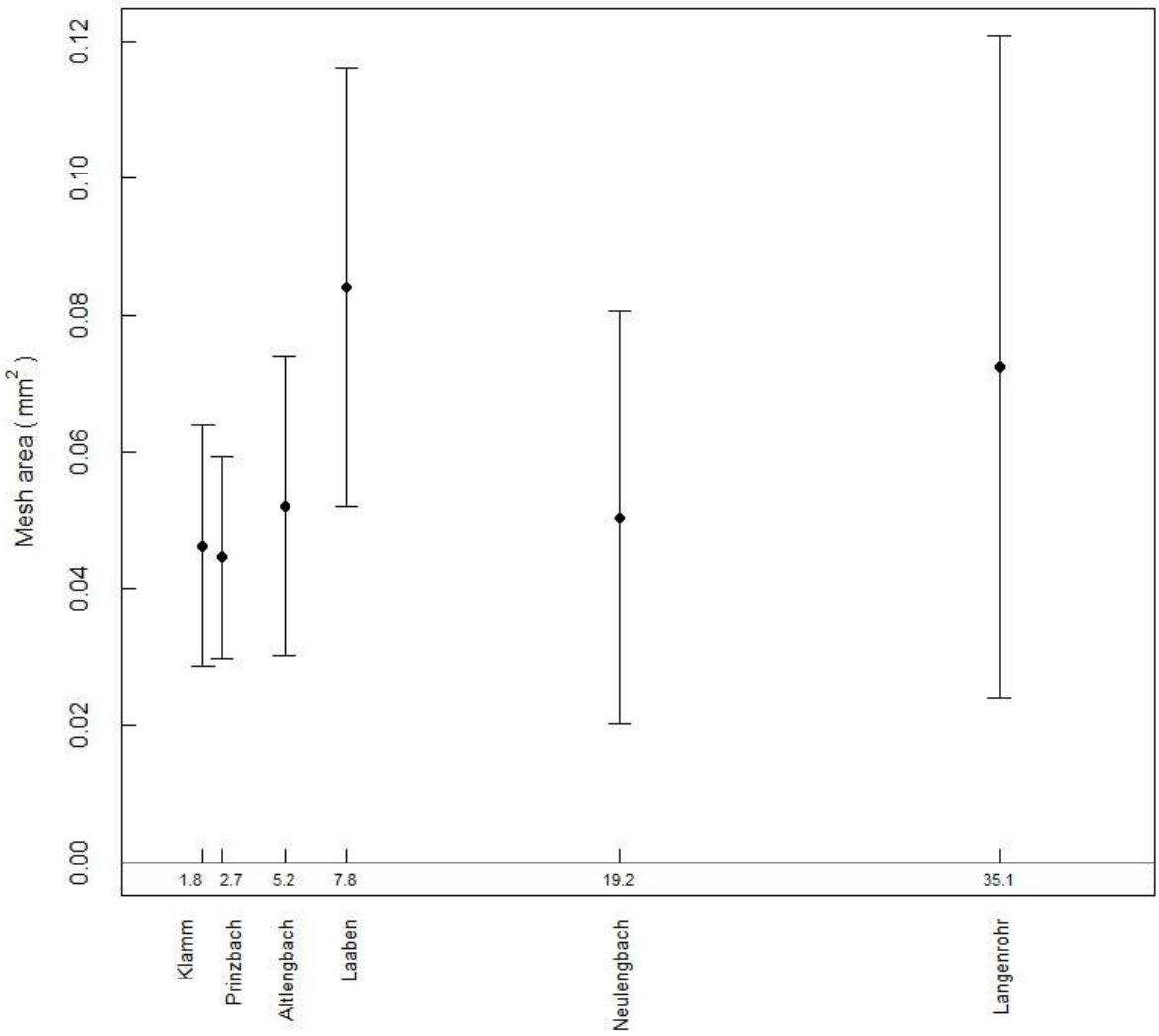

Figure 42: Mesh area of capture nets of 5th instar *Hydropsyche* species of the Große Tulln catchment. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 31 August 2014; showing the arithmetic means and standard deviations of all measured velocities at each sampling site. The sampling sites are ranked according to their spring distance (km).

4.5 Flow velocities at capture net level

Mean flow velocities measured at the center of filtering nets ranged from 14 cm s^{-1} (penultimate instar *H. angustipennis*) to 38 cm s^{-1}(ultimate instar *H. angustipennis*). The mean flow velocity for penultimate and ultimate instars of all other species was within that range.

Generally an increase in velocity at filtering net level was observed from fourth to fifth instars; however the reverse was true in *H. pellucidula/incognita*.

Table 25 summarizes mean, standard deviation and range of the measured flow velocities at net level of ultimate and penultimate instars for all Hydropsychidae species of the Große Tulln catchment.

Table 25: Flow velocities at the level of filtering nets of *Hydropsyche* species of the Große Tulln catchment. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 31 August 2014; showing the arithmetic means, standard deviations, ranges, and numbers of measured velocities (n) of ultimate and penultimate instars.

Species/Instars		**Flow velocity (cm s^{-1})**		
		Mean ± SD (cm s^{-1})	Range (cm s^{-1})	n
H.fulvipes	4	26 ± 12	16 – 50	7
	5	30 ± 0	-	1
H.instabilis	4	20 ± 10	13 – 27	2
	5	29 ± 15	5 – 82	70
H.saxonica	4	26 ± 12	7 – 46	49
	5	31 ± 12	12 – 77	81
H.siltalai	4	21 ± 8	7 – 30	7
	5	26 ± 14	5 – 45	8
H.pellucidula/incognita	4	33 ± 10	17 – 42	6
	5	25 ± 9	9 – 42	18
C.lepida	5	31 ± 6	25 – 44	7
H.angustipennis	4	14 ± 0	-	1
	5	38 ± 10	25 – 47	8
H.bulbifera	4	28 ± 12	12 – 51	27
	5	33 ± 11	11 – 67	33

When plotting spring distance versus means of site-specific filtering net velocities, no significant differences could be detected in penultimate (Figure 43) and ultimate instars (Figure 44). Mean site-specific velocities at filtering net level ranged from 23-32 cm s^{-1} in fourth and from 27-34 cm s^{-1} in fifth instar *Hydropsyche* larvae.

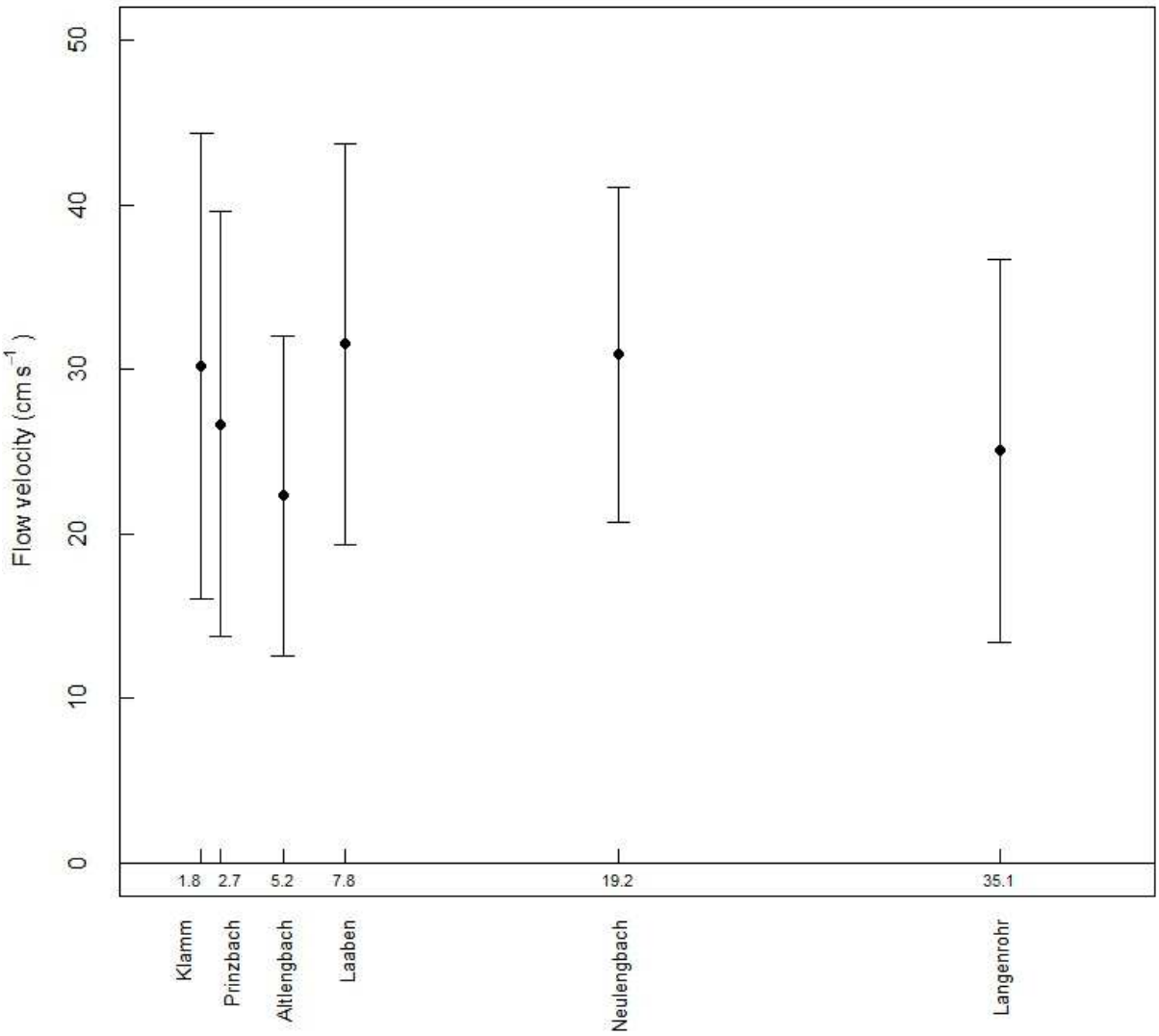

Figure 43: Flow velocity (cm s^{-1}) at the level of filtering nets of 4th instar *Hydropsyche* species of the Große Tulln catchment. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 31 August 2014; showing the arithmetic means and standard deviations of all measured velocities at each sampling site. The sampling sites are ranked according to their spring distance (km).

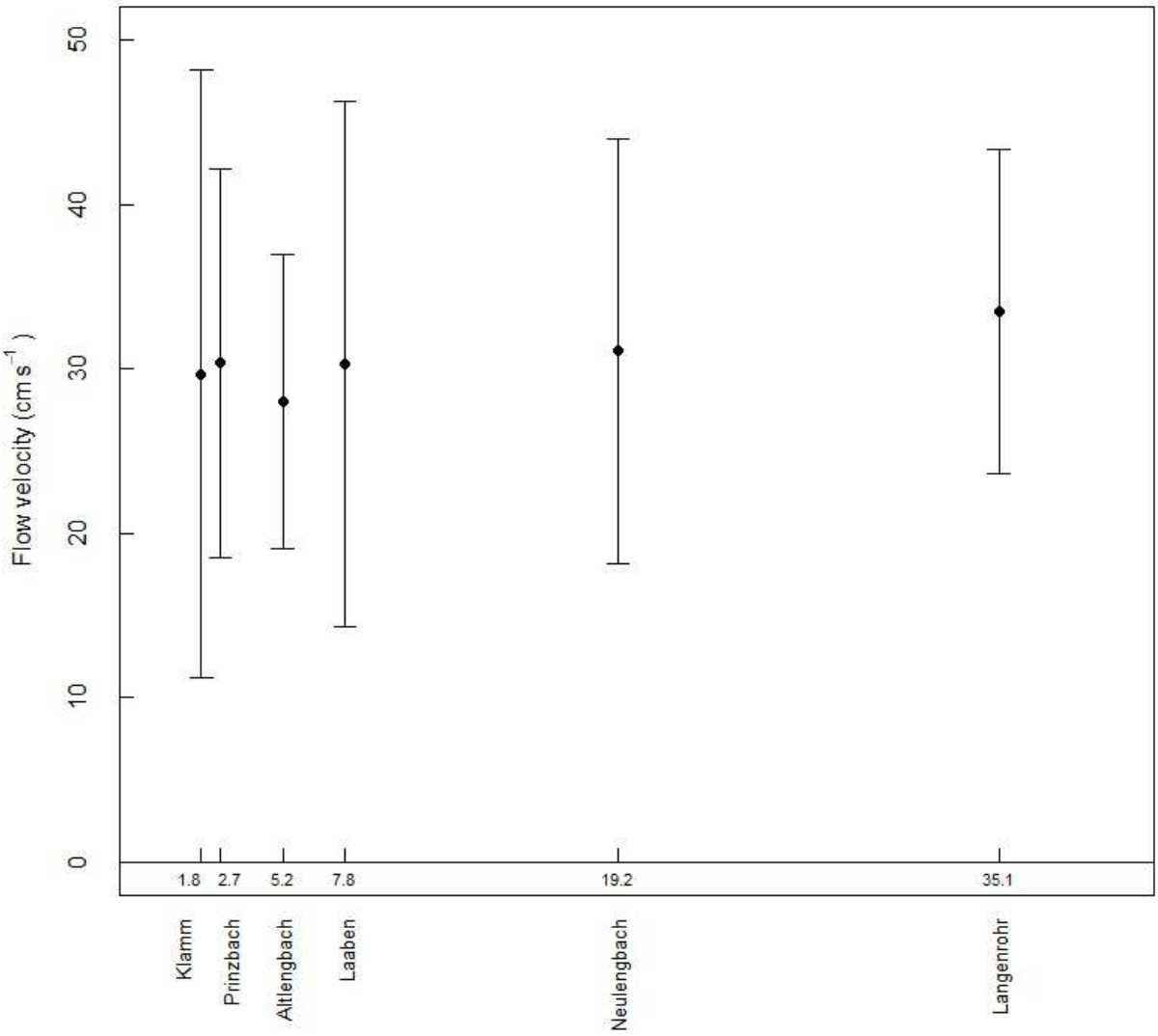

Figure 44: Flow velocity (cm s^{-1}) at the level of filtering nets of 5th instar *Hydropsyche* species of the Große Tulln catchment. Data are based on CPUE samplings over 45 minutes each, from 10 March 2014 to 31 August 2014; showing the arithmetic means and standard deviations of all measured velocities at each sampling site. The sampling sites are ranked according to their spring distance (km).

The relationship between intra-specific flow velocities at filtering net level (cm s^{-1}) and mesh area (mm^2) was only significant for 5th instar *H.saxonica*. For these larvae an increase of mesh area with increasing flow velocity at net level was detected (Figure 45).

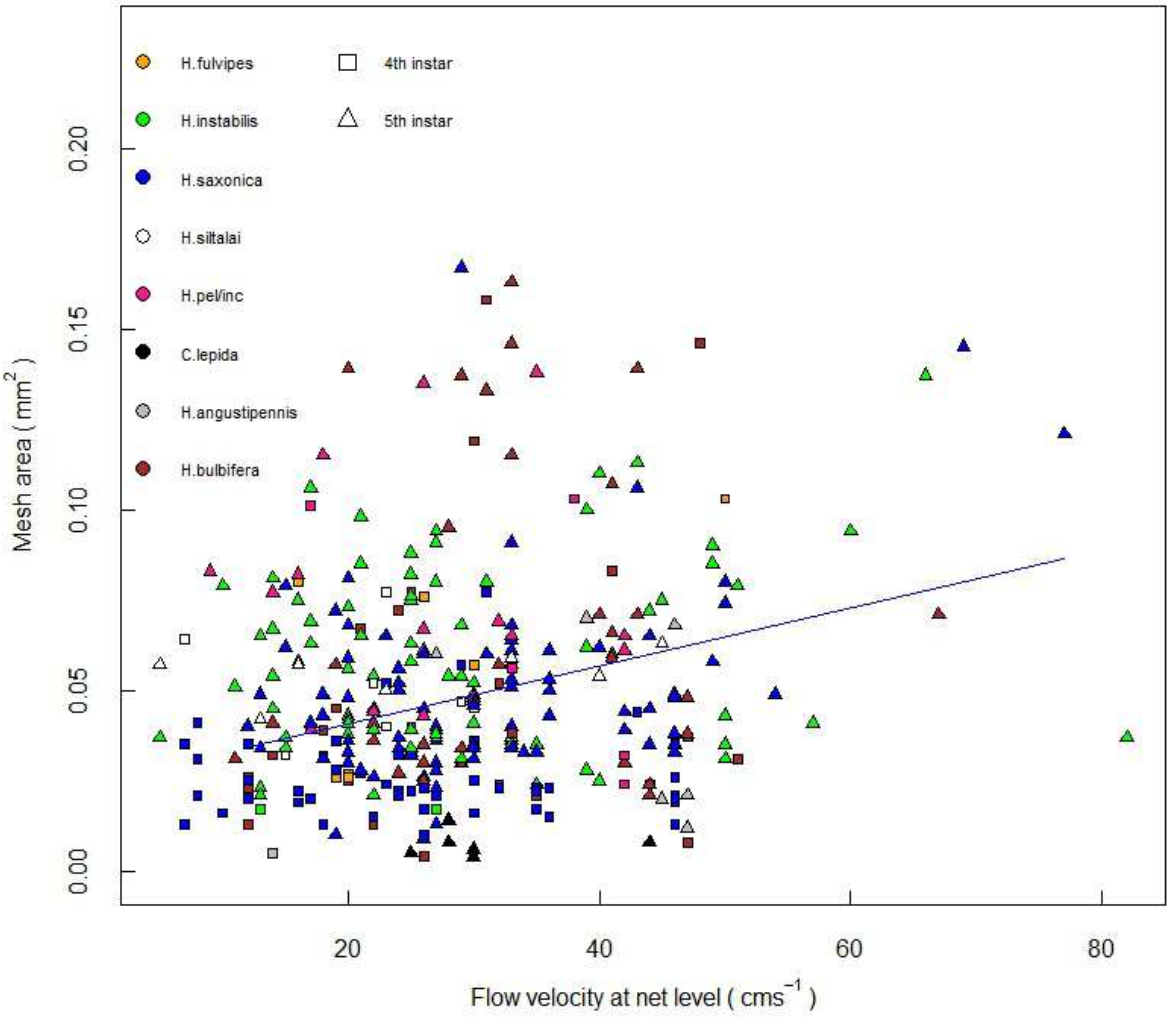

Figure 45: Regressions of flow velocity at net level (cms^{-1}) versus mesh area (mm^2) of *Hydropsyche* species of the Große Tulln catchment; species and instars are indicated by colored symbols; significant regressions are shown by colored lines. Data are based on CPUE samplings over 45 minutes each from 10 March 2014 to 31 August 2014. Regression parameters: *H. saxonica* (5th instar): y = 0.025 + 0.0008x; R^2 = 0.15; p < 0.001 *.**

5 Discussion

5.1 Species inventory

The Hydropsychidae species inventories of the six sampling sites in the Große Tulln catchment in 2104 were compared with a survey by SCHEIBLREITER (1982). Generally, the benthic habitats of the Große Tulln catchment are populated by the same eight Hydropsychidae species as in 1982 (Table 19).

5.1.1 Klamm

The population structure of *H. instabilis* (65 %) and *H. saxonica* (27 %) is highly consistent with the situation in 1982 (Table 19), indicating little changes in parameters such as water quality or river morphology. *H .instabilis* and *H. saxonica* are euryoecious (SCHEIBLREITER 1982) and mainly rhithral species (GRAF et al. 2002, BOCHERT & BIELE 2005). Their distribution along the stream continuum extends to Neulengbach, where the Große Tulln changes from hyporhithral to epipotamal. Both in 1982 and today, either *H .instabilis* or *H. saxonica* is the dominant Hydropsychidae species in all rhihtral sections of the catchment. *H. fulvipes* (SI: 1.1) was absent at Klamm in 1982 and now represents 8% of the Hydropsychidae. It is a stenoecious (SCHEIBLREITER 1982), hypokrenal species adapted to oligosaprobic conditions (GRAF et al. 2002). SCHEIBLREITER (1982) found *H. fulvipes* dominant only in immediate proximity to springs (upstream of the sampling sites Klamm and Prinzbach). The downstream movement of *H. fulvipes* to Klamm can be interpreted as an improvement of saprobity since 1982. SCHEIBLREITER (1982) measured a maximum temperature of 17.1 °C at Klamm and describes *H. fulvipes* as sensitive to water temperatures over 13°C. Since long-term temperature data for Klamm are missing, this assumption could not be tested precisely. The water temperature at Klamm is assumed to be lower than at Prinzbach because of higher altitude. The average water temperature during the sampling season from April to August at Prinzbach was 13.9 °C. Thus, for Klamm, an average slightly below the Prinzbach temperature can be expected, which is concordant with SCHEIBLREITER´s hypothesis for *H. fulvipes* temperature preferences.

5.1.2 Prinzbach

The Hydropsychidae species occurring at Prinzbach (Table 19) are the same as at Klamm. *H. saxonica* is more dominant here (93%) than at Klamm (27%). The rareness of *H .instabilis* at Prinzbach (3%) compared to Klamm (65%) is inconsistent because both sampling sites show similar characters concerning spring distance, streambed structure and physical parameters (Tables 1, 4). SCHEIBLREITER (1982) also detected *H. saxonica* (68%) more frequently than *H. instabilis* (32%) at Prinzbach. He describes the two species as euryoecious and congruent, but differing in their temperature preferences. *H. saxonica* is more adapted to low temperatures, preferring maximum water temperatures between 15°C and 20°C. In contrast, *H. instabilis* prefers maximums between 20°C and 25°C (SCHEIBLREITER 1982). HILDREW & EDINGTON (1979) found *H. instabilis* in the upper tributaries of the river Usk (Wales), with maximum water temperatures of 23°C. The temperature maximum at Prinzbach during the sampling season was 18.9°C, which agrees with the dominance of *H. saxonica*. Only the dominance of *H. instabilis* at Klamm is not congruent with this model. SCHEIBLREITER (1982) measured temperature maxima of 17.1°C at Klamm in August, the warmest month of the year. This should favor the dominance of *H. saxonica* instead of *H. instabilis* there, whereas the opposite was observed. In contrast, PHILIPSON (1969) measured the highest net spinning activity of *H. instabilis* at 12°C, which is around the average temperature during the sampling season at Klamm. These inconsistent data on temperature preferences suggest that the low frequency of *H. instabilis* at Prinzbach versus Klamm reflects local conditions other than temperature preferences. SCHEIBLREITER (1982) assumes *H. saxonica* is less resistant against dense algal growth than *H.instabilis*. Nonetheless, the abundance patterns of *H. saxonica* and *H. instabilis* between Prinzbach and Klamm are not a consequence of algal growth because epilithic algae are rare at both sites (Tables 2, 5). *H. fulvipes* is less abundant at Prinzbach (4%) than at Klamm (8%), which agrees with SCHEIBLREITER´s assessment that this species prefers cold water.

Prinzbach and Klamm represent the upstream species association of Hydropsychidae (Figure 28) in the Große Tulln catchment. This association was also detected by SCHEIBLREITER (1982), only with higher abundances of *H. instabilis* as the main difference to today´s situation.

5.1.3 Altlengbach

Altlengbach, which is located 3 km downstream of the sampling site Prinzbach, is characterized by the dominance of *H .saxonica* (49%), the co-dominance of *H. instabilis* (25%), and five sympatric Hydropsychidae species (*H. fulvipes, H. pellucidula/incognita, H. siltalai, C. lepida, H. bulbifera*) (Table 19). In 1982, *H. instabilis* was dominant (74%), *H. saxonica* (18%) co-dominant, and *H. pellucidula/incognita* (8%) sub-dominant (SCHEIBLREITER 1982).

H. saxonica has increased its frequency and moved further downstream in the Lengbach since 1982. It replaced *H. instabilis* as dominant species at three sampling sites (Prinzbach, Altlengbach, Laaben). Since the sediment at Altlengbach is partially covered by epilithic algae (Table 8), the hypothesis that *H. saxonica* is less resistant than *H. instabilis* to dense algal covers (SCHEIBLREITER 1982) is rejected. The maximum temperature during the sampling season at Altlengbach was 21.8°C, which is 3°C higher than at Prinzbach. The dominance of *H. saxonica* leads to the rejection of the hypothesis of its temperature preference between 15°C and 20°C (SCHEIBLREITER 1982).

Three new species (*H. siltalai, C. lepida, H. bulbifera*) appeared at Altlengbach since 1982. The abundance of *H. siltalai* increased in the catchment, but never exceeded sub-dominance (always < 15 %) among the Hydropsychidae. ROUX et al. (1992) found *H. siltalai* to be widespread but always rare (< 1% of Hydropsychidae) in the rhithron of the Rhone River at water temperatures below 20°C. In the Mondego River basin (Portugal), *H. siltalai* inhabited upper- and middle-, but never low reaches (FEIO et al. 2005). This agrees with the present study, in which *H. siltalai* was not present in the potamal. MALICKY (2014) found *H. siltalai* together with *H. instabilis* as dominant species in light traps along the upper reaches of many Austrian rivers.

C. lepida and *H. bulbifera* are hyporhithral – epipotamal and β-mesosaprobic - α-mesosaprobic (GRAF et al. 2002). They moved upstream since 1982. An upstream movement of these species, which tolerate high saproby, could be best explained by declining water quality. Altlengbach is located in an urbanized area in which human-induced saprobial pollution is likely. The appearance of *H. siltalai* (SI: 2), *C. lepida* (SI: 2.2) and *H. bulbifera* (SI: 2.4), which are associated with higher saprobial indices than *H. saxonica* (1.6) and *H. instabilis* (1.4), and did not occur in 1982, leads to the assumption that the saproby has increased since the 1980s.

SCHEIBLREITER (1982) detected water quality III in this river section. In this study a CI of 64 was measured at Altlengbach, which is water quality II, representing an improvement since 1982. Accordingly, the upstream movement of *C. lepida* and *H. bulbifera* is probably due to other ecological factors.

5.1.4 Laaben

The dominance of *H. instabilis* (96%) in 1982 changed into a co-dominance of *H. instabilis* (40%) and *H. saxonica* (42%) (Table 19). *H. saxonica* abundance increased similar to Altlengbach and Prinzbach. Thus a general area enlargement of *H. saxonica*, together with a downstream movement, in the whole Große Tulln catchment was observed. *H. saxonica* (SI: 1.6) is adapted to oligosaprobic - β-mesosaprobic conditions (GRAF et al. 2002). A downstream movement of *H. saxonica* can be interpreted as a sign of improving water quality. In contrast, SCHEIBLREITER (1982) describes *H. saxonica* as highly tolerant against pollution (α-mesosaprobic), underlining its euryoecious character.

H. pellucidula/incognita (15%) was not detected at Laaben by SCHEIBLREITER (1982). In 1982, *H. pellucidula* occurred only at two sampling sites in the benthos of the Große Tulln catchment (*H. incognita* described 1993 by PITSCH). It can be assumed that the abundance of *H. pellucidula/incognita* increased in the whole catchment since 1982 because it was also recorded at Altlengbach, Neulengbach and Langenrohr. *H. pellucidula/incognita* is the most euryoecious species among the Hydropsychidae of the Große Tulln catchment (GRAF et al. 2002, SCHEIBLREITER 1982). Both *H. pellucidula* and *H. incognita* inhabit river sections from epirhithral to epipotamal (GRAF et al. 2002). ROUX et al. (1992) describes *H. pellucidula* in the Rhone as ubiquitous, with a respiratory metabolism typical for both rhitral and potamal species. Because of its euryoecious character, little information about changes of water quality can be drawn from its appearance at Laaben since 1982.

SCHEIBLREITER (1982) detected water quality class I/II at Laaben, which indicates unpolluted water. In this study, water quality II was measured (CI: 65). No new source of human-induced pollution is thought to have occurred since 1982.

5.1.5 Neulengbach

Neulengbach is characterized by the dominance of *H. bulbifera* (41%) and the co-dominance of *H. pellucidula/incognita* (20%). *H. saxonica* (10%) and *H. siltalai* (13%), which were both

absent in 1982, are now present at Neulengbach (Table 19). Together with *H. saxonica* the frequency of the euryoecious species *H. siltalai* and *H. pellucidula/incognita* increased in the whole catchment since the 1980s. HILDREW & EDINGTON (1979) found *H. siltalai* and *H. pellucidula* to coexist along a 60 km-long stretch of tributaries and rhithron reaches of the river Usk (Wales). BASAGUREN & ORIVE (1990) also found their coexistence in the Cadagua River basin (Spain), with *H. pellucidula* habitat reaching somewhat further downstream. In the Große Tulln catchment, *H. siltalai* and *H. pellucidula/incognita* coexist along the whole midstream section (Laaben, Altlengbach, Neulengbach), without occurrence in the headwaters and the potamal.

In 1982, water quality III was measured at Neulengbach, caused by untreated sewage disposal (SCHEIBLREITER 1982). In this study, water quality II was measured at Neulengbach (CI: 65). Among the Hydropsychidae of the Große Tulln catchment, *H. bulbifera*, which highly dominated (97%) at Neulengbach in 1982, is the most tolerant species against low water quality, O_2 undersaturation and high temperatures (SCHEIBLREITER 1982). It is often observed as the dominating caddisfly when organic pollution is high (BASAGUREN & ORIVE 1990, FEIO et al. 2005). The abundance decrease of *H. bulbifera* (SI: 2.4), together with the downstream movement of *H. saxonica* (SI: 1.6), indicates that the saprobity decreased due to better sewage treatment at Neulengbach.

In the Große Tulln catchment, *C. lepida* (12%) showed its peak abundance at Neulengbach. Fauna Aquatica Austriaca (GRAF et al. 2002) classifies *C. lepida* as more potamal-preferring than *H. bulbifera*. It is therefore surprising that *C. lepida* does not occur at Langenrohr, the only sampling site in the potamal reach of the Große Tulln. SCHEIBLREITER (1982) found the highest abundances of *C. lepida* even upstream of Neulengbach, and also found no individuals of that species in the potamal. He concluded that *C. lepida* is much more euryoecious than expected (e.g. MALICKY 1978) and has a high tolerance spectrum for different water temperatures and saprobity. This conclusion is supported by the distribution data of *C. lepida* from this study. *C. lepida* inhabits middle reaches of the Mondego River basin (Portugal), whilst *H. bulbifera* inhabits the low reaches with higher organic pollution (FEIO et al. 2005). In light traps of large lowland rivers such as the Traun, *C. lepida* is – besides *H. incognita* – the dominating Hydropsychidae (MALICKY 2014). The capture of *C. lepida* in light traps along the Danube at Linz (MALICKY 2014) underlines its euryoecious character.

Altlengbach, Laaben, and Neulengbach represent the midstream species association (Figure 28) of the Große Tulln catchment. These river sections are characterized by a higher diversity of Hydropsychidae today compared to 1982.

5.1.6 Langenrohr

The Hydropsychidae species inventory of Langenrohr strongly coincides with that of 1982 (Table 19), suggesting that river condition and water quality were similar in 1982. *H. bulbifera* (79%) is the dominating species and *H. angustipennis* (20%) is co-dominant. The downstream species association (Figure 28) remained constant.

SCHEIBLREITER (1982) detected water quality II at Langenrohr. He hypothesized that the river underwent self-purification after human-induced pollution at Neulengbach. Water quality II (CI: 64) was also measured at Langenrohr in this study, in agreement with the constancy of the species inventory since 1982. The sampling site Langenrohr is a riffle (old horse passage across the river), with the sediments dominated by small gravel (10 – 20 cm) with dense algal cover (Table 17). *H. bulbifera* is well described for potamal reaches with sandy and muddy sediments (OTTO 1995). Due to its dominance at the riffles in Neulengbach and Langenrohr, *H. bulbifera* seems to also tolerate larger sediment particle sizes in potamal reaches.

H. angustipennis has its highest abundance at Langenrohr, which is consistent with its classification as species of the low reaches of small rivers (MALICKY 1977).

C. lepida was missing at Langenrohr both in 1982 and in 2014, even though it is classified as epipotamal species (GRAF et al. 2002). Its absence at Langenrohr cannot be explained by the riffle character (which is atypical for the epipotamal character of the Große Tulln) because *C. lepida* represents 12% of the Hydropsychidae at the fast-flowing riffle at Neulengbach (see above).

5.2 Biometry

The significant linear relation between body length and maximum head capsule width among all detected Hydropsychidae individuals of the Große Tulln catchment (Figure 29) shows the combined growth of biometric variables. Similar to the head capsule width, the dry mass of larvae increases significantly with body length (BENKE et al. 1999). Sclerotized body parts

such as the head capsule grow discontinuously, stepwise with each molt by a constant factor (DYAR 1890, CHAPMAN 1998). Head capsule width for each species can therefore be used to assess the larval instar (DALY 1985). First described by DYAR (1890) for Lepidoptera, the discontinuous growth of the head capsule was described later for caddisflies (e.g. OSWOOD 1976, HAUER & STANFORD 1982, SIEGLSTETTER et al. 1997, HROVAT & URBANIC 2012) and other insects (e.g. LOGAN et al. 1998). The stepwise increase of head capsule width between penultimate and ultimate instar was best illustrated by the data of *H. saxonica* (n=130), the most abundant species at the Große Tulln catchment (Figure 32). On a semilog scale the mean head capsule widths for 3rd, 2nd and 1st instars were extrapolated, based on the measured data for 4th and 5th instars (Figure 38). *H. fulvipes, H. pellucidula/incognita, H. siltalai, C. lepida,* and *H. angustipennis* were not abundant enough to demonstrate the gap between penultimate and ultimate instar head capsule width (Figures 30, 33 - 36). For *H. bulbifera* (n=60) no obvious split between 4th and 5th instar could be observed (Figure 37) despite abundant specimens. This diffuse transition of head capsule widths between penultimate and ultimate instar in *H. bulbifera* may indicate a less constrained growth of this species. A range of environmental variables (e.g. temperature) along inhabited river sections might lead to a differentiation in developmental processes, blurring the split between instar-specific head capsule widths.

According to their 5th instar head capsule width, the Hydropsychidae species are ranked from small to large as follows: *C. lepida*, *H. bulbifera*, *H. instabilis, H. siltalai*, *H. pellucidula/incognita*, *H. angustipennis*, *H. saxonica*, *H. fulvipes*. For the 4th instars the ranking is *H. instabilis, H. angustipennis*, *H. saxonica, H. bulbifera*, *H. pellucidula/incognita, H. siltalai*, *H. fulvipes*. No 4th instar larvae of *C. lepida* were sampled. ALSTAD (1982) suggests that the body size of the species decreases from upstream to downstream, together with the downstream decrease of flow velocity and POM size (VANNOTE et al. 1980). This hypothesis could not be fully confirmed for the Hydropsychidae of the Große Tulln catchment. The head capsule widths of the species are not continuously ranked from large to small according to their occurrence within the river continuum. The krenal/epirhithral *H. fulvipes* (GRAF et al. 2002) is the largest species, which is coherent with the hypothesis. *H. saxonica, H. instabilis*, *H. pellucidula/incognita* and *H. siltalai* are all part of the middle reach species association (Figure 28). Their median head capsule widths do not differ highly within the 4th and 5th instars (Table 21). The head capsule widths of *C. lepida* and *H. bulbifera* do not support the hy-

pothesis of downstream size decrease. *C. lepida* is the smallest species, but mainly inhabits the middle reaches. 4th instar *H. bulbifera* have larger head capsules than *H. saxonica*, although *H. bulbifera* inhabits the potamal reaches. Neither in 1982 (SCHEIBLREITER 1982) nor in 2014 the Hydropsychidae species of the Große Tulln catchment distributed regularly from upstream to downstream according to body size dimensions.

Many studies question the influence of large-scale changes in flow velocity and POM size on Hydropsychidae distribution. They suggest that flow conditions in microhabitats are more critical for distributional patterns (WILLIAMS & HYNES 1973, GEORGIAN & THORP 1992). OSBORNE & HERRICKS (1987) found no significant correlations between *Hydropsyche* body size and flow velocity. They reported strong overlaps even in microhabitat velocity preferences between four differently-sized *Hydropsyche* species.

5.3 Phenology

The larval phenology of penultimate and ultimate Hydropsychidae instars of the Große Tulln catchment between March and August 2014 are shown in Figure 39. Voltinism and phenology depend on environmental variables (VANNOTE & SWEENEY 1980, MACKAY 1986) and can thus vary between the years.

HILDREW & EDINGTON (1979) provided life-history data for *H. siltalai*, *H. instabilis* and *H. pellucidula* in the river Usk (Wales). They found that *H. pellucidula* overwinters in the 4th and 5th instars, with pupation between May and June. 5th instars were present the whole year, which indicates fast growth and long duration of the ultimate instar before pupation. These data are in accordance with the Große Tulln study, where 4th and 5th instars of *H. pellucidula/incognita* were found in March, May and August. Since *H. pellucidula/incognita* is rare in the Große Tulln, and only few samplings took place in April and June, the 4th and 5th instars are expected to occur also in April, June and July, when they were not sampled. HILDREW & EDINGTON (1979) found 5th instars of *H. siltalai* from March until July, and pupation in June, July and August. The species overwintered in the 3rd instar, followed by rapid development in spring. The flight period is between June and September (WARINGER & GRAF 2011). In the Große Tulln 5th instars of *H. siltalai* were found in May and June, agreeing with the data of HILDREW & EDINGTON (1979). As was the case for *H. pellucidula/incognita*, *H. siltalai* is rare in the catchment and might have escaped detection in some months despite

actually being present.

H. instabilis 5th instars occurred from April until July, with pupation between June and August in the river Usk (HILDREW & EDINGTON 1979). The flight period is between July and September (WARINGER & GRAF 2011). In this study the 5th instars were found from May to July, in full agreement.

PETERSEN & PETERSEN (1983) described *H. angustipennis* life-history as being similar to that of *H. pellucidula*, characterized by overwintering in the 4th and 5th instar and pupation in spring. The long flight period is from April to September (WARINGER & GRAF 2011). In the Große Tulln study, *H. angustipennis* was found in its 5th instar from March to August, with gaps in April, June and July. The June and July gaps are assumed to reflect the period when the overwintered larvae are already pupated and the new generation has not yet reached the 4th and 5th instar.

5th instar *H. saxonica* were sampled in the Große Tulln throughout the season from March to August. 4th instar *H. saxonica* were found the whole season except in June. The increase of 5th instars, and the decrease of the 4th from March to June, point to beginning pupation. The flight period lasts from May to June (WARINGER & GRAF 2011). From July on, the number of 5th instars increased again, indicating the emergence of the next generation, which overwinter mainly as 4th and 5th instars (HROVAT & URBANIC 2012). The data on the life cycle of *H. saxonica* at the Große Tulln are in accordance to HROVAT & URBANIC (2012), who investigated the life cycle of *H. saxonica* in a Slovenian karst river.

H. bulbifera 4th and 5th instars were sampled in all months of the sampling season except April. Its flight period lasts from May to September (WARINGER & GRAF 2011), which explains the consistent appearance of the 5th instar during summer.

5.4 Biometry of the capture net meshes

Among the 4th instars, the capture net mesh area of *H. saxonica* differs significantly from that of all other species except *H. instabilis* and *H. bulbifera* (Table 23). *H. saxonica* is the smallest species (except a single specimen of *H. angustipennis* and two specimen of *H. instabilis*) based on head capsule width among the 4th instars, followed by *H. bulbifera* (Table 21).

Among the 5th instars the mesh area of *C. lepida* differs significantly from all other species except *H. angustipennis* (Table 24). *C. lepida* is the smallest species among the 5th instars

based on head capsule width, followed by *H. bulbifera* (Table 21).

Mesh area and head capsule width correlate (SATTLER 1963, WALLACE 1975) because the mesh dimensions are defined by distances between mouthparts (KAISER 1965). Among the Hydropsychidae of the Große Tulln, a significant correlation between mesh area and head capsule width was found for *H. instabilis*, *H. saxonica*, *H. angustipennis* and *H. bulbifera* (Figure 40). For the other species a correlation is expected but presumably not found due to small sample sizes.

Mesh sizes tend to decrease from upstream to downstream as a consequence of adaptation to slower flow velocities and smaller POM size (EDINGTON 1968, GORDON & WALLACE 1975, MACKAY 1979, ALSTAD 1980, ALSTAD 1982). Since mesh area and head capsule width correlate, the distribution of species-specific mesh sizes along the river continuum resembles those of body size (see above): neither for the 5th nor for the 4th instars a constant decrease of mesh area along the river continuum from upstream- to downstream-inhabiting species was detected (Figures 41, 42). The hypothesis that Hydropsychidae species which inhabit downstream habitats produce smaller meshes than upstream species has to be rejected for the Große Tulln. In analogy to the situation of head capsule width, *C. lepida* produces the smallest meshes, but inhabits the fast-flowing middle reaches (see above). Species produce significantly different mesh sizes, but thereby do not follow a sequence of downstream mesh size decrease along the river continuum. Mesh size adaptations to flow conditions in microhabitats could interfere with broad-scale adaptations to flow conditions along the river continuum. Flow velocity and POM size in microhabitats are not a consequence of longitudinal zonation. A broad range of flow velocities in different microhabitats explains the broad range of mesh sizes within one river section (Figures 41, 42) (WALLACE et al. 1977, GEORGIAN & WALLACE 1981, FULLER et al. 1983, LOUDON & ALSTAD 1990, VOELZ & WARD 1996). Fast-flowing habitats on the top surface of stones are inhabited by species with large meshes, and the undersurfaces by species with small meshes (WALLACE et al. 1977). TACHET et al. (1992) found seven coexisting Hydropsychidae with different mesh sizes in one river section of the upper Rhone. Thus, microhabitat selection affects species-specific mesh size (TACHET et al. 1992, ROUX et al. 1992). The coexistence of 5 instars of one species within one river section further underlines the hypothesis of microhabitat adaptation (MUOTKA 1990). Since different instars produce different mesh sizes (KAISER 1965), they probably inhabit different microhabitats within one reach according to their body and mesh

size.

Comparing the longitudinal zonation of Hydropsychidae to other net-building caddisfly families such as Philopotamidae or Polycentropodidae provides evidence that factors apart from longitudinal zonation influence their distribution. For example, Philopotamidae with extremely fine nets occur from headwaters to downstream tidal regions (GEORGIAN & WALLACE 1981).

5.5 Flow velocities at capture net level

A slight increase of flow velocity at net level from 4th to 5th instars was detected, except for *H. pellucidula/incognita* (Table 25). When body size increases, the larvae are able to withstand higher current velocities (OSBORNE & HERRICKS 1987), and their nets with larger mesh area are able to resist higher shear stress (WALLACE 1975). Accordingly, an instar transition is expected to imply an occupation of microhabitats with faster currents in order to increase capture rates. MUOTKA (1990), however, found a constant decrease of mean microhabitat flow velocities from 3rd to 5th instar of *H. angustipennis*, *H. pellucidula* and *H. saxonica*, contradicting the observations of OSBORNE & HERRICKS (1987).

Many studies on longitudinal macroinvertebrate distribution point out that the current velocities of preferred habitats decrease downstream (e.g. ILLIES 1961, STATZNER & HIGLER 1986). The feeding strategy of Hydropsychidae, however, is well known for being adapted to fast current velocities (EDINGTON 1968, WARINGER & GRAF 2011). WALLACE et al. (1977) measured mean microhabitat velocities from 52-58 cm s^{-1} for *Hydropsyche* species of the Tallulah River (North Carolina).

Neither for the 4th nor for the 5th instar Hydropsychidae of the Große Tulln a significant decrease of site-specific preferred flow velocities from upstream to downstream was detected (Figures 43, 44). At all sampling sites from headwaters to the potamal the 4th and 5th instar Hydropsychidae select habitats with mean site specific flow velocities at net level between 23 and 34 cms^{-1} (Table 25). GEORGIAN & THORP (1992) found that flow velocity has insignificant importance for the Hydropsychidae competitive selection of microhabitats. They conclude that Hydropsychidae tend to colonize high velocity habitats, and factors like substrate size and -type are more crucial for competition between species.

EDINGTON (1968) pointed out the specialization of Hydropsychidae to high speed habitats

in comparison to other net building caddisfly families like Polycentropodidae. He observed net building for *H. instabilis* at velocities ranging from 15 – 100 cm s^{-1}. In the Große Tulln the flow velocity at *H. instabilis* net locations ranged from 5 – 82 cm s^{-1}. These broad ranges for current velocities underline the assumption of GEORGIAN & THORP (1992) that velocity is not the most crucial factor for habitat selection. Hydropsychidae seem to prefer high velocities, but are able to tolerate slow currents when other environmental factors are suitable. MUOTKA (1990) found similar results when comparing the average flow velocity for *H. pellucidula* habitats from two sampling sites. With average velocities of 56.9 and 28.7 cm s^{-1} the habitats differed highly in flow rate.

The correct measurements of flow velocities were difficult, because the propeller flow velocity measurements were presumably not precise enough to record flow velocities in microhabitats. EDINGTON (1968), MUOTKA (1990) and TACHET et al. (1992) emphasize the difficulties of microhabitat velocity measurements in the field, and the reliability of comparisons, when different measurement approaches were used.

Only for 5th instar *H. saxonica* a significant increase of mesh area with increasing flow velocity was measured (Figure 45). Large individuals that produce nets with large meshes are expected to inhabit microhabitats with fast velocities, due to higher current resistance (ALSTAD 1987 a). The reason for finding this correlation not for all species may be found in the difficulty of detecting current velocities in the microhabitats, or in the fact that current velocity is not the key determinant for Hydropsychidae when selecting a habitat (see above).

Abstract

Hydropsychidae are omnipresent in European river ecosystems. They occur in benthic habitats of all running waters, except high mountain streams and slow flowing rivulets. By filtering large amounts of seston with capture nets, they play a major role for the POM retention of a river system. The construction of the capture nets and its mesh structure were of great scientific interest since the 1960s. Longitudinal distribution in river systems, microhabitat selection and mesh size diversity of Hydropsychidae species were topics of many studies since then.

Species-specific mesh size is discussed of affecting broad scale- and microhabitat selection of Hydropsychidae in reference to POM size and flow velocity. It is still poorly understood if correlations between habitat selection and capture net mesh size exist, because results concerning this issue are inconsistent.

This study deals with the Hydropsychidae fauna of the Große Tulln catchment (Lower Austria). Species distribution and capture nets of 4th and 5th instars were analyzed from March to August 2014 at six sampling sites from headwater krenal/rhithral reaches to potamal reaches. Eight species were detected in the catchment by benthic sampling. The dominant species are *Hydropsyche saxonica*, *H. instabilis* and *H. bulbifera*. Species inventories were compared to the year 1982, studied by SCHEIBLREITER (1982).

The hypotheses of downstream body size- and capture net mesh size decrease were tested on the eight species along the river. Flow velocity was measured at net location in order to test correlations to mesh size.

The results reveal that Hydropsychidae habitats are not strictly ordered from upstream to downstream according to their body and mesh size. *Cheumatopsyche lepida*, the smallest Hydropsychidae species of the catchment, inhabits only fast flowing midstream habitats, significantly not agreeing with the hypothesis of downstream body and mesh size decrease.

Flow velocity measurements show that Hydropsychidae selectively inhabit fast flowing habitats (average velocities at net level between 23 and 34 cm s^{-1}). Significant correlations between flow velocity and mesh size were detected for two species. Microhabitat conditions are suggested to be the major determinants for Hydropsychidae distribution and niche segregation according to capture net mesh size.

Zusammenfassung

Hydropsychidae sind allgegenwärtig in den Ökosystemen der fließenden Gewässer Europas. Sie besiedeln benthische Habitate aller fließenden Gewässer mit Ausnahme von Hochgebirgsbächen und langsam fließenden kleinen Bächen. Indem sie mit ihren Fangnetzen große Mengen an Seston filtern, leisten sie einen entscheidende Beitrag zur Retention von POM in Flusssystemen. Die Konstruktion der Fangnetze und deren Maschenstruktur waren seit den 60er Jahren des vorigen Jahrhunderts von großem wissenschaftlichen Interesse. Seither waren die Verteilung der Hydropsychidae entlang eines Flusssystems, die Mikrohabitat-Wahl und die Vielfalt an Maschenweiten Thema vieler Studien. Die artspezifische Maschenweite wird als Faktor diskutiert, der die Auswahl der Makro- und Mikrohabitate je nach POM-Größe und Fließgeschwindigkeit beeinflusst. Es ist noch unklar, ob eine beständige Korrelation zwischen Habitatwahl und der Maschenweite der Fangnetze existiert, da sich die Ergebnise von Studien widersprechen.

Vorliegende Arbeit untersucht die Hydropsychiden-Fauna der Großen Tulln (Niederösterreich). Die Artenverteilung und die Fangnetzte von vierten und fünften Larvenstadien sind zwischen März und August 2014 an sechs Beprobungspunkten von quellnahen Krenal/Rhitral- Abschnitten bis zu mündungsnahen Potamal-Abschnitten analysiert worden. Insgesamt acht Arten wurden im Einzugsgebiet bei den Benthosbeprobungen festgestellt. Die dominanten Arten sind *Hydropsyche saxonica*, *H .instabilis* und *H. bulbifera*. Die Arteninventare wurden mit jenen aus dem Jahr 1982 (SCHEIBLREITER 1982) verglichen. Die Hypothese der Abnahme von Larvengröße und Maschenweite der Fangnetze von Quelle zu Mündung wurde an den acht Arten entlang des Flusses getestet. Die Fließgeschwindigkeit auf Höhe der Fangnetze wurde gemessen, um zu testen, ob eine Korrelation zu den Maschenweiten besteht.

Die Ergebnisse zeigen, dass sich die Habitate der Hydropsychidae nicht streng nach deren Larvengrößen und Maschenflächen entlang des Flusses anordnen. *Cheumatopsyche lepida*, die kleinste Hydropsychidae der Großen Tulln, bewohnt ausschließlich den schnell fließenden Mittellauf, was eindeutig nicht mit oben erwähnten Hypothesen übereinstimmt. Die Messungen der Fließgeschwindigkeit zeigen, dass Hydropsychidae ausschließlich schnell fließende Habitate besiedeln (mittlere Fließgeschwindigkeiten auf Netzhöhe zwischen 23 und 34 cm s^{-1}). Eine signifikante Korrelation zwischen Fließgeschwindigkeit und Maschenfläche konnte für zwei Arten festgestellt werden.

Die vorherrschenden Bedingungen in den Mikrohabitaten könnten der entscheidende Faktor für die Verteilung und Einnischung der Hydropsychidae und die unterschliedlichen Maschengrößen der Fangnetze sein.

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Curriculum vitae

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Nationality: **Austria**

School education:

1994 – 1998: Primary school in Ried im innkreis

1998 – 2006: Bundesrealgymnasium Ried im Innkreis. Matura: 14th June 2006

Civilian service:

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Academic education:

2007 – 2009: University of Vienna/ Bachelor´s program Molecular Biology

2009 – 2012: University of Vienna/ Bachelor´s program Ecology
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2012 – 2015: University of Vienna/ Master´s program Ecology/Limnology

Research experience:

Bachelor´s project on long time development of wetland vegetation in the Lobau (Vienna), by comparing current vegetation with ancient data.

Master´s project "Net structure and species inventory of the Hydropsychidae species (Trichoptera) of the Große Tulln catchment (Lower Austria)"

Work experience:

Since 2009: Wiener Assistenz Genossenschaft (WAG)
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Languages:

English, Italian (six years high school education)