# MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„Respiration rates of genus *Hydropsyche* (Insecta: Trichoptera) in the catchment of the Große Tulln (Lower Austria)"

verfasst von / submitted by

Cornelia Bauer BSc

angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2015 / Vienna 2015

| | |
|---|---|
| Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet: | A 066 833 |
| Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet: | Masterstudium Ökologie |
| Betreut von / Supervisor: | Ao. Univ. Prof. Dr. Johann Waringer |

# Acknowledgements

I would never have been able to finish my thesis without the guidance of my lecturer, help from friends, and support from my family.

I am grateful to **Johann Waringer**, lecturer at the Department of Limnology and Oceanography, who aroused my interest for pelagic and benthic life in inland waters already in a very early stage of my bachelor studies and since then I was dedicated to it. I am extremely thankful and indebted to him for sharing expertise, and sincere and valuable guidance and encouragement extended to me.

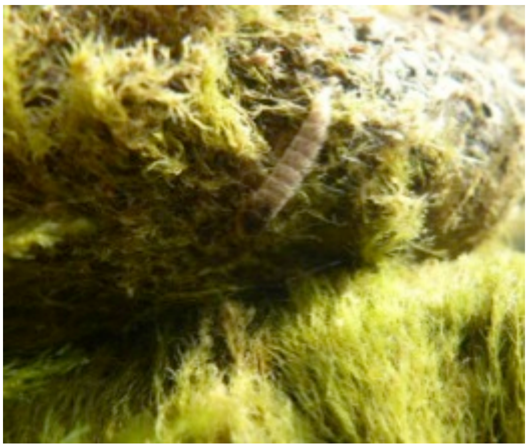
I wish to express my sincere thanks to **Hubert Krail**, for providing me with all the necessary facilities for the research.

I further thank my student colleague **Sebastian Hable** for sharing his expertise and assistance in the field.

I am also grateful to many friends and colleagues, especially **Magdalena Hirtl, Nadine Ebm** and **Barbara Mähnert**, who have accompanied me through this time and gave me their mental support, statistical advises and bore my enthusiasm for these little water insects.

I am finally thankful to my family, **Veronika Bauer**, **Stephanie Bauer** and **Florian Bauer**. I would like to express my special thanks to the latter two for their help and patience with me during the samplings at the Große Tulln.

Finally, I would like to thank my good friend **Thomas Wolfram** for always supporting me and never being short for an answer whatever advice I needed.



**The wonderful world of Hydropsychidae**

# Contents

# Introduction

The number of described species in the order Trichoptera is constantly growing. In the late 60´s about 7,000 species had been described, whereof 800 were found in Europe (Botosaneanu, 1967; Fischer, 1960-1973). More than 50 years later, 14,548 valid Trichoptera species have been recorded, belonging to 616 genera and 49 families (Trichoptera World Checklist; http://www.clemson.edu/cafls/departments/esps/database/trichopt/; 14 September 2015). The smallest amount of families (23) can be found in the Afrotropical and Neotropical Regions, whereas most families (29) were recorded in the Australasian and East Palearctic Regions. This difference in the biogeographic regions becomes particularly apparent when looking at the species presence data. While 1,099 species were reported in the Afrotropical Region, 4,865 species were found in the Oriental Region. An even greater gap can be observed when looking at the density of known, valid species. The Oriental Region features about 7.5 times as many species per square gigameter ($Gm^2$) than the Afrotropical Region (Morse, 2011).

As their greek name Trichoptera implies (*trikho*: hair and *–pteron*: wing), the adults of this insect order are identified by their hairy wings. In most species the hairs are fine and tight, but in some groups, e.g. the Hydroptilidae, they resemble the scales of a butterfly (Jacobs & Renner, 2007).

Trichoptera belong to the group of merolimnic insects (Wichard, 1978) and can either have a uni- or bivoltine life cycle (Waringer & Graf, 1997). Oviposition can happen in many different ways, but mostly the females stick the egg masses to a plain surface below the water level. The larvae build shelters and cases using silk strands originating in two long glands emerging at the tip of the labium, the so called labial gland (Wichard, 1978). They can either build fixed, tubular shelters, transportable cases or filtering nets (Waringer & Graf, 1997). Larvae can be divided into an eruciform or campodeid type. The first one has a more caterpillar-like shape while the campodeid type is mostly prognathous (Wichard, 1978). They also differ considerably in their way of living. The caterpillar-like larvae often build transportable cases, which they never leave voluntarily. They are mostly herbivores, feeding on algae or detritus. Only few of the campodeid-type larvae build cases. They mostly live in running water and are often predators (e.g. *Rhyacophila*). The majority builds filtering nets directed against the current. Generally, the larvae pupate after spending five larval instars, except a few species that have six to eight instars (Nielsen, 1942; Benedetto Castro, 1975; Malicky, 1973). The pupa leaves the case and swims to the surface where it emerges as fully-grown imago (Waringer & Graf, 1997).

Trichoptera larvae respire by means of a closed tracheal system with oxygen uptake taking place via their body surface. Some, including the larvae of *Hydropsyche*, have additional filamentous or tufted tracheal gills at the abdomen or thorax, thereby enlarging the body surface area without enlarging the body volume. At all times, the first larval instar is free of tracheal gills. During larval development, the number of tracheal gills increases with each moulting (Wichard, 1978). Therefore larvae are able to adopt morphologically and physiologically to fluctuating oxygen concentrations in a habitat. In order to do this, the respiratory surface can be enlarged or the partial pressure gradient can be changed. The former results in the number and size of the tracheal gills and varies not only from species to species but also across populations. For example, the larvae of tribe Limnephilini possess 120 to 200 tracheal gills, while the larvae of tribe Stenophylacini get along with 50 to 70 tracheal gills. Even within one species the number of tracheal gills can change: in *Limnephilus decipiens* grown up at different sites, there are significant differences in the number of tracheal gills due to different oxygen conditions (Philipson, 1954). The regulation of the partial pressure is done by ventilation of the abdomen. If the oxygen content in the water drops, the frequency of ventilation movements increases rapidly. Nevertheless the ventilation never lasts for long, as from lack of oxygen, the larvae get exhausted very soon (Wichard, 1978).

Hydropsychidae are endopterygotic insects belonging to the insect order Trichoptera, also named caddisflies. In Europe they are divided into three genera: *Hydropsyche, Cheumatopsyche* and *Diplectrona*, of which only the first two can be found in Austria (Malicky, 2013). In the family Hydropsychidae, there are 79 species in Europe, including 18 Austrian species (Graf et al., 2015).

As a member of the EPT (Ephemeroptera, Plecoptera, Trichoptera) fraction, Hydropsychidae are reliable bioindicators (Graf & Hutter, 2002). Back in 1952, Gaufin and Tarzwell correlated stream pollution with aquatic insect abundance. In 1994, Kerans and Karr developed an universal index using benthic invertebrates. It was called the Benthic index of biotic integrity (B-IBI) and used 13 taxa, including caddisflies and stoneflies. Several other authors described indices using stream macroinvertrebrates as indicators (Barbour et al., 1999; Klemm et al., 2002). Only two years later, in 1996, Wallace et al. used the EPT index in an experiment to monitor the invertebrate community in a treated and a non-treated stream and concluded that the EPT index was by far the easiest to use in terms of required time for sample processing as well as ease of application and it effectively tracked the changes in water quality.

The Große Tulln was chosen for this study, because its EPT fraction is rich and diverse and there exists a sound data base due to many studies carried out over the last decades. (e.g. Scheiblreiter, 1982; Stadler, 1992; Kölbl, 2006; Hable, 2015). Back in 1982, Scheiblreiter provided a good overview of the Trichoptera Fauna. The goal of my work was the study of respiration rates of various *Hydropsyche* species along the stream continuum in order to set a basis for further physiological investigations. This study is part of a collaboration with Sebastian Hable, BSc., who investigated the species inventory at the same sites (MSc Thesis “Net structure and species inventory of the Hydropsychidae species (Trichoptera) of the Große Tulln catchment (Lower Austria)”).

# Material & Methods

## 1. Study Area

### 1.1. Topography

The study area is situated within the Große Tulln catchment, peaking at 680 m a.s.l. at the southeastern slope of the Gföhlberg (883 m) at the pass Klammhöhe in the south-east of the district of St. Pölten Land (Lower Austria). The spring brook is called Laabenbach. At the confluence with the Anzbach at Neulengbach, the river is named Große Tulln; after 40km the Große Tulln discharges into the Danube at the east of the Rosenbrücke at Tulln (Scheiblreiter, 1982). The catchment area amounts to 202,3 km$^2$ (Figure 1).


**Figure 1. Catchment area of the Große Tulln**
**(crosses: sampling sites; based on Austrian map Fly 4.0).**

### 1.2. Geology

The subcatchment of the Laabenbach is situated within the sandstone area of the Wienerwald (flysch), which is known for its mix of marl and argillaceous shale with sandstone. In the latter turbidites or fluxoturbidites can be found (Dzulynski et. al. 1959). The genesis of flysch was initiated by instable offshore sediment accumulations sliding into a deep-sea basin. Heavier particles quickly aggregated at the bottom while small clay particles precipitated very slowly. This sedimentation process created graded bedding of flysch-sandstone with the coarse material at the bottom and the fine on top (Plöchinger & Prey, 1993). These rocks are impervious to water, which results in a high input of rain- and melt water into the river. In Neulengbach the Große Tulln traverses a narrow zone of the subalpine molasse, consisting of conglomerates, folded conglomerates and fine-grained sediments. At Inprugg, the Große Tulln enters the molasse. This zone mainly consists of sand, silt and clay, dated from the neogene, and is partly overlaid by loess. Downstream of Judenau and in the Tullnerfeld, the Große Tulln flows in a broad quaternary gravel bed. Most of the precipitation filters into permeable gravel and sand (Plöchinger & Prey, 1993).

### 1.3. Climate

In the Wienerwald area the oceanic climate creates cold summers with high precipitation and mild winters. The Tullnerfeld, however, is influenced by continental climate. In summer, the temperature is continuously higher and precipitation lower. Winter is characterized by severe frosts (Scheiblreiter, 1982).

### 1.4. History

Since 1810 the river is called Große Tulln. Historic names of the river range from Dullona to Tulnerbach or Tullnerbach. In the annals of Fulda in 884 the Große Tulln is mentioned as border between bavarians and slavic peoples (Annales Fuldenses, 884). Around 991 Henry II, Duke of Bavaria, penetrated the Ungarnhaag at the Wienerwald ridge. Thereby, the Bavarian noble man Engelricus distinguished himself, and on 29 April 998 emperor Otto III granted him the tenurial between “Dullona and Amizinesbach” (Große Tulln and Anzbach).

## 2. Sampling Sites

### 2.1. Klamm

The sampling site Klamm (Figure 2) 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 summarizes some geographical and physical data of the sampling site.

**Table 1. Geographical and physical data of the sampling site Klamm.**

| 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 $m^3s^{-1}$ |
| Slope | 47 ‰ |
| Chemical Index (CI) | 65 |
| Site insolation | 30 % |



**Figure 2. Laabenbach at the sampling site Klamm. Pi**

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 growing season.

The HOBO data logger exposed at this site was lost during a flood event.

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).

**Table 2. Distribution of microhabitat categories (Braukmann, 1987; Graf et al., 2008) at the sampling site Klamm.**

| Category | Area percentage |
|---|---|
| Macrolithal | 30 % |
| Mesolithal | 30 % |
| Akal | 25 % |
| Macropelal | 10 % |
| Xylal | 5 % |

Table 3 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

**Table 3. Limnochemical parameters at the sampling site Klamm, showing the mean (and range) of two measurements taken at 1 June 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 (-) |
| $PO_4^{3-}$ ($mgl^{-1}$) | 0.025 (0 – 0.05) |
| $NO_3^-$ ($mgl^{-1}$) | 0 |
| $NH_4^+$ ($mgl^{-1}$) | 0.015 (0 – 0.03) |
| $O_2$ (%) | 94 (89 – 99) |
| $BSB_5$ | 8.8 (7.7 – 9.9) |

## 2.2. Laaben

This sampling site at the Laabenbach (Figure 3) is located 1 km downstream of the village of Laaben. Its spring distance is 7.8 km (Table 4). At Laaben, the slope becomes lower (22 ‰). The larger mean discharge (0.21 $m^3s^{-1}$) and the stream width (5 m) underline the transformation of the Große Tulln from a spring brook at Klamm to a river at Laaben. Geographical and physical data of the sampling site are shown in Table 4.

**Table 4. Geographical and physical data of the sampling site Laaben.**

| **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 $m^3s^{-1}$ |
| Slope | 22 ‰ |
| Chemical Index (CI) | 65 |
| Site insolation | 20 % |

**Figure 3. Laabenbach at the sampling site Laaben. Pictures were taken on 5 May, 2015.**

The dense riparian forest reduces site insolation to 20 %. The streambed and sediments are diverse, and are characterized by riffle-pool sequences and accretion zones at the banks.

The water temperature at the sampling site Laaben was measured from April 2014 until November 2014 (Figure 4). The highest recorded temperature was 22.6 °C, the lowest 3.9 °C; mean water temperature was 13.5 °C.

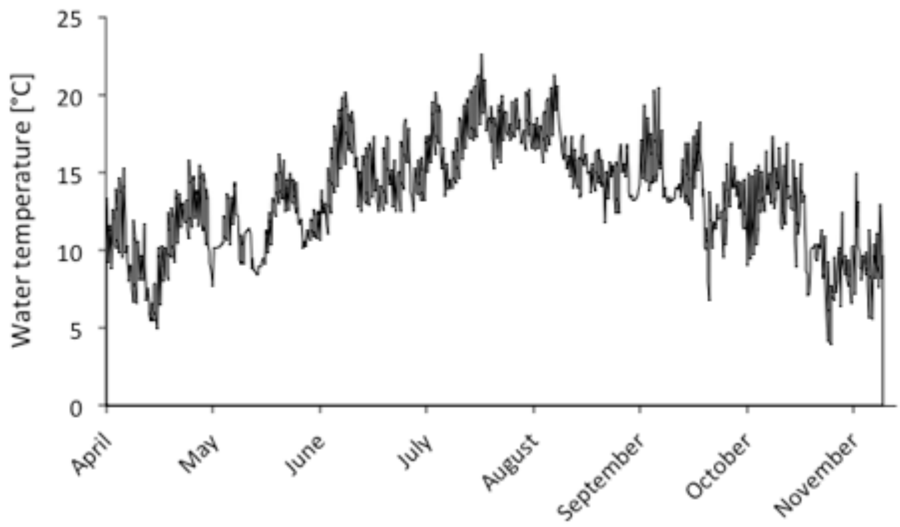



**Figure 4. Water temperature profile at the sampling site Laaben from March to November 2014.**

Grain sizes rangedfrom cobbles to sand at this site with Mesolithal dominating (Table 5). At the banks, organic matter like mud (Micropelal), coarse detritus (Macropelal) and dead wood (Xylal) is represented. Some cobbles (up to 5 %) were covered by epilithic algae (Lithophythal).

**Table 5. Distribution of microhabitat categories (Braukmann,1987; Graf et al., 2008) at the sampling site Laaben.**

| Category | Area percentage |
|---|---|
| Macrolithal | 10 % |
| Mesolithal | 35 % |
| Akal | 20 % |
| Psammal | 10 % |
| Macropelal | 10 % |
| Micropelal | 5 % |
| Xylal | 5 % |
| Lithophytal | 5 % |

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

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

**CI Parameters**

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

## 2.3. Prinzbach

The Prinzbach is a tributary of the Lengbach, discharging between the villages Altlengbach and Steinhäusl. Like Klamm, this sampling site represents a spring brook (2.7 km spring distance, Figure 5). The geophysical stream parameters (Table 7) are similar to Klamm, except elevation, which is 200 meters lower (335 m a.s.l.).

**Table 7. 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 $m^3s^{-1}$ |
| Slope | 40 ‰ |
| Chemical Index (CI) | 69 |
| Site insolation | 30 % |

**Figure 5. Prinzbach sampling site. Pictures were taken on 5 May, 2015.**

Stream width (up to 2.5 m at base discharge), the dense riparian forest and the low site insolation (30 %) also are close to the situation at Klamm. However, with a slope of 40 ‰ the inclination is less steep.

Figure 6 illustrates the water temperature regime at the sampling site Prinzbach from April 2014 to November 2014. The lowest measured water temperature was 3.6 °C, the highest 23.7 °C; mean water temperature was 13.0 °C at this site during the sampling time.

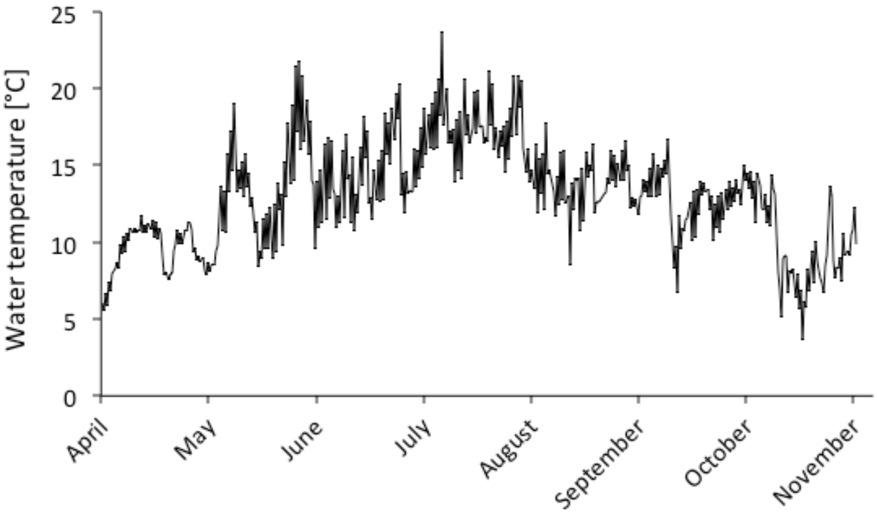



**Figure 6. Water temperature profile at the sampling site Prinzbach from March to November 2014.**

Mesolithal was dominating at the streambed, with large cobbles (Macrolithal) and sand aggregations (Psammal) in between (Table 8). Due to the dense canopy of riparian deciduous forest, coarse particulate organic matter (Macropelal and Xylal) was up to 20 % at the sediment surface. No visible epilithic algal biofilms or higher plants covered the sediments.

**Table 8. Distribution of microhabitat categories (Braukmann, 1987; Graf et al., 2008) at the sampling site Prinzbach.**

| Category | Area percentage |
|---|---|
| Macrolithal | 20 % |
| Mesolithal | 30 % |
| Akal | 10 % |
| Psammal | 20 % |
| Macropelal | 15 % |
| Xylal | 5 % |

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

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

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

## 2.4. Altlengbach

This sampling site is located at the Lengbach in the village of Altlengbach. Here the river has been straightened. The spring distance is 5.2 km. As in Laaben, the river at Altlengbach is characterized by the transformation from a spring brook to a middle reach river. Stream width (5 m) and mean discharge are close to the situation at Laaben, with inclination up to 9.5 ‰, typical for the central section of the catchment. Table 10 summarizes the geographical and physical data of the sampling site.

**Table 10. Geographical and physical data of the sampling site Altlengbach.**

| **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 $m^3s^{-1}$ |
| Slope | 9.5 ‰ |
| Chemical Index (CI) | 64 |
| Site insolation | 50 % |

Figure 7. Lengbach sampling site at Altlengbach. Pictures were taken on 5 May, 2015.

The mean site insolation is up to 50 %, due to the fact that the riparian forest is present only at the hydrological left side of the river. Cobbles for bank stabilization were installed at the right side (Figure 7).

The water temperature at the sampling site Altlengbach was measured from April 2014 until November 2014 (Figure 8). The highest recorded temperature was 21.9 °C, the lowest 6.5 °C; mean water temperature was 14.3 °C.

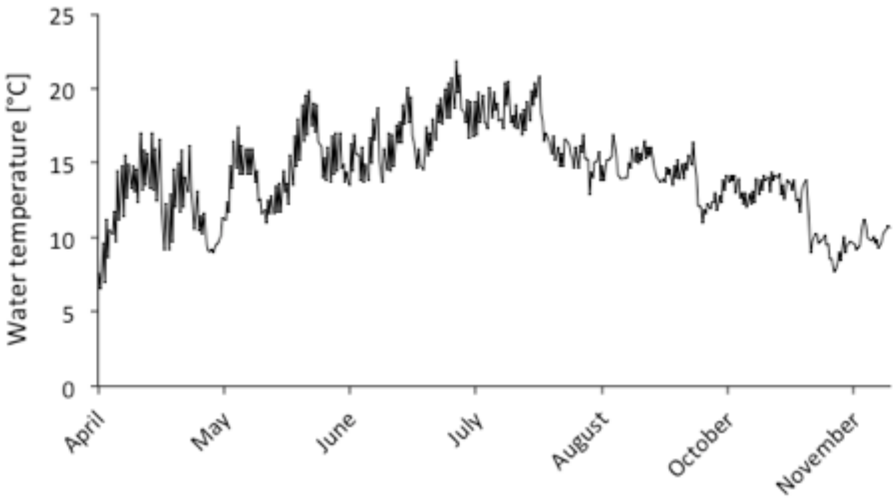



Figure 8. Water temperature profile at the sampling site Altlengbach from March to November 2014.

Because of heterogeneity loss due to straightening, flow velocity was more homogenous and there was less fine sediment accumulation at this site; pools were lacking. Macro- and meso-lithal dominated, and there was little mud, detritus or deadwood. Many stones were covered by epilithic algae (20 %), which can be interpreted as eutrophication due to the proximity to urbanized areas (Altlengbach, Steinhäusl) upstream of the sampling point (Table 11).

**Table 11. Distribution of microhabitat categories (Braukmann, 1987; Graf et al., 2008) at the sampling site Altlengbach.**

| Category | Area percentage |
|---|---|
| Macrolithal | 30 % |
| Mesolithal | 30 % |
| Akal | 5 % |
| Psammal | 5 % |
| Macropelal | 5 % |
| Micropelal | 5 % |
| Lithophytal | 20 % |

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

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

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

## 2.5.Neulengbach

This sampling site is located about 1 km downstream of the city of Neulengbach. From Neulengbach on, the Große Tulln enters the molasse and its downstream reaches, shown by less inclination (3.9 ‰) and less canopy cover of the riparian forests (80 % site insolation). The width of the river is up to 6 m at Neulengbach, its spring distance 19.2 km. Table 13 summarizes some geographical and physical data of the sampling site.

**Table 13. Geographical and physical data of the sampling site Neulengbach.**

**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 $m^3s^{-1}$ |
| Slope | 3.9 ‰ |
| Chemical Index (CI) | 65 |
| Site insolation | 80 % |

The river was straightened at Neulengbach, causing heterogeneity loss of the streambed and creating large riffle areas with high flow velocities at this site (Figure 9). Mean discharge is up to 0.27 $m^3s^{-1}$.

**Figure 9. Große Tulln sampling site at Neulengbach. Pictures were taken on 5 May, 2015.**

Figure 10 summarizes the water temperature regime at the sampling site Neulengbach from April 2014 to November 2014. The lowest measured water temperature was 6.4 °C, the highest 25.8 °C; mean temperature was 15.4 °C at this site during the sampling period.

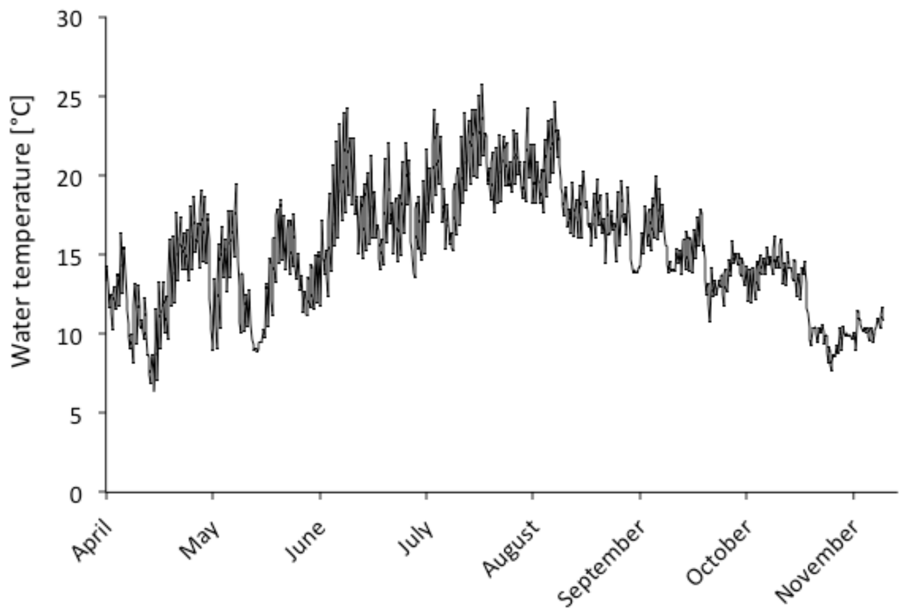



**Figure 10. Water temperature profile at the sampling site Neulengbach from March to November 2014.**

The grain size of the bed sediments at Neulengbach was very homogenous, dominated by Mesolithal. Detrital particles were missing, but mud patches (Micropelal) along the banks were present. Epilithic algae (Lithophythal) covered large fractions of the sediments (30 %), which indicated high nutrient loads due to agricultural activities in the Tullner Feld (Table 14).

**Table 14. Distribution of microhabitat categories (Braukmann, 1987; Graf et al., 2008) at the sampling site Neulengbach.**

| Category | Area percentage |
|---|---|
| Macrolithal | 15 % |
| Mesolithal | 40 % |
| Akal | 5 % |
| Psammal | 5 % |
| Micropelal | 5 % |
| Lithophytal | 30 % |

Table 15 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

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

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

## 2.6. Langenrohr

This sampling site is located in the Tullner Feld, on the western outskirts of Langenrohr. The distance to the spring is 35.1 km, and the mouth is only 4 km downstream. Here, the Große Tulln enters its potamal zone. Slope levels off to only 0.9 ‰. Site insolation is 100 % due to a lack of riparian canopy, and stream width is up to 10 m. Table 16 summarizes some geographical and physical data of the sampling site. The river is completely straightened and dammed along both banks.

**Table 16. Geographical and physical data of the sampling site Langenrohr.**

| **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 $m^3s^{-1}$ |
| Slope | 0.9 ‰ |
| Chemical Index (CI) | 64 |
| Site insolation | 100 % |

**Figure 11. Große Tulln sampling site at Langenrohr. Pictures were taken on 5 May, 2015.**

At this sampling site the high flow velocity and low water depth are somewhat atypical for a potamon section due to a ford that is mainly used by horsemen (Figure 11). Up- and downstream of this site flow velocity is reduced, and water depth increases to more than 1 m. The mean discharge of 0.35 $m^3s^{-1}$ is the highest among the six sampling sites.

The water temperature at the sampling site Langenrohr was measured from April 2014 until November 2014 (Figure 12). The highest recorded temperature was 26.7 °C, the lowest 7.3 °C; mean water temperature was 16.8 °C.

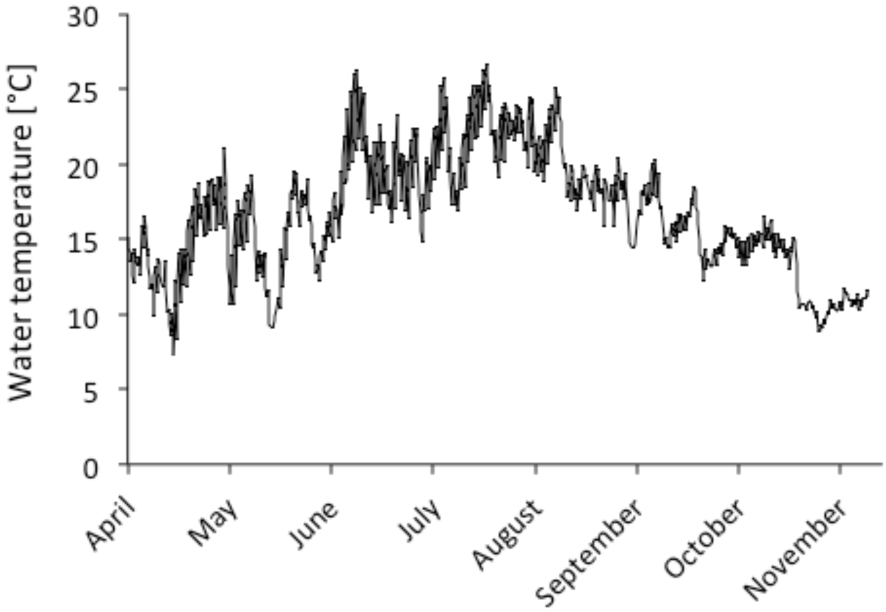



**Figure 12. Water temperature profile at the sampling site Langenrohr from March to November 2014.**

Grain sizes of 10 cm diameter (Mesolithal) dominated the sediments within the ford area of this sampling site (Table 17), with cobbles (Macrolithal) in between. The banks were covered with muddy sediments (Micropelal). All stones were covered by epilithic algae (Lithophythal), which indicated high nutrient concentrations in the water. Up- and downstream of the ford, the sediments are characterized by smaller grain sizes with sand and organic mud dominating.

**Table 17. Distribution of microhabitat categories (Braukmann, 1987; Graf et al., 2008) at the Langenrohr sampling site. The area percentage of Lithophytal is treated separately.**

| Category | Area percentage |
|---|---|
| Macrolithal | 20 % |
| Mesolithal | 60 % |
| Psammal | 10 % |
| Micropelal | 10 % |
| Lithophytal | 95 % |

Table 18 summarizes the limnochemical dataset, which served as a basis for the calculation of the chemical index.

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

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

# 3. Material and Methods

## 3.1. Physicochemical parameters

In March 2014 eight HOBO temperature data loggers (Onset) were placed at the sampling sites and were recovered in November 2014. On 1 June and 12 August 2014, limnochemical parameters were measured and choriotopes for each sampling mapped.

Conductivity (µS $cm^{-1}$), pH, and water temperature (°C) were measured with a WTW pH 330 pH meter, and conductivity with the WTW LF 300 conductivity meter. For phosphate

($PO_4^{3-}$; mg $l^{-1}$) and ammonium ($NH_4^+$; mg $l^{-1}$) colorimetric tests by Merck and for nitrate ($NO_3$; mg $l^{-1}$) the colorimetric test by Aquanal® were used. Oxygen content ($O_2$; %) was measured with a titration kit by Merck. For the $BOD_5$ (biochemical oxygen demand) the samples taken at each site were incubated for 5 days at 20 °C. After this incubation period, oxygen was measured again and the difference calculated.

## 3.2. Microhabitat categories

Table 19 summarizes the microhabitat types applicable for the substrate mapping at the sampling sites.

**Table 19. Microhabitat categories (Braukmann, 1987; Graf et al., 2008).**

| Category | Grain size range | Description |
|---|---|---|
| Macrolithal | > 20 cm | Stones, boulders, rocks |
| Mesolithal | 5 – 20 cm | coarse gravel, hand-sized cobbles |
| Akal | > 5 mm - 5 cm | Fine to medium-sized gravel |
| Psammal | 0.1 - 5 mm | Fine gravel and sand |
| Macropelal | | Deposits of coarse organic material (e.g., fallen leaves and branches, mixed with gravel and sand) |
| Micropelal | | Fine detritus, mud |
| Lithophytal | | Epilithic moss or algae (submerged) |
| Xylal | | Tree trunks (deadwood), branches, roots, etc |

The area percentages of the choriotoptypes were estimated in steps of 5 % each. Categories with less than 5% area percentage were not considered.

## 3.3. Sampling of Hydropsychidae larvae

For the sampling of larval Hydropsychidae a wooden glass-bottom frame was built (Figure 13) for avoiding reflections on the water surface and for facilitating the detection of larvae. The larvae sampled were put into a container filled with water from the sampling site and brought to the laboratory at the Department of Limnology and Bio-Oceanography at the University of Vienna.

**Figure 13. Wooden glass bottom frame used for larval collections.**

## 3.4. Laboratory keeping

In the laboratory, two flow channels were used for keeping the larvae (Figure 14). Water flow was maintained by two water pumps, and water and sediments for the flow channels were brought along from the sampling sites. After collection of the larvae, they were brought to the laboratory and placed into the flow channels to acclimatize to laboratory conditions for the following measurements.

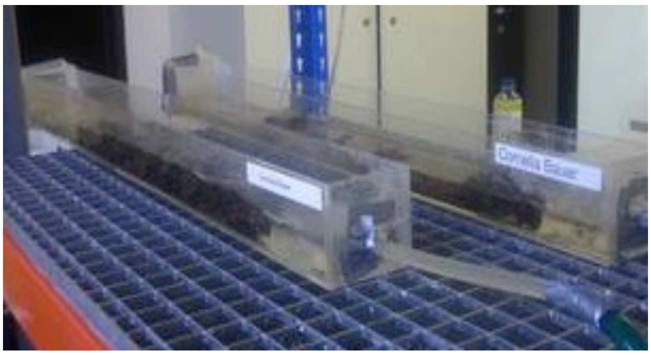


**Figure 14. Flow channels used for keeping the larvae prior to experiments.**

## 3.5. Respiration measurements

For the respiration measurements, a computer with installed Software OXY4v2_30FB was connected to an OXY-4 mini respirometer (Figure 15). Four fiber optic cables were linked to the device. Glass vials (Figure 16a) were prepared with optical sensor spots (optodes), which were connected to the fiber optic cables. The sensor spots work without water flow, are non-invasive and can be used in disposables. Another advantage is their small size. The oxygen content was measured in mg $l^{-1}$. For each measurement, the glass vials had to be sealed in

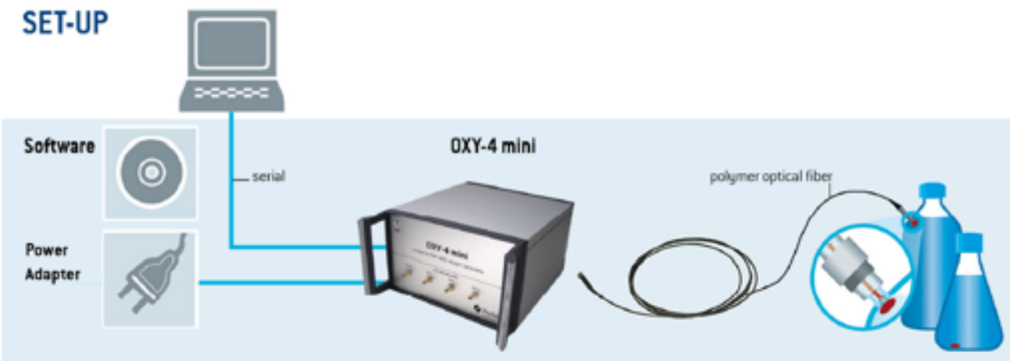



**Figure 15. Set-up for respiration measurements.**

order to guarantee accurate oxygen measurements. Different types of vials were used to choose optimum size for the respiration measurements. Furthermore, a stable water temperature had to be ensured by placing the vials into water containers within fridges using four constant temperatures (5, 10, 15, 25 °C). In order to acclimatize the larvae to the experimental temperatures, small aquaria were installed in the fridges (Figure 16b).


**Figure 16 (a) Glass-vials used for respiration measurements. 16 (b) Aquaria used for acclimatization of Hydropsychidae larvae.**

First, 39 ml glass vials with plastic plugs were used, which led to high oxygen losses during the three-hour measurement. Next, smaller vials (9 ml) were used to avoid oxygen stratification within the vial. The high mortality rate, however, proved that the size of this type was too small. In the end, auto sampler glass vials (39 ml) with silicone septa and caps were used to prevent gas diffusion. To exclude bacterial respiration the vials were autoclaved in a steam sterilizer (Varioklav Type 400). In addition, the water used for the respiration measurements was filtered with a filtration pump in two steps. In the first step the water was pre-filtered with glass-microfiber filters (MGC, particle retention ≥ 1.2 µm; Munktell). In the second step GF/F glass microfiber filters with a particle retention of 0.7 µm by Whatman were used. With this method the water from the Tulln could be filtered in high amounts and short time.

After 24 hours of acclimatization in ventilated aquaria at 5 °C, 10 °C, 15 °C or 25 °C the respiration measurements started. Only one temperature was measured at the same time. The glass vials were stored in the same climate chamber, after autoclavation, to ensure that the vials had the same temperature as the water. For each measurement the full vials were put into a water bath in the climate chamber. After 30 minutes one larva was put into each vial with one empty vial used as blank. After 60 minutes the larvae were released and put into another climate chamber for another 24-hour acclimatization. Each larva was used for two constant temperatures.

## 3.6. Identification and biometry of Hydropsychidae larvae

After preserving the larvae used for two experiments in 70% ethanol, they were identified under a binocular microscope (Stereo Lumar.V12, Zeiss) using the key of Waringer & Graf (2011).

Maximum head capsule width (Figure 17) used for instar determination was measured by using the same binocular microscope.

**Figure 17. Measurement of maximum head capsule width of *Hydropsyche saxonica.***

The identified and staged larvae were dried in a WTB Binder ED 400 compartment dryer at 60 °C to constant weight which was checked with a Sartorius R 180 D scale.

## 3.7. Statistical analysis

Environmental data (e.g. pH, conductivity, water temperature, nutrients, oxygen content) were evaluated in order to characterize the habitats using Excel for Mac 2011. Biometrical data (head capsule width) were used for instar determination of the species and correlated with dry weight data using Excel for Mac 2011. Dry weight of larvae was studied in order to standardize respiration rates. Respiration data were analyzed using Excel for Mac 2011 and SPSS for Windows.

To test for significant differences between groups, normality distribution was checked and t-tests were performed using R Studio Version 0.98.490. Graphs were done in Excel for Mac 2011 and R Studio Version 0.98.490.

# Results

## 1. Species inventory and abundance

In total, 8 Hydropsychidae species were collected from May until October 2014 at 6 sampling sites in the catchment area of the Große Tulln, Lower Austria. The inventory consisted of *Cheumatopsyche lepida* (PICTET, 1834) and 7 taxa of genus *Hydropsyche* PICTET, 1834, including two morphologically difficult species. For the respiration measurements of the present study four abundant taxa were chosen and a total of 43 specimens of *H. saxonica* McLACHLAN, 1884, 22 specimens of *H. instabilis* (CURTIS, 1834), 20 specimens of *H. pellucidula* (CURTIS, 1834) / *incognita* PITSCH, 1993 and 56 specimens of *H. bulbifera* McLACHLAN, 1878 were collected. Table 20 contains the total species inventory collected in the joint study of Hable (2015).

**Table 20. *Hydropsyche* species sampled at six sampling sites within the catchment of the Große Tulln. Data are based on CPUE samplings over 45 minutes, from 13 March 2014 to 30 August 2014; showing the percentage of individuals from the present study and from Scheiblreiter 1982 (numbers in brackets). The chemical index (CI) is shown for each sampling site. Species are ranked according to their longitudinal distribution from upstream to downstream (Hable, 2015).**

| **Species** | **Sampling Site (CI)** | | | | | |
|---|---|---|---|---|---|---|
| | Klamm (65) | Prinzbach (69) | Altlengbach (64) | Laaben (65) | Neulengbach (65) | Langenrohr (64) |
| *H. fulvipes* (CURTIS 1834) | 8 (0) | 4 (-) | 2 (-) | - (-) | - (-) | - (-) |
| *H. instabilis* (CURTIS 1834) | 65 (66) | 3 (32) | 25 (74) | 40 (96) | 3 (1) | - (-) |
| *H. saxonica* McLACHLAN 1884 | 27 (34) | 93 (68) | 49 (18) | 42 (3) | 10 (-) | - (-) |
| H. *pellucidula* (CURTIS 1834)/*incognita* PITSCH 1993 | - (-) | - (-) | 7 (8) | 15 (-) | 20 (-) | 1 (-) |
| *H. siltalai* DÖHLER 1963 | - (-) | - (-) | 11 (-) | 1 (-) | 13 (-) | - (1) |
| *C. lepida* (PICTET 1834) | - (-) | - (-) | 3 (-) | - (1) | 12 (2) | - (-) |
| *H. angustipennis* (CURTIS 1834) | - (-) | - (-) | - (-) | 1 (-) | 1 (-) | 20 (19) |
| *H. bulbifera* McLACHLAN 1878 | - (-) | - (-) | 3 (-) | 1 (-) | 41 (97) | 79 (80) |

## 2. Habitat parameters

Based on water temperature measurements of data loggers exposed from April to November 2014 (Table 21), we observed maxima during the summer months, which is typical for a river in the nemoral zone (Hauer et al. 2000; Hauer and Hill 2007). As a combination of increasing spring distance and decreasing riparian canopy cover, mean water temperatures increased from 13.0 °C at Prinzbach station (Strahler stream order 2) to 16.8 °C at the potamal station Langenrohr (stream order 5). Minima were as low as 3.5 °C at Prinzbach station, whereas water temperatures were up to 26.7 °C at Langenrohr. Generally, daily temperature fluctuations decreased downstream.

**Table 21 Synopsis of water temperature data obtained by Hobo data loggers in 2014 at five sampling stations within the Große Tulln catchment.**

| **Parameters** | **Sampling station** | | | | |
|---|---|---|---|---|---|
| | Prinzbach | Altlengbach | Laaben | Neulengbach | Langenrohr |
| Number of water temp. measurements | 422 | 422 | 896 | 896 | 896 |
| Max (°C) | 23.68 | 21.86 | 22.62 | 25.81 | 26.68 |
| Min (°C) | 3.58 | 6.47 | 3.89 | 6.37 | 7.28 |
| Mean (°C) | 12.99 | 14.31 | 13.47 | 15.41 | 16.75 |
| SD (°C) | 3.48 | 2.99 | 3.40 | 3.80 | 4.06 |
| Daily amplitude (°C) | 1.21 | 0.79 | 1.05 | 1.05 | 1.04 |
| First data point | 16. Apr | 16. Apr | 03. Apr | 03. Apr | 03. Apr |
| Last data point | 13.Nov | 13. Nov | 13. Nov | 13. Nov | 13. Nov |
| Strahler stream order | 2 | 4 | 5 | 5 | 5 |

## 3. Biometry

Intraspecific head capsule widths differed highly significantly ($p<0.001$, t-test) between the 4th and 5th instars but not between the investigated species within a given instar ($p>0.05$, t-test).

**Table 22. Head capsule widths of larvae of four abundant *Hydropsyche* species collected in the Große Tulln catchment.**

| **Species** | **Head capsule width [mm]** | | | | | |
|---|---|---|---|---|---|---|
| | **4th instar** | | | **5th instar** | | |
| | **Mean** | **SD** | **Range** | **Mean** | **SD** | **Range** |
| *H. bulbifera* | 1.130 | 0.082 | 0.903 - 1.202 | 1.262 | 0.040 | 1.208 - 1.347 |
| *H. instabilis* | 1.118 | 0.076 | 0.950 - 1.246 | 1.488 | 0.175 | 1.295 - 1.844 |
| *H. pell/incog* | 1.091 | 0.079 | 0.992 - 1.277 | 1.610 | 0.117 | 1.397 - 1.798 |
| *H. saxonica* | 1.085 | 0.072 | 1.011 - 1.260 | 1.693 | 0.089 | 1.509 - 1.867 |

In descending order, maximum head capsule widths of 4th instars were observed in *H. pellucidula/incognita* (1.277 mm), *H. saxonica* (1.260 mm), *H. instabilis* (1.246 mm) and *H. bulbifera* (1.202 mm). For the 5th instars, this ranking changed: maximum head capsule widths were recorded in *H. saxonica* (1.867 mm), followed by *H. instabilis* (1.844 mm), H. *pellucidula/incognita* (1.798 mm) and *H. bulbifera* (1.347 mm) (Table 22).

Size-frequency histograms of maximum head capsule widths oft he four *Hydropsyche* taxa collected in the Große Tulln taxa are shown in Figure 18. Except in *H. bulbifera* penultimate and ultimate instars were well defined and separated.

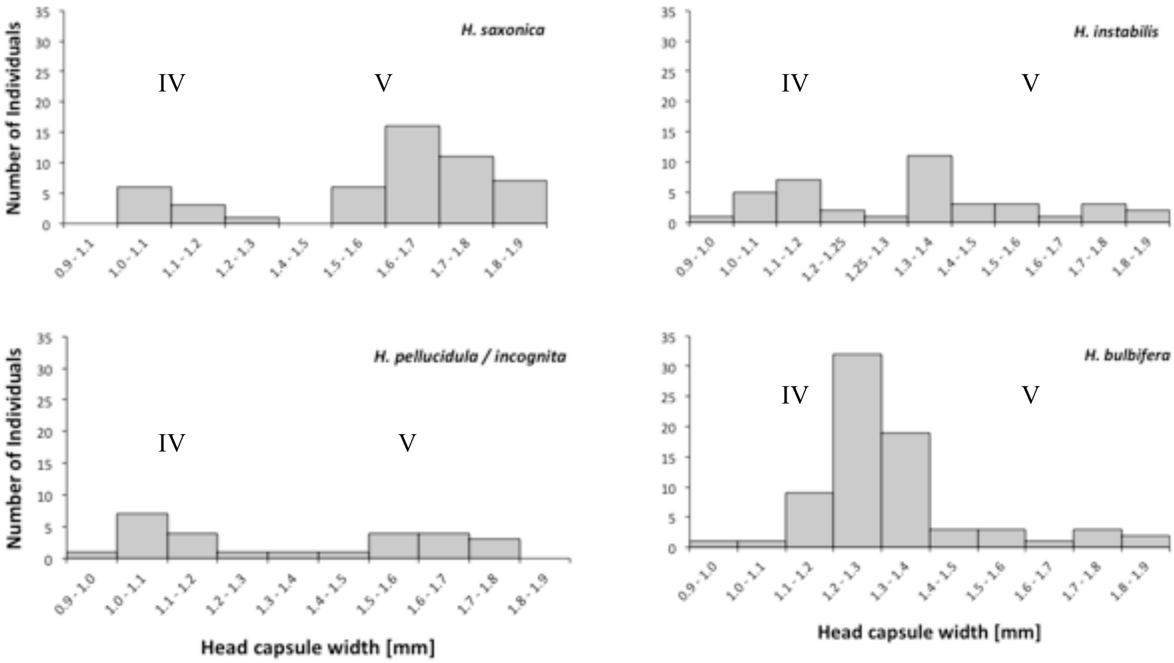



**Figure 18. Frequency plots of head capsule widths of penultimate and ultimate larval instars of four *Hydropsyche* species of the Große Tulln catchment.**

Dry weight data of the collected *Hydropsyche* species of the Große Tulln catchment are shown in Table 23. Arithmetic means and standard deviations of all *Hydropsyche* species ranged from 0.0014-0.0024 ± 0.005-0.0014 g dry weight in penultimate instars and from 0.0023-0.0048 ± 0.0014-0.0021 g dry weight in ultimate instars.

**Table 23. Dry weights of 4th and 5th instar larvae of four *Hydropsyche* species.**

| Species | Dry weight [mg] | | | | | |
|---|---|---|---|---|---|---|
| | 4th instar | | | 5th instar | | |
| | Mean | SD | Range | Mean | SD | Range |
| *H. bulbifera* | 1.4 | 0.5 | 0.5 - 2.2 | 2.3 | 1.4 | 0.9 - 6.5 |
| *H. instabilis* | 2.4 | 1.4 | 0.5 - 5.2 | 4.8 | 2.0 | 1.1 - 10.2 |
| *H. pell/incog* | 1.8 | 1.2 | 0.5 - 4.3 | 2.8 | 1.6 | 0.9 - 6.5 |
| *H. saxonica* | 1.6 | 0.6 | 1.0 - 3.1 | 3.7 | 2.1 | 1.1 - 9.7 |

In descending order, the maximum dry weights of 4th instars were observed in *H. instabilis* (0.0052 g), *H. pellucidula/incognita* (0.0043 g), *H. saxonica* (0.0031 g) and *H. bulbifera* (0.0022 g). For 5th instars, this ranking changed: maximum dry weights were recorded in *H. instabilis* (0.0102 g), followed by *H. saxonica* (0.0097 g). *H. pellucidula/incognita* and *H. bulbifera* showed equal maxima (0.0065 g). We observed highly significant differences (p<0,001, t-test) between interstadial dry weights (g) of the larvae.

The relationship between maximum head capsule width (mm) and larval dry weight (g) was highly significant ($p<0.001$; $R^2=0.14$; Figure 19).

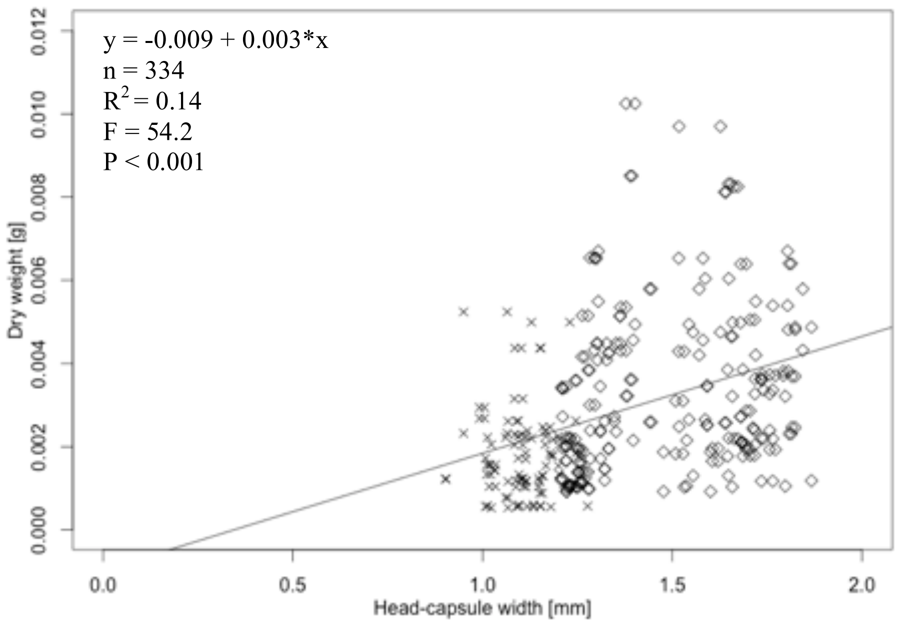



**Figure 19 Relationship between head capsule widths and dry weights of four *Hydropsyche* species collected in the Große Tulln catchment. Crosses = penultimate instars; diamonds = ultimate instars.**

# 4. Respiration

## 4.1. Respiration blanks

In order to determine background respiration rates of vials filled with filtered water from the field only (particle and biota size passing the filter ≤ 0.7µm), blanks were measured for ultimate and penultimate instars and for each experimental temperature (5, 10, 15 and 25 °C; Figure 20 a, b).

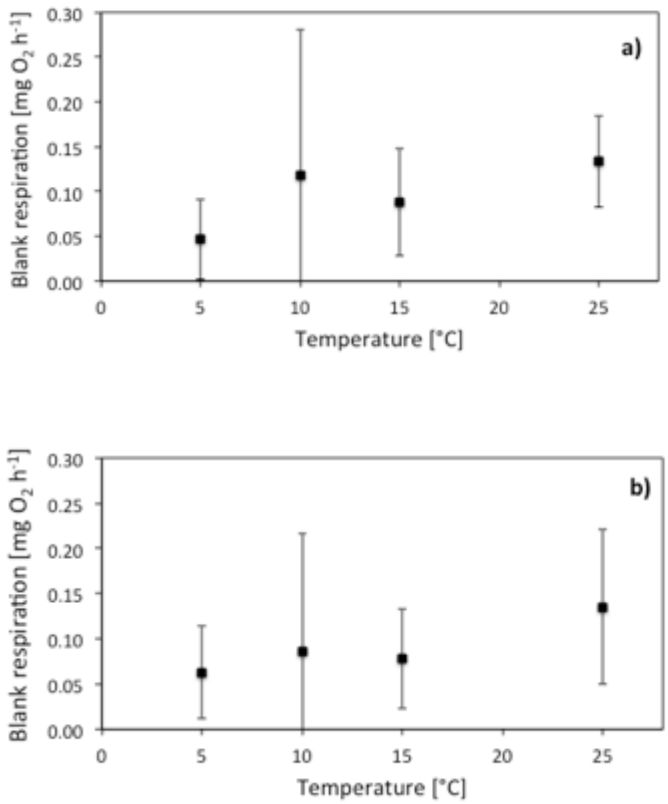



**Figure 20. Blank respiration (mg $O_2$ per hour) for experimental setups for penultimate (a) and ultimate (b) instars (arithmetic means ± SD).**

Blank respiration rates (Figure 20) ranged from 0.0 to 0.67 mg $O_2$ per hour and were not significantly different at different constant temperatures ($p>0.05$). Means of blank respiration for each temperature were used as corrections for larval respiration.

## 4.2. Respiration rates versus dry weights in larval *Hydropsyche*

We observed an experimental decrease of respiration (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$) with increasing dry weight (Figure 21a). This relationship was consistent with respiration rates at instar level where respiration was significantly higher (p<0.05) in penultimate than in ultimate instars (Figure 21b).

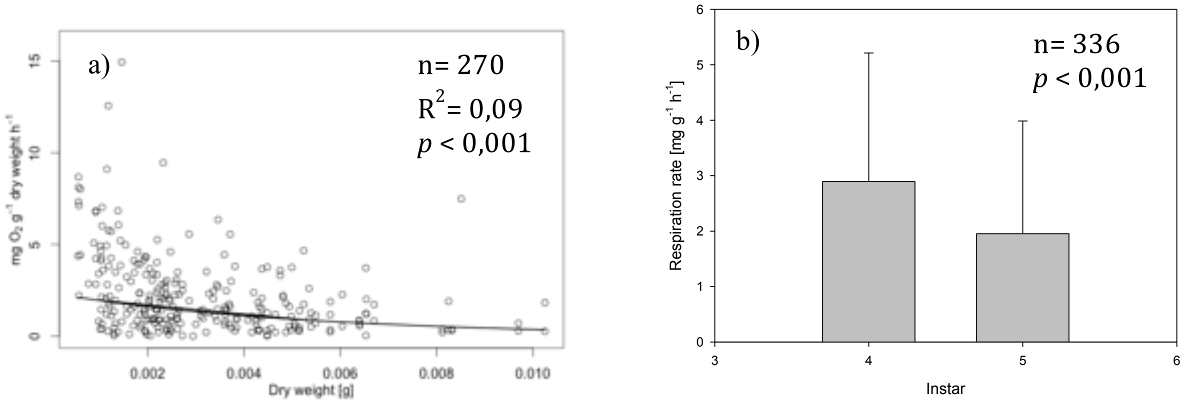



**Figure 21. a: Relationship between dry weight (g) and respiration rate (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$); b: Respiration rates (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$) of penultimate and ultimate instars of *Hydropsyche spp.***

Within a given instar, specimen with low dry weights generally had higher respiration rates than larger larvae, although there were outliers, especially in penultimate instars (Figure 22 a, b).

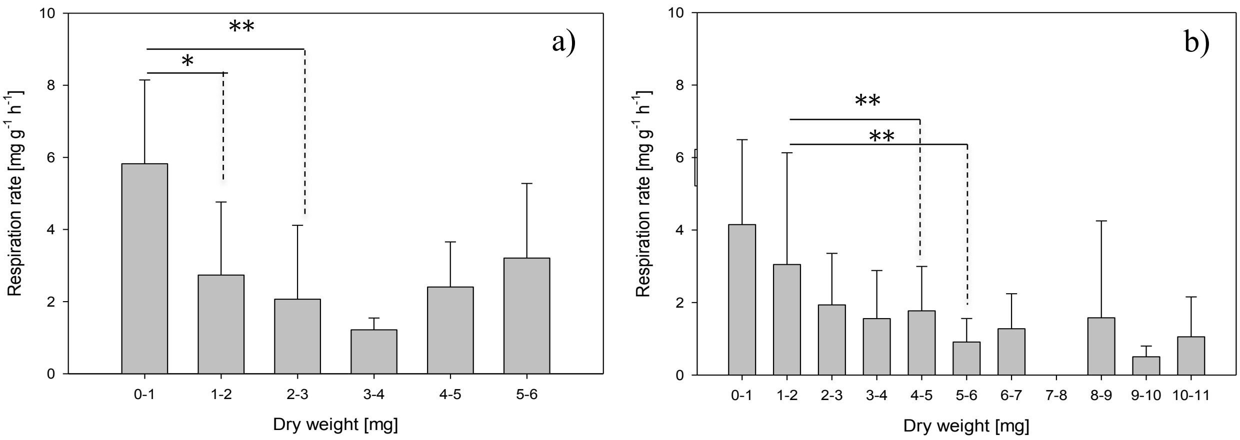



**Figure 22. Respiration rates (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$) within dry weight ranges of penultimate (a) and ultimate instars (b).**

## 4.3. Respiration rates versus water temperature in larval *Hydropsyche*

### 4.3.1. Respiration rates of *Hydropsyche* larvae at constant temperatures in the laboratory

When plotting constant water temperatures (5, 10, 15 and 25 °C) versus respiration rates (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$) we generally observed increasing respiration rates (Figure 23). This was especially true in *H. bulbifera* (Figure 23 d). In the other species, larvae in the 25 °C treatment were mostly inactive and probably impacted by the high temperature, resulting in almost stagnant respiration rates (Figure 23 a, c). There was also a slight decrease in respiration at 15°C in *H. instabilis* and *H. pellucidula/incognita*.

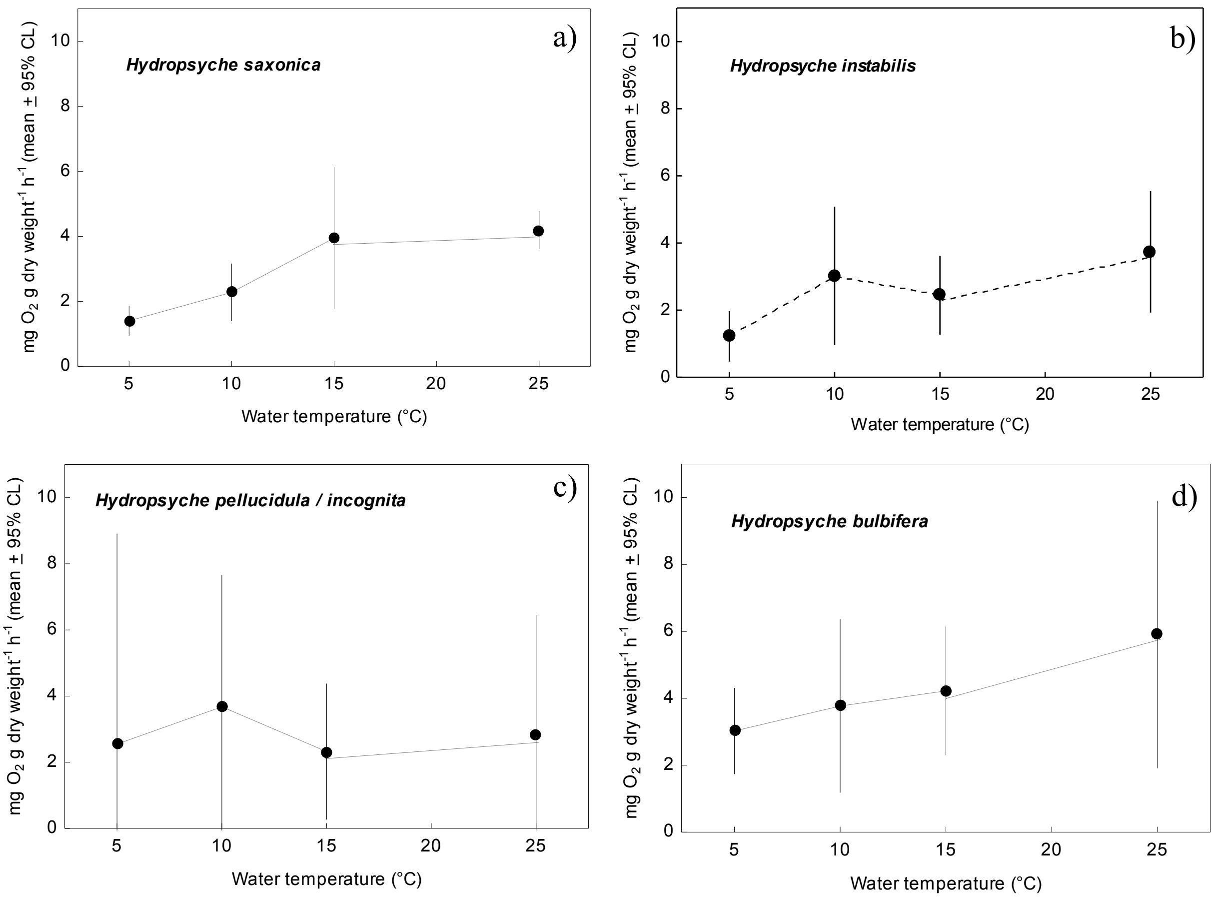



**Figure 23. Relationship between constant water temperatures (5, 10, 15 and 25 °C) and standardized respiration rates (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$) in final instar larvae of *H. saxonica* (a), *H. instabilis* (b), *H. pellucidula/incognita* (c) and *H. bulbifera* (d).**

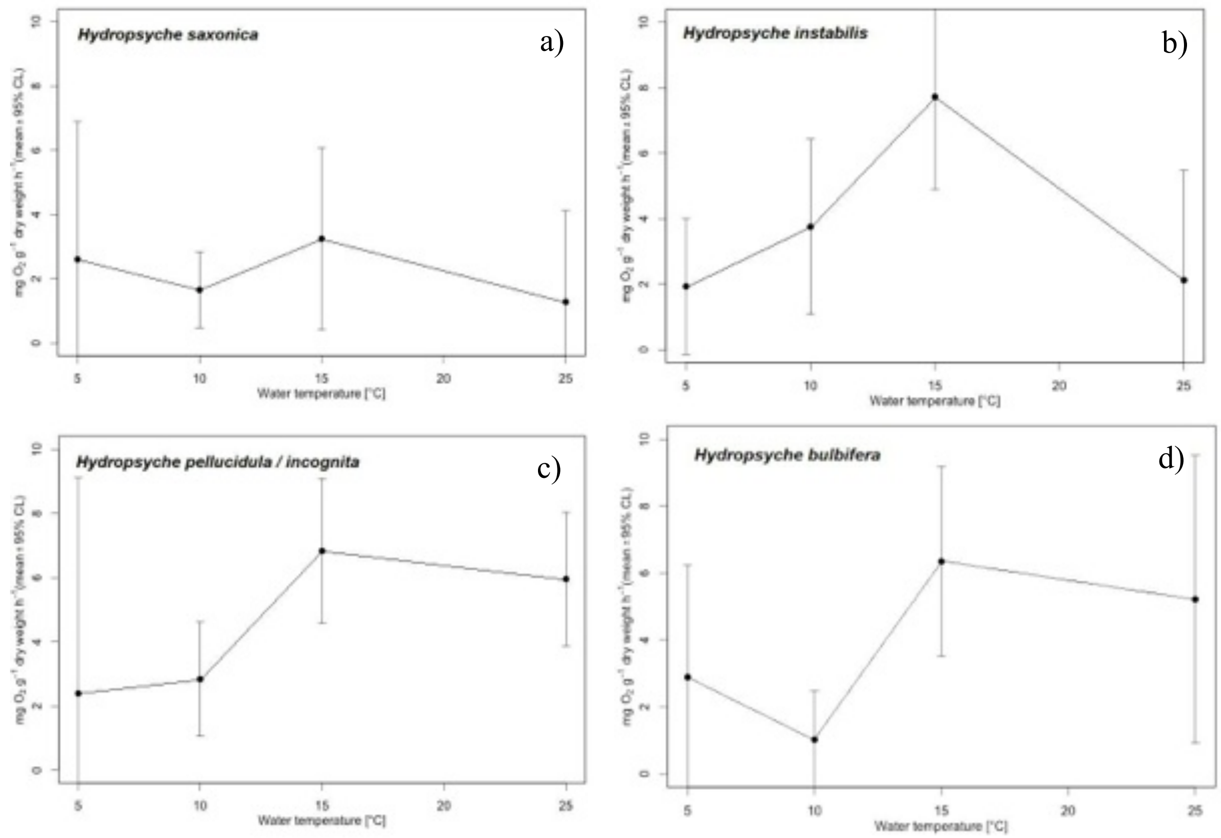



**Figure 24. Relationship between constant water temperatures (5, 10, 15 and 25 °C) and standardized respiration rates (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$) in final instar larvae of *H. saxonica* (a) *H. instabilis* (b), *H. pellucidula/incognita* (c) and *H. bulbifera* (d).**

Except for *H. saxonica*, an increase in respiration rates with increasing temperature can be observed in penultimate instars (Figure 24).

### 4.3.2. Respiration rates versus longitudinal distribution of larval *Hydropsyche*

When ranking *Hydropsyche* species according to spring distances of their collection sites within the Große Tulln catchment, respiration rates (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$) at 5 and 10 °C were lowest in *H. saxonica* and *H. instabilis*, reflecting their upstream position in the stream continuum (Figure 25 a, b). At 15 and 25 °C, minimum respiration rates shifted to *H. instabilis* and *H. pellucidula/incognita* (Figure 25 c, d), with the latter species collected most frequently in the transition zone from the rhithron to the potamon.

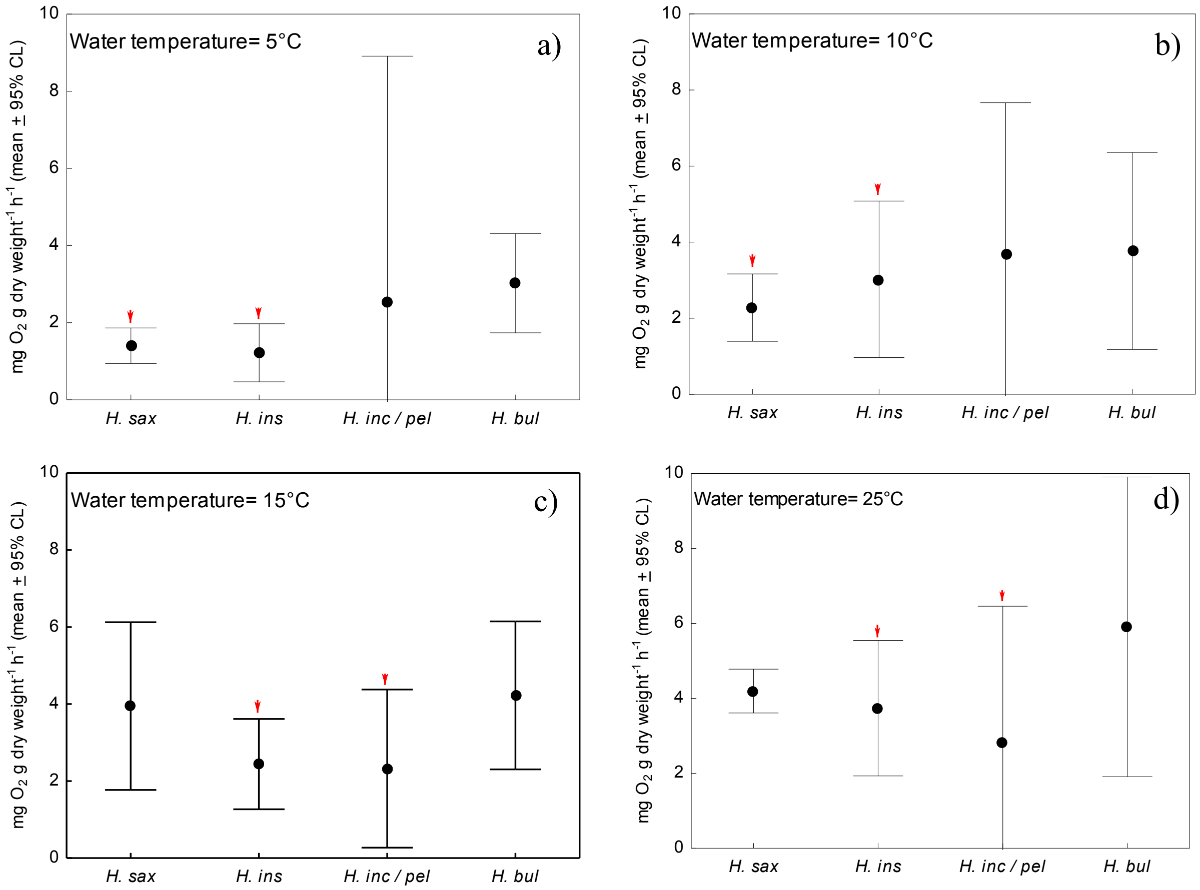



**Figure 25. Synopsis of species specific respiration rates (mg $O_2$ $g^{-1}$ dry weight $h^{-1}$; mean ± SE) within each constant temperature (5, 10, 15 and 25 °C).**

At the species-specific appropriate ambient water temperatures respiration rates were at minimum (Figure 25, red arrows), reflecting low respiration energy losses and the ability to incorporate maximum energy from food uptake into growth and reproduction. This mechanism might improve competition of a given species in its specific stream section.

# Discussion

## 1. Species inventory and abundance

In Austria, 19 Hydropsychidae species including one subspecies *(Hydropsyche angustipennis angustipennis*) belonging to two genera (*Cheumatopsyche, Hydropsyche*) can be found (Graf et al., 2015). In the present study, 4 abundant species including one species pair *(Hydropsyche pellucidula/incognita*) (Table 20) belonging to one genus were collected in the Große Tulln catchment for the respiration experiments. Basically the recorded species coincide with previous studies. Scheiblreiter (1982) detected 9 species from 2 genera in the Große Tulln catchment (Lower Austria). Table 20 shows the succession of species along the stream continuum of the Große Tulln.

### 1.1. Klamm

For the sampling site Klamm this study compares the population structure of three species with the study of Scheiblreiter 1982. *H. fulvipes* is a typical krenal species adapted to oligosaprobic conditions and is present only in the most upper regions of the river (Graf et al., 2002). In the stream continuum it is followed by *H. instabilis*, which inhabits epi- to metarhithral (Scheiblreiter, 1982; Graf et al. 2002; Bochert and Biele, 2005) sections of the river, and by *H. saxonica*, which prefers well-shaded forest brooks. The current situation is very similar, with *H. instabilis* accounting for 65 % in the present study compared to 66 % back in 1982. The percentage of *H. saxonica* decreased from 34 % to 27 %. This indicates little changes in abiotic parameters, e.g. water quality or river morphology. *H. instabilis* and *H. saxonica* were also present down to the sampling site Neulengbach, where the Große Tulln changes from hyporhithral to epipotamal. In most rhithral sections of the river, *H. saxonica* and *H. instabilis* alternate in dominance, confirming Scheiblreiter (1982). In 1982, *H. fulvipes* could not be found at the sampling site Klamm, but is now present (8 %). *H. fulvipes* was recorded in 1982 only in immediate vicinity of the spring. This downstream movement indicates that saprobity must have improved since 1982.
Scheiblreiter (1982) hypothesizes that the absence of *H. fulvipes* at the sampling site Klamm is due to its sensitiveness to water temperatures over 13 °C because he measured a maximum water temperature of 17.1 °C. For the present study, no water temperature data are available for this sampling site, but water temperatures were measured at the Prinzbach sampling site (which is at lower altitude than Klamm but has a similar morphology) with a mean of 13.9 °C

during the sampling season from April to August 2014. This would support Scheiblreiters hypothesis.

## 1.2. Prinzbach

In the catchment area of the Große Tulln, the sampling sites Klamm and Prinzbach constitute the upstream Hydropsychidae species community. At Prinzbach, the same *Hydropsyche* species were found as at Klamm. Although the two sampling sites have similar spring distance, streambed structure and abiotic parameters (Table 1,7), *H. saxonica* (93 %) is the dominant species compared to *H. instabilis* (3 %). This is equivalent to the results of Scheiblreiter (1982). Furthermore, he detected that their temperature preferences differed. According to the latter, *H. saxonica* is more adapted to water temperatures between 15 and 20 °C, whereas *H. instabilis* prefers temperatures between 20 and 25 °C. Hildrew and Eddington (1979) found *H. instabilis* in the upper tributaries of the river Usk in Wales, which had a maximum water temperature of 23 °C. With a temperature maximum of 18.9 °C at the sampling site Prinzbach, the dominance of *H. saxonica* is congruent with these findings. Nonetheless, Philipson (1969) measured the net spinning activity of *H. instabilis* which were highest values at 12 °C, which matches the water temperatures during the sampling season at Klamm. The low frequency of *H. instabilis* at Prinzbach compared to Klamm might be due to other local parameters that were not recorded in this study.
In accordance with Scheiblreiter's conclusion that *H. fulvipes* prefers colder water, only 4 % were detected at Prinzbach sampling site in contrast to 8 % at Klamm.

## 1.3. Altlengbach

In Altlengbach a very interesting shift of Hydropsychidae species has occurred since the study of Scheiblreiter in 1982. The total species number of three increased to seven species of the genus *Hydropsyche*. Not only the quantity changed, but the species dominance has shifted as well. While in 1982, *H. instabilis* was clearly dominant (74 %) with *H. saxonica* (18 %) and *H. pellucidula/incognita* (8 %) being only co- and subdominant, the 2014 study showed a dominance of *H. saxonica* (49 %), followed by *H. instabilis* (25 %) and five sympatric Hydropsychidae species (*H. fulvipes, H. pellucidula/incognita, H. siltalai, C. lepida, H. bulbifera*).
Consequently, *H. saxonica* not only replaced *H. instabilis* as the dominant species at three sampling sites (Prinzbach, Altlengbach, Laaben), it also increased in abundance and moved downstream in the Lengbach since 1982. Scheiblreiter (1982) hypothesized that the high

abundance of *H. instabilis* can be explained by a higher resistance against dense algal mats, compared to *H. saxonica*. Due to the partially algae-covered sediment in Altlengbach in 2014 (Table 11), that hypothesis can be rejected.

With the three new species at the sampling site Altlengbach (*H. siltalai, C. lepida, H. bulbifera*) the species diversity increased since 1982. In many studies, *H. siltalai* inhabited the upper- or middle but never the lower reaches of a river (Feio et al., 2005; Roux et al., 1992; Malicky, 2014). In the Rhone, Roux et al. (1992) reported *H. siltalai* in the rhithral zone of the river. Although it was found nearly everywhere in the rhithral, it was always rare (<1 %). In the Mondego River basin in Portugal, Feio et al. (2005) also detected *H. siltalai*, but never in the lower reaches. In the light traps deployed by Malicky (2014), *H. siltalai* and *H. instabilis* most often occurred together, as co-dominant species, in many upper reaches of Austrian rivers. This agrees with the results of the present study. For this sampling site, Scheiblreiter (1982) measured a water quality of III. In 2014, the measured water quality was II (CI: 64), which indicates an improvement in water quality over the last 32 years. As *C. lepida* and *H. bulbifera* are the most tolerant species with respect to pollution, their upstream movement must be due to other ecological factors.

### 1.4. Laaben

In 1982, *H. instabilis* dominated (96 %) at the sampling site. This has now changed into a co-dominance of *H. saxonica* (42 %) and *H. instabilis* (40 %) (Table 20). Similar to Altlengbach and Prinzbach the frequency of *H. saxonica* increased since 1982. *H. saxonica* is now present not only in a larger section of the river but has also moved further downstream within the reach. This might reflect a better water quality.

Scheiblreiter (1982) did not record *H. pellucidula/incognita*, whereas in this study it accounted for 15 %. While in 1982 *H. pellucidula/incognita* occurred only in Altlengbach, it was now detected at four different sampling sites. This leads to the conclusion that *H. pellucidula/incognita* has expanded its habitat in the Große Tulln catchment over the last 32 years. As Roux et al. described in 1992, *H. pellucidula* is ubiquitous in the Rhone River and has a typical rhithral/potamal respiratory distribution. This was confirmed by Graf et al. (2002), who categorized *H. pellucidula* and *H. incognita* as epirhithral and epipotamal species. Because *H. pellucidula/incognita* are euryoecous and were recorded at the sampling site Laaben in 1982, no conclusions about water quality can be drawn. Scheiblreiter (1982) measured water quality class I/II at Laaben, which is similar to our results (water quality II, CI: 65). Accordingly, the stream at Laaben is apparently unpolluted and no human-induced pollution has been reported since 1982.

## 1.5. Neulengbach

In 1982, *H. bulbifera* showed a very clear dominance of 97 % at the sampling site Neulengbach (Scheiblreiter, 1982) (Table 20). This changed by 2014, when *H. bulbifera* remains the dominant species, but its percentage distribution decreased to 41 %. Like in Altlengbach, the total number of Hydropsychidae species increased. Two new species have been found at this sampling site since then. Together with *H. saxonica,* the abundance of the euryoecous species *H. siltalai* and *H. pellucidula/incognita* increased since 1982. No co-occurrence of *H. siltalai* and *H. pellucidula/incognita* was recorded in the present study, but it has been observed elsewhere. An example is the Usk River (Wales, Great Britain), where *H. siltalai* and *H. pellucidula/incognita* coexist along a 60-km-long stretch of tributaries and rhithron reaches (Hildrew and Edington, 1979). Furthermore, Basaguren and Orive (1990) stated their coexistence in the Cadagua River basin in Spain.

A comparison of water quality again shows a difference between 1982 (water quality III) and 2014 (water quality II, CI: 65). This fits with the abundance decrease of *H. bulbifera*, which is known to be the most tolerant species with respect to water quality, oxygen and water-temperatures (Scheiblreiter, 1982). Some studies also observed it to be the dominating species at high organic pollution (Basaguren & Orive, 1990; Feio et al., 2005). This, and the down-stream movement of *H. saxonica*, indicates a better sewage treatment at Neulengbach.

*C. lepida*, which is classified as a potamal species in the Fauna Aquatica Austriaca (Graf et al., 2002), showed its highest abundance at the sampling site Neulengbach and was not found at Langenrohr, the only potamal reach of the Große Tulln. Scheiblreiter (1982) had very similar results and hypothesized that *C. lepida* is much more euryoecous than expected (e.g. Malicky, 1978). The current results suggest that it has a high tolerance range for different water temperatures and saprobity. A similar result was found in the Mondego River basin in Portugal, where *C. lepida* was found in middle reaches, while *H. bulbifera* inhabited lower reaches which where higher organically polluted (Feio et al., 2005). In light traps deployed by Malicky (2014), adults of *C. lepida* were captured along the Danube at Linz and in large lowland rivers such as the Traun. This supports its euryoecous character.

### 1.6. Langenrohr

At the sampling site Langenrohr the same species were found as in 1982. This suggests similar conditions concerning water quality and river morphology. In 1982, Scheiblreiter defined a water quality of II at Langenrohr, which he explained by self-purification of the Große Tulln downstream of Neulengbach (water quality III). The present study also yielded a water quality of II here. The dominant species is *H. bulbifera* (79 %), compared to 80 % in 1982. It coexists with *H. angustipennis* (20 %), the latter being 1% more abundant than in 1982.
The most pollution-tolerant species, *H. bulbifera*, indicates the transition zone of the hyporhithral to the epipotamal sections of small rivers (Waringer, 2011). *H. bulbifera* is also found in potamal reaches with mainly sandy and muddy sediments (Otto, 1995).
The sampling site Langenrohr is a riffle (horse ford) where small gravel with dense algal mats dominate the sediment (Table 17). This leads to the conclusion that *H. bulbifera* can tolerate larger sediment particle sizes. Normally, small, polluted lowland rivers are inhabited by *H. angustipennis* (Malicky, 1977), which is also confirmed by its highest abundance at this sampling site.
Although *C. lepida* is classified as an epipotamal species (Graf et al. 2002), it was absent at this sampling site both then and today. Nonetheless, this cannot be due to the fast-flowing section of the river because *C. lepida* was found (12 %) at the sampling site Neulengbach, which is a fast-flowing riffle.

## 2. Habitat parameters

Changes in habitat parameters can have many effects on the distribution of insects (Antvogel & Bonn, 2001; Subramanian & Sivaramakrishnan, 2005). In water, one of these important parameters is temperature regulation. This regulation depends manly on the geometry of the water mass and water density (Schwoerbl & Brendelberger, 2005). In summer-warm streams such as the Große Tulln (Schwoerbl & Brendelberger, 2005), water temperature increases from spring to mouth (Hauer et al., 2000; Macan, 1958; Edington, 1966; Langford, 1970; Edington & Hildrew, 1973; Boon & Shires, 1976). In such stream types, water temperature commonly reaches a minimum of 0 °C in winter, whereas in summer temperature can even exceed 30 °C (Hauer and Benke 1986; Lowe and Hauer 1999). With maxima between 21.9 °C and 26.7 °C, the Große Tulln can be classified as a summer-warm stream. In Table 21 the sampling sites are ranked from spring to mouth and, except for the sampling site Prinzbach, water temperature increases downstream. The slightly warmer maximum temperature at Prinzbach might be explained by higher solar radiation, as the canopy was not completely closed at this site. The minimum water temperatures do not completely follow this pattern.

The temperature profile along the stream continuum is often very distinctive and can therefore be used for classification of running waters (Ule, 1925; Brehm & Ruttner, 1926). The first differentiations into glacier-, spring-, mountain- and lowland rivers involved determining annual and daily water temperature amplitudes based on longitudinal zonation (Illies, 1952, 1961; Ward, 1986), as discussed in detail by Wimmer and Moog (1994). The connection between maximum daily temperature amplitude and stream order number was established by Vannote and Sweeney (1980), where diurnal water temperature pulses are well correlated with the latter (Figure 26). Accordingly, the highest temperature amplitudes are present in the lower headwaters and middle reaches, which does not fully agree with the observed pattern in the Große Tulln. This deviation can be mostly explained by shading effects of the canopy or its removal.

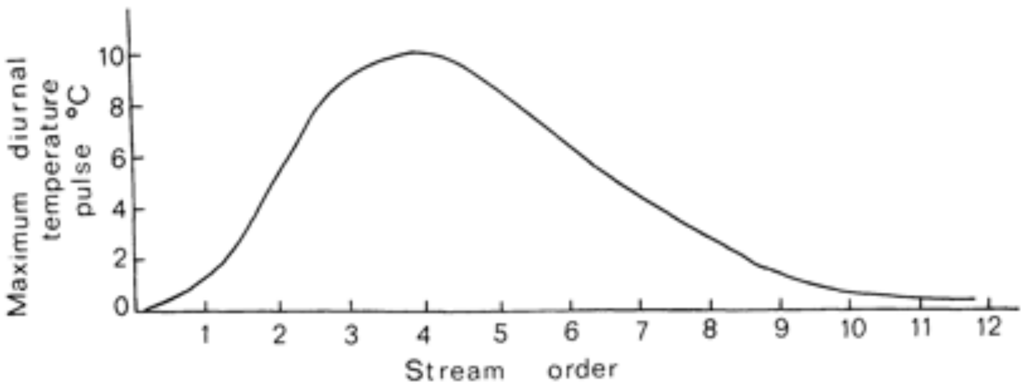



**Figure 26. Maximum daily water temperature amplitudes over the range of Strahler stream orders (modified by: Vannote & Sweeney, 1980).**

## 3. Biometry

Biometry of insects has been the object of study since the 1890s, when Dyar measured the head capsule widths of Lepidoptera larvae and described a discontinuous growth. A stepwise growth with each molt by a constant factor was also observed (Dyar 1890; Chapman 1998). This stepwise growth of head capsule width was used to determine the larval instar (Daly, 1985). This method was later also described for caddisflies (Oswood 1976; Hauer & Standford, 1982; Sieglstetter et al., 1997; Hrovat & Urbanis, 2012) and other insects (Logan et al., 1998). The correlation of head capsule width and dry weight showed a significant increase (Figure 19). This was also demonstrated by Benke et al. in 1999.

Within this study, the stepwise growth between 4$^{th}$ and 5$^{th}$ larval instars was best illustrated by the data of *H. saxonica* (n=43) and *H. bulbifera* (n=56) (Figure 18). For *H. pellucidu-*

*la/incognita* (n= 20) and *H. instabilis* (n=22) this gap between penultimate and ultimate instar was less obvious, most probably because of insufficient data. *H. instabilis*, for example, inhabits a broad range of habitats from hyporhithral to headwaters. This exposed them to many different abiotic and biotic parameters, which could trigger differences in development at the different sites. In the Große Tulln catchment, the Hydropsychidae species ranked according to the ultimate instar from small to larger was as follows: *H. saxonica, H. pellucidula/incognita, H. instabilis* and *H. bulbifera*.

An interesting hypothesis of Alstad (1982) proposes a decrease of body size from upstream to downstream, due to the downstream decrease of flow velocity and POM size (Vannote et al., 1980). For the Hydropsychidae in the Große Tulln catchment, this hypothesis could be only partly confirmed. In Table 22 the species are ranked from smallest to largest head capsule width. This also reflects their occurrence in the river continuum. Only *H. instabilis* and *H. pellucidula/incognita* did not follow this pattern because they both already belong to middle reach communities. As the 5$^{th}$ instars of *H. bulbifera* have the smallest head capsule widths, the hypothesis of downstream size decrease is proven.

There is an ongoing debate about the influence of large-scale changes of flow velocity and POM size on the distribution of Hydropsychidae. Some studies show that flow velocity changes in microhabitats have a much greater influence on population structure than large-scale changes (Williams & Hynes, 1973; Georgian & Thorp, 1992). To support this thesis, Osborne and Herricks (1987) examined the correlation between flow velocity and *Hydropsyche* body size but could not find any significant results; in fact they detected a strong overlap in flow velocity preferences between *Hydropsyche* species.

## 4. Respiration

In aquatic insects, oxygen is taken up by passive diffusion and triggered by concentration differences (Spicer & Gaston, 1999; Jacobsen, 2000). Two temperature-dependent factors limit oxygen uptake: the kinematic viscosity of water and the diffusion coefficient of oxygen (Rostgaard & Jacobsen, 2005).

In aquatic environments, the availability of oxygen is one of the most important parameters for benthic communities (Ward, 1992; Chapman et al., 2004; Uzunov & Kovachev, 1987). The distribution of aquatic insects can highly be influenced by oxygendepletion. This, in turn, can impact the ecological recovery of aquatic systems (e.g. Neumann, 1994; Becker, 1987). In inland waters, fluctuations in oxygen concentrations are a result of complex diurnal and annual variations depending on abiotic and biotic parameters such as current velocity, light intensity, human activities and additional input of organic matter (e.g. Jacob & Walther, 1981; Paerl et al., 1998).

## 4.1. Respiration blanks

In aquatic environments, respiration is one of the most complicated parameters to measure. Nonetheless, it is of great ecological and biogeochemical importance and crucial for our understanding of the global carbon cycle. In water, four key biological components determine overall respiration: bacteria, algae, heterotrophic protists and zooplankton (Del Giorgio & Williams, 2005). Solomon et al. (2013) reported a background respiration ranging from 0.017 to 2.1 mg $O_2$ $l^{-1}$ $d^{-1}$, which is the range of the present study (0.0 - 0.3 mg $O_2$ $l^{-1}$ $h^{-1}$). For the four experimental temperatures (5, 10, 15 and 25 °C) the blank respiration measurements of penultimate and ultimate instars were not significant (Figure 20).

## 4.2. Respiration rates versus dry weight in larval *Hydropsyche*

A key topic in physiology is the correlation between metabolic rates and body size. When discussing respiration rates in relation to dry weight, it is clear that metabolic mechanisms will always vary with body size due to the enormous diversity in the organisms' anatomy, physiological processes, adaptations to different environmental parameters, etc. (Adolph, 1949). Thereby, absolute body size is a mandatory factor in order to determine many physiological processes (Bertalanffy, 1957). Major advances in understanding the correlation between weight and metabolic rates were made more than 160 years ago. Early results demonstrated that oxygen consumption decreases with increasing body size (Sarrus & Rameaux, 1839; Bergmann, 1847; Bergmann & Leukart, 1852; Richet, 1885, 1889). The results of the present study clearly agree with this principle (Figure 21a). This was also evident when examining the penultimate and ultimate instars. As shown in Figure 21b, $4^{th}$ larval instars show a significantly higher respiration rate than $5^{th}$ larval instars. Based on Figure 19, penultimate instars have a lower dry weight than ultimate instars. Subdividing penultimate larval instars into weight classes, a decrease of oxygen consumption was significant only in the first three groups (Figure 22a). The increase of the higher weight classes was not significant and remains unclear. Figure 22b also confirms the hypothesis of respiratory decrease with higher dry weight.

## 4.3. Respiration rates versus water temperature in larval *Hydropsyche*

### 4.3.1. Respiration rates of *Hydropsyche* larvae of constant temperatures in the laboratory

In the upstream and middle reaches of a stream, the high turbulent flow, low microbial respiration and higher solubility of oxygen at low water temperatures create oxygen concentrations close to saturation (Rostgaard & Jacobsen, 2005). The water used for the experimental treatments was stirred and thereby enriched with oxygen. At the beginning of each respiration measurement, the oxygen saturation ranged from 90 to 100 % (Truesdale et al., 1955).

Besides oxygen saturation also temperature, activity level, supply and quality of food, and physical and chemical stress affect metabolism and therefore oxygen consumption (Rostgaard & Jacobsen, 2005). Especially in temperate regions, respiration rates of macroinvertebrates range broadly with temperature (Collardeau, 1961; Feldmeth, 1970; Philipson & Moorhouse, 1976; Hildrew & Edington, 1979; Roux, 1979; Howell & Voshell, 1982; Bales & Badcock, 1986). In the present study, *Hydropsyche* larvae were acclimatized for several days or weeks prior to the respiration measurements. Generally, measuring single specimens at different temperatures may not fully display respiration patterns of natural assemblages at different temperatures (Hynes, 1970).

For trichopterans with dry weights of 2 mg, Colardeau (1961) measured respiration rates of 0.7-2.4 mg $O_2$ $g^{-1}$ dry weigth $h^{-1}$ at temperatures between 10 and 25°C. Rostgaard and Jacobsen (2005) report somewhat higher respiration rates between 2.0 and 4.1 mg $O_2$ $g^{-1}$ dry weigth $h^{-1}$ at temperatures between 10 and 24°C. The latter values were also observed in the present study. For the 5°C experiment, respiratory rates were close to 1.5 mg $O_2$ $g^{-1}$ dry weigth $h^{-1}$. Compared to Colardeau (1961), the higher values could be explained by the method used: closed bottles and shorter experimental duration result not only in higher respiration rates, but also in increased data scatter (Kamler, 1969). This was also observed when the experimental water was stirred (Feldmeth, 1970; Roux, 1979; Golubkov et al., 1992) and artificial substrate was present (Roux, 1979).

In 1979, Hildrew and Edington observed an increase of the respiration rate with increasing temperature. Except for the 15 °C measurement of *H. instabilis* and *H. pellucidula/incognita*, this was also observed in the present study (Figure 23). For penultimate instars (Figure 24), this pattern was less clear and only valid for *H. instabilis* and *H. pellucidula/incognita*. Edington and Hildrew (1973) explained this observation by an increase in the efficiency of assimilating energy into tissue growth and in adjusting activity levels to resource availability.

### 4.3.2. Respiration rates versus longitudinal distribution of larval *Hydropsyche*

In *Hydropsyche* distinct longitudinal zonation patterns from headwater to mouth can be observed (Decamps 1968; Badcock 1974; Gordon & Wallace 1975; Hildrew & Edington 1979; Alstad 1980, 1986). This succession reflects changes in ambient water temperature and respiratory rates (Hildrew & Edington, 1979; Roux et al., 1992). Generally, low oxygen consumption is the basis for minimizing respiration losses and for optimizing incorporation of food items; these mechanisms also explain the succession of the four species studied. While *H. saxonica* and *H. instabilis* apparently have optimal respiratory rates at 5 – 10 °C, *H. instabilis* and *H. pellucidula/incognita* prefer ambient water temperatures of 15 – 25 °C.

# References

Adolph, E. F. 1949. "Quantitative relations in the physiological constitutions of mammals." *Science*, 109: 579-585.

Alstad, D. N. 1982. "Current speed and filtration rate link caddisfly phylogeny and distributional patterns on a stream gradient." *Science*, 216: 533-534.

Alstad, D. N. 1980. "Comparative biology of the common Utah Hydropsychidae (Trichoptera)." *Amer. Midl. Nat.,* 103: 167-174.

Alstad, D. N. 1986. "Dietary overlap and net-spinning caddisfly distributions." *Oikos*, 47: 251-252.

Annales Fuldenses Pars. IV. 884. "Imperator in terminis Noricorum et Sclavorum cum Zuentibaldo colloquium habuit; Pars V, 884, prope flumen Tullinam, Monte Camiano colloquium habuit". Commission zur Pflege vaterländischer Geschichte der kaiserlichen Akademie der Wissenschaften (Hrsg.): *Archiv für Kunde österreichischer Geschichts-Quellen. 10. Band*, kaiserlich-königliche Hof- und Staatsdruckerei, Wien 1853, 11 p.

Antvogel, H. & Bonn, A. 2001. "Environmental parameters and microspatial distribution of insects: a case study of carabids in an alluvial forest." *Ecography,* 24: 470-482.

Badcock, R. M. 1974. "The distribution of the Hydropsychidae in Britain." - In: Malicky, H. (ed.), Proc. *1st Int. Symp. Trichoptera*, Junk, The Hague, 49-58 pp.

Bales, M. T. & Badcock, R. M. 1986. "Respiration rates and distribution of caddis larvae in relation to acclimation to temperature." *In Proceedings of the 5th International Symposium on Trichoptera*, Lyon, 179-183 pp.

Basaguren, A. & Orive, E. 1990. "The relationship between water-quality and caddisfly assemblage structure in fast running rivers – The river Cadagua basin." *Environmental Monitoring and Assessment,* 15: 35-48.

Benedetto Casto, L. 1975. "Ökologie und Produktionsbiologie von *Agapetus fuscipes* CURT. im Breitenbach 1971-1972". *Archiv für Hydrobiologie*, Supplement 45, 305-375.

Becker, G. 1987. "Net-building behaviour, tolerance and develop- ment of two caddisfly species from the river Rhine *(Hydropsyche contubernalis* and *H. pellucidula)* in relation to the oxygen content." *Oecologia,* 73: 242-250.

Benke, A. C., Huryn, A. D., Smock, L. A. & Wallace, J. B. 1999. "Length-mass relationships for freshwater macroinvertebrates in North America with particular reference to the southeastern United States." *Journal of the North American Benthological Society,* 18: 308-343.

Bergmann, C. 1847. "Über die Verhältnisse der Wärmeökonomie der Tiere zu ihrer Grösse." *Göttinger Studien*, 1: 1-395.

Bergmann, C. & Leuckart, R. 1852. "Anatomisch-physiologische Übersicht des Tierreichs." *J.B. Mueller*, Stuttgart.

Bertalanffy v., L. 1957. "Quantitative Laws in Metabolism and Growth." *The Quarterly Review of Biology*, 32, 3: 217-231.

Bochert, R. & Biele, S. 2005. "Ein Beitrag zur Kenntnis der Trichoptera-Fauna Mecklenburg-Vorpommerns: Warbel und Thuerkower Bach." *Lauterbornia,* 55: 25- 34.

Boon, P. J. 1976. "Studies on the distribution of certain caddis-fly larvae in the North Tyne river system, with particular reference to the Hydropsychidae (Insecta, Trichoptera)." *Unpublished Ph.D. thesis*, University of Newcastle-upon-Tyne.

Boon, P. J. & Shires, S. W. 1976. "Temperature studies on a river system in north-east England." *Freshwater Biology*, 6: 23-32.

Botosaneanu, L. 1967. "Trichoptera". In Illies, J. (Hrsg.) 1967. "Limnofauna Europaea: Eine Zusammenstellung aller die europäischen Binnengewässer bewohnenden mehrzelligen Tierarten mit Angaben über ihre Verbreitung und Ökologie". *Gustav Fischer*, Stuttgart, 474 pp.

Braukmann, U. 1987. "Zoozönologische und saprobiologische Beiträge zu einer allgemeinen regionalen Bachtypologie". *Schweizerbart*, Stuttgart, 355 pp.

Brehm, V. & Franz Ruttner. 1926. "Die Biocönosen der Lunzer Gewässer." *Internationale Revue der gesamten Hydrobiologie und Hydrographie,* 16: 281-331.

Chapman, R. F. 1998. "The insects: structure and function. 4th edition." *Cambridge University Press*, Cambridge, 771 pp.

Chapman, L. J., Schneider, K. R., Apodaca, C. & Chapman C. A. 2004. "Respiratory Ecology of Macroinvertebrates in a Swamp- River System of East Africa." *Biotropica,* 36: 572-585.

Collardeau, C. 1961. "Influence de la température sur la consommation d ´oxygéne de quelques laves de Trichoptéres." *Hydrobiologia,* 18: 252–264.

Curtis, McLachlan, Pitsch & Pictet. 2013. "Trichoptera, Hydropsychidae. Fauna Europaea" Version 2.6.2, http://www.faunaeur.org (accessed on 27.04.2015).

Daly, H. V. 1985. "Insect morphometrics." *Annual Review of Entomology,* 30: 415-438.

Décamps, H. 1968."Vicariance écologique chez les Trichopteres des Pyrénées.- *Ann. Limnol.,* 3: 339-577.

Del Giorgio, P. A. & Williams P. J. le B. 2005. eds. "Respiration in aquatic ecosystems." *Oxford University Press*, USA, 315 pp.

Dyar, H. G. 1890. "The number of moults of lepidopterous larvae." *Psyche,* 5: 420-422.

Dzulynski, S., Ksiazkiewicz, M. & Kuenen, Ph. H. 1959. "Turbidites in flysch of the Polish Carpathian Mountains." *Geological Society of America Bulletin,* 70: 1089-1118.

Edington, J. M. 1962. "The autecology and taxonomy of certain trichopterous larvae." *Unpublished Ph.D. thesis*, University of Durham, 131 pp.

Edington, J. M. 1966. "Some observations on stream temperature." *Oikos*, 15: 265-273.

Edington, J. M. & Hildrew, A. G. 1973. "Experimental observations relating to the distribution of net-spinning Trichoptera in streams." *Verhandlungen der Internationalen-Vereinigung für theoretische und angewandte Limnologie*, 18: 1549-1558.

Feio, M. J., Vieira-Lanero, R., Ferreira, V. & Graca, M. A. S. 2005. "The role of environment in the distribution and composition of Trichoptera assemblages in streams." *Archiv für Hydrobiologie,* 164: 493-512.

Feldmeth, C. R. 1970. "The respiratory energetics of two species of stream caddis fly larvae in relation to water flow." *Comparative Biochemistry and Physiology,* 32: 193–202.

Fischer, F. C. J. 1960-1973. "Trichopterorum Catalogus". Bd. 1-15. Amsterdam.

Gaufin, A. R. & Tarzwell, C. M. 1952. "Aquatic invertebrates as indicators of stream pollution". *Public Health Reports*, 67: 57-64.

Georgian, T. J. & Thorp, J. H. 1992. "Effects of microhabitat selection on feeding rates of net-spinning caddisfly larvae." *Ecology,* 73: 229-240.

Golubkov, S. M., Tiunova, T. M. & Kocharina, S. L. 1992. "Dependence of the respiration rate of aquatic insects upon the oxygen concentration in running and still water." *Aquatic Insects*, 14: 137–144.

Gordon, A. E. & Wallace, J. B. 1975. "Distribution of the family Hydropsychidae (Trichoptera) in the Savannah river basin of North Carolina, SouthCarolina and Georgia." *Hydrobiologia,* 46: 405-423.

Graf, W., Grasser, U. & Waringer, J. 2002. "Trichoptera.- Teil III. In: MOOG, O. (Ed.), Fauna Aquatica Austriaca (2nd Ed)." *Wasserwirtschaftskataster*, Bundesministerium für Land- und Forstwirtschaft, Umwelt und W asserwirtschaft, Wien, 43 pp.

Graf, W. & Hutter G. 2002. "Köcherfliegen (Insecta:Trichoptera) aus Vorarlberg (Österreich), I-Vorstellung des Projektes: Erforschung der Köcherfliegenfauna Vorarlbergs und erste Ergebnisse". *Vorarlberger Naturschau*, Dornbirn, 11: 223-226.

Graf, W., Murphy, J., Dahl, J., Zamora-Munoz, C. & Lopez-Rodriguez, M. J. 2008. "Distribution and ecological preferences of European freshwater organisms. Volume 1. Trichoptera". *Sofia-Moscow, Pensoft Publishing*, 388 pp.

Graf, W., Murphy, J., Dahl, J., Zamora-Muñoz, C., López-Rodríguez M. J. & Schmidt-Kloiber, A.: Dataset "Trichoptera". www.freshwaterecology.info - the taxa and autecology database for freshwater organisms, Version 6.0 (accessed on 25.06.2015).

Hable, S. 2015. "Net structure and species inventory of the Hydropsychidae species (Trichoptera) of the Große Tulln catchment (Lower Austria)". *Masterarbeit Universität Wien*, 81 pp.

Hauer, F. R. & Stanford, J. A. 1982. "Ecology and life histories of 3 net spinning cad- disfly species (Trichoptera: Hydropsychidae) in the Flathead river, Montana, USA." *Freshwater Invertebrate Biology,* 1: 18-29.

Hauer, F. R. & Benke, A. C. 1987. "Influence of temperature and river hydrograph on backfly growth rates in a subtropical blackwater river." *Journal of the North American Benthological Society,* 6: 251-261.

Hauer, F. R., Stanford, J. J. & Giersch, J. J. 2000. "Distribution and abundance patterns of macroinvertebrates in a mountain stream: An analysis along multiple environmental gradients." *Verhandlungen der Internationalen Vereinigung für Theorestische und Angewandte Limnologie,* 27: 1485–1488.

Hauer, F. R. & Hill, W. R. 2007. "Chapter 5 - Temperature, Light, and Oxygen, In: Methods in Stream Ecology (Second Edition)." *Academic Press*, 103–117.

Hildrew, A. G. 1970. "Ecological and physiological studies on some net-spinning Trichoptera in relation to their distribution." *Unpublished Ph.D. thesis*, University of Wales.

Hildrew, A. G. & Edington, J. M. 1979. "Factors facilitating the coexistence of Hydropsychid caddis larvae (Trichoptera) in the same river system." *Journal of animal ecology,* 48: 557-576

Howell, D. A., Voshell, J.R. & Jr. 1982. "The effects of body weight and temperature on the metabolic rate of *Hydropsyche* venularis Banks (Trichooptera: Hydropsychidae)." *Comparative Biochemistry and Physiology,* 71: 401–405.

Hrovat, M. & Urbanic, G. 2012. "Life cycle of Rhyacophila fasciata Hagen, 1859 and *Hydropsyche* saxonica McLachlan, 1884 in a Dinaric karst river system." *Aquatic Insects,* 34: 113-125.

Hynes, H. B. N. 1970. "The Ecology of Running Waters." *Liverpool University Press*, Liverpool, 555 pp.

Illies, J. 1952. "Die Mölle." *Arch. f. Hydrolbiologie,* 46: 424-612.

Illies, J. 1961 "Versuch einer allgemeinen biozönotischen Gliederung der Fließgewässer." *Internationale Revue der gesamten Hydrobiologie und Hydrographie,* 46: 205-213.

Jacob, U. & Walther, H. 1981. "Aquatic insects larvae as indicators of limiting minimal contents of dissolved oxygen." *Aquatic Insects,* 3: 219-224.

Jacobs, W. & Renner, M. 2007. "Biologie und Ökologie der Insekten. Ein Taschenlexikon". 4. Auflage. *Elsevier GmbH,* München, 756 pp.

Jacobsen, D. 2000. "Gill size of trichopteran larvae and oxygen supply in streams along a 4000 m altitude gradient of altitude." *Journal of the North American Benthological Society*, 19: 329–343.

Kamler, E. 1969. "A comparison of the closed-bottle and flowing-water methods for measurement of respiration in aquatic invertebrates." *Polskie Archiwum Hydrobiologii*, 16: 31–49.

Kerans, B. L. & Karr, J. R. 1994. "A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley." *Ecological Applications*, 4: 768-785.

Klemm, D. J., Blocksom, K. A., Thoeny, W. T., Fulk, F. A., Helihy, A. T., Kaufmann, P. R. & Cormier, S. M. 2002. "Using macroinvertebrates as indicators of ecological conditions for streams in the Mid-Atlantic highlands region". *Environmental Monitoring and Assessment*, 78: 169-212.

Kölbl, K. 2006. "Wassermoose als Bioindikatoren für Gewässergüte in Fließgewässern am Beispiel von drei Flüssen in Niederösterreich, Traisen, Perschling und Große Tulln." *Diplomarbeit Universität Wien*. 50 pp.

Langford, T. E. 1970. "The temperature of a British river upstream and downstream of a heated discharge from a power station." *Hydrobiologia*, 35: 353-375.

Logan, J. A., Bentz, B. J., Vandygriff, J. C. & Turner, D. L. 1998. "General program for determining instar distribution from headcapsule widths: example analysis of mountain pine beetle (Coleoptera: Scolytidae)." *Environmental Entomology,* 27: 555-563

Lowe, W. H. & Hauer, F. R. 1999. " Ecology of two net-spinning caddisflies in a mountain stream: distribution, abundance and metabolic response to a thermal gradient." *Canadian Journal of Zoology,* 77: 1637-1644.

Macan, T. T. 1958. "The temperature of a small stony stream." *Hydrobiologia,* 12: 89-106.

Malicky, H. 1973."Trichoptera (Köcherfliegen)". In: Helmcke, J. G., Starck, D. & Wermuth, H. (Hrsg.). "Handbuch der Zoologie". IV Band: Arthropoda, 2. Hälfte: Insecta. Zweite Auflage. 2. Teil: Spezielles: 29, *De Gruyter*, Berlin, New York, 114 pp.

Malicky, H. 1977. "Trichoptera (Köcherfliegen)." In: *Handbuch der Zoologie*, IV Band, Arthropoda, Zweite Auflage, Lunz am See, 114 pp.

Malicky, H. 1978. "Koecherfliegen-Lichtfallenfang am Donauufer in Linz (Trichoptera)." *Linzer biologische Beiträge,* 10: 135-140.

Malicky, H. 2013. "Fauna Europaea: Trichoptera,Hydropsychidae". Fauna Europaea version 2.6.2, http://www.faunaeur.org.

Malicky, H. 2014. "Lebensräume von Köcherfliegen (Trichoptera)." *Denisia,* 34: 280 pp.

Morse, J. C. 2011. "The Trichoptera World Checklist" *Magnolia Press*, Zoosymposia, 5: 372-380.

Nessimian, J. L. & Dumas, L. L. 2010. "Description of the immature stages of Leptonema tridens (Insecta: Trichoptera: Hydropsychidae) from southeastern Brazil with notes on its biology." *Zoologia (Curitiba),* 27: 465-471.

Neumann, D. 1994. "Ökologische Probleme im Rheinstrom." *Nord- rhein-Westfälische Akademie der Wissenschaften,* 407: 43-83.

Nielsen, A. 1942. "Über die Entwicklung und Biologie der Trichopteren mit besonderer Berücksichtung der Quelltrichopteren Himmerlands". - *Archiv für Hydrobiologie*, Supplement 17: 255-631.

Osborne, L. L. & Herricks, E. E. 1987. "Microhabitat characteristics of *Hydropsyche* (Trichoptera: Hydropsychidae) and the importance of body size." *Journal of the North American Benthological Society,* 6: 115-124.

Oswood, M. W. 1976. "Comparative life histories of the Hydropsychidae (Trichoptera) in a Montana lake outlet." *American Midland Naturalist,* 96: 493-497.

Paerl, H. W., Pinckney, J. L., Fear, J. M. & Peierls, B. L. 1998. "Ecosystem responses to internal and watershed organic matter loading: Consequences for hypoxia in the eutrophying Neuse river estuary, North Carolina, USA." *Marine Ecology Progress Series,* 166: 17-25.

Philipson, G. N. 1954."The effect of water flow and oxygen concentrationon six species of caddisfly (Trichoptera) larvae." - *Proc. Zool. Soc.,* London, 124: 547-564.

Philipson, G. N. 1969. "Some factors affecting the net-spinning of the caddis fly Hydropsyche instabilis Curtis (Trichoptera, Hydropsychidae)." *Hydrobiologia,* 34: 369-377.

Philipson, G. N. 1976. "Respiratory behaviour of larvae of four species of the Family Polycentropodidae (Trichoptera)." *Freshwater Biology*, 6: 347–353.

Plöchinger, B. & Prey, S. 1993. "Der Wienerwald: mit 3 Tabellen im Text. (Second edition)" *Borntraeger,* Berlin, 168 pp. ISBN: 3-443-15059-4.

Richet, C. 1885. „Récherches de calorimetre“. *Arch. Physiol,* 6: 237-291.

Richet, C. 1889. „La chaleur animale.“ Paris, 307 pp.

Roux, C. 1979. "The influence of some ecological factors on the metabolism–temperature curve of the larvae of Limnephilus rhombicus (Trichoptera, Limnephilidae)." *Freshwater Biology,* 9: 111–117.

Roux, C., Tachet, H., Bournaud, M. & Cellot, B. 1992. "Stream continuum and metabolic rate in the larvae of five species of *Hydropsyche* (Trichoptera)." *Ecography,* 15: 70-76.

Rostgaard, S. & Jacobsen, D. 2005. "Respiration rate of stream insects measured in situ along a large altitude range." *Hydrobiologia,* 549: 79-98.

Sarrus & Rameaux. 1839. „Application des sciences accessoires et principalement des mathématiques à la physiologie générale.“ *Bull. Acad. R. Med,* 3: 1094-1100.

Solomon, C.T., et al. 2013. "Ecosystem respiration: drivers of daily variability and background respiration in lakes around the globe." *Limnology and Oceanography,* 58: 849-866.

Scheiblreiter, H. 1982. "Ein Beitrag zur Kenntnis der Köcherfliegenfauna der Großen Tulln (Niederösterreich)." *Dissertation Universität Wien*, Wien, 309 pp.

Schmidt-Kloiber, A. & Hering, D. 2015. www.freshwaterecology.info - an online tool that unifies, standardises and codifies more than 20,000 European freshwater organisms and their ecological preferences. Ecological Indicators, 53: 271-282. doi: 10.1016/j.ecolind.2015.02.007 (accessed on 25.06.2015).

Schwoerbel, J. & Brendelberger, H. 2005. "Einführung in die Limnologie. 9. Auflage." *Elsevier GmbH*, München, 340 pp.

Sieglstetter, R., Agasse, F. & Caquet, T. 1997. "Ecological segregation of two species of *Hydropsyche* (Trichoptera: Hydropsychidae) in a European second-order stream (Essonne, France)." *Journal of Freshwater Ecology*, 12: 269-279.

Stadler, F. C. 1992. "Untersuchung der Süßwasser-Molluskenfauna der niederösterreichischen Donauzubringer Kleine Tulln, Große Tulln und Pielach, mit besonderer Berücksichtigung und Demonstration statistisch-numerischer Analysemethoden." *Diplomarbeit Universität Wien*, 80 pp.

Spicer, J. I. & Gaston, K. J. 1999. "Amphipod gigantism dictated by oxygen availability." *Ecology Letters,* 2: 397–403.

Subramanian, K. A. & Sivaramakrishnan, K. G. 2005. "Habitat and microhabitat distribution of stream insect communities of the Western Ghats." *Current Science,* 89: 976-987.

Truesdale, G. A., Downing, A. L. & Lowden, G. F. 1955. "The solubility of oxygen in pure water and sea water." *J. appl. Chem.*, London, 5: 53-62.

Ule, W. 1925. "Physiographie des Süßwassers." *Leipzig; Wien: Deuticke*, 154 pp.

Uzunov, Y. & Kovachev, S. 1987. "The macrozoobenthos of Struma River: An example of a recovered community after the elimination of a heavy industrial impact with suspended material." *Arch. Hydrobiol./Suppl*, 76: 169-196.

Vannote, R. L., Minshall, K., Cummins, K. W., Sedell, J. R. & Cushing, C. E. 1980. "The river continuum concept." *Canadian Journal of Fisheries and Aquatic Sciencies,* 37: 130-137.

Wallace, J. B., Grubaugh, J.W. & Whiles, M.R. 1996. "Biotic indices and stream ecosystem processes: results from an experimental study". *Ecological Applications*, 6: 140-151.

Ward, J. V. 1986. "Altitudinal zonation in a Rocky mountain stream." *Archiv Hydrobiol/Suppl*, 74: 133-199.

Ward, J. V. 1992. "Aquatic Insect Ecology. 1. Biology and Habitat." *John Wiley & Sons,* New York, USA, 456 pp.

Waringer, J. & Graf W. 2011: "Atlas der mitteleuropäischen Köcherfliegenlarven." - *Erik Mauch Verlag*, Dinkelscherben, 469 pp. ISBN: 978-3-00-032177-1.

Wichard, W. 1978. "Die Köcherfliegen (Trichoptera)". *A. Ziemsen Verlag*, Wittenberg Lutherstadt, 63 pp.

Williams, N. E. & Hynes, H. B. N. 1973. "Microdistribution and feeding of the net- spinning caddisflies (Trichoptera) of a Canadian stream." *Oikos,* 24: 73-84.

Wimmer, R. & Moog, O. 1994. "Flußordnungszahlen österreichischer Fließgewässer." *Umweltbundesamt*, 640 pp.

# Index of Figures

# Index of Tables

# Abstract

In the order Trichoptera, the larvae of the net-spinning Hydropsychidae represent one of the families that do not build transportable cases. They colonize fast-flowing river systems worldwide and even settle on shorelines of freshwater lakes. Due to their global distribution and physiological sensitivity, they possess a high potential for bioindication, enabling assessments of river water quality based on the population structure of the Hydropsychidae. Moreover, they contribute to the purification of rivers by filtering particulate organic matter with their nets. The focus of previous studies has therefore been on the succession of Hydropsychidae along the longitudinal continuum, their selection of microhabitats based on different parameters, and the diversity of mesh widths.

This thesis examines key abiotic parameters such as pH, conductivity and water temperature within the Große Tulln catchment in 2014. At six different sampling sites, penultimate and ultimate instar larvae of the genus *Hydropsyche* were sampled regularly between March and September 2014 and brought to the laboratory. The respiration rates of 4 different species were analyzed. Generally, the respiration rates correlate positively with water temperature. The species-specific minima in the respiration rates with regard to water temperature reflect the longitudinal distribution of the species along the course of the river. From spring to mouth, the abundance maxima show the following sequence: *H. saxonica, H. instabilis, H. pellucidula/incognita* and *H. bulbifera*. Moreover, an expected negative significant correlation between respiration rate and dry weight could be confirmed.

# Zusammenfassung

Innerhalb der Ordnung der Trichoptera repräsentieren die Larven der netzbauenden Hydropsychidae eine der wenigen Familien ohne transportable Köcher. Sie besiedeln weltweit schnell strömende Fließgewässer und finden sich sogar an den Uferlinien einiger Frischwasserseen. Ihre globale Verteilung und ihre physiologische Sensibilität verleiht ihnen ein hohes Bioindikationspotential. So sind beispielsweise einige Arten sensibel gegenüber Schadstoffen und Verunreinigungen. Somit können anhand der Populationsstruktur der Hydropsychidae Aussagen über die Gewässergüte gemacht werden. So tragen sie zum Beispiel zur Reinigung des Flusses bei, indem sie mit ihren Fangnetzen partikuläres Material aus der fließenden Welle filtern. Thema bisherheriger Untersuchungen waren daher die Sukzession der Hydropsychidae innerhalb des Längskontinuums, die Wahl der Mikrohabitate und die Fangnetzmorphologie.

Im Rahmen der vorliegenden Arbeit wurden abiotische Schlüsselparameter wie pH, Leitfähigkeit und Wassertemperatur des Wienerwaldflusses Große Tulln im Jahr 2014 erhoben. An sechs Beprobungsstandorten wurden regelmäßig zwischen März und September 2014 Larven des 4. und 5. Stadiums der Gattung *Hydropsyche* entnommen und im Labor die Respirationsraten von 4 Arten bestimmt.

Die Respirationsraten korrelieren generell positiv mit der Wassertemperatur. Die artspezifischen Minima der Respirationsraten pro Temperatur spiegeln die longitudinale Verteilung der Arten innerhalb des Flusslaufes wider: von der Quelle zur Mündung lösen sich die Abundanzmaxima von *H. saxonica*, *H. instabilis*, *H. pellucidula/incognita* und *H. bulbifera* ab. Weiters wurde ein signifikanter Zusammenhang zischen Respiration und Trockengewicht festgestellt. Die Hypothese zur Abnahme der Respirationsrate mit Zunahme des Trockengewichtes konnte somit ebenfalls bestätigt werden.

# Curriculum Vitae

## Personal Data



| | |
|---|---|
| - Name: | Cornelia Bauer, B.Sc. |
| - Born: | 06.06.1991 in Wien |
| - Address: | Fischergasse 47, A-2462 Wilfleinsdorf |
| - Telephone number: | +43(0)660 5908700 |
| - E-mail: | conny.bauer@gmx.at |



## Education

| | |
|---|---|
| - 1997–2001 | Primary school Sacré Cœur Vienna |
| - 2001–2009 | Theresianische Akademie Vienna<br>Graduation: successfulness certificate of a higher school on 18.06.2009 |
| - 2010-2013 | Bachelor studies in Biology at the University of Vienna<br>Graduation: June 2013 (specialization in ecology) |
| - Since 2013 | Master studies in Ecology at the University of Vienna (specialization in limnology and oceanography) |
| - Since 2014 | Master´s thesis "Respiration rates of genus *Hydropsyche* (Insecta: Trichoptera) in the catchment of the Große Tulln (Lower Austria)" University of Vienna, Faculty of Life Sciences, Department of Limnology |

## Working Experience

| | |
|---|---|
| - 07.2005 | Trainee at the Vienna Airport AG |
| - 08.2006 | Trainee at Uniqa insurance |
| - 07.2009 | Trainee at Salesianer Miettex |
| - 08. & 09.2010 | Trainee at Institute for biomedical research of the medical university of Vienna |
| - 2011 - 2012 | private tutor at Lernquadrat (Bruck an der Leitha) |
| - 2012 - 2013 | private tutor at Learn4Life (Bruck an der Leitha) |
| - Since 2012 | Fitness trainer at Mrs. Sporty Hainburg |
| - Since 2015 | Laboratory representative at Biotop Landschaftsgestaltung GmbH Weidling |
| - June 2015 | Tutor of the course "Kenntnis mitteleuropäischer Lebensgemeinschaften", University of Vienna, Faculty of Life Sciences, Department of Limnology |

## Languages

| | |
|---|---|
| - English: | fluently (language teaching in school for 6 years, Cambridge Certificate) |
| - French: | fluently (language teaching in school for 8 years, DELF) |
| - Russian: | Basics (language teaching in school for 3 years) |
| - Latin: | written language (language teaching in school for 6 years) |