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Tools for instar determination of European caddisfly larvae (Insecta: Trichoptera)

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Abstract

The paper explores the adult-forewing-length to larval-head-width relationship as a basis for instar determination of final instar caddisfly larvae on a family level. In addition, reference data from published sources were used to extract series of percentage-head-width increments and factors-of-increase for penultimate to first instars. This material provides estimates for head widths of earlier instars on the family level.

Keywords

biometry; wing length; head width; correlation

Introduction

In addition to identification, there are several reasons for the assignment of larval caddisflies to their actual instar ('staging'). Population and food-web studies heavily rely on knowledge of which larval instars of a given species are present at the study site at any given time, since ontogenetic diet shifts at certain instar numbers are well reported for a number of species (Wallace 1975; Benke & Wallace 1997; Cereghino 2010). A well-studied example in this context are the larvae of Hydroptilidae and Ptilocolepidae which are free-living, gathering collectors that feed on Fine Particulate Organic Matter (FPOM) in the first four instars, whereas the cased, final larval instars are shredders, scrapers, or piercers living on periphyton or sucking contents from the cells of filamentous algae (Morse *et al.* 2019). Besides diet shifts, there may be also instar-specific (micro-) habitat shifts during ontogeny based on the grain sizes of mineral-sediment particles (Martini 2018). Other fields where instar determination is of intrinsic importance are life history studies (see references in Table 2) where quiescence periods may exist in certain larval instars (Denis & Malicky 1985). Finally, most larval identification keys are based on final instar larvae only; so knowledge concerning which larval instar awaits identification is important unless the key considers multiple different instars (e.g., Wallace *et al.* 2003).

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In the context of larval taxonomy, the staging of unknown larvae is also essential. In cases where species affiliation between adults and larvae cannot be based on DNA sequences from the “barcode region” of the mitochondrial cytochrome c oxidase region (e.g., Vicentini *et al.* 2020) or on discarded larval sclerites in a pupation shelter or cocoon with exuviae of a mature pupa enclosing an identifiable pharate adult (“metamorphotype method,” Milne 1938), this affiliation is often based on the fact that identifiable adults and conspecific larvae are collected at the same site. Obviously, for the subsequent descriptions, knowledge whether the material belongs to the final, penultimate, or earlier instar becomes essential (Waringer & Graf 2020).

Although the need for staging of caddisfly larvae is high, the methods are limited and often very time-consuming, especially when rearings are involved. Therefore, biometric tools for instar determination are presented, based on the correlation between adult forewing length and maximum head width of final instar larvae; in addition, series of head width data (given as percentage of mean final instar head width) derived from published sources allow for subsequent estimates of head width for earlier instars.

Material and methods

For creating the database, wing length data given by Malicky (2004) for the complete European species inventory were used, taking the minimum and maximum for the full range of male *plus* female forewing length, and excluding brachypterous taxa. For maximum larval head widths of final instars, the following references were consulted: Decamps 1966, 1970; Decamps & Magne, 1966; de Viedma & de Jalon 1980; Edington & Hildrew 1995; Evtimova & Kenderov 2016; Fjellheim 1980; Forcellini *et al.* 2013; Graf *et al.* 2011, 2015; Grenier *et al.* 1969; Johansson *et al.* 1991; Kachalova 1969; Karaouzas 2009, 2013, 2014a, 2014b, 2016a, 2016b, 2018a, 2018b; Karaouzas & Waringer 2016, 2017; Karaouzas *et al.* 2015, 2018; Kucinic *et al.* 2008, 2010, 2011a, 2011b, 2015, 2016; Kumanski 1971; Kumanski *et al.* 2004; Nozaki & Itou 1998; Previsic *et al.* 2014; Rinne & Wiberg-Larsen 2017; Ruiz-Garcia & Ferreras-Romero 2007; Ruiz-Garcia *et al.* 2004, 2018; Sainz-Bariain & Zamora-Munoz, 2015; Sipahiler 2013; Solem, 1985; Szczesny 1978; Tachet *et al.* 2001, 2018; Tanida *et al.* 1999; Vera 1979; Vicentini *et al.* 2020; Vieira-Lanero 2000; Vieira-Lanero *et al.* 1996, 1997a, 1997b, 2001, 2005, 2008a, 2008b, 2009; Vitecek *et al.* 2020a, 2020b; Wallace *et al.* 2003; Waringer & Graf 2009, 2011, 2014a, 2014b, 2018, 2020; Waringer & Karaouzas 2017a, 2017b; Waringer & Malicky 2016a, 2016b, 2017, 2018a, 2018b, 2018c, 2018d, 2018e; 2019a, 2019b, 2019c, 2019d, 2020; Waringer *et al.* 2008a, 2008b, 2009, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2013c, 2013d, 2014, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2017c, 2018a, 2018b, 2020, in review.

For the relationship between forewing length (mm) and maximum head width (mm) of final instar larvae on the family level, maxima and minima of the full range of wing lengths (males + females) were paired with maxima and minima of head width. Using the regression module of the software package STATISTICA 7.1 (© StatSoft, Tulsa, OK 74104, USA), linear regressions were calculated and plotted. In order to enable regression analysis also for families with only very few taxa in the European Trichoptera fauna, data for 2 to 3 species-

poor families were pooled. In Limnephilidae, regression analysis was subdivided to the subfamily or tribe level (Table 1).

Table 1

Linear regression equations for the relationship between forewing length (x ; mm) and the head width of final instar larvae (y ; mm) for European caddisfly families. Also shown is the number of species included, the coefficient of determination (r^2) and the level of significance (P).

Family (number of species included)	Regression equation	r^2	P
Rhyacophilidae (50)	$y = 0.38 + 0.07x$	0.55	<0.000
Glossosomatidae + Ptilocolepidae (15)	$y = 0.25 + 0.06x$	0.71	<0.000
Hydroptilidae (13)	$y = 0.11 + 0.04x$	0.36	<0.01
Philopotamidae (9)	$y = 0.47 + 0.08x$	0.52	<0.01
Polycentropodidae + Ecnomidae + Arctopsychidae (23)	$y = 0.31 + 0.15x$	0.72	<0.05
Psychomyiidae (15)	$y = 0.34 + 0.06x$	0.38	<0.001
Hydropsychidae (31)	$y = 0.82 + 0.07x$	0.39	<0.000
Phryganeidae + Odontoceridae + Calamoceratidae (17)	$y = 0.55 + 0.08x$	0.71	<0.000
Brachycentridae (11)	$y = 0.55 + 0.03x$	0.52	<0.000
Thremmatidae + Helicopsychidae (7)	$y = 0.49 + 0.02x$	0.23	<0.000
Goeridae (10)	$y = 0.80 + 0.03x$	0.45	<0.01
Lepidostomatidae (5)	$y = 0.09 + 0.10x$	0.91	<0.000
Apataniidae (13)	$y = 0.57 + 0.03x$	0.41	<0.000
Limnephilidae: Dicosmoecinae + Limnephilini (50)	$y = 0.43 + 0.08x$	0.74	<0.000
Drusinae (50)	$y = 0.75 + 0.06x$	0.44	<0.000
Chaetopterygini + Chilostigmini (14)	$y = 1.02 + 0.03x$	0.28	<0.000
Stenophylacini (50)	$y = 0.82 + 0.05x$	0.35	<0.000
Sericostomatidae (9)	$y = 1.28 + 0.04x$	0.36	<0.01
Molannidae + Beraeidae (16)	$y = 0.61 + 0.03x$	0.40	<0.000
Leptoceridae (42)	$y = 0.07 + 0.08x$	0.65	<0.000

For providing basic data for the estimation of penultimate instar to first instar larval head widths on the family level, percentages based on mean final instar head widths were calculated for each instar, using the references listed in Table 2. These data were the basis for the calculation of the factor of increase (mean, with range) for each family. No head width data on early instars were available for Calamoceratidae or Chilostigmini (Limnephilidae).

Table 2

Estimation of head widths for larval instars of families of European Trichoptera, based on mean final instar head widths. No head-width data on early instars are available for Calamoceratidae or Limnephilidae: Chiloistigmini. In addition to the references listed in column 4, the following databases were used for early instar head width nearly for all families: Edington & Hildrew 1995; Rinne & Wiberg-Larsen 2017; Wallace *et al.* 2003.

Family	Mean head width of penultimate instar to first instar, given as percentage of mean final instar head width [#]	Factor of increase; mean (with range)	References	Remarks
Rhyacophilidae	68; 48; 33; 22	1.48 (1.37–1.53)	Elliott 1968; Graf <i>et al.</i> 2009; Martini 2018	
Glossosomatidae [*]	Glossosomatinae: 75; 53; 30; 2; Agapetinae: 75; 57; 43; 32; 25; 18	1.44 (1.31–1.57) 1.40 (1.13–2.00)	Nielsen 1942; Becker 2005	In Agapetinae, instar number is 7 throughout Europe (Becker 2005)
Ptilocolepidae	86; 63; 49; 41	1.29 (1.20–1.37)	Ito <i>et al.</i> 2014; Wiberg-Larsen <i>et al.</i> 1991	Including data for North American <i>Palaegrapetus nearcticus</i> Banks 1936
Hydroptilidae	85; 65; 55; 48	1.21 (1.15–1.31)	Nielsen 1948	
Philopotamidae	71; 42; 19; 13	1.50 (1.28–1.94)	Elliott 1981	
Polycentropodidae	65; 41; 26; 16	1.58 (1.43–1.74)	Elliott 1968	
Ecnomidae	71; 45; 30; 2	1.54 (1.50–1.58)		
Psychomyiidae	72; 44; 30; 21	1.48 (1.36–1.62)		
Hydropsychidae	64; 39; 23; 15	1.64 (1.35–2.14)	Andersen & Klubnes 1983; Elliott 1986	
Arctopsychidae	68; 43; 28; 18	1.54 (1.47–1.60)		
Phryganeidae	69; 43; 30; 16	1.51 (1.15–1.94)		
Brachycentridae	65; 41; 33; 22	1.54 (1.33–1.84)	Martini 2018	
Thremmatidae	70; 47; 33; 23	1.44 (1.35–1.54)	Kehl 2005; Waringer <i>et al.</i> 2020	
Goeridae	71; 47; 29; 22	1.50 (1.25–1.72)	Waringer 1987	
Lepidostomatidae	64; 40; 26; 13	1.59 (1.39–1.72)		
Apatanidae	70; 49; 32; 23	1.44 (1.29–1.56)	Solem 1985	
Limnephilidae: Dicosmoecinae	72; 52; 37; 26	1.40 (1.38–1.41)	Zweidick 2020	
Limnephilidae: Drusinae	64; 41; 25; 15	1.58 (1.50–1.75)	Martini 2018; Waringer 1987	
Limnephilidae: Limnephilini	71; 52; 30; 18	1.43 (1.16–1.69)	Gislason 1993	

Family	Mean head width of penultimate instar to first instar, given as percentage of mean final instar head width [#]	Factor of increase; mean (with range)	References	Remarks
Limnephilidae: Chaetopterygini	69; 45; 29; 22	1.51 (1.41–1.71)	Andersen & Tysse 1984, Waringer 1987, Waringer <i>et al.</i> 2009	
Limnephilidae: Stenophylacini	71; 47; 31; 21	1.47 (1.23–1.79)	Martini 2018; Waringer 1987; Waringer <i>et al.</i> 2013a	
Sericostomatidae	77; 58; 39; 28; 20 (6 instars) 80; 61; 43; 28; 20; 12 (7 instars) 0.83; 0.59; 0.49; 0.39; 0.29; 0.21; 0.17; 0.13; 0.10	1.40 (1.32–1.49) 1.58 (1.02–1.86) 1.31 (1.20–1.41)	Elliott 1969 Iversen 1973; Wagner 1990 Denis 1981	Instar number variable (6–10)
Odontoceridae	64; 43; 27; 14	1.63 (1.40–1.90)	Elliott 1982	
Molannidae	66; 48; 32; 24	1.48 (1.44–1.58)		
Helicopsychidae	67; 45; 30; 18	1.55 (1.49–1.67)	Vaughn 1985	Data based on North American <i>Helicopsyche boreali</i> . (Hagen 1861 in Hagen & Uhler 1861)
Beraeidae	75; 53; 29; 23 (5 instars) 78; 61; 59; 49; 32 (6 instars)	1.49 (1.21–1.91) 1.26 (1.22–1.35)		Instar number variable (5–6)
Leptoceridae	61; 39; 25; 11	1.62 (1.37–2.20)		

* For Agapetinae, pronotum-length data given by Becker (2005) were transformed to head-width to pronotum-length relationship.

Numbers in *italic*, for some missing data on early instars were extrapolated from published head-width data using semilog regressions of instar number versus head width as given by Dyar's rule (Dyar 1890).

Results and Discussion

Number of instars

There is consensus that the number of instars in most European Trichoptera larvae is five, with the exception of Glossosomatidae, Sericostomatidae, and Beraeidae (Rinne & Wiberg-Larsen 2017; Wallace *et al.* 2003). In Sericostomatidae, almost all authors reported difficulties in the separation of consecutive larval instars which range from 5 (Nielsen 1942) over 6 (Elliott 1969) or 7 (Iversen 1973; Rennerich & Schuhmacher 1983; Wagner 1990) to even 10 in *Sericostoma galeatum* Rambur 1842 (laboratory rearings at 15°C; Denis 1981). In Glossosomatidae, there are 5 instars in Glossosomatinae, but 7 instars in Agapetinae throughout Europe (Becker 2005). In Beraeidae, 5 instars are listed for British populations of *Beraea maurus* (Curtis 1834) and *Ernodes articularis* (Pictet 1834) (Wallace *et al.* 2003), but 6 instars for Finnish populations (Rinne & Wiberg-Larsen 2017). Errors involving the correct establishment of instar numbers in caddisfly larvae may be due to the fact that the earliest instars are easily overlooked (Iversen 1973), or the fact that size-frequency distributions of male and female larvae in some species tend to be bimodal in the last instar, corresponding with size differences in adults, as shown by, e.g., Elliott (1982) and Brittain & Bildeng (1995).

Limitations of morphological instar determination

Unfortunately, the morphological staging of final instar larvae is possible only in three families: Hydroptilidae, Hydropsychidae, and Leptoceridae. Hydroptilidae exhibit hypermetamorphosis: They mature through the early instars rapidly and then transform into the final larval instar with a much-enlarged abdomen that is generally compressed (Fig. 1) or depressed (Morse *et al.*, 2019). Hypermetamorphosis is closely coupled with the fact that a transportable case is not constructed before the fifth, final instar. In his seminal and exemplary paper on the postembryonic development and biology of the Hydroptilidae, Nielsen (1948) summarized this important fact by stating: ‘...it has been fully confirmed by my investigations....that the biological limit’ (i.e., the transition from larvae without to larvae with cases) ‘coincides with the moult between the 4th and the 5th instar’. Therefore, the presence of the transportable case earmarks final instar hydroptilid larvae (Fig. 1). In Hydropsychidae, final instar larvae can be readily identified by the presence of soft, fringe-like buds of pupal gills on both sides of abdominal segments III to VII (Fig. 2), situated in lateral position near the posterior segmental border (Pitsch 1993). Finally, last instar leptocerid larvae are characterized by the presence of additional subocular (Fig. 3) and sometimes also supra-ocular ecdysial lines on the parietalia, the latter observed in some facultative sponge-feeding species, e.g., *Ceraclea senilis* (Burmeister 1839). The subocular ecdysial line may also be fitted with a dorsal branch (e.g., in *Erotesis baltica* McLachlan 1877) (Wallace *et al.* 2003).

Chaetotaxy also plays an important role in morphological instar determination. The number of primary setae remains constant over all larval instars and constitute the exclusive setation pattern on certain parts of the larval body, including the clypeal apotome (except Ptilocolepidae, Beraeidae, Goeridae, and Apataniidae), pleurae, tarsal claws, thoracic sterna, abdominal segments, and parts of the anal prolegs. On other parts of the larval body, e.g., on

the thoracic nota and the coxae, increasing numbers of secondary setae are added to the primary setation at each larval moult after the first instar (Siltala 1907). A reliable instar determination character for first instars throughout all families is the number of primary tactile setae on each pronotum half, which uniformly is 5, with 4 on the pronotal surface (Dsa21-4) and 1 anterolateral setae (DAL1) (Fig. 4; Siltala 1907; Hetrick *et al.* 1998). Furthermore, one pronotal pit may be present near the anterior pronotal border in addition to a single face pit which is always present (arrows in Fig. 5). Unfortunately, due to high variability, the increasing numbers of secondary setae in instars 2 to 5 is only useful at the species level for certain taxa. For example, the number of pronotal primary setae (and pits) in *Polycentropus flavomaculatus* (Pictet 1834) in instars one to five is 5 (2), 9–11 (2), 16–21 (2), 27–31 (2) and 36–40 (2), respectively. In fact, chaetotaxy works very well also at the family level for first instars, providing the basis for family keys (Siltala 1907; Hetrick *et al.* 1998), but can hardly be used at the family level for higher instars due to a high variability of secondary setation, demonstrating the limitations of the morphological approach.

Biometric instar determination

Generally, the most reliable biometric parameter in instar determination of caddisfly larvae is the maximum width of the head capsule, although other measures such as larval body length (Majecki *et al.* 1997) or pronotum length (Becker 2005) also have been used. Such data are mostly analyzed as size-frequency histograms which allow graphical separation of instars, at least when overlaps between instars are negligible (e.g., Elliott 1982; Waringer 1989); for this approach, Dyar's rule can yield additional information (Dyar 1890). However, such an approach is time-consuming, because a high number of collected specimens is necessary. An alternative approach is a method using the relationship between biometric parameters of adult and larval caddisflies. By far the most available biometric parameter of adult Trichoptera is forewing length; this measure has been consistently cited for the complete European species inventory by Malicky (2004), and is frequently included in diagnoses of new species descriptions (e.g., Malicky 2014; Vitecek *et al.* 2020b). Forewing length (x ; mm) and final instar head width (y ; mm) were found to be linear on an arithmetic scale (pooled data for all families in Fig. 5; regressions at the family level in the Appendix). Therefore, this relationship was given by the regression equation:

$$y = a + bx$$

where the intercept a and the slope of the regression line b are constants. The regression equations were a good fit to the data, and F-values from the variance ratio were at least significant ($P < 0.05$), and in 15 out of 20 cases the P level was well < 0.001 . When using this tool, wherever an identified adult is at hand, the minimum and maximum of the published forewing length (x ; Malicky 2004) can be inserted in the appropriate regression equation given in Table 1 of the family in question, yielding an estimate of the range of final instar head width y of the associated larva.

The proportion of the variance of y due to the regression of y on x (coefficient of determination r^2) ranged from 0.28 in Chaetopterygini and Chilostigmini to 0.91 in

Lepidostomatidae (Table 1). Generally, the coefficient of determination simply mirrors the current state of larval taxonomy. Let's take Limnephilidae as an example: the decreasing r^2 values of 0.74, 0.44, 0.35 and 0.28 for Limnephilini, Drusinae, Stenophylacini and Chaetopterygini, respectively, neatly fit the group-specific proportion of existing larval descriptions in relation to undescribed larvae. In many groups with low r^2 (Table 2), only single head-width data points are available per species; pairing single head-width data points with the two maxima of forewing length necessarily adds to scatter, decreasing the coefficient of determination. Therefore, future efforts in larval taxonomy should focus on such groups with low coefficients of determination. As a consequence, even highly significant correlations with noisy data can impair regression predictions with the possibility of unprecise estimations in some (sub-)families where biometrical data on larvae are scarce.

Table 2 provides information for estimating mean head widths of penultimate to first instars; for this, column 2 includes series of decreasing mean percentages based on final-instar-head width. For using this tool, take the final-instar-head width obtained by the regression equations in Table 1 and calculate the percentage of the latter using column two of Table 2. For taxa where 5 larval instars are present, mean percentages (with 95% CL and range) for pooled families were found to be 70% (± 2 ; 61–86) for fourth instars, 45% (± 3 ; 39–65) for third, 31% (± 3 ; 19–55) for second, and 21% (± 3 ; 11–48) for first instars.

Dyar's rule (Dyar 1890) reflects the fact that during larval development species-specific growth increments are predictable and can be expressed by a relatively constant factor. Ranges of the factor of increase indicated in Table 2, therefore, reflect scatter because many taxa were included for each family. The lowest factors of increase were observed in Hydroptilidae (1.15), the highest in Leptoceridae (2.20). In families where more than five instars are present, the factor of increase was generally lower (Table 2). For pooled data including all 451 species investigated, the mean of the factor of increase for pooled families was 1.48 (± 0.04) which is close to the factor of increase between midpoints of instar-specific larval head widths of 1.5 given by Mackay (1978).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

- Andersen T, Klubnes R. The life histories of *Hydropsyche siltalai* Döhler, 1963 and *H. pellucidula* (Curtis, 1834) (Trichoptera, Hydropsychidae) in a West Norwegian river. *Aquatic Insects*. 1983; 5:51–62. DOI: 10.1080/01650428309361125
- Andersen T, Tysse Å. The life cycle of *Chaetopteryx villosa* (Fabricius, 1798) (Trichoptera: Limnephilidae) in a lowland- and a mountain-stream in Western Norway. *Aquatic Insects*. 1984; 6:217–232. DOI: 10.1080/01650428409361187

- Banks N. Four New Trichoptera from the United States. *Arbeiten über Morphologische und Taxonomische Entomologie aus Berlin-Dahlem*. 1936; 3:265–268.
- Becker G. Life cycle of *Agapetus fuscipes* (Trichoptera, Glossosomatidae) in a first-order upland stream in central Germany. *Limnologica*. 2005; 35:52–60. DOI: 10.1016/nimno.2005.01.003
- Benke AC, Wallace JB. Trophic basis of production among riverine caddisflies. Implications for food web analysis. *Ecology*. 1997; 78:1132–1145. DOI: 10.1890/0012-9658(1997)078[1132:TBOPAR]2.0.CO;2
- Botosaneanu L. Description de quatre nouvelles espèces de trichoptères de Roumanie. *The Annals and magazine of natural history*. 1960; 13(3):113–120. DOI: 10.1080/00222936008650902
- Brittain JE, Bildeng R. Life cycle of *Arctopsyche ladogensis* (Trichoptera) in a regulated Norwegian river. *Regulated Rivers: Research & Management*. 1995; 10:71–79. DOI: 10.1002/rrr.3450100203
- Burmeister, H. *Handbuch der Entomologie* 2. F. Enslin; Berlin: 1839. 757–1050. [in German]
- Cereghino R. Shift from an herbivorous to a carnivorous diet during the larval development of some *Rhyacophila* species (Trichoptera). *Aquatic Insects*. 2010; :129–135. DOI: 10.1076/aqin.24.2.129.4898
- Curtis J. Descriptions of some hitherto nondescript British Species of May-flies of Anglers. *The London and Edinburgh Philosophical Magazine and Journal of Science*. 1834; 4:212–218. DOI: 10.1080/14786443408648304
- Décamps H. Nouvelles larves pyrénéennes du genre *Rhyacophila* [Trichoptères]. *Annales de Limnologie*. 1966; 2:183–202. DOI: 10.1051/limn/1966001
- Décamps H. Les larves de Brachycentridae (Trichoptera) de la faune de France. *Taxonomie et écologie*. *Annales de Limnologie*. 1970; 6:51–73. DOI: 10.1051/limn/1970009
- Décamps H, Magné J. Contribution à l'étude de *Micropterna fissa* McL. et des Trichoptères cavernicoles (*Stenophylax*, *Micropterna*, *Mesophylax*). *Annales de Limnologie*. 1966; 2:527–535. DOI: 10.1051/limn/1966011
- Denis C. Données sur la biologie et les stades du développement de *Sericostoma galeatum* RAMBUR (Trichoptera, Sericostomatidae). *Rivista di Idrobiologia*. 1981; 20:425–439.
- Denis C, Malicky H. Etude du cycle biologique de deux Limnephilidae: *Limnephilus minos* et *Limnephilus germanus* (Trichoptera). *Annales de Limnologie*. 1985; 21:71–76. DOI: 10.1051/limn/1985006
- de Viedma MG, de Jalon DG. Descriptions of four larvae of *Rhyacophila* (*Pararhyacophila*) from the Lozoya River, Central Spain, and key to the species of the Iberian Peninsula (Trichoptera: Rhyacophilidae). *Aquatic Insects*. 1980; 2:1–12. DOI: 10.1080/01650428009361002
- Dyar HG. The number of molts of lepidopterous larvae. *Psyche*. 1890; 5:420–422. DOI: 10.1155/1890/23871
- Eaton AE. VI. On the Hydroptilidae, a family of the Trichoptera. *Transactions of the Entomological Society of London*. 1873:125–151.
- Edington, JM, Hildrew, AG. A Revised Key to the Caseless Caddis Larvae of the British Isles with Notes on Their Ecology. *Freshwater Biological Association Scientific Publication*; 1995. 134
- Elliott JM. The life histories and drifting of Trichoptera in a Dartmoor stream. *Journal of Animal Ecology*. 1968; 37:615–625. DOI: 10.2307/3078
- Elliott JM. Life history and biology of *Sericostoma personatum* Spence (Trichoptera). *Oikos*. 1969; 20:110–118. DOI: 10.2307/3543750
- Elliott JM. Quantitative study of the life cycle of the net-spinning caddis *Philopotamus montanus* (Trichoptera: Philopotamidae) in a Lake District stream. *Journal of Animal Ecology*. 1981; 50:867–883. DOI: 10.2307/4143
- Elliott JM. A quantitative study of the life cycle of the case-building caddis *Odontocerum albicorne* (Trichoptera: Odontoceridae) in a Lake District stream. *Freshwater Biology*. 1982; 12:241–255. DOI: 10.1111/j.1365-2427.1982.tb00619.x
- Evtimova VV, Kenderov LA. First confirmed record of the larva of *Calamoceras illiesi* Malicky and Kumanski, 1974 (Trichoptera) from Europe, with notes on its morphology. *Aquatic Insects*. 2016; 37:317–326. DOI: 10.1080/01650424.2016.1256411

- Fjellheim A. Differences in drifting of larval stages of *Rhyacophila nubila* (Trichoptera). *Holarctic Ecology*. 1980; 3:99–103. DOI: 10.1111/j.1600-0587.1980.tb00714.x
- Forcellini M, Statzner B, Tachet H. A revised description of the larva of *Homilia leucophaea* (Rambur 1842) (Trichoptera: Leptoceridae) and comparisons with the known western European *Athripsodes* larvae. *Zootaxa*. 2013; 3682:191–199. DOI: 10.11646/zootaxa.3682.1.10 [PubMed: 25243283]
- Gislason, GM. In: Otto, C, editor. *Proceedings of the Seventh International Symposium on Trichoptera*; Umeå, Sweden. 3–8 August 1992; Leiden: Backhuys Publishers; 1993. 171–175.
- Graf W, Pauls SU, Waringer J. The larva of *Rhyacophila ferox* Graf, 2006 (Trichoptera: Rhyacophilidae) from the Eastern Alps (Carinthia, Austria). *Aquatic Insects*. 2009; 31:111–117. DOI: 10.1080/01650420802627159 [PubMed: 27069288]
- Graf W, Ku ini M, Previši A, Pauls SU, Waringer J. The larva of *Ecclisopteryx malickyi* Moretti, 1991 (Trichoptera: Limnephilidae: Drusinae), with comments on the genus. *Zoosymposia*. 2011; 5:136–142. DOI: 10.11646/zoosymposia.5.1.11
- Graf W, Vitecek S, Previši A, Malicky H. New species of Limnephilidae (Insecta: Trichoptera) from Europe: Alps and Pyrenees as harbours of unknown biodiversity. *Zootaxa*. 2015; 3911:381–395. DOI: 10.11646/zootaxa.3911.3.5 [PubMed: 25661619]
- Grenier S, Décamps H, Giudicelli J. Les larves de Goeridae (Trichoptera) de la faune de France. *Taxonomie et écologie. Annales de Limnologie*. 1969; 5:129–161. DOI: 10.1051/limn/1969012
- Hagen HA, Uhler PR. Synopsis of the Neuroptera of North America, with a list of the South American species. Prepared for the Smithsonian institution. *Smithsonian Miscellaneous Collections*. 1861; 4:1–347. DOI: 10.5962/bhl.title.22092
- Hetrick ND, Morse JC, West JL. Descriptions and phylogeny of four limnephiloid caddisflies (Trichoptera) based on first instars. *Annals of the Entomological Society of America*. 1998; 91:497–514. DOI: 10.1093/aesa/91.5.497
- Ito T, Wisseman RW, Morse JC, Colbo MH, Weaver JS III. The genus *Palaeagapetus* Ulmer (Trichoptera, Hydroptilidae, Ptilocolepinae) in North America. *Zootaxa*. 2014; 3794:201–221. DOI: 10.11646/zootaxa.3794.2.1 [PubMed: 24870319]
- Iversen TM. Life cycle and growth of *Sericostoma personatum* Spence (Trichoptera, Sericostomatidae) in a Danish spring. *Entomologica Scandinavica*. 1973; 3:323–327. DOI: 10.1163/187631273X00282
- Johansson A, Nilsson A, Svensson BW. Larval morphology, habitat and distribution of *Limnephilus diphys* (Trichoptera, Limnephilidae). *Entomologisk Tidskrift*. 1991; 112:19–25.
- Kachalova OL. Larva of *Rhyacophila pascoei* McL., larva nova (Trichoptera, Rhyacophilidae). *Revue d'Entomologie de L'URSS*. 1969; 48:636–638.
- Karaouzas I. The larva of *Hydropsyche peristerica* Botosaneanu & Marinkovic-Gospodnetic, 1968 (Trichoptera: Hydropsychidae), with some notes on its ecology. *Aquatic Insects*. 2009; 31:139–143. DOI: 10.1080/01650420802623786
- Karaouzas I. The larvae of the Aegean endemic caddisflies *Hydropsyche debirasi* Malicky 1974 and *Hydropsyche kleobis* Malicky 2001 (Trichoptera: Hydropsychidae) with notes on their ecology and zoogeography. *Zootaxa*. 2013; 3636:472–477. DOI: 10.11646/zootaxa.3637.4.6
- Karaouzas I. The larva of *Rhyacophila loxias* Schmid, 1970 (Trichoptera: Rhyacophilidae) with notes on its ecology. *Aquatic Insects*. 2014a; 36:15–26. DOI: 10.1080/01650424.2014.999793
- Karaouzas I. Description of the larva of *Philopotamus achemenus* Schmid 1959 (Trichoptera: Philopotamidae) and a larval key for species of *Philopotamus* in Greece. *Zootaxa*. 2014b; 3815:428–344. DOI: 10.11646/zootaxa.3815.3.8
- Karaouzas I. The larvae of *Hydropsyche rhadamanthys* Malicky 2001 and *Hydropsyche sarpedon* Malicky 2001 (Trichoptera: Hydropsychidae), endemics of Crete (South Aegean, Greece), with notes on their ecology. *Zootaxa*. 2016a; 4097:557–566. DOI: 10.11646/zootaxa.4097.4.7 [PubMed: 27394566]
- Karaouzas I. The larva of *Wormaldia asterusia* Malicky 1972 (Trichoptera: Philopotamidae) with notes on its ecology and an update on the *Wormaldia* of Greece with a larval key for species of the genus. *Zootaxa*. 2016b; 4000doi: 10.11646/zootaxa.4200.3.4

- Karaouzas I. The larvae of three Greek species of *Hydropsyche* (Trichoptera: Hydropsychidae) and key for larvae of known Aegean *Hydropsyche* species. *Zootaxa*. 2018a; 4382:381–392. DOI: 10.11646/zootaxa.4382.2.9 [PubMed: 29689925]
- Karaouzas I. The larva of *Hydropsyche perseus* Malicky 2001, endemic to Kerkyra (Corfu) Island, including a key for the known *Hydropsyche* larvae of the Greek islands. *Zootaxa*. 2018b; 4504:296–300. DOI: 10.11646/zootaxa.4504.2.10 [PubMed: 30486032]
- Karaouzas I, Waringer J. The larva of *Lepidostoma doehleri* Malicky 1976 (Trichoptera: Lepidostomatidae) with notes on ecology and a key to larvae for species of the genus in Greece. *Zootaxa*. 2016; 4189:588–592. DOI: 10.11646/zootaxa.4189.3.9
- Karaouzas I, Waringer J. The larva of *Polycentropus ierapetra* Malicky 1972 (Trichoptera: Polycentropodidae), including a key to the larvae of genus *Polycentropus* (Curtis 1835) in the Hellenic western Balkan region. *Zootaxa*. 2017; 4294:586–592. DOI: 10.11646/zootaxa.4294.5.7
- Karaouzas I, Graf W, Ku ini M, Vu kovi I, Waringer J. The larva of *Rhyacophila balcanica* Radovanovic 1953 (Trichoptera: Rhyacophilidae) with notes on ecology. *Zootaxa*. 2015; 4057:444–450. DOI: 10.11646/zootaxa.4057.3.10 [PubMed: 26701493]
- Karaouzas I, Ibrahim H, Waringer J. The larva of *Rhyacophila palmeni* McLachlan 1879 (Trichoptera: Rhyacophilidae) from Greece and Kosovo with notes on ecology and zoogeography including a key to the known Greek *Rhyacophila* larvae. *Zootaxa*. 2018; 4514:97–106. DOI: 10.11646/zootaxa.4514.1.8 [PubMed: 30485956]
- Kehl S. *Thremma gallicum* McLachlan, 1880: Zur Biologie, Ökologie und Verbreitung einer faunistischen Besonderheit Deutschlands. *Entomologie Heute*. 2005; 17:13–26.
- Ku ini M, Previši A, Gottstein S, Hrašovec B, Stani -Koštroman S, Pernek M, Deli A. Description of the larvae of *Drusus radovanovici septentrionis* Marinkovi -Gospodneti , 1976 and *Drusus croaticus* Marinkovi -Gospodneti , 1971 (Trichoptera: Limnephilidae) from Bosnia and Herzegovina and Croatia. *Zootaxa*. 2008; 1783:1–17. DOI: 10.11646/zootaxa.1783.1.1
- Ku ini M, Previši A, Štani -Koštroman S, Franjevi M, Seri Jelaska L, Deli A, Posilovi H. Description of the larvae of *Drusus ramae* Marinkovi -Gospodneti and *Drusus medianus* Marinkovic-Gospodneti (Trichoptera: Limnephilidae) with some genetic, distributional, ecological, faunal and conservation notes. *Zootaxa*. 2010; 2484:1–24. DOI: 10.11646/zootaxa.2484.1.1
- Ku ini M, Previši A, Graf W, Šeri Jelaska L, Stani -Koštroman S, Waringer J. Larval description, genetic and ecological features of *Drusus radovanovici radovanovici* Marinkovic-Gospodneti, 1971 (Trichoptera, Limnephilidae) with some phylogenetic and taxonomic data on the bosnicus group in the Balkan Peninsula. *Deutsche Entomologische Zeitschrift*. 2011a; 58:135–153. DOI: 10.1002/mmnd.201100010
- Ku ini M, Previši A, Stani -Koštroman S, Graf W, Franjevi M, Posilovi H, Waringer J. Morphological and ecological features of *Drusus* larvae from the *D. bosnicus* Group on the Balkan Peninsula with description of the larva of *Drusus klapaleki* Marinkovi -Gospodneti , 1971. *Zoosymposia*. 2011b; 5:244–254. DOI: 10.11646/zoosymposia.5.1.18
- Ku ini M, Previši A, Graf W, Mihoci I, Šoufek M, Stani -Koštroman S, Lelo S, Vitecek S, Waringer J. Larval description of *Drusus bosnicus* Klapálek 1899 (Trichoptera: Limnephilidae), with distributional, molecular and ecological features. *Zootaxa*. 2015; 3957:85–97. DOI: 10.11646/zootaxa.3957.1.7 [PubMed: 26249056]
- Ku ini M, Previši A, Mihoci I, Krpa V, Živi I, Stojanovi Mrnjav i Vojvoda A, Katuši L. Morphological features of larvae of *Drusus plicatus* Radovanovi (Insecta, Trichoptera) from the Republic of Macedonia with molecular, ecological, ethological, and distributional notes. *ZooKeys*. 2016; 598:75–97. DOI: 10.3897/zookeys.598.7311
- Kumanski K. Beitrag zur Kenntnis der Wasserstadien einiger *Rhyacophila*-Arten (Rhyacophilidae, Trichoptera). *Bulletin de l'Institut de Zoologie et Musée*. 1971; 33:49–69.
- Kumanski K, Waringer J, Graf W. The larva of *Hydropsyche tabacarui* Botosaneanu, 1960 (Trichoptera: Hydropsychidae), including a re-description of the female. *Aquatic Insects*. 2004; 26:289–295. DOI: 10.1080/0165-0420400001286
- Mackay RJ. Larval identification and instar association in some species of *Hydropsyche* and *Cheumatopsyche* (Trichoptera: Hydropsychidae). *Annals of the Entomological Society of America*. 1978; 71:499–509. DOI: 10.1093/aesa/71.4.499

- McLachlan, R. A Monographic Revision and Synopsis of the Trichoptera of the European Fauna. Part 6. Vol. 68. John van Voorst and Friedländer & Sohn; London and Berlin: 1877. 281–348.
- Majecki J, Grzybewska M, Reddy R. Density, production and life cycle of *Brachycentrus subnubilus* Curtis (Trichoptera: Brachycentridae) in a lowland river, Central Poland. *Hydrobiologia*. 1997; 354:51–56. DOI: 10.1023/A:1003099003493
- Malicky H. Weitere neue Arten und Fundorte von westpaläarktischen Köcherfliegen (Trichoptera), vor allem aus dem östlichen Mediterrangebiet. *Mitteilungen der Entomologischen Gesellschaft Basel*. 1972; 22:25–68.
- Malicky, H. Atlas of European Trichoptera, Second Edition. Springer; 2004. 359
- Malicky H. Neue Beiträge zur Kenntnis asiatischer und mediterraner Köcherfliegen (Trichoptera). *Braueria*. 2014; 41:43–50.
- Martini, J. Diversity, microhabitat distribution and life cycles of Trichoptera in the Schreierbach (Lunz, Lower Austria) Master thesis. University of Vienna; 2018. 77
- Milne MJ. The "metamorphotype method" in Trichoptera. *Journal of the New York Entomological Society*. 1938; 46:435–437.
- Morse JC, Frandsen PB, Graf W, Thomas JA. Diversity and ecosystem services of Trichoptera. *Insects*. 2019; 10doi: 10.3390/insects10050125
- Nielsen A. Über die Entwicklung und Biologie der Trichopteren mit besonderer Berücksichtigung der Quelltrichopteren Himmerlands. *Archiv für Hydrobiologie*. 1942; (Supplement 17):255–631.
- Nielsen, A. Postembryonic Development and Biology of the Hydroptilidae. *Det Kongelige Danske Videnskabernes Selskab; Biologiske Skrifter, Bind V, Nr.1. I Kommision Hos Ejnar Munksgaard; København: 1948. 200*
- Nozaki T, Itou M. Immature stages of *Brachypsyche sibirica* (Martynov) (Trichoptera: Limnephilidae). *Entomological Science*. 1998; 1:423–426.
- Pictet, FJ. *Recherches pour Servir à l'Histoire et à l'Anatomie des Phryganides*. Geneva: 1834. 235[in French]
- Pitsch, T. Zur Larvaltaxonomie, Faunistik und Ökologie mitteleuropäischer Fließwasser-Köcherfliegen (Insecta: Trichoptera) Landschaftsentwicklung und Umweltforschung. Schriftenreihe des Fachbereichs Landschaftsentwicklung, Sonderheft S8, Technische Universität Berlin; 1993. 316[in German]
- Previši A, Graf W, Vitecek S, Ku ini M, Bálint M, Keresztes L, Pauls SU, Waringer J. Cryptic diversity of caddisflies in the Balkans: The curious case of *Ecclisopteryx* species (Trichoptera: Limnephilidae). *Arthropod Systematics & Phylogeny*. 2014; 72:309–329. [PubMed: 25810791]
- Rambur, MP. *Histoire Naturelle des Insectes. Névroptères*. Librairie Encyclopédique de Roret; Paris: 1842. 534[in French]
- Rennerich, J; Schuhmacher, H. In: Morse, JC, editor. Some aspects of the casebuilding behaviour of the burrowing caddis-larvae of *Sericostoma personatum* Kirby & Spence 1826; Proceedings of the Fourth International Symposium on Trichoptera; Clemson, South Carolina. 11-16 July 1983; 1983. 301–305.
- Rinne, A, Wiberg-Larsen, P. Trificon Publishers; Finland: 2017. Trichoptera larvae of Finland; 151
- Ruiz-García A, Ferreras-Romero M. The larva and life history of *Stenophylax crossotus* McLachlan, 1884 (Trichoptera: Limnephilidae) in an intermittent stream from the southwest of the Iberian Peninsula. *Aquatic Insects*. 2007; 29:9–16. DOI: 10.1080/01650420601153308
- Ruiz-García A, Salamanca-Ocaña JC, Ferreras-Romero M. The larvae of *Allogamus gibraltarius* González & Ruiz, 2001 and *Allogamus mortoni* (Navas, 1907) (Trichoptera, Limnephilidae), two endemic species of the Iberian Peninsula. *Annales de Limnologie*. 2004; 40:343–349. DOI: 10.1051/limn/2004031
- Ruiz-García A, Zamora-Muñoz C, Garzón A, Ferreras-Romero M. Description of the last instar larva of *Stenophylax espanioli* Schmid 1957 (Trichoptera: Limnephilidae) from southern Iberian Peninsula with the barcode of the species and synoptic key for identification of the known *Stenophylax* larvae from the Iberian Peninsula. *Zootaxa*. 2018; 4388:292–300. DOI: 10.11646/zootaxa.4388.2.11 [PubMed: 29690460]
- Sainz-Bariáin M, Zamora-Muñoz C. Larval descriptions of *Annitella esparraguera* (Schmid 1952) and *Annitella iglesiasi* González & Malicky 1988 (Trichoptera: Limnephilidae), two endemic species

- from Southern Europe. *Zootaxa*. 2015; 4006:347–360. DOI: 10.11646/zootaxa.4006.2.6 [PubMed: 26623771]
- Siltala AJ. Trichopterologische Untersuchungen No. 2. Über die postembryonal Entwicklung der Trichopteren-Larven. *Zoologische Jahrbücher*. 1907; Supplement, 9
- Sipahiler F. The larva of *Calamoceras illiesi* Malicky & Kumanski, 1974 (Trichoptera, Calamoceratidae). *Nova Acta Cientifica Compostelana (Biologia)*. 2013; 20:21–26.
- Solem J. Norwegian Apatania Kolenati (Trichoptera: Limnephilidae): Identification of larvae and aspects of their biology in a high-altitude zone. *Entomologica Scandinavica*. 1985; 16:161–174. DOI: 10.1163/187631285X00252
- Szczesny B. Larvae of the subfamily Drusinae (Insecta: Trichoptera) from the Polish part of the Carpathian Mts. *Acta Hydrobiologica*. 1978; 20:35–53.
- Tachet H, Morse JC, Berly A. The larva and pupa of *Pseudoneureclipsis lusitanicus* Malicky, 1980 (Trichoptera: Hydropsychoidea): Description, ecological data and taxonomical considerations. *Aquatic Insects*. 2001; 23:93–106. DOI: 10.1076/aqin.23.2.93.4917
- Tachet H, Coppa G, Forcellini M. A comparative description of the larvae of *Psychomyia pusilla* (Fabricius 1781), *Metatype fragilis* (Pictet 1834), and *Paduniella vandeli* Décamps 1965 (Trichoptera: Psychomyiidae) and comments to the larvae of other species belonging to these three genera. *Zootaxa*. 2018; 4402:9–112. DOI: 10.11646/zootaxa.4402.1.4
- Tanida K, Nozaki T, Itou M. The larval stage of *Chilostigma sieboldi* McLachlan (Trichoptera, Limnephilidae), with notes on taxonomy and distribution. *Aquatic Insects*. 1999; 21:153–160. DOI: 10.1076/aqin.21.2.153.4536
- Vaughn CC. Life history of *Helicopsyche borealis* (Hagen) (Trichoptera: Helicopsychidae) in Oklahoma. *The American Midland Naturalist*. 1985; 113:76–83. DOI: 10.2307/2425349
- Vera R. La larva de *Limnephilus guadarramicus* Schmid, 1955 (Trich. Limnephilidae). *Boletín de la Asociación Española de Entomología*. 1979; 3:65–71.
- Vicentini H, Wyler S, Waringer J. The larva of *Hydropsyche doehleri* Tobias 1972, based on Swiss material (Hydropsychidae, Trichoptera). *Zootaxa*. 2020; 4786:535–545. DOI: 10.11646/zootaxa.4786.4.5
- Vieira-Lanero, R. Doctoral Thesis. University of Santiago de Compostela; Galicia: 2000. Las larvas de los Tricópteros de Galicia (Insecta: Trichoptera); 611[in Spanish]
- Vieira Lanero R, González MA, Cobo F. The larva of *Allogamus laureatus* (Návas 1918) (Trichoptera: Limnephilidae). *Aquatic Insects*. 1996; 8:37–44. DOI: 10.1080/01650429609361600
- Vieira-Lanero R, González MA, Cobo F. The larva of *Limnephilus wittmeri* Malicky, 1872 (Insecta, Trichoptera: Limnephilidae). *Spixiana*. 1997a; 20:173–177.
- Vieira-Lanero R, González MA, Cobo F. The larva of *Adicella meridionalis* Morton, 1906 (Trichoptera, Leptoceridae). *Aquatic Insects*. 1997b; 19:123–128. DOI: 10.1080/01650429709361645
- Vieira-Lanero R, González MA, Cobo F. Descripción de las larvas de dos endemismos ibéricos del género *Rhyacophila*: *R. melpomene* Malicky, 1976 y *R. laufferi* Navás, 1918 (Trichoptera, Rhyacophilidae). *Graellsia*. 2001; 57:29–37. DOI: 10.3989/graelisia.2001.v57.i1.293
- Vieira-Lanero R, González MA, Cobo F. The larva of *Drusus bolivari* (McLachlan, 1880) (Trichoptera: Limnephilidae: Drusinae). *Aquatic Insects*. 2005; 27:85–93. DOI: 10.1080/01650420512331390672
- Vieira-Lanero R, González MA, Cobo F. The larva of *Micrasema cenerentola* Schmid, 1952 (Insecta: Trichoptera: Brachycentridae). *Ferrantia*. 2008a; 55:133–140.
- Vieira-Lanero R, González MA, García AR, Cobo F. The larva and female of *Rhyacophila fonticola* Giudicelli & Dakki, 1984 (Trichoptera: Rhyacophilidae), an interesting Betic–Rifean endemic species. *Aquatic Insects*. 2008b; 30:21–28. DOI: 10.1080/01650420701687148
- Vieira-Lanero R, González MA, Cobo F. The larva of *Plectrocnemia laetabilis* McLachlan, 1880 (Trichoptera; Polycentropodidae; Polycentropodinae). *Annales de Limnologie*. 2009; 39:135–139. DOI: 10.1051/limn/2003011
- Vitecek S, Martini J, Zittra C, Kuhlmann H, Vieira A, Waringer J. The larva of *Drusus dudor* Oláh, 2017, including an updated key to larval Drusinae Banks, 1916 (Insecta, Trichoptera,

- Limnephilidae). ZooKeys. 2020a; 908:137–155. DOI: 10.3897/zookeys.908.47032 [PubMed: 32066990]
- Vitecek S, Graf W, Martini J, Zित्रा C, Handschuh S, Kuhlmann H, Vieira A, Hess M, Heckes U, Erzinger F, Pauls SU, et al. A new Drusinae species from the western Alps with comments on the subfamily and an updated key to filtering carnivore larvae of Drusinae species (Insecta: Trichoptera: Limnephilidae). Zootaxa. 2020b; 4790:491–504. DOI: 10.11646/zootaxa.4790.3.4 [PubMed: 32565673]
- Wagner R. A laboratory study on the life cycle of *Sericostomapersonatum* (Kirby & Spence), and light dark-dependent food consumption. Hydrobiologia. 1990; 208:201–212. DOI: 10.1007/BF00007785
- Wallace JB. The larval retreat and rood of *Arctopsyche*, with phylogenetic notes on feeding adaptations in Hydropsychidae larvae (Trichoptera). Annals of the Entomological Society of America. 1975; 68:167–173. DOI: 10.1093/aesa/68.L167
- Wallace, ID, Wallace, B, Philipson, GN. A Key to the Case-bearing Caddis Larvae of Britain and Ireland. Vol. 61. Freshwater Biological Association Scientific Publication; 2003. 259
- Waringer J. Spatial distribution of Trichoptera larvae in the sediments of an Austrian mountain brook. Freshwater Biology. 1987; 18:469–482. DOI: 10.1111/j.1365-2427.1987.tb01332.x
- Waringer J. Life cycle, horizontal microdistribution and current resistance of *Allogamus auricollis* (Trichoptera: Limnephilidae) in an Austrian mountain brook. Freshwater Biology. 1989; 22:177–188. DOI: 10.1111/j.1365-2427.1989.tb01094.x
- Waringer J, Graf W. The larva of *Dipletrona magna* Mosely, 1930 (Trichoptera: Hydropsychidae). Aquatic Insects. 2009; 31:19–24. DOI: 10.1080/01650420802334053 [PubMed: 26973367]
- Waringer, J, Graf, W. Atlas of Central European Trichoptera Larvae. Erik Mauch Verlag; Dinkelscherben: 2011. 468
- Waringer J, Graf W. The larva of *Athripsodes genei* (Rambur 1842) (Trichoptera, Leptoceridae). Zootaxa. 2014a; 3869:75–82. DOI: 10.11646/zootaxa.3869.1.7 [PubMed: 25283900]
- Waringer J, Graf W. The larva of *Oecetis tripunctata* (Fabricius, 1793). (Trichoptera, Leptoceridae). ZooKeys. 2014b; 445:117–126. DOI: 10.3897/zookeys.445.8153
- Waringer J, Graf W. The larva and pupa of *Apatania stylata stylata* Navas 1916, with an updated key to larvae of the European species of genus *Apatania* Kolenati 1848 (Apataniidae, Trichoptera). Freshwater Science. 2018; 38:203–212. DOI: 10.1086/701800
- Waringer J, Graf W. The larva of *Plectrocnemia scruposa* McLachlan 1880 (Trichoptera, Polycentropodidae). Zootaxa. 2020; 4816:115–122. DOI: 10.11646/zootaxa.4816.L8
- Waringer J, Karaouzas I. The larva of *Agapetus episkopi* Malicky 1972 (Trichoptera: Glossosomatidae), including a key to the larvae of Glossosomatidae of the Hellenic western Balkan region. Zootaxa. 2017a; 4329:73–80. DOI: 10.11646/zootaxa.4329.L3 [PubMed: 29242482]
- Waringer J, Karaouzas I. The larva of *Schizopelex huettingeri* Malicky 1974 (Trichoptera: Sericostomatidae), including a preliminary key to the Sericostomatidae larvae of the Hellenic western Balkan region. Zootaxa. 2017b; 4311:271–279. DOI: 10.11646/zootaxa.4311.2.8
- Waringer J, Malicky H. The larvae of *Micropterna coiffaiti* Decamps 1963, *Micropterna taurica* Martynov 1917, and *Potamophylax goulandrionum* Malicky 1974 (Trichoptera: Limnephilidae), including a key to the hitherto known Stenophylacini larvae of the Hellenic western Balkan region. Zootaxa. 2016a; 4175:43–56. DOI: 10.11646/zootaxa.4175.1.4
- Waringer J, Malicky H. The larvae of the European species of genus *Apataniana* Mosely, 1936 (Trichoptera, Apataniidae): Descriptions, key and ecology. Zookeys. 2016b; 586:121–134. DOI: 10.3897/zookeys.586.7758
- Waringer J, Malicky H. The larvae of *Sericostoma bergeri* Malicky, 1973 and *Sericostoma herakles* Malicky, 1999 (Trichoptera, Sericostomatidae). ZooKeys. 2017; 695:123–133. DOI: 10.3897/zookeys.695.14531
- Waringer J, Malicky H. The larvae of *Rhyacophila rougemonti* McLachlan 1880, *Rhyacophila trifasciata* Mosely 1930, *Rhyacophila pallida* Mosely 1930, and *Rhyacophila tarda* Giudicelli 1968 (Trichoptera: Rhyacophilidae), including a discriminatory matrix to the *Rhyacophila* larvae

- with tetrafilament abdominal gills from Italy and Corsica. *Zootaxa*. 2018a; 4526:516–530. DOI: 10.11646/zootaxa.4526A5 [PubMed: 30651503]
- Waringer J, Malicky H. The larvae of *Beraemyia aphyrt* Malicky 1972, *Beraemyia kutsaftikii* Malicky 1975, and *Beraemyia matsakii* Malicky 1980 (Trichoptera: Beraeidae), including a discriminatory matrix to the Greek Beraeidae larvae. *Zootaxa*. 2018b; 4527:255–268. DOI: 10.11646/zootaxa.4527.2.6 [PubMed: 30651465]
- Waringer J, Malicky H. The larvae of *Sericostoma sasbaddes* Malicky 2010 *S. maclachlanianum* Costa 1884, *S. clypeatum* Hagen 864, and *S. siculum* McLachlan 1876 (Trichoptera: Sericostomatidae), including a preliminary key to the Sericostomatidae larvae of European Ecoregion 3 (Italy, Corsica, and Malta). *Zootaxa*. 2018c; 4379:517–528. DOI: 10.11646/zootaxa.4379.4.4 [PubMed: 29689963]
- Waringer J, Malicky H. Larva of *Halesus nurag* Malicky 1974 (Trichoptera: Limnephilidae) and diagnostic key for the limnephilid larvae of Sardinia. *Zootaxa*. 2018d; 4425:555–566. DOI: 10.11646/zootaxa.4425.3.8 [PubMed: 30313301]
- Waringer J, Malicky H. Identification and morphology of an apataniid caddisfly larva from the Levant: *Apatania cypria* Tjeder 1952 *Zootaxa*. 2018e; 4382:185–191. DOI: 10.11646/zootaxa.4382.1.8
- Waringer J, Malicky H. Identification and morphology of a rhyacophilid caddisfly larva from Cyprus: *Rhyacophila aphrodite* Malicky 1975. *Zootaxa*. 2019a; 4623:563–570. DOI: 10.11646/zootaxa.4623.3.8
- Waringer J, Malicky H. The larva of *Plectrocnemia renetta* Malicky 1975 (Trichoptera, Polycentropodidae), including a discriminatory matrix to the larvae of *Plectrocnemia* Stephens 1836 species of Greece. *Zootaxa*. 2019a; 4568:372–382. DOI: 10.11646/zootaxa.4568.2.11
- Waringer J, Malicky H. The larvae of *Athripsodes longispinosus longispinosus* (Martynov 1909), *Athripsodes longispinosuspaleochora* (Malicky 1972), and *Athripsodes bilineatus aegeus* Malicky 1999 (Trichoptera: Leptoceridae), including a discriminatory matrix to the larvae of genus *Athripsodes* Billberg 1820 in Greece. *Zootaxa*. 2019c; 4609:485–498. DOI: 10.11646/zootaxa.4609.3.5
- Waringer J, Malicky H. The larvae of *Limnephilus minos* Malicky 1970 and *Mesophylax impunctatus aduncus* (Navas 1923) (Trichoptera: Limnephilidae), including a discriminatory matrix for the Greek limnephilid larvae with multifilament gills. *Zootaxa*. 2019d; 4612:187–204. DOI: 10.11646/zootaxa.4612.2.3
- Waringer J, Malicky H. The larva of *Rhyacophila hartigi* Malicky 1971, including a discriminatory matrix to the Italian *Rhyacophila* larvae with tufted multifilament gills (Rhyacophilidae, Trichoptera). *Zootaxa*. 2020; 4731:103–114. DOI: 10.11646/zootaxa.4731.L7
- Waringer J, Graf W, Pauls S, Cianficconi F. The larvae of *Drusus improvisus* McLachlan, 1884, *Drusus camerinus* Moretti, 1981 and *Drusus aprutiensis* Moretti, 1981 (Trichoptera: Limnephilidae: Drusinae). *Aquatic Insects*. 2008a; 30:269–279. DOI: 10.1080/01650420802334046 [PubMed: 26973365]
- Waringer J, Graf W, Pauls S, Vicentini H, Lubini V. DNA based association and description of the larval stage of *Drusus melanchaetes* McLachlan, 1876 (Trichoptera: Limnephilidae: Drusinae) with notes on ecology and zoogeography. *Limnologica*. 2008b; 38:34–42. DOI: 10.1016/nimno.2007.09.001 [PubMed: 26997681]
- Waringer J, Graf W, Ku ini M, Previši A, Vu kovi I. The larva and life cycle of *Annitella apfelbecki* (Klapalek, 1899), including a redescription of *Melampophylax nepos* (McLachlan, 1880) (Trichoptera: Limnephilidae). *Aquatic Insects*. 2009; 31:71–80. DOI: 10.1080/01650420802616327 [PubMed: 26997687]
- Waringer J, Graf W, Malicky H. Description of the larvae of *Limnephilus femoratus* (Zetterstedt, 1840) and *Limnephilus subnitidus* McLachlan, 1875, with additional notes on *Limnephilus picturatus* McLachlan, 1875 (Trichoptera: Limnephilidae). *Aquatic Insects*. 2011a; 33:371–380. DOI: 10.1080/01650424.2011.640335
- Waringer J, Botosaneanu L, Le Guellec G. The larva of *Alpopsyche ucenorum* (McLachlan 1876) (Trichoptera: Limnephilidae) with notes on its systematic position and ecology. *Zootaxa*. 2011b; 2967:44–50.
- Waringer J, Graf W, Malicky H. The larvae of *Allogamus antennatus* (McLachlan 1876), *Allogamus mendax* (McLachlan 1876) and *Allogamus pertuli* Malicky 1975 (Trichoptera: Limnephilidae)

- with notes on ecology and zoogeography. *Zootaxa*. 2012a; 3351:27–38. DOI: 10.11646/zootaxa.3351.1.3
- Waringer J, Graf W, Malicky H. Description of the larvae of *Anabolia lombarda* Ris, 1897 and *Limnephilus sericeus* (Say, 1824), with additional notes on *Limnephilus flavospinosus* Stein, 1874 (Trichoptera: Limnephilidae). *Aquatic Insects*. 2012b; 34:93–105. DOI: 10.1080/01650424.2012.718084
- Waringer J, Graf W, Malicky H. Problems associated with extrapolating ecological traits to higher-than-species level exemplified in the description of the larvae of *Potamophylax haidukorum* Malicky, 1999, *Potamophylax winneguthi* (Klapalek, 1902) and *Melampophylax austriacus* Malicky, 1990. *Limnologica*. 2013a; 43:441–450. DOI: 10.1016/nimno.2013.02.001
- Waringer J, Graf W, Malicky H. The larva of *Psilopteryx psorosa* (Kolenati 1860) (Trichoptera: Limnephilidae) with notes on ecology and zoogeography. *Zootaxa*. 2013b; 3694:579–586. DOI: 10.11646/zootaxa.3694.6.5 [PubMed: 26312312]
- Waringer J, Graf W, Bálint M, Ku ini M, Pauls SU, Previši A, Keresztes L, Vitecek S. The larvae of *Drusus franzressli* Malicky 1974 and *Drusus spelaeus* (Ulmer 1920) (Trichoptera: Limnephilidae: Drusinae) with notes on ecology and zoogeography. *Zootaxa*. 2013c; 3637:1–16. DOI: 10.11646/zootaxa.3637.1.1 [PubMed: 26046172]
- Waringer J, Graf W, Bálint M, Ku ini M, Pauls SU, Previši A, Keresztes L, Vitecek S. The larva of *Drusus vinconi* Sipahiler, 1992 (Trichoptera, Limnephilidae, Drusinae). *ZooKeys*. 2013d; 317:69–80. DOI: 10.3897/zookeys.317.5749
- Waringer W, Graf H, Malicky H. The larvae of *Stenophylax mitis* McLachlan 1875 and *Allogamus hiliaris* (McLachlan 1876a) (Trichoptera: Limnephilidae), with notes on ecology and zoogeography. *Zootaxa*. 2014; 3780:375–387. DOI: 10.11646/zootaxa.3780.2.9 [PubMed: 24871842]
- Waringer J, Graf W, Bálint M, Ku ini M, Pauls SU, Previši A, Keresztes L, Ibrahim H, Živi I, Bjelanovi K, Krpa V, Vitecek S. Larval morphology and phylogenetic position of *Drusus balcanicus*, *D. botosaneanui*, *D. serbicus* and *D. tenellus* (Trichoptera: Limnephilidae: Drusinae). *European Journal of Entomology*. 2015a; 112:344–361. DOI: 10.14411/eje.2015.037 [PubMed: 26997882]
- Waringer J, Lubini V, Hoppeler F, Pauls SU. DNA-based association and description of the larval stage of *Apatania helvetica* Schmid 1954 (Trichoptera, Apataniidae) with notes on ecology and zoogeography. *Zootaxa*. 2015b; 4020:244–256. DOI: 10.11646/zootaxa.4020.2.2 [PubMed: 26624099]
- Waringer J, Vitecek S, Graf W. Larval morphology and identification of *Rhyacophila meyeri* McLachlan 1879 (Trichoptera: Rhyacophilidae). *Zootaxa*. 2016a; 4093:559–565. DOI: 10.11646/zootaxa.4093.4.7 [PubMed: 27073321]
- Waringer J, Previši A, Ku ini M, Graf W, Vitecek S, Keresztes L, Bálint M, Pauls SU. Larval morphology of the Western Balkans endemic caddisflies *Drusus krusniki* Malicky 1981, *D. vernonensis* Malicky 1989, and *D. vespertinus* Marinkovic-Gospodnetic 1976 (Trichoptera, Limnephilidae, Drusinae). *Zootaxa*. 2016b; 4083:483–500. DOI: 10.11646/zootaxa.4083.4.2 [PubMed: 26985141]
- Waringer J, Malicky H, Graf W, Vitecek S. The larva of *Adicella syriaca* Ulmer 1907, including a key to the European larvae of *Adicella* McLachlan, 1877 (Trichoptera, Leptoceridae). *ZooKeys*. 2017a; 711:131–140. DOI: 10.3897/zookeys.711.20121
- Waringer J, Malicky H, Živi I, Vicentini H. The larvae of the European *Helicopsyche* species (Trichoptera: Helicopsychidae). *Zootaxa*. 2017b; 4277:561–572. DOI: 10.11646/zootaxa.4277.4.6 [PubMed: 30308631]
- Waringer J, Graf W, Sipahiler F, Malicky H. The larvae of *Silo chrisiammos* Malicky 1984 and *Lithax musaca* Malicky 1972 (Trichoptera: Goeridae), including a key to the Goeridae larvae of the Eastern and Hellenic western Balkan regions. *Zootaxa*. 2017c; 4306:67–80. DOI: 10.11646/zootaxa.4306.1.3
- Waringer J, Karaouzas I, Malicky H. The larvae of *Rhyacophila tsurakiana* Malicky 1984, *Rhyacophila gudrunae* Malicky 1972, and *Rhyacophila biegelemeri* Malicky 1984, including an update for the larval key to the Greek species of genus *Rhyacophila* Stephens 1836 (Rhyacophilidae,

- Trichoptera). *Zootaxa*. 2018a; 4508:85–100. DOI: 10.11646/zootaxa.4508.L5 [PubMed: 30485998]
- Waringer J, González MA, Martín L, Martínez J, Erzinger F, Pauls SU. DNA-based association and description of the larval stage of *Apatania theischingerorum* Malicky 1981 (Trichoptera, Apataniidae), with notes on its ecology. *Zootaxa*. 2018b; 4418:161–170. DOI: 10.11646/zootaxa.4418.2.5 [PubMed: 30313594]
- Waringer J, González MA, Malicky H. Discriminatory matrix for the larvae of the European *Thremma* species (Trichoptera: Thremmatidae). *Zootaxa*. 2020; 4718:451–466. DOI: 10.11646/zootaxa.4718.4.1
- Waringer J, Martini J, Vitecek S. A remarkable caddisfly from the Vjosa River catchment: *Thremma anomalum* McLachlan. 1876
- Wiberg-Larsen P, Iversen TM, Thorup J. First Danish record of *Ptilocolepus granulatus* (Pictet) (Trichoptera, Hydropsychidae). *Entomologisk Meddelelser*. 1991; 59:45–50.
- Zweidick, OGJ. Thesis. University of Natural Resources and Life Sciences; Vienna: 2020. Macroinvertebrate Communities of Perennial and Intermittent Streams in Bioregion 14 (“Grazer Feld und Grabenland“ Austria: Styria) with a Special Focus on Caddisflies; 125

Figure 1.
Ithytrichia lamellaris Eaton 1873, fifth instar larva with case.

Figure 2.
Hydropsyche tabacarui Botosaneanu 1960, fifth instar larva, abdominal segments VI–IX
(white ovals = pupal gill buds).

Figure 3.
Athripsodes longispinosus paleochora (Malicky 1972), fifth instar larva, head, right anterolateral (arrow = subocular ecdysial line).

Figure 4. *Halesus rubricollis* (Pictet 1834), first instar larva, pronotum, dorsal (white numerals refer to setal positions; arrows indicate pits). Scale bars: 0.5 mm in Figs. 1 and 3, 1 mm in Fig. 2, 0.1 mm in Fig. 4.

Figure 5.

Linear regression (with 95% confidence bands) of forewing length versus final instar head width, based on pooled data of 451 European Trichoptera species across all families, showing the regression equation, the coefficient of determination, and the probability level for the relationship.