

© Entomologica Fennica. 15 March 2007

Preimaginal feeding habits of *Dictyogenus fontium* (Plecoptera, Perlodidae) in an alpine brook in NW Italy

Stefano Fenoglio*, Tiziano Bo and Giorgio Malacarne

Fenoglio, S., Bo, T. & Malacarne, G. 2007: Preimaginal feeding habits of *Dictyogenus fontium* (Plecoptera, Perlodidae) in an alpine brook in NW Italy. — Entomol. Fennica 18: 27–31.

The feeding habits of *Dictyogenus fontium* nymphs were investigated in the Rio Olen, an alpine brook in NW Italy. In an analysis of the gut contents of 84 nymphs, we detected evident trophic preferences: Chironomidae (Diptera) were the major component of the prey ingested, independently of their availability in the substratum. Plant detritus and algae were also an important part of the diet of this carnivorous stonefly. The findings are discussed on the basis of ecological considerations.

S. Fenoglio, T. Bo & G. Malacarne, University of Piemonte Orientale, Di.S.A.V., Via Bellini n. 25, 15100 Alessandria, Italy; *corresponding author's e-mail: fenoglio@unipmn.it

Received 5 December 2005, accepted 16 March 2006

1. Introduction

Benthic communities in running water are composed almost exclusively of insects: they constitute an estimated 70–90% of the macro-invertebrate species in streams and rivers (Minshall 1969). Plecoptera is one of the most important orders in these ecosystems, indeed often the dominant order (Zwick 2000, Elliott 2004). For this reason, many studies have investigated different aspects of the ecology and life-history of this group (Tierno de Figueroa & Fochetti 2001, Stewart & Stark 2002).

In recent years, there has been increasing interest in stonefly food habits. Since the pioneering study of Richardson and Gaufin (1971), research has been conducted on food selection (Feminella & Stewart 1986), ontogenetic shifts in the diet (Bo & Fenoglio 2005) and functional grouping (Short & Ward 1981 – feeding mechanisms, according to the RCC, River Continuum Concept, Vannote *et al.* 1980).

Plecoptera nymphs are the most abundant predators in many lotic systems. In particular, Plecoptera Systellognatha is the dominant predator group in fishless alpine streams, with a key ecological role as top-down control elements in benthic communities (Zanetell & Peckarsky 1996, Wipfli & Gregovich 2002). Peckarsky and Dodson (1980) analysed the colonisation process of instream artificial substrata and found that substrata containing predaceous stoneflies were less colonised, confirming that these predators can significantly influence benthic community structure. Optimal foraging theory, as formulated by Krebs (1978), predicts that predators opt for the most advantageous prey according to different factors, such as encounter rate, prey density, energy contents, handling time and others. Fuller and Stewart (1977, 1979) investigated food habits of many Plecoptera species, quantifying electivity and food preferences of stonefly larvae in relation to food availability: they demonstrated the existence of seasonal and ontogenetic shifts,

dietary overlaps, daily periodicity and prey size electivity. Predaceous stoneflies exhibit a great variety of food habits: some species seem to be extremely selective, feeding mainly on certain prey (Fenoglio & Bo 2004), while other species are more opportunistic, eating the most abundant organisms in the benthic community (Allan & Flecker 1988, Dudgeon 2000). Moreover, studies have shown that several Systellognatha have varied food habits, feeding not only on living animal prey but also on plant detritus (Lillehammer 1988). For this reason, Stewart and Stark (2002) stated that some stonefly species would not fit into any of the stereotyped categories defined by dominant food or feeding mechanisms, e.g. the five functional feeding groups sensu RCC (scrapers, shredders, predators, filterers and collector-gatherers). Hence, the food habits of unstudied species cannot be inferred from their phylogenetic position.

Dictyogenus fontium (Ris, 1896) is a typical orophilous species, endemic to the Alps (Consiglio 1980, Ravizza & Ravizza-Dematteis 1991, Fochetti 1995, Brittain & Saltveit 1996). As its specific name suggests, this mountain stonefly lives in small springs and brooks at altitudes ranging from 1,000 to 2,600 m a.s.l., where it is often the only Perlodidae (Ravizza & Ravizza-Dematteis 1990).

The aim of this study was to analyse the diet of *D. fontium* nymphs in a typical alpine environment.

2. Material and methods

On 29–30 September 2005, *D. fontium* nymphs were collected in a 100 m uniform riffle of the Rio Olen brook (UTM 414652–5079947; 2,100 m a.s.l.). The sampling station is a typical alpine lotic environment, characterized by high slope, coarse riverbed and fast flowing water. Riparian vegetation is almost absent, except for some *Sorbus aucuparia*. This lotic system shows good environmental quality, corresponding to an environment without traces of human-induced alteration (first class in the Italian Extended Biotic Index, Ghetti 1997). The main abiotic parameters are reported in Table 1. Samplings were carried out with a kick-net sampler (20 x 20 cm; mesh

Table 1. Main abiotic parameters in the sampling station, Rio Olen brook (NW Italy).

Temperature (°C)	4.8
pH	7.7
Conductivity (µS/cm)	78.0
Alkalinity (mg HCO ₃ ⁻ /l)	26.0
Cl ⁻ (mg/l)	0.5
SO ₄ ²⁻ (mg/l)	4.2
PO ₄ ³⁻ (mg/l)	< 0.1
NO ₃ ⁻ (mg/l)	0.6
NO ₂ ⁻ (mg/l)	< 0.01
NH ₄ ⁺ (mg/l)	< 0.4

size of 500 µm) early in the morning, because Systellognatha are considered mainly nocturnal feeders (Vaught & Stewart 1974). We also collected Surber samples in the same riffle to assess the presence and abundance of taxa in the natural benthic invertebrate population. Samples were preserved in 90% ethanol. In the laboratory, all organisms were counted and identified to the genus level, except for Lumbriculidae and early instars of some Diptera, which were identified to the family level.

The total length of *D. fontium* nymphs was measured (0.1 mm accuracy) and the nymphs were processed to assess food consumption by means of gut contents analysis. Guts were removed and the contents of the alimentary canal were analysed by the transparency method for slides. Fragments of animal prey were identified to the lowest taxonomic level possible. Identification of prey was based on sclerotized body parts, particularly head capsules, mouthparts and leg fragments. Stewart and Stark (2002) stated that the count of sclerotized fragments (i.e. head capsules) can give a reasonably accurate count of prey consumed, and weights or volumes could be extrapolated, if necessary, from morphometric weight-volume relationships of prey. To investigate possible feeding preferences, we compared the gut contents with the natural composition and abundance of macroinvertebrate communities in the riverbed using the trophic electivity index of Ivlev (1961):

$$E = (ri - pi) / (ri + pi)$$

where ri = the proportion of ingested species and pi = the relative abundance in the benthic commu-

nity. Feeding preferences were also quantified using another electivity index (McCormick 1991):

$$E^* = (W_{i-1} / N) / W_{i+1} / N$$

where

$$W_i = (r_i / p_i) / \sum r_i / p_i$$

In this formula, r_i = the proportion of ingested species, p_i = the relative abundance in the benthic community, and N = the number of food items. Both indexes range from -1.0 to 1.0. A value of -1.0 means total avoidance, 1.0 indicates preference and 0 indicates indifference. The presence of algae and detritus (e.g. fragments of terrestrial vegetation) was recorded and quantified on a scale of 0-3 (0 = no presence; 3 = highest abundance class).

3. Results

We examined the gut contents of 84 *Dictyogenus fontium* nymphs and we collected 760 macroinvertebrates belonging to 26 taxa. The taxa list and relative macroinvertebrate abundance in the riverbed are reported in Table 2. The mean length of *D. fontium* immature stages was 12.9 mm, with a minimum of 8.0 mm and a maximum of 17.5 mm.

During the laboratory analysis, we found four

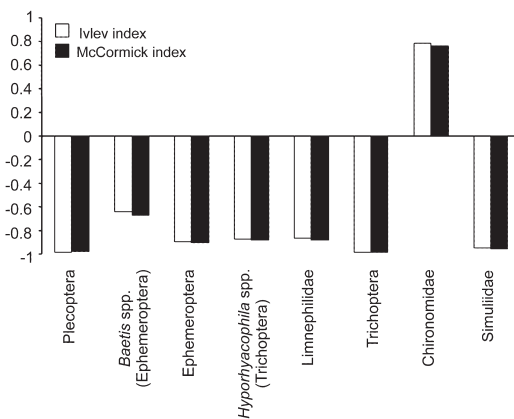


Fig. 1. Electivity indexes for macroinvertebrate taxa in the diet of *Dictyogenus fontium* nymphs in Rio Olen brook.

Table 2. Relative abundance (% value in the community) of macroinvertebrates collected in the natural riverbed.

Taxa	Relative abundance (%)	FFG (*)
Plecoptera		
<i>Leuctra</i> sp.	3.68	Sh
<i>Nemoura</i> sp.	4.61	Sh
<i>Protonemura</i> sp.	2.63	Sh
<i>Chloroperla susemicheli</i>	3.16	P
<i>Siphonoperla montana</i>	1.58	P
<i>Isoperla</i> sp.	1.05	P
<i>Dictyogenus fontium</i>	5.05	P
Ephemeroptera		
<i>Ecdyonurus</i> sp.	8.95	Sc
<i>Rhithrogena</i> sp.	1.58	Sc
<i>Epeorus alpicola</i>	2.11	Sc
<i>Baetis melanonyx</i>	5.79	Cg
<i>Baetis</i> sp.	2.63	Cg
Trichoptera		
<i>Rhyacophila</i> sp.	11.32	P
<i>Hyporhyacophila</i> sp.	2.11	P
<i>Drusus</i> sp.	5.26	Sh
<i>Monocentra lepidoptera</i>	2.63	Sh
<i>Cryptothrix nebulicola</i>	2.63	Sh
Diptera		
Chironomidae	11.58	Cg
Limoniidae	2.11	P
Empididae	1.05	P
Simuliidae	8.11	F
<i>Lispe</i> sp.	1.45	P
<i>Prionocera</i> sp.	0.53	Sh
Oligochaeta		
Lumbriculidae	3.68	Cg
<i>Eiseniella tetraedra</i>	0.53	Cg
Crustacea		
<i>Niphargus</i> sp.	0.13	Cg
Platyhelminthes		
<i>Crenobia alpina</i>	2.50	P
Arachnida		
Hydracarina	1.58	P

(*) FFG: f unctional feeding groups (Cg = collector-gatherers; F = filterers; P = predators; Sc = scrapers; Sh = shredders. see Merritt and Cummins 1996).

completely empty guts. Fine plant fragments and algae were present in 82% of the examined guts. Furthermore, plant detritus was virtually the only element found in five nymphs; interestingly, these five nymphs were of very different size, from 10.4 to 17.5 mm (total length).

Results of the feeding preference analysis are reported in Fig. 1. Considering all specimens collected, the most important prey group was Chiro-

nomidae (Diptera): it constituted 68.8% of total ingested items and was present in 65.5% of guts. Ephemeroptera, mainly Baetidae, was the second most frequent group, occurring in 9.5% of guts. In two specimens, we found heads and other body parts of Limnephilidae (Trichoptera) and in one gut there was an entire specimen of *Hyporhyacophila* sp. (Trichoptera). Plecoptera legs and fragments were present in only one gut. Interestingly, some organisms that were quite abundant in the natural environment, such as *Rhyacophila* sp., *Hyporhyacophila* sp. (Trichoptera) and *Prosimulium* sp. (Diptera), were almost absent in the diet of *D. fontium*.

4. Discussion

Several studies have examined food habits in stoneflies (Fuller & Stewart 1979, Peckarsky 1980, Allan & Flecker 1988). The problem of an accurate assessment of feeding habits and food electivity has been pointed out in many papers and summarized in the work of Peckarsky (1984): the exclusion of particular prey items from the predator's diet could be related to several causes, such as effective prey escape mechanisms, low prey availability or lack of habitat overlap between prey and predator.

The aquatic nymphs of large Systellognatha have long been considered almost exclusively carnivorous. However, in recent studies, plant material and algae have been recorded in gut contents of *Dinocras cephalotes* (Lucy *et al.* 1990), *Perlodes microcephalus* (Fenoglio *et al.* 2005), *Isoperla grammatica* (Malmqvist *et al.* 1991) and *Dictyogenus alpinum* (Fenoglio & Bo 2004). This study demonstrates that the importance of plant detritus in the diet of these organisms could be more important than previously supposed; we also suggest that this resource could be particularly significant in oligotrophic and extreme habitats, such as alpine brooks. Flexible feeding habits could be an efficient adaptation to fluctuating and poor food resources.

The second main finding of our study is the evidence of trophic selection in the diet of *D. fontium* immature stages. We found an evident preference for Chironomidae: although larvae of this family were the most abundant organisms in

the Rio Olen brook, the two indexes revealed that their presence in the diet was related to active selection and preference (Ivlev index = 0.79, McCormick index = 0.76). This consistent pattern of election of Chironomidae and avoidance of other abundant organisms could be related to ecological and behavioural factors; for example, Simuliidae could be difficult to catch because they inhabit microhabitats difficult to explore (upper surface of stones in fast flowing environments). On the other hand, the relatively abundant caddisflies of the family Rhyacophilidae may be a difficult prey because of their large size and predaceous habits.

In conclusion, this study provides evidence that the diet of *D. fontium* in alpine environments is not strictly carnivorous and is characterised by trophic selection for a few selected prey.

Acknowledgements. We thank Paolo Agosta and Massimo Pessino for help during field sampling. We are also indebted to Peter Zwick and an anonymous referee for their constructive comments.

References

- Allan, J. D. & Flecker, A. S. 1988: Prey preference in stoneflies: a comparative analysis of prey vulnerability. — *Oecologia* 76: 495–503.
- Bo, T. & Fenoglio, S. 2005: Age-related shift in the diet of *Perla marginata* in a woodland Apennine creek of NW Italy (Plecoptera: Perlidae). — *Entomol. Generalis* 28: 147–154.
- Brittain, J. E. & Saltveit, S. J. 1996: Plecoptera, Stoneflies. — In: Nilsson, A. (ed.), *Aquatic Insects of North Europe. A Taxonomic Handbook*, Vol. 1: 55–75. Apollo Books, Stenstrup. 274 pp.
- Consiglio, C. 1980: La distribuzione dei Plecotteri italiani. — In: *Lavori della Società Italiana di Biogeografia — Il popolamento delle acque interne italiane*: 383–393. Lito Tipo Valbonesi, Forlì. 612 pp.
- Dudgeon, D. 2000: Indiscriminate feeding by a predatory stonefly (Plecoptera: Perlidae) in a tropical Asian stream. — *Aquatic Insects* 22: 39–47.
- Elliott, J.M. 2004: Prey switching in four species of carnivorous stoneflies. — *Freshwater Biol.* 49: 709–720.
- Feminella, J. W. & Stewart, K. W. 1986: Diet and predation by three leaf-associated stoneflies in an Arkansas mountain stream. — *Freshwater Biol.* 16: 521–538.
- Fenoglio, S. & Bo, T. 2004: Trophic characterization of *Dictyogenus alpinus* (Pictet, 1842 — Plecoptera, Perlodidae) nymphs in the high Po Valley (NW Italy). — *Zool. Baetica* 15: 167–174.
- Fenoglio, S., Bo, T. & Cucco, M. 2005: Winter prey prefer-

- ence of *Perlodes microcephalus* (Pictet, 1833) (Plecoptera, Perlodidae) nymphs in an Apenninic creek, Northwestern Italy. — *Entomol. News* 116: 245–252.
- Fochetti, R. 1995: Plecotteri. — In: Minelli, A., Ruffo, S. & La Posta, S. (ed.), Checklist delle specie della fauna italiana, Bologna. 3 pp.
- Fuller, R. L. & Stewart, K. W. 1977: The food habits of stoneflies (Plecoptera) in the upper Gunnison River, Colorado. — *Environ. Entomol.* 6: 293–302.
- Fuller, R. L. & Stewart, K. W. 1979: Stonefly (Plecoptera) food habits and prey preference in the Dolores River, Colorado. — *Am. Midl. Naturalist* 101: 170–181.
- Ghetti, P. F. 1997: Manuale di applicazione dell'Indice Biotico Esteso. — Provincia Autonoma di Trento, Trento. 222 pp.
- Ivlev, V. S. 1961: Experimental ecology of the feeding of fishes. — Yale University Press., New Heaven.
- Krebs, J. R. 1978: Optimal foraging: Decision rules for predators. — In: Krebs R. & Davis N. B (eds.), *Behavioral Ecology: An Evolutionary Approach*: 23–63. Blackwell Scientific Publications, London.
- Lillehammer, A. 1988: Stoneflies (Plecoptera) of Fennoscandia and Denmark. — Scandinavian Science Press, Leiden. 165 pp.
- Lucy, F., Costello, M. J. & Giller, P. S. 1990: Diet of *Dinocras cephalotes* and *Perla marginata* (Plecoptera Perlidae) in a south-west Irish stream. — *Aquatic Insects* 12: 199–207.
- Malmqvist, B., Sjöström, P. & Frick, K. 1991: The diet of two species of *Isoperla* (Plecoptera: Perlodidae) in relation to season, site, and sympatry. — *Hydrobiologia* 213: 191–203.
- McCormick, P. V. 1991: Lotic protistan herbivore selectivity and its potential impact on benthic algal assemblages. — *J. North Am. Benthol. Soc.* 10: 238–250.
- Merritt, R. W. & Cummins, K. W. 1996: An introduction to the aquatic insects of North America. — Kendall / Hunt, Dubuque, IO. 860 pp.
- Minshall, G. W. 1969: Community structure in natural stream systems. — In: *The stream ecosystem*. Inst. For Water research Michigan State University, Technical report n. 7: 2–30.
- Peckarsky, B. L. 1980: Predator-prey interactions between stoneflies and mayflies: behavioural observations. — *Ecology* 61: 932–943.
- Peckarsky, B. L. 1984: Predator-prey interactions among aquatic insects. — In: Resh V. H. & Rosemberg D. M. (eds), *The ecology of aquatic insects*: 196–254. Praeger, New York.
- Peckarsky, B. L. & Dodson, S. I. 1980: Do stonefly predators influence benthic distributions in streams? — *Ecology* 61: 1275–1282.
- Ravizza, C. & Ravizza Dematteis, E. 1990: The stonefly fauna of the Oropa Valley (Pennine Alps) (Plecoptera). — *Boll. Mus. reg. Sci. nat. Torino* 8: 321–342.
- Ravizza, C. & Ravizza Dematteis, E. 1991: Altitudinal, seasonal and coenotic distribution patterns of stoneflies (Plecoptera) in the Oropa Valley (Pennine Alps). — *Mem. Ist. Ital. Idrobiol.* 49: 29–50.
- Richardson, J. W. & Gaufin, A. R. 1971: Food habits of some western stonefly nymphs. — *T. Am. Entomol. Soc.* 97: 91–121.
- Short, R. A. & Ward, J. V. 1981: Trophic ecology of three winter stoneflies (Plecoptera). — *Am. Midl. Naturalist* 105: 341–347.
- Stewart, K. W. & Stark, B. P. 2002: Nymphs of North American stonefly genera (Plecoptera). Second Edition. The Caddis Press, Columbus, Ohio. 510 pp.
- Tierno de Figueroa, J. M. & Fochetti R. 2001: On the adult feeding of several European stoneflies (Plecoptera). — *Entomol. News* 112: 130–134.
- Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R. & Cushing, C. E. 1980: The river continuum concept. *Can. J. Fish. Aquat. Sci.* 37: 130–137.
- Vaught, G. L. & Stewart, K. W. 1974: The life history and ecology of the stonefly *Neoperla clymene* (Newman) (Plecoptera: Perlidae). — *Ann. Entomol. Soc. Am.* 67: 167–178.
- Wipfli, M. S. & Gregovich, D. P. 2002: Export of invertebrates and detritus from fishless headwater streams in southeastern Alaska: implications for downstream salmonid production. — *Freshwater Biology* 47: 957–969.
- Zanetell, B. A. & Peckarsky, B. L. 1996: Stoneflies as ecological engineers: hungry predators reduce fine sediments in stream beds. — *Freshwater Biology* 36: 569–577.
- Zwick, P. 2000: Phylogenetic system and zoogeography of the Plecoptera. — *Annu. Rev. Entomol.* 45: 709–745.