Aquatic Insects
Vol. 31, Supplement 1, 2009, 401–407

Taylor & Francis
Taylor & Francis Group

Preimaginal feeding habits of *Isoperla carbonaria* Aubert, 1953 (Plecoptera: Perlodidae)

Stefano Fenoglio[a]*, Tiziano Bo[a], Manuel Jesús López-Rodríguez[b], José Manuel Tierno de Figueroa[b] and Giorgio Malacarne[a]

[a]*Dipartimento di Scienze dell'Ambiente e della Vita, Università del Piemonte Orientale ''A. Avogadro'', Alessandria, Italy;* [b]*Departamento de Biología Animal, Facultad de Ciencias, Universidad de Granada, Granada, Spain*

(*Received 6 October 2008; final version received 18 November 2008*)

Feeding habits of larval *Isoperla carbonaria* Aubert, 1953 have been investigated in the Rio Alpetto, an Alpine creek of northwestern Italy. This species is characterised by relatively small size and rheophilous habits, and inhabits streams above 350 m a.s.l. in the Alps, Apennines and Sicily. In this study, we analysed the gut contents of 72 larvae of this species, with the aim of investigating feeding preferences and to assessing the existence of size-related shifts in the trophic spectrum. Larvae were collected from a single reach, whose benthic coenosis was also determined. We detected evident trophic preferences in the diet: few taxa constituted the greatest part of the ingested items, independently from their availability in the substratum. Moreover, we observed that largest larvae fed on a broader number of taxa. These findings are discussed and compared with data obtained from other Systellognatha species.

Keywords: stoneflies; predator; diet; Alps, gut contents

Introduction

Large invertebrate predators play a main role in many aquatic systems, where they act as top-down control elements in the benthic community (Wipfli and Gregovich 2002). In alpine fast flowing lotic systems, these predators are mainly represented by Plecoptera: Systellognatha. In these environments, carnivorous stoneflies may have a great ecological importance. Allan (1983) reported that the dry weight of insect preys consumed by stoneflies in a Rocky Mountain stream could be about half the weight consumed by trout. In this frame, Perlidae and Perlodidae represent the most interesting subjects of study.

Isoperla carbonaria Aubert, 1953 (Perlodidae) is a rheophilous species, present in some Italian mountainous river systems, with a total length of approximately 10–13 mm (Consiglio 1980). In the Western Alps, *I. carbonaria* is quite common (Fochetti 1995), and its presence in the high Po valley was reported for the first time by Ravizza Dematteis and Ravizza (1988). As a species of Perlodidae, it is supposed to be carnivorous, but nothing has been known about its trophic role up to

*Corresponding author. Email: fenoglio@unipmn.it

ISSN 0165-0424 print/ISSN 1744-4152 online

DOI: 10.1080/01650420802650862
http://www.informaworld.com

now. The aim of this study is to describe the diet of *I. carbonaria* in a lotic system of the Western Alps, investigating feeding preferences and size-related trophic changes.

Materials and methods

In June and July 2006, *I. carbonaria* larvae were collected in a 100 m uniform riffle of the Rio Alpetto (44° 40′ 20.87″ N, 7° 10′ 18.78″ E; 1600 m a.s.l.). In the sampled station, Rio Alpetto is a typical alpine lotic environment, characterised by high slope, coarse riverbed and fast flowing waters. Riparian vegetation is almost absent, except for some specimens of *Sorbus aucuparia* L., *Alnus viridis* (Chaix), and *Fraxinus excelsior* L. This lotic system shows a good environmental quality, corresponding to an environment without trace of human-inducted alteration (first class in the Italian Extended Biotic Index, Ghetti 1997). Samplings were carried out with a kick-net sampler (mesh size of 250 μm) early in the morning, because Systellognatha are considered to be chiefly nocturnal feeders (Vaught and Stewart 1974). Furthermore, in the same reach we assessed the presence and abundance of the benthic community by using a Surber net (20 × 20 cm; mesh 250 μm). Samples were preserved in 90% ethanol. In the laboratory, all organisms were counted and identified to genus level, except for a few groups (e.g. some Oligochaeta and early instars of some Diptera and Trichoptera), which were identified to family level. *I. carbonaria* larvae were measured (total length to 0.1 mm accuracy) and processed to assess food consumption by means of gut contents analysis. The contents of the alimentary canal of some small specimens (<10.0 mm total length) were analysed following the transparency method proposed by Bello and Cabrera (1999), widely employed in stonefly feeding studies (Tierno de Figueroa and Sánchez-Ortega 1999; Tierno de Figueroa et al. 2003; Cammarata et al. 2007) with slight variations: each larva was introduced in a vial with Hertwig's liquid for 48 hours at 25°C. Afterwards, cleared individuals were located on a microscope slide glass with a cover glass on. For large-sized larvae (>10.0 mm total length), we removed the gut dissecting the specimens, then we extracted and analysed the contents of the alimentary canal. As previously observed by the authors, the use of both methods brings no difference in the results. Identification of preys was based on sclerotised body parts, particularly head capsules, mouthparts and leg fragments. To investigate the existence of feeding preferences, gut contents were compared with the natural composition and abundance of the riverbed macroinvertebrate community 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 community. Feeding preferences were also quantified using another electivity index (McCormick 1991): $E^* = (W_i - 1/N)/W_i + 1/N$, where $W_i = (r_i/p_i)/\Sigma r_i/p_i$. 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.

Results

In total we analysed the diet of 72 *I. carbonaria* larvae and we collected and identified 1367 benthic macroinvertebrates from the riverbed. Benthic communities were composed of typical orophilous and stenothermic taxa (Table 1). Mean length of

Table 1. List of macroinvertebrates collected in the Rio Alpetto station. FFG: functional feeding groups.

Taxa		FFG*
Plecoptera		
Leuctridae	*Leuctra* sp.	**Sh**
Chloroperlidae	*Chloroperla susemicheli*	**P**
Nemouridae	*Nemoura* sp.	**Sh**
	Protonemura sp.	**Sh**
Perlodidae	*Isoperla* sp.	**P**
Ephemeroptera		
Heptageniidae	*Ecdyonurus* sp.	**Sc**
	Electrogena sp.	**Sc**
	Rhithrogena sp.	**Sc**
	Iron alpicola	**Sc**
Baetidae	*Baetis* sp.	**Cg**
Trichoptera		
Odontoceridae	*Odontocerum albicorne*	**Sh**
Sericostomatidae	*Sericostoma* sp.	**Sh**
Polycentropodidae		**F**
Limnephilidae		**Sh**
Rhyacophilidae	*Rhyacophila* sp.	**P**
	Hyporhyacophila sp.	**P**
Philopotamidae		**F**
Diptera		
Thaumaleidae	*Thaumalea* sp.	**Sc**
Ceratopogonidae		**P**
Dixidae		**Cg**
Chironomidae		**Cg**
Limoniidae		**P**
Tipulidae	*Prionocera* sp.	**Sh**
Simuliidae		**F**
Empididae		**P**
Coleoptera		
Hydraenidae		**Sc**
Elmidae		**Cg**
Oligochaeta		
Lumbricidae	*Eiseniella tetraedra*	**Cg**
Lumbriculidae		**Cg**
Naididae		**Cg**
Platyhelminthes		
Planariidae	*Crenobia alpina*	**P**

*Sh = Shredders, Sc = Scrapers, Cg = Collectors-gatherers, F = Filterers, P = Predators.

studied *I. carbonaria* immature stages was 11.0 $\pm$ 1.69 mm SD, with a minimum of 6.50 mm and a maximum of 13.5 mm. Analysing gut contents, we noticed that 19.4% of larvae had completely empty guts. In 54 specimens we found animal remains, while in 53 specimens we detected the presence of vegetal detritus, hyphae and algae. Furthermore, in 12 guts we discovered the presence of sand and inorganic detritus. Results of the application of electivity indexes are reported in Figures 1 and 2. Considering all specimens collected, the most important prey group in the guts were Diptera Chironomidae: they constituted nearly 59.5% of total ingested items, but represented only 5.9% of the benthic community. We also noticed an evident

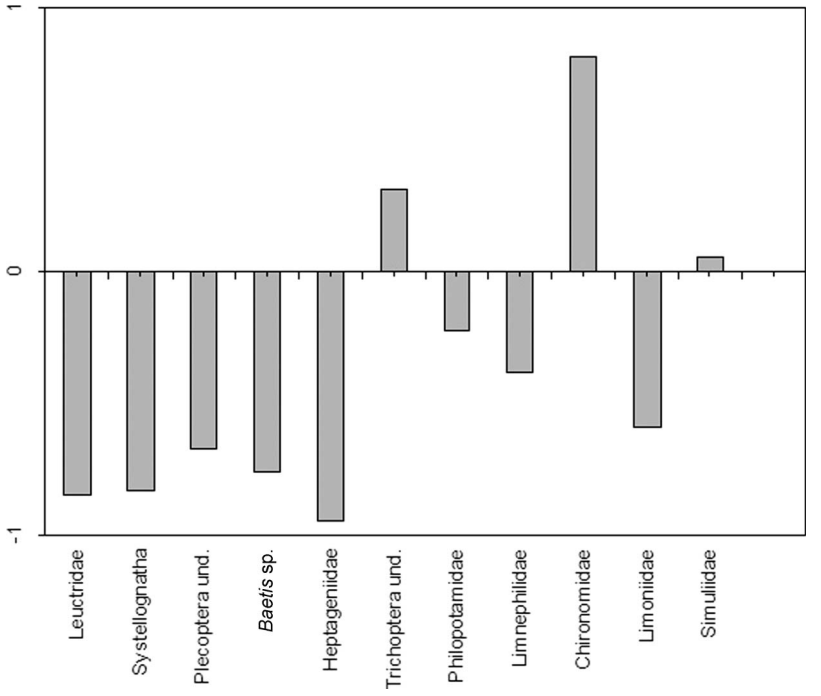

Figure 1. Ivlev's electivity index.

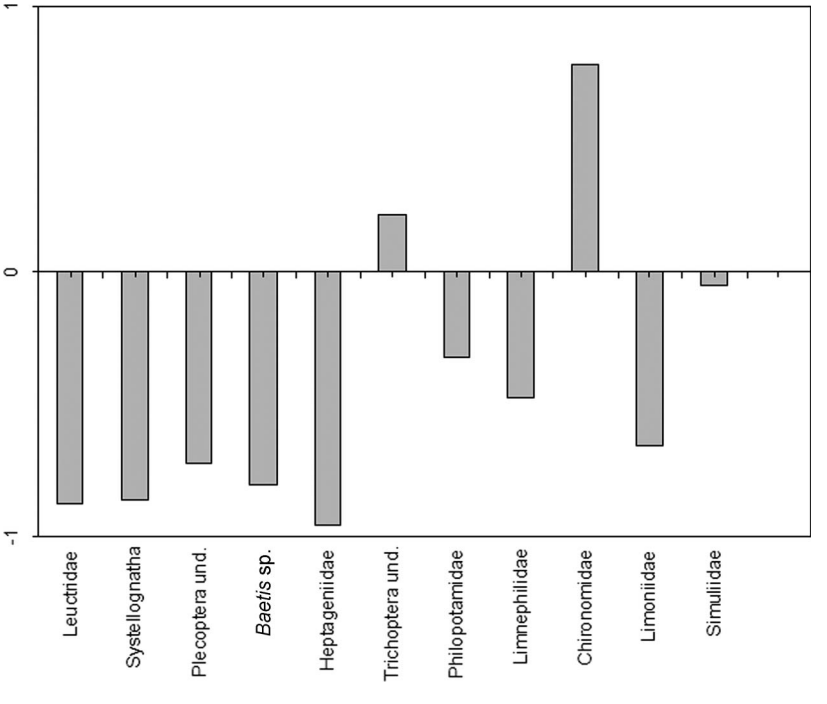

Figure 2. McCormick's electivity index.

change in the diet of larvae of different size. After dividing specimens into three-dimensional classes (smallest: total length < 8.5 mm; medium sized: 8.5–10.0 mm; largest: > 10.0 mm) we noticed that the largest ones fed on a broader number of taxa (ANOVA $F_{2, 69} = 2.86$, $P < 0.05$; Figure 3).

Discussion

Because of their importance as top predators in small lotic environments, studies on carnivorous Plecoptera feeding habits represent a useful tool to investigate lotic food webs, behavioural and ecological aspects of stream organism relationships, but up to now only a few studies have analysed Alpine species (e.g. Fenoglio and Bo 2004; Maiolini and Silveri 2005; Fenoglio et al. 2007; Silveri et al. 2008). A first interesting result we discuss is the presence of an evident trophic mechanism of selection in *I. carbonaria*. Its diet was dominated by Chironomidae. Interestingly, Ephemeroptera were scarcely consumed: for example Heptageniidae represented 23.3% of the community and 0.6% of the gut contents, and Baetidae 22.3% and 3.1%, respectively. It is well known that predaceous stoneflies forage across the surface of the substratum, seeking preys mainly by using their antennae, and that they can use hydrodynamic cues to distinguish between preys (Peckarsky and Wilcox 1989). Nevertheless, some studies noticed different trophic preferences among predaceous species, clearly showing that selection for particular prey taxa is a trait which varies among different species of stoneflies (Molles and Pietruszka 1987; Williams 1987; Dudgeon 2000). Particularly in Alpine environments, Chironomidae may be discriminated and actively hunted by *I. carbonaria*. They constitute the preferred food item, probably because they are relatively abundant in the study area, they are not particularly fast for escaping, and they are easy to ingest and assimilate (due to their handling size and thin exoskeleton). This positive selection was also found in some other European *Isoperla* species such as

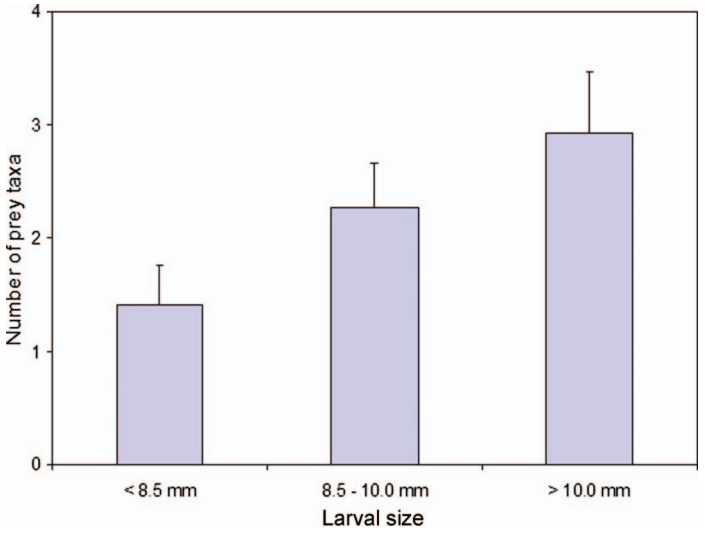

Figure 3. Number of prey taxa in the guts of the three age groups of *I. carbonaria* larvae (mean $\pm$ SE).

I. acicularis (Despax, 1936), *I. moselyi* (Despax, 1936) (Berthélemy and Lahoud 1981), and *I. rivulorum* (Pictet, 1842) (Silveri et al. 2008).

This work also partially supports the hypothesis that vegetal detritus could represent an important component of Systellognatha diet, following what has been reported by other authors (Lucy et al. 1990). Interestingly, these results confirm what has been found in other two species of Perlodidae, whose trophic habits were recently investigated in the same Alpine area: *Dyctiogenus alpinus* (Fenoglio and Bo 2004) and *D. fontium* (Fenoglio et al. 2007). The importance of vegetal detritus in the alimentation of alpine Perlodidae could be more important than previously supposed, probably because this resource could be particularly significant in oligotrophic and extreme habitats, such as alpine brooks. Finally, we detected an increase in the trophic spectrum of larvae related with larval size: smaller individuals fed on fewer taxa, while the largest ones captured a wide range of organisms. The broader diet of larger individuals could be due to a greater ability of consuming different preys, also characterised by a larger size [as previously pointed out for some species of stoneflies (Sheldon 1980)], and in the capacity of exploring more microhabitats in the riverbed. Nevertheless, experimental studies are needed to confirm these hypotheses.

Acknowledgements

We thank the Parco del Po Cuneese and Regione Piemonte, Pianificazione Risorse Idriche, for their interest and support, S. Iorio for help with field sampling and Dr. Arnold Staniczek for his useful comments.

References

Allan, J.D. (1983), 'Food consumption by trout and stoneflies in a Rocky Mountain stream, with comparison to prey standing crop', in *Dynamics of Lotic Ecosystems*, eds. T.D. Fontaine and S.M. Bartell, Ann Arbor, MI: Science Publishers.

Bello, C.L., and Cabrera, M.I. (1999), 'Uso de la técnica microhistológica de Cavender y Hansen en la identificación de insectos acuáticos', *Boletín Entomológico Venezolano*, 14, 77–79.

Berthélemy, C., and Lahoud, M. (1981), 'Régimes alimentaires et pièces bucales de quelques Perlodidae et Perlidae des Pyrénées (Plecoptera)', *Annales de Limnologie*, 16, 159–182.

Cammarata, M., Fenoglio, S., López-Rodríguez, M.J., Bo, T., and Tierno de Figueroa, J.M. (2007), 'Prey selection of *Perla grandis* (Rambur, 1841) nymphs (Plecoptera, Perlidae) in Borbera Stream (NW Italy)', *Boletín de la Sociedad Entomológica Aragonesa*, 41, 271–274.

Consiglio, C. (1980), 'La distribuzione dei Plecotteri italiani', *Il popolamento delle acque interne italiane*, Forlì: Valbonesi.

Dudgeon, D. (2000), 'Indiscriminate feeding by a predatory stonefly (Plecoptera: Perlidae) in a tropical Asian stream', *Aquatic Insects*, 22, 39–47.

Fenoglio, S., and Bo, T. (2004), 'Trophic characterization of *Dictyogenus alpinus* (Pictet, 1842 – Plecoptera, Perlodidae) nymphs in the high Po Valley (NW Italy)', *Zoologica Baetica*, 15, 167–174.

Fenoglio, S., Bo, T., and Malacarne, G. (2007), 'Preimaginal feeding habits of *Dictyogenus fontium* (Ris, 1896) (Plecoptera, Perlodidae) in an alpine brook (Olen – NW Italy)', *Entomologica Fennica*, 18, 26–23.

Fochetti, R. (1995), 'Plecotteri. 3', in *Checklist delle specie della fauna italiana*, eds. A. Minelli, S. Ruffo and S. La Posta, Bologna: Calderini.

Ghetti, P.F. (1997), *Manuale di applicazione dell'Indice Biotico Esteso*, Trento: Provincia Autonoma di Trento.

Ivlev, V.S. (1961), *Experimental Ecology of the Feeding of Fishes*, New Haven, CT: Yale University Press.

Lucy, F., Costello, M., and Giller, P.S. (1990), 'Diet of *Dinocras cephalotes* and *Perla bipunctata* (Plecoptera, Perlidae) in a South West Irish stream', *Aquatic Insects*, 12, 199–207.

Maiolini, B., and Silveri, L. (2005), 'Feeding habits of *Dyctiogenus fontium* (Plecoptera Perlodidae) in Alpine streams (Trentino – NE Italy)', *Studi trentini di scienze naturali – Acta biologica*, 82, 77–83.

McCormick, P.V. (1991), 'Lotic protistan herbivore selectivity and its potential impact on benthic algal assemblages', *Journal of the North American Benthological Society*, 10, 238–250.

Molles, M.C. Jr., and Pietruszka, R.D. (1987), 'Prey selection by a stonefly: the influence of hunger and prey size', *Oecologia*, 72, 473–478.

Peckarsky, B.K., and Wilcox, R.S. (1989), 'Stonefly nymphs use hydrodynamic cues to discriminate between prey', *Oecologia*, 79, 265–270.

Ravizza Dematteis, E., and Ravizza, C. (1988), 'Les Plécopteres de la vallée supérieure du Po (Alpes Cotiennes). Notes faunistiques et écologiques', *Annales de Limnologie*, 24, 243–260.

Sheldon, A.L. (1980), 'Resource division by perlid stoneflies (Plecoptera) in a lake outlet ecosystem', *Hydrobiologia*, 71, 155–162.

Silveri, L., Tierno de Figueroa, J.M., and Maiolini, B. (2008), 'Feeding habits of Perlodidae (Insecta, Plecoptera) in the hyporheic habitats of Alpine streams (Trentino-NE Italy)', *Entomologica Fennica*, 19, 176–183.

Tierno de Figueroa, J.M., and Sanchez-Ortega, A. (1999), 'Imaginal feeding of certain systellognathan stonefly species (Insecta, Plecoptera)', *Annals of the Entomological Society of America*, 92, 218–221.

Tierno de Figueroa, J.M., Sezzi, E., and Fochetti, R. (2003), 'Feeding in the genus *Tyrrhenoleuctra* (Plecoptera Leuctridae)', *Bollettino della Società Entomologica Italiana*, 134, 207–210.

Vaught, G.L., and Stewart, K.W. (1974), 'The life history and ecology of the stonefly *Neoperla clymene* (Newman) (Plecoptera: Perlidae)', *Annals of the Entomological Society of America*, 67, 167–178.

Williams, D.D. (1987), 'A laboratory study of predator-prey interactions of stoneflies and mayflies', *Freshwater Biology*, 17, 471–490.

Wipfli, M.S., and Gregovich, D.P. (2002), 'Export of invertebrates and detritus from fishless headwater streams in south-eastern Alaska: implication for downstream salmonid production', *Freshwater Biology*, 47, 957–969.