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Feeding habit of *Notoperla archiplatae* (Plecoptera) larvae in a North Patagonia Andean stream, Argentina

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Abstract

The feeding habit of *Notoperla archiplatae* (Plecoptera) larvae was assessed by means of the observation of mouthparts morphology and gut contents analysis. Larvae of different sizes were collected from the Ñireco stream, in the North Patagonian Andes. Mouthparts morphology was indicative of a phytophagous diet. Diet was composed mainly of diatoms; therefore, periphyton was sampled and compared with gut contents through an electivity index in order to determine if *N. archiplatae* selectively consumed certain diatom species. This analysis showed that the insects preferred erect diatoms, especially those with an arborescent habitus. Based on mouthpart morphology and gut content, *N. archiplatae* was assigned to the scrapers functional feeding group.

Introduction

The characterisation of feeding mechanisms by function and the subsequent use of such information in aquatic insect ecology, provides an insight into primary consumer pattern (Lamberti & Moore, 1984). In particular, feeding habits of the Plecoptera have been intensively studied in the Northern Hemisphere (Allan, 1982; Stewart & Stark, 1988) and most of them are recognised as shredders or predators, while only few are classified as scrapers (Merrit & Cummins, 1996). Hynes (1976) noted that most Southern Hemisphere Plecoptera families feed primarily upon decaying plant material. However, Sephton & Hynes (1983) reported that the Gripopterygidae from Australia consume both detritus and fine material, including algae. In the Southern Hemisphere, the Gripopterygidae was found to be the most species-rich family, with maximum richness occurring in high mountain streams of South America (Illies, 1963). Although there is a considerable lack of information, low order Andean-Patagonian streams appear suitable environments for Plecoptera development. Wais (1990) surveyed the macrozoobenthos of the Río Negro and, more recently, Albariño (1997) reported 13 Plecoptera species from the Ñireco stream, most of them belonging to the Gripopterygidae.

Within Gripopterygidae, the genus *Notoperla* is only found in cold running waters of Chile and Argentina (Illies, 1963). In particular, *Notoperla archiplatae* (Illies) occurs in streams of the North Patagonian Andes, between 33° 45′ S and 41° 08′ S (Illies, 1963). Albariño (1997) reported this species as one of the largest stoneflies restricted to the upper section of the Ñireco stream. In this study, we examined the feeding habit of *N. archiplatae* by means of the observation of mouthpart morphology and the analysis of gut contents. We also compared the gut content to available food resource in order to assess feeding selectivity.

Study area

Sampling was carried out in Ñireco stream (41° 08′ S; 71° 17′ W). Headwaters are located in the eastern slope of Ventana mountain at 1700 m a.s.l., flowing through a dense forest of *Nothofagus pumilio* (P. & E.) Krasser, locally called ‘lenga’. Then, the stream runs

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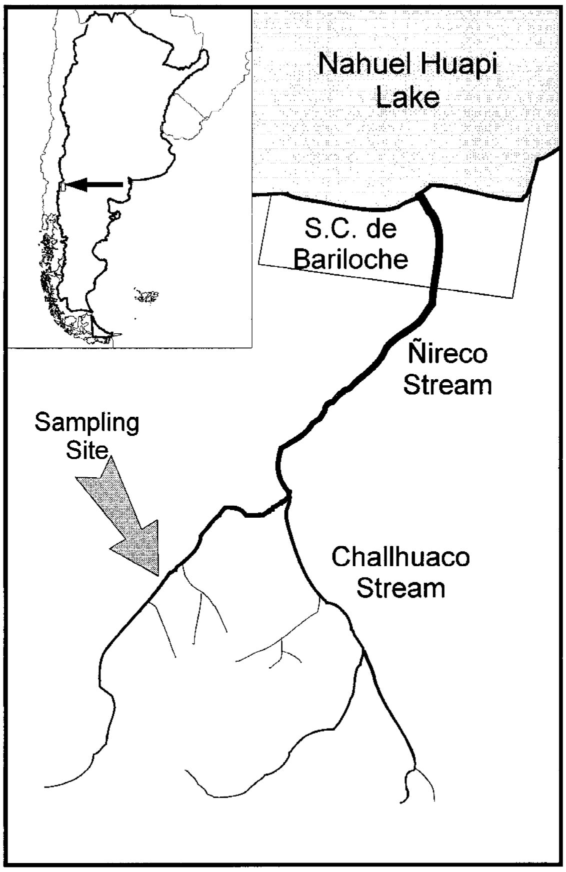


Figure 1. Geographic location of Ñireco stream and the sampling station.

across an open valley until its end at Nahuel Huapi lake (769 m a.s.l.) (Figure 1).

A sampling station, corresponding with the restricted distribution of *N. archiplatae* (Albariño, 1997), was established in the upper stream section at 1080 m a.s.l. (Figure 1). In this section, the slope is steep (10%) and the stream is 3–4 m wide and 15 cm deep. The narrow channel has small falls and wood debris dams that increase the retention of organic matter. The system drains an igneous watershed with boulders-cobbles substrate.

Methods

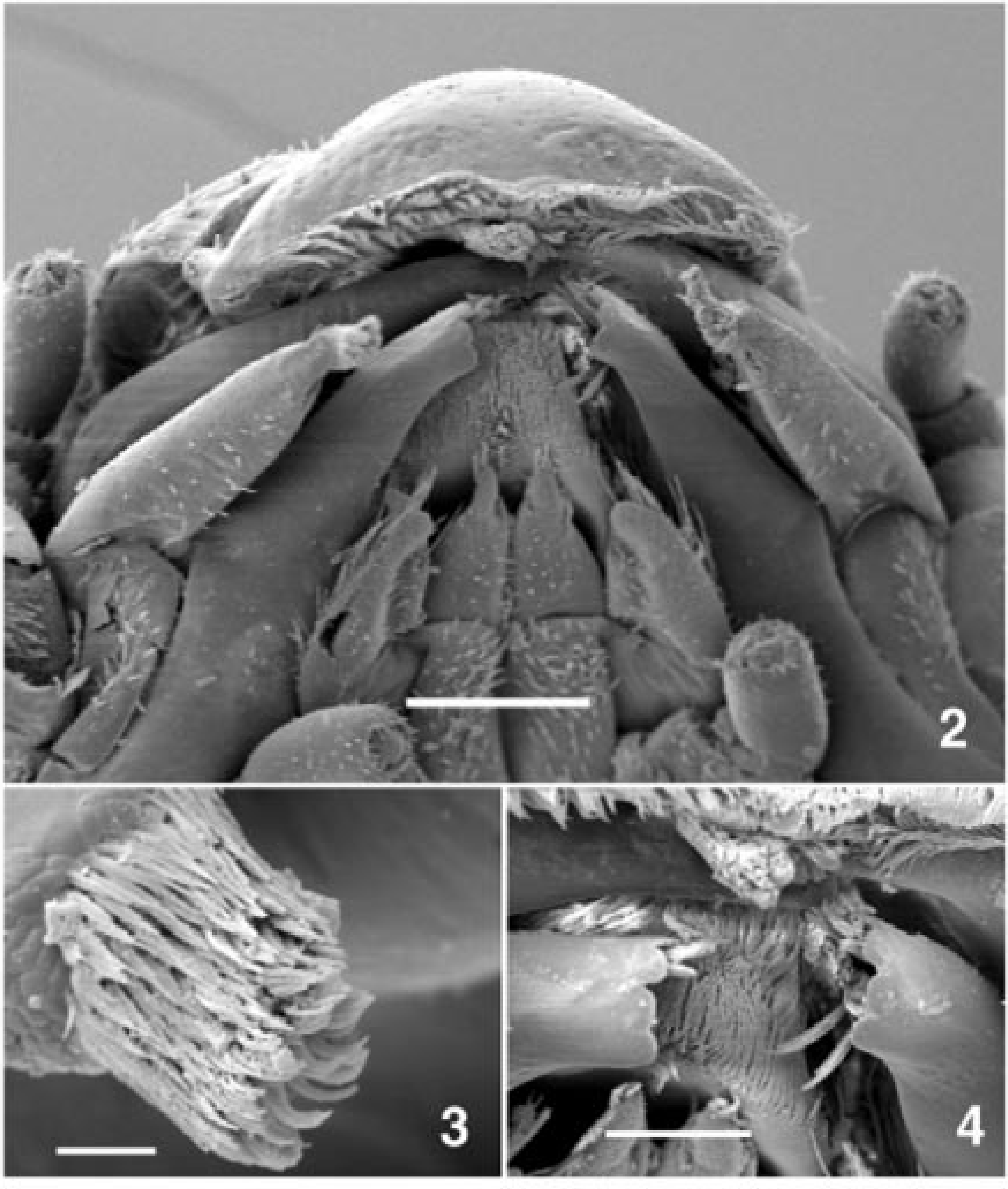
Sampling was conducted in January, March and June 1998, in order to obtain a wide size range of larvae. On each sampling date, water temperature, conductivity and dissolved oxygen were measured with a thermistor, conductimeter, and oxymeter, respectively. Samples were taken at two locations, one covered by dense forest (shaded) and the other in an open site (illuminated). At each site, macroinvertebrates were obtained with a Surber sampler (0.09 m^2 and 200 μm mesh size), and fixed with 10% formalin. At least eight replicate samples were collected on each date. Periphyton was collected from ten stones, each approximately 40 cm in diameter. Each stone was scraped five times with a stiff nylon brush attached to the piston of a 20 ml disposal plastic syringe. The sampler was placed firmly against the rock surface with a rubber ring and the piston with the brush was rotated several times. Then the piston was drawn up the barrel of the syringe, drawing the loose periphyton into the syringe. This apparatus scraped an area equal to 2.8 cm^2. Samples were fixed with 4% formalin.

In the laboratory, *Notoperla archiplatae* individuals were separated from other taxa under a stereomicroscope. Pronotum width was measured with a micrometer eyepiece, and specimens were dried and weighed to determine biomass. Mouthparts were examined under a stereomicroscope. Heads were dissected and dried in absolute ethanol for observation under the scanning electronic microscope.

Gut contents were analysed using two procedures. Foregut contents of 14 individuals were analysed following Palmer & O'Keeffe (1992) and Palmer et al. (1993a). The foregut content was homogenised in distilled water with a pipette and filtered through a 0.45 μm membrane filter. Filters were cleared with immersion oil and 15 randomly selected fields per slide were counted under a direct microscope at 400 $\times$ magnification. Nine food categories were identified: (1–3) plant fragments divided in three size classes:

1. 0.5–70.0 μm (PFa),
2. 70.0–250.0 μm (PFb),
3. 250.0–1000.0 μm (PFc);
4. diatoms;
5. amorphous matter;
6. fungi;
7. inorganic matter;
8. invertebrate remains; and
9. pollen.

The area covered by each item was measured with a graduate eyepiece. Quantification of each item was based on the fraction of area covered relative to the total area covered by the gut contents. As diatoms were found to be a preferred food, we also determined whether *N. archiplatae* selectively consumed certain diatom species. In this case, gut contents of 8 –



Figures 2–4. Notoperla archiplatae mouthparts SEM micrographs. (2) General view, scale: 200 μm; (3) Detail of the right galea tip's brush, scale: 20 μm; (4) detail of the lacineae tips, scale: 100 μm.

12 individuals of each sampling date and site were processed following the same methodology as for periphyton samples.

Periphyton samples were treated with peroxide in order to oxidise organic matter to facilitate the identification, counting and measuring of diatoms. Samples were mounted in Naphrax® and examined under a direct microscope at 1000×. A minimum of 500 valves was counted in each sample. Identifications were performed according Krammer & Lange-Bertalot (1986, 1988 and 1991).

Feeding preferences were quantified using an electivity index (McCormick, 1991):

$$E^* = \frac{W_i - 1/N}{W_i + 1/N},$$

where

$$W_i = \frac{r_i/p_i}{\Sigma r_i/p_i},$$

where r_i = the proportion of ingested species, p_i = the relative abundance in the periphyton, and N = the number of food items. This index ranges from -1 to 1. A value of -1 means total avoidance, 1 indicates preference and 0 indicates indifference.

For all comparisons, statistical differences of means were tested using Mann-Whitney test (Sokal & Rohlf, 1981).

Results

Water temperature varied from 14.3 °C (January) to 3.5 °C (June) at the open site and from 9.8 °C (January) to 3 °C (June) at the shaded site. Conductivity was highest in January (58 μS cm^{-1}) and lowest in June (45 μS cm^{-1}). Dissolved oxygen was always near saturation.

Individuals of *N. archiplatae* ranged between 1.5 mm and 3.3 mm in pronotum width and 1.43 mg and 41.44 mg in dry weight. The smallest individuals were found in January and the largest ones in June (Table 1). Size distributions also differed between the shaded and illuminated sites (Table 1), being significantly larger in the latter in January and June but not in March, both in terms of dry weight and pronotum width.

The SEM observations of heads revealed the presence of well-developed and well-sclerotised mandibles and maxilae. The former have an apical wide scope-like tooth and an inner margin with subapical sharp teeth and reduced molar area. The maxilae present lacineae and galeae of about equal size (Figure 2). The two-segmented galeae have an apical dense crown of bristles of 40 μm length (Figure 3). The lacineae have apical rounded teeth and sharp ventral margins (Figure 4). Maxillary palps are stout and long. Labium presents glossae and paraglossae of equal lengths and short and stout palps (Figure 2). Labrum is concave and has a dense fringe of hairs in its margin.

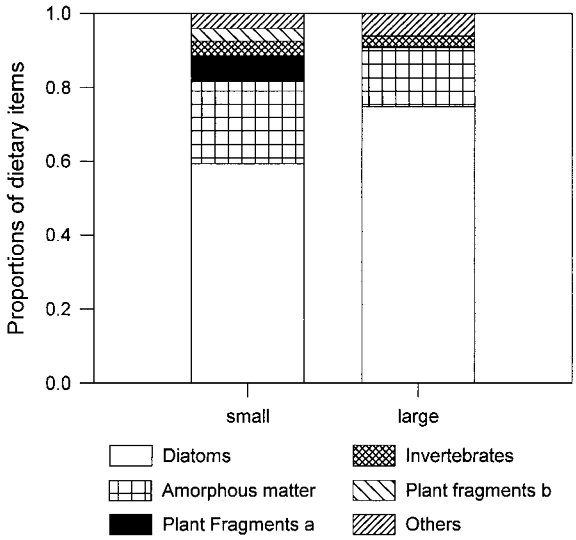


Figure 5. Food item proportions in the gut contents from individuals smaller than 1 cm length (small) (pronotum width < 0.2 cm) and larger than 1 cm length (large) (pronotum width > 0.2 cm).

The analysis of the foregut showed that gut contents had an overall similarity throughout the size range for the specimens examined (Figure 5). Diatoms were the dominant item in all guts. Amorphous matter was the second most abundant item and the other components were less than 10% and not present in all guts. However, there was a significant difference in plant fragments between the large individuals (body length>1 cm; pronotum width>0.2 cm) and the small individuals (body length <1 cm; pronotum width <0.2 cm). In the latter, total plant fragments represented 10% of the gut content whereas only a 0.55% in the larger individuals.

Periphyton was composed mainly of diatoms but there also were some patches of the chrysophycean *Hydrurus foetidus* (Villars) Trev. The periphytic assemblage consisted of 51 species of diatoms, but the number of species found at each site varied between 32 and 36. The diatom cell density obtained for the illuminated site was 600, 4200 and 4000 cell mm^{-2} and in the shade it was 1200, 1300 and 1800 cell mm^{-2} in January, March and June respectively.

Table 1. Pronotum width and dry mass of *Notoperla archiplatae* in the three sampling occasions. References: (*) indicate significant differences between the shaded and the illuminated site, Mann-Whitney test

	Shaded site		Illuminated site	
	Pronotum width (mm)	Dry mass (mg)	Pronotum width (mm)	Dry mass (mg)
January*	1.50 ± 0.10	2.01 ± 0.34	1.82 ± 0.07	4.51 ± 0.39
March	2.40 ± 0.08	6.09 ± 0.41	2.27 ± 0.08	8.51 ± 0.81
June*	2.90 ± 0.04	14.16 ± 1.12	3.30 ± 0.08	26.94 ± 1.73

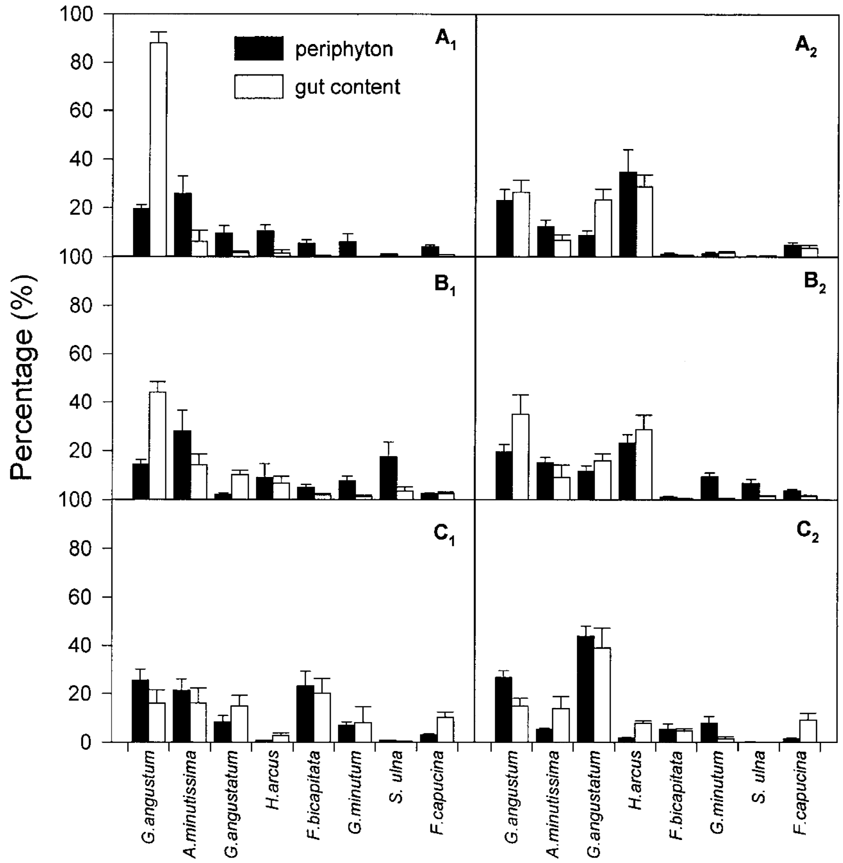


Figure 6. Comparison between the dominant diatom species (in order of mean abundance) in the periphyton (filled bars) and in the gut contents (empty bars) in all sampling occasions. (A) January; (B) March; (C) June; (1) shade; (2) light.

The periphytic diatom community of Ñireco stream was composed of species commonly found in oligotrophic environments, with fresh-brackish water, cold or temperate, pH near or over 7 and with moderate to constantly high dissolved oxygen levels (De Wolf, 1982; Van Dam et al., 1994). The dominant diatom species (mean abundance > 10%) were *Gomphonema angustum* Agardh, *Achnanthes minutissima* Kutz., *Gomphonema angustatum* (Kutz.) Rabh., *Hannaea arcus* (Ehr.) Patrick, *Fragilaria bicapitata* Mayer and *Synedra ulna* (Nit.) Ehr., at the different sites and dates (Figure 6, filled bars). *Gomphonema angustum* was the only species that comprised over 10% of the community on all sampling dates at both sites, without significant differences between sites and dates. *Achnanthes minutissima* also comprised over

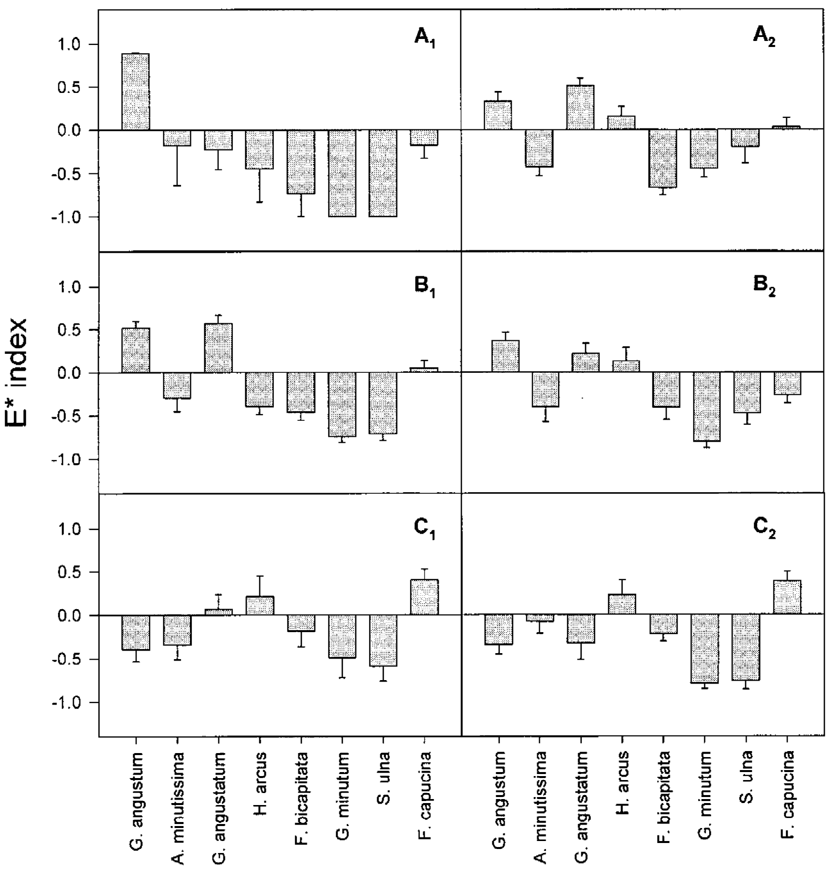


Figure 7. Electivity index (E^*) for the most abundant diatom species (in order of mean abundance) in all sampling occasions. (A) January; (B) March; (C) June; (1) shade; (2) light.

10% of the community on most sampling dates. It was always more abundant in the shaded site. In the open site, *Hannaea arcus* was the dominant species in January and March and *Gomphonema angustatum* was dominant in June. In the shaded site, *A. minutissima* and *G. angustum* were dominant and *S. ulna* and *F. bicapitata* were abundant in March and June respectively. The periphytic cell size spectra had a bimodal pattern (Figure 8, filled bars). The first maximum corresponded to cells between 8 and 16 μm while the second was between 56 and 64 μm.

The specific composition of diatoms in the gut generally reflected periphytic composition in the stream but differed significantly in the relative abundance of some dominant species (Figure 6, empty bars). *G. angustum* generally was preferred, with the highest electivity values in the shade. However, this species was avoided by the largest individuals (June sampling, $E^* < 0$) and *A. minutissima* was usually avoided (Figure 7).

The smallest individuals of *N. archiplatae* showed a preference for *G. angustum* (Figure 7, A$_1$), while those in the illuminated site preferred *G. angustatum* (Figure 7, A$_2$). As individuals grew, the selectivity for *G. angustum* increased in the open site (Figure 7, B$_2$) and remained high in the shade (Figure 7, B$_1$). *G. angustatum* was selected both in the open site and in the shade (Figure 7, B$_1$ and B$_2$). The largest individuals showed low overall selectivity (Figure 7, C$_1$ and C$_2$), although *Fragilaria capucina* Desm. and *Hannaea arcus*, were eaten in higher proportion than they were in the periphyton (Figure 6). *Gomphoneis minutum* and *Synedra ulna*, the largest diatoms in the periphyton of the Ñireco stream, were in general avoided.

Diatom species found in the periphyton of Ñireco stream can be assigned to five main habitus (Table 2). Based on these guilds, significant statistical differences between the relative abundance in the periphyton and the gut contents can be found (Figure 9). The arborescent habit is largely preferred in

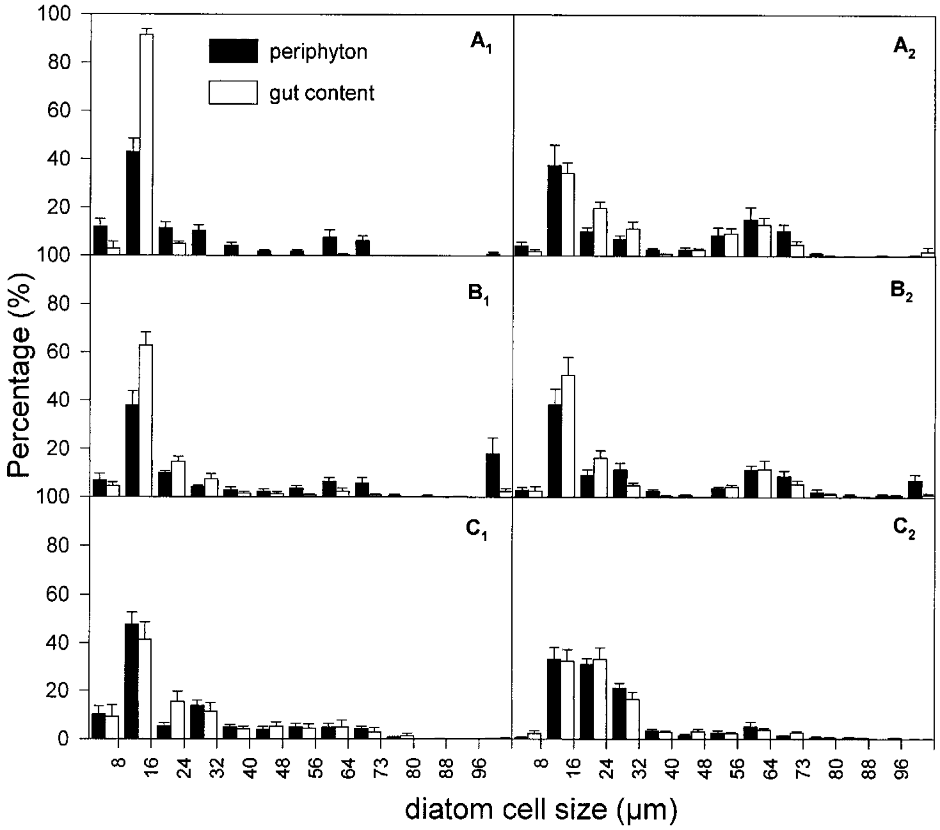


Figure 8. Comparison between the percentage of diatom size ranges in the periphyton (filled bars) and in the gut contents (empty bars) in all sampling occasions. (A) January; (B) March; (C) June; (1) shade; (2) light.

January and March, but not in June. In the individuals found in June, rosette forming diatoms became the most selected ones. Prostrate diatoms were always avoided while the adnate and filamentous habits were avoided in some cases and in others there were no significant differences (Figure 9).

The smallest individuals contained a relatively high proportion of diatoms between 8 and 16 μm compared with periphyton in the stream. By contrast, no clear size preference was exhibit by the largest individuals (Figure 8, filled bars).

Discussion

The maxilae and mandibles generally reflect a scraping-grinding function in herbivores (Merrit & Cummins, 1996) and, according to the description of the mouthparts of some phytophagous Gripopterygidae (Sephton & Hynes, 1983), *N. archiplatae*'s mouthparts seem to correspond to this type. Based on the small size (40 μm length) and the dense structure of the apical brushes, it can be inferred that they could be used to remove material that is tightly bound to the substrate. The brush on the galea and the presence of small proportion of detritus in the gut (Figure 5) would make *Notoperla archiplatae* a grazer-brusher. Nevertheless, the larvae are structurally equipped for scraping and brushing and they probably exploit any material on rock surface. Similar observations were done by Palmer et al. (1993b) for the mayfly larvae *Afronurus harrisoni* found both in riffles and stony backwaters. This is an interesting example of similar functional morphologies across taxonomic groups.

Gut content analysis showed a preference for diatoms by all larval sizes. The mouthpart morphology and the gut contents of *N. archiplatae* indicated that it is an herbivore. Insect larvae ingest algal cells, detrital particles, or animals within a particular particle size range (Cummins, 1973). So, it became necessary to look into the periphyton composition (available

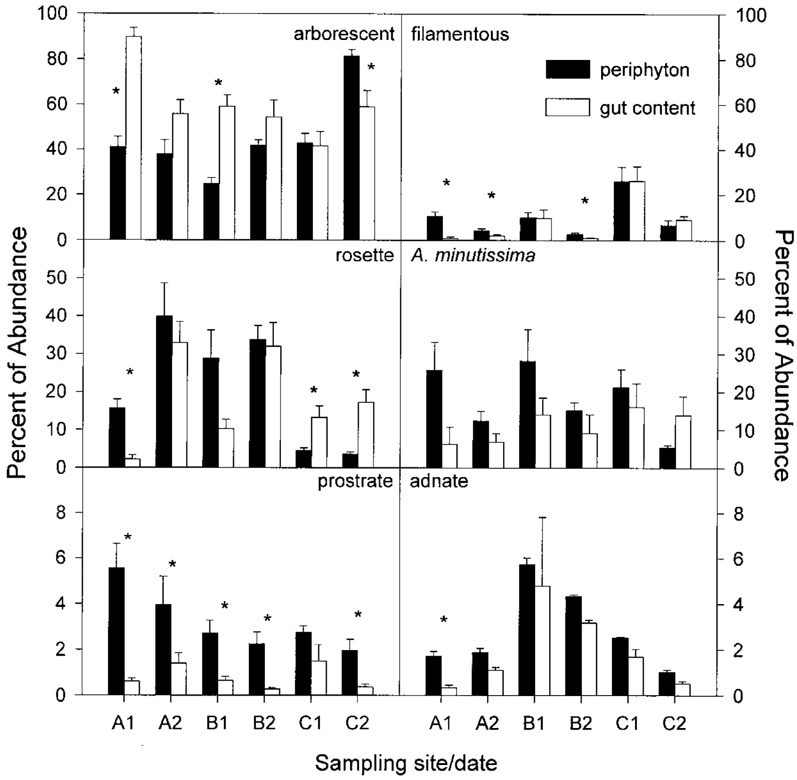


Figure 9. Comparison between the percentage of diatom habits in the periphyton (filled bars) and in the gut contents (empty bars) in all sampling occasions. (A) January; (B) March; (C) June; (1) shade; (2) light. References: (*) indicate significant differences between the periphyton and the gut contents, Mann-Whitney test ($p<0.05$).

food resource) and compare it with the food that was ingested.

Light is the primary abiotic constraint on photosynthesis in most shaded streams (DeNicola & McIntire, 1991; Hill et al., 1995). DeNicola & Hoagland (1996) showed that irradiance affected herbivores both directly and indirectly through light associated changes in algal biomass. In the Ñireco stream, a higher diatom density was registered in the illuminated site. In this place also *N. archiplatae* showed a higher density and individual biomass (Table 1) and this distribution would probably reflect the abundance of food resources.

Diatoms are considered to be the most abundant members of the epilithic algal communities (Cholnoky, 1968), so it is expected that they constitute the main diet of a scraper. Although protein, lipids and carbohydrate levels are relatively low in diatoms because of the siliceous valve, the presence of puncta in the cell wall permits many insects to rapidly digest the citoplasm, making diatoms a good food source despite their high ash levels (Lamberti & Moore, 1984). In the Ñireco stream, periphyton was composed mainly of diatoms and these algae were the most common food item in all *N. archiplatae* examined (mean proportion = 59%).

On the other hand, the chrysophycean *Hydrurus foetidus* was present in the periphyton but was rare in the guts. Lamberti & Moore (1984) indicated that attached diatoms are a preferred food source for many grazers, whereas filamentous forms and blue-green algal species are often avoided due to their thick cell walls or mucous coating. In this case, *H. foetidus* seemed to be avoided by *N. archiplatae*.

Hynes (1976) postulated that any animal that habitually lives on the upper surface of stones has little choice but to feed on algae, though many are remarkably unselective and eat whatever they scrape off. However, *N. archiplatae* appeared not only to prefer diatoms, but also to prefer certain sizes and growth forms (Figures 8 and 9). Lamberti & Moore (1984) found evidence that small, closely adherent diatoms, such as *Achnanthes* and *Navicula*, are only lightly grazed. As was observed in this study, low-lying,

Table 2. Diatom habits (based on Roemer et al., 1984; Katoh, 1992;Kutka & Richards, 1996) found in the periphyton of Ñireco stream

Habit	Taxa	Characteristics
Adnate	*Achnanthes*[a], *Cocconeis*, *Rhoicosphaenia*	Monoraphid; adhered to substratum surface by mucilage in a prostrate orientation.
Prostrate	*Brachisira*, *Caloneis*, *Epithemia*, *Navicula*, *Nitzschia*, *Reimeria*	Biraphid; adjacent to the substratum surface in a prostrate orientation without being adhered.
Filamentous	*Cyclotella*, *Melosira*, *Diatoma*, *Meridion*, *Fragilaria*[b]	Centric or araphid; chain forming, not adhered to the substratum surface.
Arborescent (Stalk)	*Cymbella*, *Gomphoneis*, *Gomphonema*	Biraphid, usually heteropolar; adhered to the substratum surface by a mucilage stalk.
Rosette forming	*Fragilaria capucina*, *Hannaea*, *Synedra*	Araphid; perpendicular to the substratum, adhered by a short mucilage stalk
	Achnantes minutissima	Often adhered to stalks of arborescent diatoms.

[a] Except *A. minutissima*.
[b] Except *Fragilaria capucina*.

prostrate diatoms better resist grazing than those with stalked or erect physiognomies (Summer & McIntire, 1982). Although adnate and prostrate were not preferred, they were present in low abundance in the guts. This indicates that *N. archiplatae* is able to feed on small closely adherent diatoms, which may have been reached by the galea's brush. However, the arborescent habitus would be more accessible as it was always preferred. Among this habit, there seemed to be a preference for the smallest cells, such as *G. angustum* and an avoidance of the largest ones, such as *Gomphoneis minutum*.

Our study indicates that the specimens of *N. archiplatae* from the upper section of the Ñireco stream are herbivorous and belong to the scraper-brusher functional feeding group. Our results also showed that this species preferred erect diatoms, especially those with an arborescent habit. Andean streams flowing through *Nothofagus pumilio* forest are basically heterotrophic rhithronic systems (Albariño & Balseiro, 1998). Although the allochthonous organic matter input by *N. pumilio* is high, the development of a diatom community capable of growing under low light intensities makes possible the existence of large plecopteran grazers such as *Notoperla archiplatae*.

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References

Albariño, R. J., 1997. Spatial distribution of the Plecoptera from an andean-patagonic lotic environment in Argentina. Rev. Brasil. Biol. 57: 629–636.

Albariño, R. J. & E. G. Balseiro, 1998. Larval size and leaf conditioning in the breakdown of *Nothofagus pumilio* leaves by *Klapopteryx kuscheli* (Insecta, Plecoptera) in a South Andean stream. Internat. Rev. Hydrobiol. 83: 397–404.

Allan, J. D., 1982. Feeding habits and prey consumption of three setipalpian stoneflies (Plecoptera) in a mountain stream. Ecology 63: 26–34.

Cholnoky, B. J., 1968. Die Öcologie der Diatomeen in Binnengewässer. J. Cramer, Lehre.

Cummins, K. W., 1973. Trophic relation of aquatic insects. Ann. Rev. Ent. 18: 183–206.

De Wolf, H., 1982. Method of coding of ecological data from diatoms for computer utilisation. Geological Survey of the Netherlands: 96–98.

DeNicola, D. M. & C. D. McIntire, 1991. Effects of hydraulic refuge and irradiance on grazer-periphyton interactions in laboratory streams. J. N. Am. Benthol. Soc. 10: 251–262.

DeNicola, D. M. & K. D. Hoagland, 1996. Effects of solar spectral irradiance (visible to UV) on a prairie stream epilithic community. J. n. am. Benthol. Soc. 15: 155–169.

Hill, W. R., M. G. Ryon & E. M. Schilling, 1995. Light limitation in stream ecosystem: responses by primary producers and consumers. Ecology 76: 1297–1309.

Hynes, H. B. N., 1976. The Ecology of Running Waters. University of Toronto, Toronto: 555 pp.

Illies, J., 1963. Revision der sudamerikanischen Gripopterygidae (Plecoptera). Mitteilungen der Schweizerischen Entomologischen Gesellschaft 36: 145–248.

Karouna, N. K. & R. L. Fuller, 1992. Influence of four grazers on periphyton communities associated with clay tiles and leaves. Hydrobiologia 245: 53–64.

Katoh, K., 1992. Correlation between cell density and dominant growth form of the epilithic diatom assemblages. Diatom Research. 7(2): 77–86.

Krammer, K. & H. Lange-Bertalot, 1986. Bacillariophyceae, 1. In Ettl, H., J. Gerloff, H. Heynig & D. Mollenhauer (eds), Süsswasserflora von Mitteleuropa. Fisher Verlag, G. Jena: 876 pp.

Krammer, K. & H. Lange-Bertalot, 1988. Bacillariophyceae, 2. In Ettl, H., J. Gerloff, H. Heynig & D. Mollenhauer (eds), Süsswasserflora von Mitteleuropa. Fisher Verlag, G. Jena: 596 pp.

Krammer, K. & H. Lange-Bertalot, 1991. Bacillariophyceae, 3. In Ettl, H., J. Gerloff, H. Heynig & D. Mollenhauer (eds), Süsswasserflora von Mitteleuropa. Fisher Verlag, G. Jena: 574 pp.

Kutka, F. J., C. Richards, 1996. Relating diatoms assemblage structure to stream habitat quality. J. n. am. Benthol. Soc. 15: 469–480.

Lamberti, G. A. & J. W. Moore, 1984. Aquatic insects as primary consumers. In Resh, V. H. & D. M. Rosenberg (eds), The Ecology of Aquatic Insects. Praeger, New York, 164–195

McCormick, P. V., 1991. Lotic protistan herbivore selectivity and its potential impact on benthic algal assemblages. J. n. am. Benthol. Soc. 10: 238–250.

Merritt, R. W. & K. W. Cummins, 1996. Aquatic Insects of North America. Kendall/Hunt, Iowa: 862 pp.

Palmer, C., J. O'Keeffe, A. Palmer, T. Dunne & S. Radloff, 1993a. Macroinvertebrate functional feeding groups in the middle and lower reaches of the Buffalo River, Eastern Cape, South Africa. I. Dietary variability. Freshwat. Biol. 29: 441–453.

Palmer, C., J. O'Keeffe & A. Palmer, 1993b. Macroinvertebrate functional feeding groups in the middle and lower reaches of the Buffalo River, Eastern Cape, South Africa. II. Functional morphology and behaviour. Freshwat. Biol. 29: 455–462

Palmer, C. G. & J. H. O'Keeffe, 1992. Feeding patterns of four macroinvertebrate taxa in the headwaters of the Buffalo River, Eastern Cape. Hydrobiologia 228: 157–173.

Roemer, S. C., K. D. Hoagland and J. R. Rosowski, 1984. Development of freshwater periphyton community as influenced by diatom mucilages. Can. J Bot. 62: 1799–1813.

Sephton, D. H. & H. B. Hynes, 1983. Food and Mouthpart Morphology of the Nymphs of Several Australian Plecoptera. Aust. J. mar. Freshwat. Res. 34: 893–908.

Sokal, R. R. & F. J. Rohlf, 1981. Biometry. Freeman and Co., San Francisco. 859 pp.

Stewart, K. W. & B. P. Stark, 1988. Nymphs of North American stonefly genera (Plecoptera). Thomas Say Found. Ser, Ent. Soc. Am. 12: 1–460.

Summer, W. T. & C. D. McIntire, 1982. Grazer-periphyton interactions in laboratory streams. Arch. Hydrobiol. 93: 135–157

Van Dam, H., A. Mertens & J. Sinkeldam, 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Neth. J. Aquat. Ecol. 28: 117–133.

Wais, I. R., 1990. A checklist of the benthic macroinvertebrates of the Negro river basin, Patagonia, Argentina, including an approach to their functional feeding groups. Acta Limnol. Brasil. 3: 829–845.