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# Adult and Nymphal Feeding in the Stonefly species Antarctoperla michaelseni and Limnoperla jaffueli from Central Chile (Plecoptera: Gripopterygidae)

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The study of nymphal and adult (both male and female) feeding of two Gripopterygidae species from Central Chile [*Antarctoperla michaelseni* (Klapálek 1904) and *Limnoperla jaffueli* (Navás 1928)] shows that: (a) *A michaelseni* nymphs feed mainly on detritus, followed by vegetable remains and fungi hyphae, while *L jaffueli* nymphs feed mainly on diatoms and detritus; (b) *A michaelseni* nymphs are shredders while *L jaffueli* nymphs are scrapers; (c) the main component of the studied species adult diet is Pinaceae pollen, contrasting with the widely pointed for the adult Gripopterygidae; (d) this last result shows the existence of an adaptation to a completely new food resource; (e) no sexual differences in diet are found for both species; and (f) the standardized Levins' index value is very similar for the two taxa (both nymphs and adults) and show that they present a reduced niche breadth.

**Key words:***Antarctoperla michaelseni* (Klapálek 1904) –*Limnoperla jaffueli* (Navás 1928) –diet – Levins' index – South America

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El estudio de la alimentación de ninfas y adultos (tanto machos como hembras) de dos especies de Gripopterygidae de Chile Central [*Antarctoperla michaelseni* (Klapálek 1904) y *Limnoperla jaffueli* (Navás 1928)] muestra que: 1) las ninfas de *A michaelseni* se alimentan principalmente de detritus, seguido por restos vegetales y hifas de hongos, mientras que las de *L jaffueli* se alimentan principalmente de diatomeas y detritus; 2) las ninfas de *A michaelseni* pueden ser consideradas como fragmentadotas, mientras que las de *L jaffueli* como raspadoras; 3) el principal componente de la dieta de los adultos de las especies estudiadas es el polen de Pinaceae, lo que difiere con lo señalado ampliamente para los adultos de Gripopterygidae; 4) este último resultado muestra la existencia de adaptación a una fuente de alimento completamente nueva; 5) no se encuentran diferencias sexuales significativas en la dieta en ninguna de las especies; y 6) el valor del índice de Levins estandarizado es muy similar para los dos taxa (tanto en ninfas como en adultos) y muestra que tienen reducida amplitud de nicho trófico.

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**Palabras clave:** *Antarctoperla michaelseni* (Klapálek 1904) – *Limnoperla jaffueli* (Navás 1928) – Plecópteros – polen de Pinaceae – dieta – Sudamérica

# 1 Introduction

Feeding habits are one of the most important aspects of insect biology, but the diet of Plecoptera is scarcely known, mainly the adult one [Stewart 1994, Tierno de Figueroa & Fochetti 2001]. This lack of knowledge is particularly marked for the Southern Hemisphere species that constitute the taxon Antarctoperlaria Zwick 1969.

Regarding the nymphal feeding, it is generally accepted that the great majority of Antarctoperlaria, including Gripopterygidae Enderlein 1909, are phtophagous-detritivorous (as Arctoperlarian Euholognatha Zwick 1969), with bacteria and fungi as the actual nutritive component of the diet, although this is a simplification [Zwick 1980]. First, zoophagous or phyto-zoophagous species of Gripopterygidae nymphs and other Antarctoperlaria have been cited in literature [Hynes 1976, Sephton & Hynes 1983, Yule 1990, Smith & Collier 2000, Monakov 2003]. Moreover, the food spectrum must be studied for each particular species [Stewart & Stark 1993, López-Rodríguez & Tierno de Figueroa 2004].

Although several authors have pointed out that some Antactoperlarian species do not feed at all during the adult stage, it is widely accepted that the adult Gripopterygidae feed on fungi, algae and leaves, and produce faecal pellets [Wisely 1953, Neboiss 1959, Froehlich 1969, Benedetto 1970, Hynes 1974, 1976). Nevertheless, data are from isolated observations and/or from particular species.

The aim of this paper is to study the diet of two Gripopterygidae species from Chile: *Limnoperla jaffueli* (Navás 1928) (subfamily Gripopteryginae Enderlein 1909) and *Antarctoperla michaelseni* (Klapálek 1904) (subfamily Antarctoperlinae Enderlein 1909). Adult (both male and female) and nymphal feeding will be analyzed. The two species' diet will be statistically compared and the Levins' index for niche breadth will be applied to Plecoptera for the first time.

# 2 Material and methods

Individuals of both adults and nymphs of *L jaffueli* and *A michaelseni* were collected from the following sites:

1. – Chile V Región: Los Perales, Estero Marga-Marga (33°09'S/71°19'W), pluvial regime: 25-VIII-2003, 30 nymphs of *L jaffueli.* A. Vera leg.

The sampling site is situated in Cordillera de La Costa, and sourrounded by sclerophilic forest. *Rubus ulmifolius, Eucalyptus globulus, Peumus boldus, Quillaja saponaria, Lithrea caustica, Maytenus boaria, Acacia caven,* crops for dry farming, and Poaceae are present in the river banks.

2. – Chile VII Región: Río Curanilahue, sector Los Ruiles (35°49'S/72°38'W), pluvial regime: 31-V-2005, 28 nymphs of *A michaelseni,* 8-VIII- 2005, 34 males, 5 females of *A michaelseni* & 15 males, 1 female of *L jaffueli,* 13-VIII-2005, 5 males, 11 females of *L jaffueli.* A. Vera leg.

The sampling site is situated in Cordillera de La Costa, 5 km away from the sea, opposite to Reserva Forestal Los Ruiles. Autochthonous vegetation has been almost completely removed, while *Pinus radiata* and *Eucalyptus* sp have been widely cultivated. *Acacia melanoxylon* has colonized some riparian sectors.

Native vegetation is composed of *Nothofagus glauca, N. dombeyi, Quillaja saponaria, Persea lingue, Cryptocarya alba, Lithrea caustica* and *Maytenus boaria* Adults were collected beating mainly *Chusquea coleu, Chusque* sp, *Blechnum chilense, Luma chequen, Fuchsia magellanica* and *Teline monspessulana*.

Some individuals of the studied species (*A michaelseni:* 1 female, 3 males and 3 nymphs; *L jaffueli:* 2 females, 3 males and 3 nymphs) were kept in Tierno de Figueroa's collection, in order to have a representation of these taxa.

Adult sampling was done by beating the riparian vegetation. Nymphs were collected with a kick net of 500 µm mesh size from submerged vegetation, muddy sediment and leaf remains. Both life stages were preserved in 70% ethanol and brought to the laboratory where, in order to study the gut contents, they were transparented following the methodology of BELLO & CABRERA [1999] usually used in Plecoptera feeding studies [TIERNO DE FIGUEROA et al 1998, TIERNO DE FIGUEROA & SÁNCHEZ-ORTEGA 1999, 2000, TIERNO DE FIGUEROA & FOCHETTI 2001, DERKA et al 2004, LÓPEZ-RODRÍGUEZ & TIERNO DE FIGUEROA 2006a, 2006b]. Every individual was introduced in a vial with Herwitgs' liquid (a variation of Hoyer's liquid) for 20–24 hours and put into an oven at 65°C. After this time the specimens were put on a glass slide with a cover glass on, and observed with an Olympus microscope where the absolute content percentage (measured as percentage of occupied area) at 40x, and the relative percentage of each component present in the gut at 400x, were estimated.

The statistical processing of the data was done using STATISTICA 7.1. Mean, standard deviation and minimum and maximum were calculated, as well as the Kolmogorov-Smirnov test (the most appropriate test for a low number of cases) for estimating if there were significant differences among the composition of the two species' diet. Nonparametric statistics were used given that the normality assumption was not fulfilled. The Levins' index [LEVINS 1968] for niche breadth was also calculated, and the Hurlbert standardization [HURLBERT 1978] was applied. The scale of the latter index varies between 0 and 1: the higher the value the higher the niche breadth. The Levins' index ($B$) and the Hurlbert standardization ($B_A$) are calculated as shown below:

$$B = 1 / (\Sigma p_j^2)$$

$$B_A = (B\text{-}1) / (n\text{-}1)$$

where: $p_j$= fraction of items in the diet that are of food category $j$, and $n$= number of possible resource states.

## 3 Results and discussion

The results of this study (**Tab 1**) show that *A michaelseni* nymphs feed mainly on detritus, followed by vegetable remains and fungi hyphae, while *L jaffueli* nymphs feed mainly on diatoms and detritus. In the latter species, vegetable remains are represented in a low percentage. It is usually accepted that both species are shredders [VALDOVINOS 2001]; nevertheless, according with our data, only *A michaelseni* nymphs fit with it, while *L jaffueli* nymphs behave more as scraper. Moreover, when comparing both species, significant differences are found in the absolute content percentages (K-S test $p< 0.01$), indicating that *L jaffueli* nymphs proportionally ingest a higher amount of food. Only for the case of diatoms and fungi hyphae, the differences are significant (K-S test $p< 0.001$) between both species, that may be a consequence of differences in availability between streams. The standardized Levins' index value ($B_A$) is very similar for the two taxa (*A michaelseni* $B_A$ = 0,145; *L jaffueli* $B_A$ = 0,127). These values show that *A michaelseni* and *L jaffueli* nymphs have a reduced niche breadth.

**Tab 1:** Absolute and relative percentages of gut content of *Antarctoperla michaelseni* (Klapálek 1904) and *Limnoperla jaffueli* (Navás 1928) (Plecoptera: Gripopterygidae).

| | *Antarctoperla michaelseni* | | | | *Limnoperla jaffueli* | | | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean | S.D. | min-max | N | Mean | S.D. | min-max |
| % absolute | 25 | 27,60 | 29,73 | 0-95 | 27 | 47,41 | 32,41 | 0-90 |
| % fungi (hyphae) | 16 | 11,88 | 12,52 | 0-40 | 21 | 0,76 | 1,22 | 0-4 |
| % fungi (spores) | 16 | 1,94 | 2,72 | 0-10 | 21 | 0,33 | 0,80 | 0-3 |
| % detritus | 16 | 59,31 | 29,64 | 5-100 | 21 | 37,29 | 32,28 | 0-100 |
| % vegetable remains | 16 | 25,88 | 34,19 | 0-95 | 21 | 4,52 | 6,76 | 0-25 |
| % pollen (Pinaceae) | 16 | 0,25 | 1,00 | 0-4 | 21 | 0,00 | 0,00 | 0-0 |
| % pollen (Fabaceae) | 16 | 0,25 | 1,00 | 0-4 | 21 | 0,00 | 0,00 | 0-0 |
| % pollen (others) | 16 | 0,19 | 0,54 | 0-2 | 21 | 0,05 | 0,22 | 0-1 |
| % phyllidia | 16 | 0,31 | 1,25 | 0-5 | 21 | 0,00 | 0,00 | 0-0 |
| % diatoms | 16 | 0,00 | 0,00 | 0-0 | 21 | 57,05 | 35,25 | 0-100 |

The fact that in *L jaffueli* diatoms are the main component of the nymphal diet may be a consequence of the higher availability of them in the stream, given that a layer of diatoms was found around the body of every nymph. Moreover, the difference found in the nymphal diet of this species between the studied individuals and those from literature [Valdovinos 2001] let us think that the feeding habits of the nymphs of some species may vary among different localities or even among different seasons, as pointed for the European Nemouridae *Protonemura meyeri* (Pictet, 1842) [López-Rodríguez & Tierno de Figueroa 2006a]. Thus, generalizations about feeding functional group or diet composition of a species, genus or family may be inexact [Stewart & Stark 1993] and future researches on particular species from different sites are necessary to actually understand the feeding biology of stoneflies.

The adults of *A michaelseni* (**Tab 2**) feed mainly on Pinaceae pollen (*Pinus radiata* pollen), followed by detritus and, in a lower percentage, by fungi. There are no significant differences in food composition between sexes (K-S test $p > 0.05$ for every component). The food composition of *L jaffueli* adults (**Tab 3**) is very similar to the one of the previous species, and significant differences between sexes are also not detected (K-S test $p > 0.05$ for every component). The high percentage of diatoms found in *L jaffueli* females corresponds to only one individual. A comparison between both species shows no significant differences for every food component (K-S test $p > 0.10$), except for Fabaceae pollen (probably *Acacia melanoxylon* pollen) (K-S test $p < 0.05$) although this component is only punctual in the species diet. When applying the standardized Levins' index we observe that the results are quite similar for both species (*A michaelseni* $B_A = 0{,}205$; *L jaffueli* $B_A = 0{,}202$), which shows that they have also reduced niche breadth.

It is outstanding the fact that the main component of the studied species adult diet is Pinaceae pollen, contrasting with the widely pointed for the adult Gripopterygidae (fungi, algae and leaves) [Wisely 1953, Neboiss 1959, Froehlich 1969, Benedetto 1970, Hynes 1974, 1976]. Moreover, as it has been demonstrated for species of other Plecoptera families, the adult food spectrum is usually very wide and actual monofagous species are not known [Zwick 1980].

**Tab 2:** Absolute and relative percentages of gut content of *A michaelseni* (Klapálek 1904) adults (Plecoptera: Gripopterygidae).

| | *Antarctoperla michaelseni* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ♂ | | | | ♀ | | | | Total | | | |
| | N | Mean | S.D. | min-max | N | Mean | S.D. | min-max | N | Mean | S.D. | min-max |
| % absolute | 31 | 48,23 | 27,74 | 0-90 | 4 | 51,50 | 41,70 | 1-100 | 35 | 48,60 | 28,87 | 0-100 |
| % fungi (hyphae) | 27 | 8,67 | 15,74 | 0-75 | 4 | 11,75 | 16,09 | 0-35 | 31 | 9,06 | 15,55 | 0-75 |
| % fungi (spores) | 27 | 5,44 | 8,60 | 0-36 | 4 | 11,25 | 19,31 | 0-40 | 31 | 6,19 | 10,26 | 0-40 |
| % pollen (Pinaceae) | 27 | 51,93 | 30,94 | 0-99 | 4 | 51,25 | 35,68 | 15-100 | 31 | 51,84 | 30,93 | 0-100 |
| % pollen (Fabaceae) | 27 | 4,11 | 18,19 | 0-95 | 4 | 0,50 | 0,58 | 0-1 | 31 | 3,65 | 16,98 | 0-95 |
| % pollen (others) | 27 | 0,70 | 2,11 | 0-10 | 4 | 0,25 | 0,50 | 0-1 | 31 | 0,65 | 1,98 | 0-10 |
| % detritus | 27 | 26,00 | 26,01 | 0-88 | 4 | 26,75 | 25,71 | 0-53 | 31 | 26,10 | 25,55 | 0-88 |
| % vegetable remains | 27 | 4,26 | 10,04 | 0-40 | 4 | 0,75 | 1,50 | 0-3 | 31 | 3,81 | 9,43 | 0-40 |
| % diatoms | 27 | 0,00 | 0,00 | 0-0 | 4 | 0,00 | 0,00 | 0-0 | 0,00 | 0,00 | 0,00 | 0-0 |

**Tab 3:** Absolute and relative percentages of gut content of *L jaffueli* (Navás 1928) adults (Plecoptera: Gripopterygidae).

| | *Limnoperla jaffueli* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ♂ | | | | ♀ | | | | Total | | | |
| | N | Mean | S.D. | min-max | N | Mean | S.D. | min-max | N | Mean | S.D. | min-max |
| % absolute | 17 | 41,18 | 26,13 | 0-80 | 10 | 40,00 | 39,02 | 0-100 | 27 | 40,74 | 30,78 | 0-100 |
| % fungi (hyphae) | 14 | 3,43 | 5,61 | 0-20 | 9 | 2,78 | 5,29 | 0-15 | 23 | 3,17 | 5,37 | 0-20 |
| % fungi (spores) | 14 | 8,79 | 19,95 | 0-75 | 9 | 3,11 | 3,22 | 0-8 | 23 | 6,57 | 15,72 | 0-75 |
| % pollen (Pinaceae) | 14 | 63,57 | 25,22 | 10-95 | 9 | 35,00 | 31,02 | 0-85 | 23 | 52,39 | 30,48 | 0-95 |
| % pollen (Fabaceae) | 14 | 3,00 | 4,04 | 0-15 | 9 | 2,78 | 3,07 | 0-8 | 23 | 2,91 | 3,62 | 0-15 |
| % pollen (others) | 14 | 0,57 | 1,87 | 0-7 | 9 | 0,56 | 1,33 | 0-4 | 23 | 0,57 | 1,65 | 0-7 |
| % detritus | 14 | 16,93 | 15,76 | 4-60 | 9 | 41,78 | 32,06 | 0-88 | 23 | 26,65 | 25,96 | 4-88 |
| % vegetable remains | 14 | 3,86 | 7,38 | 0-20 | 9 | 5,11 | 9,75 | 0-30 | 23 | 4,35 | 8,19 | 0-30 |
| % diatoms | 14 | 0,00 | 0,00 | 0-0 | 9 | 10,00 | 30,00 | 0-90 | 23 | 3,91 | 18,77 | 0-90 |

In fact, the main component of the diet in the studied species is an allochthonous plant, widely cultivated in the study area, showing that both species have adapted their feeding habits to a new resource.

The obtained data carry on supporting the hypothesis of Tierno de Figueroa & Fochetti [2001] pointing that only small size stoneflies eat food during their adult stage.

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MITSCH W J (Ed): **Global Wetlands: Old World and New.** – [XXIV + 967 pp, num fig + tab, 195 x 260 mm, balacr hardcov]. – **Publ:** Elsevier Science, Amsterdam – Lausanne – New York – Oxford – Shannon – Tokyo; **ISBN:** 0-444-81478-7; **Pr:** US$ 285,50/Dfl 500,--. – – – [EGR-Nr 2.320]

Wetlands are ecosystems disappearing with increasing velocity from the earth's surface. The book comprises the results of a wetlands conference at Ohio State University in 1992. It is basically divided into five parts (introduction, biogeochemistry, ecological engineering, modelling and analysis, policy and management) with a total of twelve sections. Part 1, section 1, gives an introduction to ecology and management of Old and New World wetlands. It deals with the historical development, common extant, and function (production, coastal and inland river deltas, great riverine forests, salt marshes, constructed wetlands and many more) of these endangered ecosystems. Information on the history of wetland ecology, the scientific state of the art and the challenge to conservation science in the 21st century is given.

Part 2 deals with wetland biogeochemistry. Section 2 informs about biogeochemical cycles in Old and New World wetlands. Ideas for a scientific base for functional assessment procedures, the role of river corridors and riparian forests in de-nitrification (eg. from agricultural discharge) the impact of former land use on nutrient cycling, and the role of environmental methane in the Amazon River floodplain are discussed. Section 3 deals predominantly with organic matter, nutrient import and export in salt marshes. Some long-term data are provided and the use of modelling in relation to such wetland ecology and conservation is demonstrated.

Part 3, ecological engineering, covers three sections. Section 4 informs about the dependence of water quality on the functioning of natural and constructed wetlands. Water quality problems are presented, and the use of wetlands to keep or even improve water quality in various parts of the world (eg. under harsh climatic conditions) are provided. Success and success measures for restored wetlands worldwide are presented. Section 5 informs about tools for wetland management, spatially-integrated models and functional analysis techniques. Wetlands among others act as sinks for phosphorous; constructed wetlands for waste water treatment with vertical flow systems need less than 5 $m^2$ per person equivalent. It was shown that experiments with varying hydroperiods improved nitrogen and phosphorous removal as well as metal retention compared to continuous-flow treatments by a factor of 2. Section 6 deals with wetland creation and restoration.