Nymphal feeding of the genus *Madenemura* Paulian, 1949 (Plecoptera: Notonemouridae) from Madagascar

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The stonefly fauna of Madagascar is poorly known. In fact, only one genus, *Madenemura* Paulian, 1949, has been reported from this biogeographically unique island. This genus belongs to the family Notonemouridae, the only arctoperlarian family with an exclusively Southern Hemisphere distribution (Zwick 2000). It is difficult to estimate the number of species of *Madenemura* because undescribed species are known, some species are known only from females and the holotypes of the described species in the Tsimbazaza Museum, Madagascar, have disappeared. Until now, only three taxonomic studies of Malagasy Plecoptera have been published, all by Paulian (1949, 1951, 1959), in which seven species were described and some new species remained to be investigated.

Apart from the scarcity of taxonomic information, knowledge of biological and ecological aspects of this genus is virtually lacking. Only a general work on the role of deforestation on stream insects characterizes this genus as a shredder, inferred from the gut analysis of twelve specimens from Ranomafana National Park (Benstead & Pringle 2004). Thus, the aim of our study is to improve the knowledge on the feeding habits of *Madenemura* nymphs, both from different localities and from a larger number of specimens.

Nymphs of *Madenemura* sp. were collected from the following sites in Madagascar: 2 nymphs, Basin n. 104, Makis River, 12°31′40″S 49°10′09″E, 28 March 1994; 15 nymphs, Mangoro Basin, Ankenheny River, 19°21′23″S 47°18′46″E, 6 March 1995; 10 nymphs, Mangoro Basin, river without name, 19°21′00″S 47°19′11″E, 8 March 1995; 10 nymphs, Namorona Basin, river without name, 21°15′07″S 47°26′36″E, 6 February 1996; 3 nymphs, Betsiboka Basin, Vanjainanitra River, 18°26′03″S 47°56′40″E, 31 October 1996.

No notable differences were found among the studied specimens, which agreed perfectly with the general morphology of *Madenemura* described by Paulian (1949). Voucher specimens were deposited in the Tierno de Figueroa collection University of Granada, Spain. Nymphs were preserved in 70 % ethanol and transported to the laboratory where, in order to study the gut content, they were cleared following the methodology of Bello & Cabrera (1999) used previously in plecopteran feeding studies (Tierno de Figueroa & Sánchez-Ortega 1999, 2000; Fenoglio & Tierno de Figueroa 2003), *i.e.* every individual was kept in a vial with Hertwig's solution (a variation of Hoyer's solution) and placed in an oven at 35 °C for 56 hours. The cleared specimens were then mounted on slides, and examined using an Olympus microscope.

For the quantitative analysis of the gut contents, the percentage of different types of food was estimated using an ocular micrometer: absolute gut content (measured as percentage of occupied area) was identified at ×40, and the relative percentage of each ingested component in the gut, were estimated at ×400 magnification. Head width of all nymphs was measured (n = 40; mean = 1.29, range = 1.00–1.57, S.E. = 0.02). The STATISTICA 7.1 software package was used to analyse the data.

Gut contents were present in 34 of the 40 nymphs studied. In Table 1 the percentage of gut occupied by food (% Total) and the percentages

Table 1. Gut contents of *Madenemura* nymphs.

	n	Mean	±S.E.	Range
% Total	40	62.95	5.15	0–98
% Vegetal fragments	34	79.62	4.85	12–100
% Fungi + microorganisms	34	3.71	0.80	0–20
% Detritus	34	16.68	4.89	0–86

% Total = total % of gut occupied by food. Other rows = % of gut contents by specific components.

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of plant fragments, fungi and associated microorganisms, and detritus are reported. Means, minima, maxima and standard errors were calculated.

It is usually accepted, from other genera studied in different biogeographical regions, that Notonemouridae feed on leaf fragments, obtaining nutrition from the microbial community that colonize this allochthonous material (coarse particulate organic matter, CPOM), especially bacteria and fungi (Davis & Winterbourn 1977; Zwick 1980). Moreover, Benstead & Pringle (2004) indicated the dependence of some Malagasy insects, including *Madenemura,* on terrestrial carbon sources *i.e.* leaf litter. According to these authors, the M*adenemura* diet includes leaf and wood particles with some amorphous detritus and filamentous red algae.

Our data (Table 1) suggest that *Madenemura* belongs mainly to the 'shredder' functional feeding group (*sensu* Cummins & Merritt 1996), confirming the results of Benstead & Pringle (2004). Studies conducted on the Notonemuridae genera, such as the study on the diet of *Afronemoura* spp. nymphs in the Buffalo River, South Africa (Palmer & O'Keeffe 1992) or the study on *Aphanicerca* spp. (Reynolds *et al.* 1997) using stable-isotope techniques, support the hypothesis that the entire family has shredding feeding habits, feeding mainly on vascular plant material.

This result is very interesting because recent studies have emphasized that there are usually few insects that are shredders in tropical lotic environments (Pringle *et al.* 1993). In these systems, the decomposition of plant material to fine particulate organic matter is mainly performed by macroconsumers, such as crustaceans or fish, or by enhanced microbial activity (Graça *et al.* 2001, Dobson *et al.* 2002).

Thus, we conclude that *Madenemura* nymphs occupy in Madagascar a trophic niche similar to that of Nemouridae, Taeniopterygidae and Leuctridae in Northern Hemisphere (Stewart & Stark 2002).

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