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Allometric growth in *Anacroneuria* Klapálek 1909 nymphs (Plecoptera Perlidae)

FENOGLIO S., BO T. and G. MALACARNE

Università del Piemonte Orientale, Di.S.A.V., Via Bellini 25, 15100 Alessandria, Italy (E-mail: fenoglio@unipmn.it)

Changes in the form of an organism often are simple automatic consequences of differences in the intrinsic growth rate of different body parts. Allometry has attracted growing interest in these last years, in part because the study of growth patterns illuminates not only metrical but also important biological processes. In this study we examined differences in the ratio among total body length, abdomen length and head capsule width in *Anacroneuria* Klapálek 1909 nymphs (Plecoptera Perlidae). We noticed that, while the relationship between body length and head capsule width is linear and isometric, the relationship between body and abdomen lengths is exponential and allometric: larger nymphs have relatively larger abdomens. We hypothesize that energetic and reproductive constraints are on the basis of this allometric development.

Key Words: allometry, Plecoptera, *Anacroneuria*, Neotropics, Honduras.

INTRODUCTION

The term allometry refers to three distinct phenomena (SCHILICHTING & PIGLIUCCI 1998): i) ontogenetic, i.e. the growth of an organ in relation to body size during the growth of a single individual; ii) static, i.e. the relationship among individuals between two organs after growth has ceased or in a single developmental stage; iii) evolutionary or phylogenetic, i.e. the size relationship between organs across species. Static allometry has enchanted biologists for longtime, with special emphasis on holometabolous insects (STERN & EMLEN 1999). Ontogenetic allometry has attracted growing interest in these last years, in part because the study of growth patterns illuminates not only metrical but also important biological processes. In particular, differences in the growth rate among body parts are referred to allometric growth. It is common practice to study allometric growth on the basis of bivariate plots of the dimensions of two body parts or the dimension of a body part against body size. Allometric studies related to insect development are particularly difficult in holometabolous insects, because the appendages of the adults develop from structures that not grow at the same time as the larval body. In this large group, the growth of most imaginal structures is concentrated in pre-pupal and pupal periods (NIJHOUT & WHEELER 1996). Allometric relationships could be more easily analyzed in hemimetabolous insects (KLINGENBERG & ZIMMERMANN 1992). In this context, Plecoptera represent a good subject of study, especially because large-sized nymphs of Systellognatha can be easily collected and measured.

In this study, we investigated the relationships among body parts and body size in *Anacroneuria* nymphs (Plecoptera Perlidae). Neotropical stoneflies of the genus *Anacroneuria* are an interesting subject for systematic, biogeographical, phylogenetic and ecological studies (STARK 1998, ZWICK 2000, FENOGLIO & MORISI 2001, FENOGLIO & TIERNO DE FIGUEROA 2003). During field collections in Nicaragua, Guatemala, and Honduras (FENOGLIO 1999, 2005), the first author noticed evident differences in the relative length of the abdomen among nymphs of different dimensions.

Aim of this study is to investigate this difference in the growth rate, adding some biological explanation.

MATERIALS AND METHODS

The study is based on morphometric data from samples collected in Honduras in the period 5-8 July 2005. We analyzed *Anacroneuria* Klapálek 1909 nymphs from a single sampling station in the Rio Cangrejal, located in the Atlantic slope of Honduras, near La Ceiba (16P0527722 UTM 1738481, 180 m a.s.l.). In this site, Rio Cangrejal is a typical Caribbean mountain stream, with coarse substratum, fast flowing waters and no traces of environmental contamination. Immature stages were collected with a 500 μm-mesh net, stored in 75% ethanol and later measured in the laboratory with an ocular micrometer mounted on a Nikon SMZ 1500 with an accuracy of 0.01 mm. To standardize the measurements, we collocated each nymph in a Petri capsule below a glass slide.

The following three measures were taken from each individual (a) total length; (b) abdomen length; (c) head capsule width.

RESULTS

We measured 47 *Anacroneuria* nymphs (smaller nymphs <6.0 mm, n = 17; intermediate 6.0 - 9.0 mm, n = 18; larger nymphs > 9.0, n = 12). Nymphs showed different sizes, representing a wide range of growth phases (Fig. 1). The largest nymph measured 13.3 mm, and the smallest 2.9 mm. The minimum abdominal length was 0.68 mm and the maximum 7.64 mm. The smallest head capsule width was 0.44 mm, with a maximum of 3.12 mm.

We detected an evident relationship between total body length and head width (Fig. 2), with a linear growth of the cephalic capsule during ontogenesis. This relationship was strongly isometric, and the following equation: Head capsule = 0.24 total body length – 0.34 was highly significant (R^2 = 0.93).

On the contrary, comparing abdomen and total length we detected an evident allometric trend (Fig. 3), with an exponential growth of the abdominal segments: minute nymphs showed relatively smaller abdomens than large nymphs. The relationship between total body and abdomen was explained by the following exponential equation: Abdomen length = 0.59 $e^{0,19 \text{ total body length}}$ (R^2 = 0.95).

DISCUSSION

Changes in the relative dimensions of tissues, organs, appendages and other body parts have been known from long time. HUXLEY (1932) stated that many changes in the organism form are simple mechanical consequences of differences in the intrinsic growth rate of body parts, i.e. consequences of allometric relationships. In his pioneeristic work, VON BERTALANFFY (1957) investigated the existence of quantitative laws in metabolism and growth. Two types of allometric growth relation are known: the first obtains when two structures grow simultaneously with different ratios, while the second obtains while one structure grows while the other is static (NIJHOUT & WHEELER 1996). We detected an evident allometric trend in the relationship between total length and abdominal length in *Anacroneuria* nymphs: longer nymphs showed relatively larger abdomens compared to smaller nymphs, with an evident difference in the growth ratio between these structures. On the contrary, the relationship between cephalic capsule width and total length was strictly linear.

Besides these metric considerations, we could hypothesize some biological reason for this phenomenon. Recent studies demonstrated an evident change in feeding activity between nymphal and adult stages of *Anacroneuria*. FENOGLIO (2003) demonstrated that nymphs of this genus are active predators, feeding on a wide range of aquatic organisms. Moreover, FENOGLIO & TIERNO DE FIGUEROA (2003), examining the diet of *Anacroneuria*, evidenced that feeding seems to have little or no importance in the adult life of this large Perlidae. Adults of these genus do not feed, as happens in some other aquatic insect groups, such as mayflies, large systellognathan stoneflies and some caddisflies. Apparently, energetic demands of these organisms depend exclusively on the rich diet of the preimaginal stages. It is likely that the absence of feeding activity in adult life strongly influence also reproductive aspects: gametogenesis and the growth and maturation of reproductive structures happens in *Anacroneuria* during the last phases of the preimaginal stage (FENOGLIO & ROŚCISZEWSKA 2003), when the organism can rely on a high proteic, carnivorous diet. Since the non-feeding species tend to emerge with almost fully formed gametes, in this last nymphal phase a n exponential increase in the dimension of abdomen could be necessary, in order to host the reproductive structures. We hypothesize that an allometric increase of abdomen growth rate in the last nymphal stages could be related to energetic balances and reproductive requirements.

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Fig. 1. *Anacroneuria* nymphs. Small and large nymphs showed relatively different dimensions in the abdomen length.

Fig. 2. Relationship between total body length and head capsule width in *Anacroneuria* nymphs.

Fig. 3. Relationship between total body length and abdomen length in *Anacroneuria* nymphs.

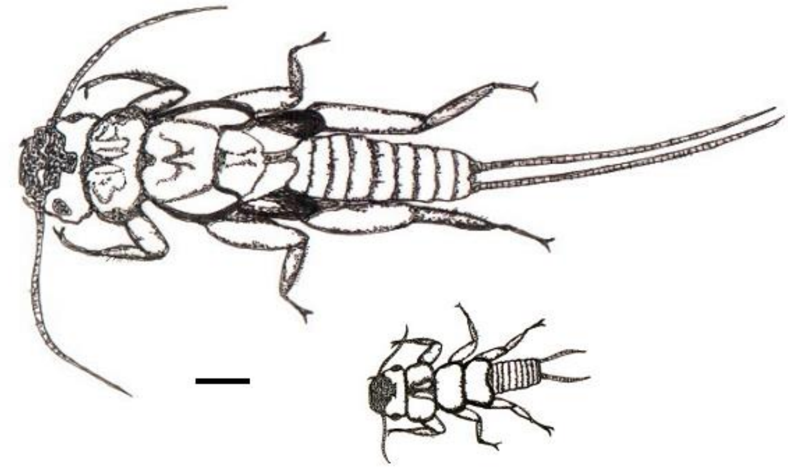

Fig. 1

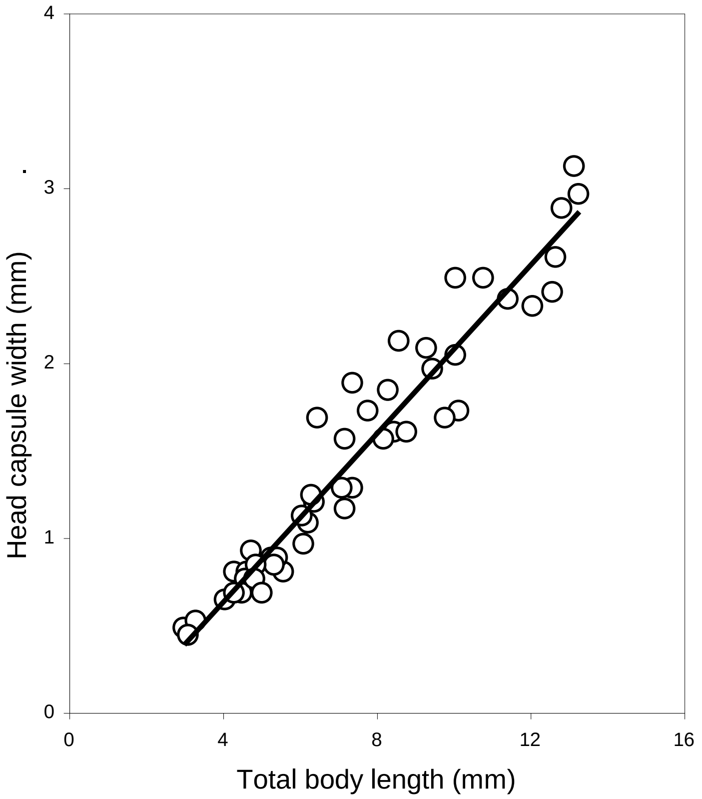

Fig. 2

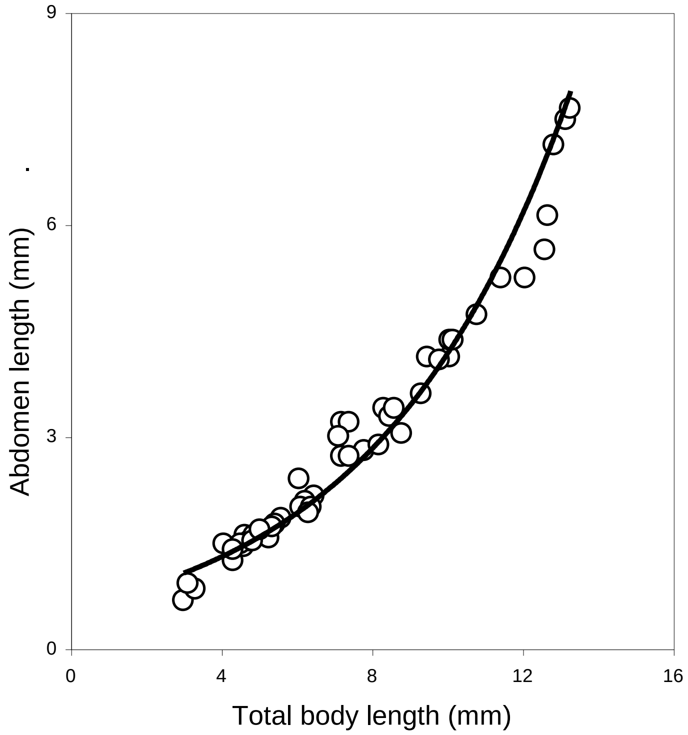

Fig. 3