ALLOMETRIC LARVAL RELATIONS OF EUPHAUSIA MUCRONATA SARS 1885

Carlos Melo U. and Tarsicio Antezana J.*

ABSTRACT. Allometric or isometric growth of *E. mucronata* larvae and juveniles are established for various body parts. Morphometric data obtained from exuviae of larvae and juveniles reared in the laboratory are generally consistent with allometry of growth of the carapace shown in individuals grown in the ocean, but slightly different for the telson and uropod growth of early furciliae. Changes in the size of the carapace with respect to telson, uropod and abdomen from calyptopis to juveniles were related to changes in feeding, swimming activity and gonad development during ontogeny.

INTRODUCTION

Descriptions of larval stage sequences have been given in the literature for many species and these are summarized by Mauchline and Fisher (1969). Some of the included species occur in the Southeastern Pacific, however no reference is known yet of any aspect of the ontogeny of *E. mucronata* endemic to the Chile-Peru Current.

The necessity of identifying larval forms of this species in plankton samples for ecological studies led us to carry out the larval development under laboratory conditions and to compare it with larval sequences obtained in the ocean. Particular attention was given to the allometric growth of larvae and older components of the population.

Morphometric relations had to be established between body parts or segments since entire animals were not measured but only exuviae or exuviae parts were available during rearing experiments.

* *Departamento de Oceanología, Universidad de Chile, Sede Valparaíso, Casilla 13-D, Viña del Mar.*

MATERIAL AND METHODS

This study is based on larvae, juveniles and adult specimens sorted out from plankton samples preserved in 5% formalin, of the Krill (Cruise 3-4) and South Tow (Cruise 3) expeditions at various latitudes along the coast of Chile and Peru (Antezana 1978), and also from similarly preserved samples of larval swarms encountered in coastal waters off Valparaíso in the fall.

Live material was collected during spring and winter in order to follow larval development under laboratory conditions. When molting occurred exuviae were collected for examination and measured inmediately afterward under a stereoscopic microscope.

Exuviae of the calyptopis stages maintained the shape of the animals and were frequently found complete, whereas those of furcilia stages commonly showed a wrinkled or torn out carapace.

The following measurements and observations were made (fig. 1) of the calyptopis exuviae: length of abdomen, length of abdomen plus telson with terminal spines; in the furcilia and juvenile exuviae: length of carapace, of the abdomen, of abdomen plus telson with terminal spines, of the 5th plus 6th abdominal segments, of uropods, of telson with and without terminal spines, number of setose and non-setose pleopods, number of terminal telson spines.

The following measurements and observations were added when preserved planktonic calyptopis and furcilia stages were studied: diagnostic features of each stage (abdomen segmentation in calyptopis, 2nd antenna segmentation in late furciliae) and carapace length. For juvenile and adult stages the following measurements were taken: length of carapace, of abdomen, of telson, and wet and dry weights. Individual wet weight was measured after exposing the animal to the air over a porous paper until no transfer of water noted; individual dry weight was measured after drying the animal in a stove at 100°C for 30 minutes.

Data were linearly fitted using the Bartlett regression procedure.

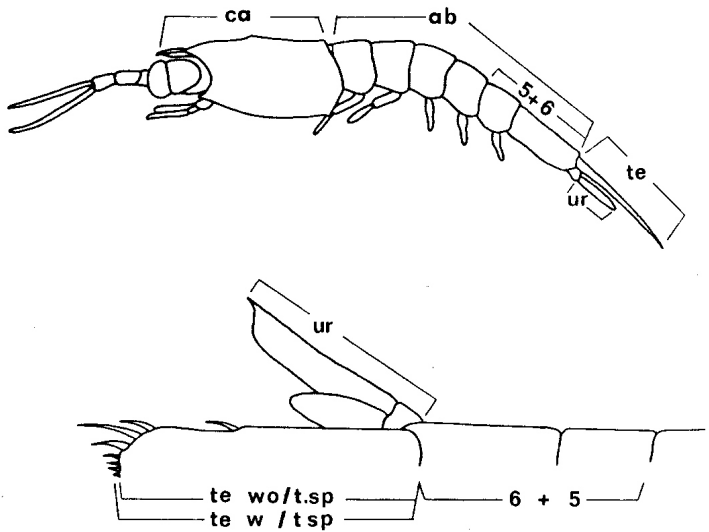

Fig. 1. Measurements taken in furciliae and juveniles of *E. mucronata*. ab: abdomen length; ca: carapace length; te: telson length; te w /tsp: length of telson plus terminal spines; te wo/t.sp: length of telson excluding terminal spines; ur: uropod length; 5+6: length of 5th plus 6th abdominal segments.

RESULTS

General morphology, size and biomass

The carapace of euphausiids covers all cephalothoracic somites in furcilia, juvenile and adult phases. In earlier phases it also covers the procephalic somite (acron). Most species present a rostrum, a dorsal keel over the gastric area and one or two pairs

of lateral denticles, as conspicuous morphological features. The carapace of *E. mucronata* has a rather short rostrum in juveniles and adults, and is remarkably obtuse and long in the furcilia stages. The measure of the carapace length, the rostrum included, represents a good measure of cephalothorax length in juveniles and adults, but may overestimate total size of the animal in furcilia stages because of their elongated rostral plate.

The five anterior segments of the abdomen have similar lengths and decreasing heights from anterior to posterior as compared to the sixth, which presents a distinct shape in most species including *E. mucronata*. Furthermore, the tergum of the third abdominal segment is protruded in a dorsal spine and the fourth and fifth in spinules which are noticeable in late juvenile stages. The measurements of the six abdominal segments as a whole, or the fifth plus the sixth, represent well the length of the abdomen in all stages but show a tendency to overestimate the total animal size when taken in bent preserved specimens.

The caudal fan consists of the telson and the uropods. The most peculiar ornaments of the telson in juveniles and adults are 2-3 pairs of dorso-lateral spines, one pair of postero-lateral spines and one terminal spine. In earlier phases the distribution, number, form and length of the spines change along with general shape and size of the telson and uropods.

The weight of an organism is expected to be an exponential function of its body length. This relation stands for the 2 mm-24 mm body length range of *E.mucronata* which corresponds to furcilia, juveniles, and adults; no data were taken for smaller sized larvae. In fact, wet weights and dry weights plotted functions of body length (figs. 2a-b) show good exponential fits, with maximum dispersion of data points at the higher sizes. Reproductive stage, sex, stomach fullness or measuring techniques, as well as natural variability, may explain such dispersion.

As expected, a linear relation exists between wet and dry weights (fig. 2c) through the entire size range, the dry weight accounting for 20 percent of the wet weight, a figure somewhat higher than that given by Lasker (1966) for *E. pacifica*. Similar dispersion occurs in larger individuals.

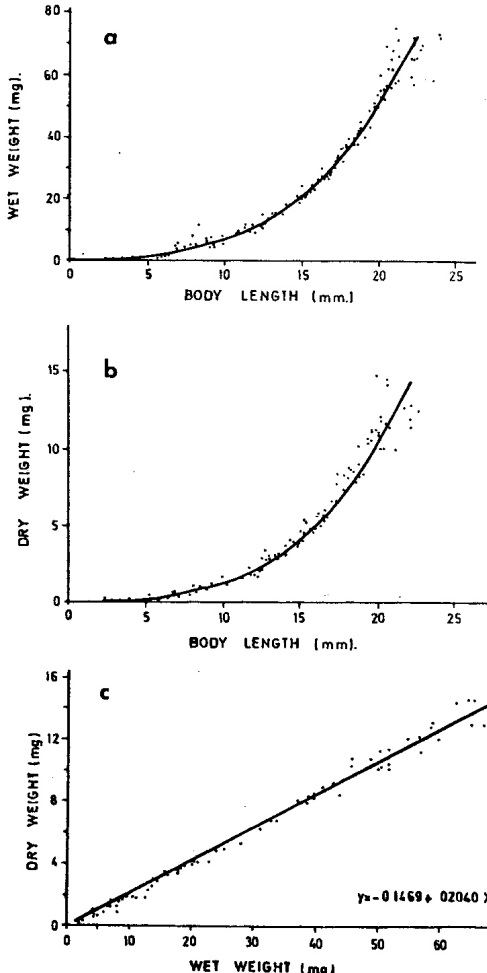

Fig. 2. Weight and body length relationships in late furciliae, juveniles and adults of *E. mucronata* a) Wet weight v/s body length; b) Dry weight v/s body length; c) Dry weight v/s wet weight.

Allometric relations

Oceanic preserved animals.

Carapace, abdomen and telson lengths relative to total length can be fitted to straight lines through late furcilia, juvenile and adult sizes of *E. mucronata* (fig. 3a). Constant proportions of body parts through the size range are about 23 percent for the carapace, 55 percent for the abdomen and 20 percent for the telson. Similar isometry of size can be established by plotting carapace and telson lengths as functions of abdomen length (figs. 3b-c); these relations will be used to estimate larval growth, since body length is not an easy measure to take in exuviae. A consistent deviation from the straight line of the lower extreme values can be noted in both relations: abdomen values fall below the line and carapace and telson above it, moving the Y intercept to a positive value which is absurd. When telson and abdomen lengths are plotted (with respect to body length) separately for the lower part of the size range (figs. 4a-b) differences in the slopes between calyptopis-juvenile and adult sizes are clearly established: for the abdomen the slope is 0.62 in the lower extreme of the size range versus 0.56 in the entire range, and for the telson it is 0.17 in the lower extreme of the size range vs. 0.19 over the entire range.

A closer examination of the carapace, abdominal segments, and telson as a function of abdomen length in this lower size range of *E. mucronata* corresponding to furcilia and earlier stages, shows straight line relationships (figs. 5a-d). When these relations are compared to those in the juvenile-adult size range, notable differences appear. The slope in the carapace-abdomen relation diminishes from 0.44 in juvenile-adult to 0.21 in furcilia, and the slope in the telson-abdomen relation decreases slightly from 0.34 in juvenile-adult to 0.29 in furcilia. In other words, by the later furcilia stages and abrupt increase of the proportion of the abdomen to the carapace and a slight increase relative to the telson occurs. The fifth plus sixth abdominal segments length vs. abdomen length (fig. 5b) show a greater slope than in the telson and even greater than in the carapace-abdomen relations; the same trend toward an increasing proportion over carapace and telson is expected in the juvenile-adult size range.

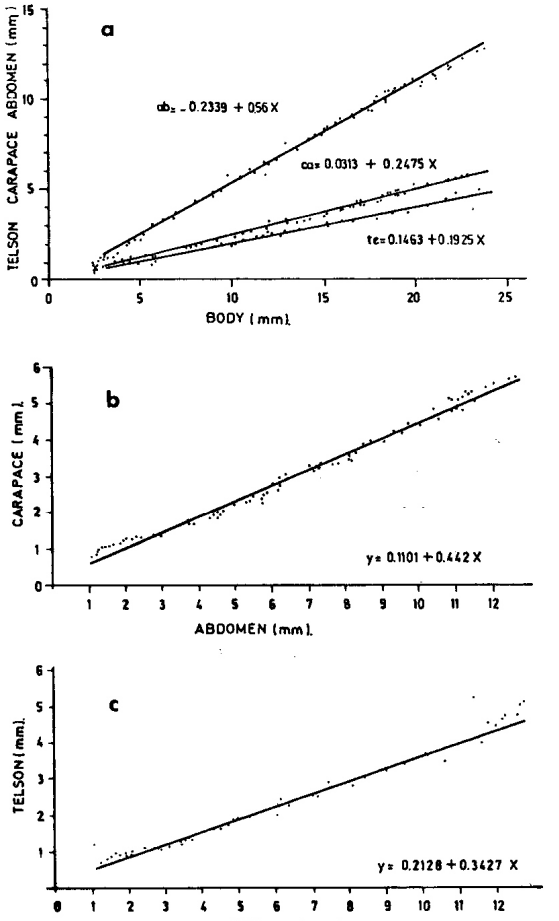

Fig. 3. Length relationships in late furciliae, juveniles and adults of E. *mucronata*, a) Carapace, abdomen, telson v/s body length; b) Carapace v/s abdomen length c) Telson v/s abdomen length.

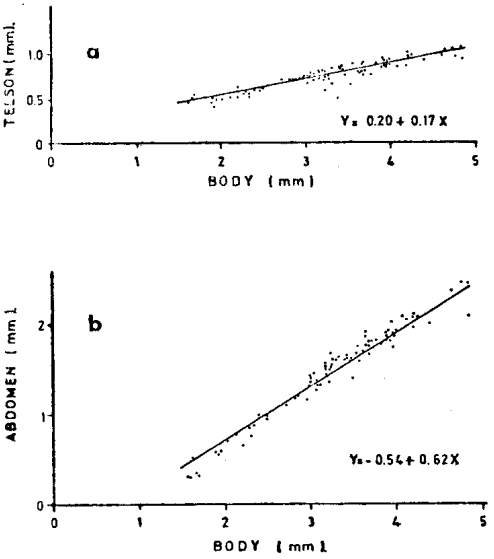

Fig. 4. Length relationships within the late calyptopis to early juvenile size range of *E. mucronata* grown in the ocean. a) Telson versus body length; b) Abdomen v/s body length.

Laboratory reared larvae and juveniles.

Morphometric relations in exuviae of calyptopis reared to late juveniles are compared to those from plankton collections by superimposing data from rearing over the pre-established relations of body parts as a function of abdominal length through the range of size covered in the rearing experiments (figs. 6a-b). Abdomen length is used instead of body length since the latter could not be measured in the exuviae.

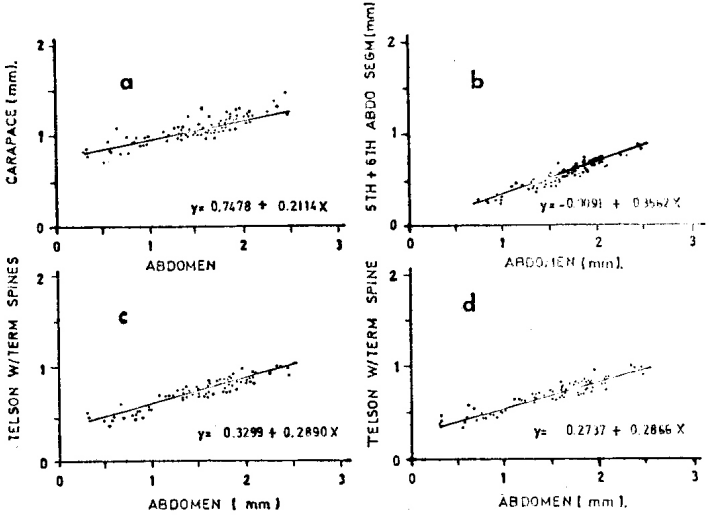

Fig. 5. Length relationships in the size range of calyptopis and furcilia stages of *E. mucronata* grown in the ocean. a) Carapace v/s body length; b) 5th + 6th abdominal segments v/s abdomen length; c) Telson with terminal spines v/s abdomen length; d) Telson without terminal spines v/s abdomen length.

The separate lines in fig. 6a represent distinct linear relations for individuals smaller and larger than 2.5 mm abdomen length, larvae and juveniles respectively, as described above.

Although values of exuvial carapace length are somewhat scattered, at the smaller sizes and rather scarce at sizes larger than 1.5 mm (fig. 6a), a consistent non-linear relation is apparent; the major break occurring at about the late furcilia (2.5 mm abdominal length).

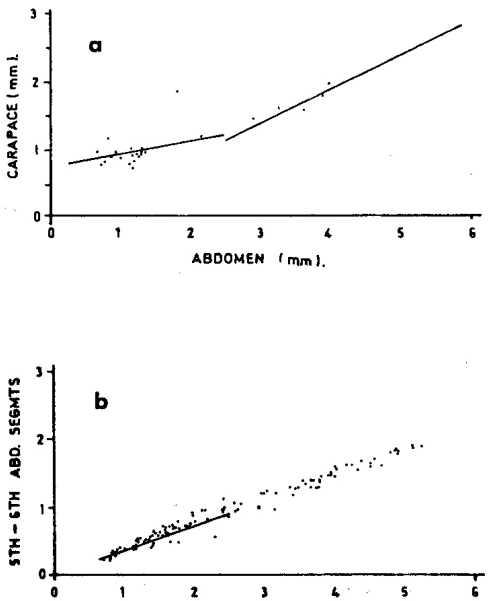

Fig. 6. Length relationships within the calyptopis to juveniles size range of *E. mucronata* reared in the laboratory (data points) and grown in the ocean (regression lines). a) Carapace v/s abdomen length; b) 5th + 6th abdominal segments v/s abdomen length.

Data of exuvial telson length fall around the furcilia and juvenile lines from ocean-grown specimens, but show slight non-linearity at the calyptopis-furcilia transition (fig. 7a). In

other words, growth of the telson, relative to the abdomen, seems higher in early furcilia reared in the laboratory, decreasing progressively toward later furcilia and juveniles.

The uropod length shows a non-linear relation with the abdomen length (fig. 7b), similar to that observed for the telson, which is confirmed by the straight line relation between telson and uropod lengths (fig. 7c). This relative decreasing growth of uropod and telson from calyptopis to late furcilia is shown on general illustrations of stages of other species such as *E. gibboides*, *E. sanzoi* (Knight 1975, 1976), and others (John 1936).

The length of fifth plus sixth abdominal segments, as measured in the exuviae, shows a linear relation with the abdomen length (fig. 6b); the slope is coincident with that estimated in furcilia from field samples but most points fall above the line; this is attributed to differences in measuring technique.

In summary, morphometric data obtained from exuviae of larvae and juveniles reared in the laboratory are generally consistent with allometry of growth of the carapace shown in individuals grown in the ocean but slightly different for the telson and uropod growth of early furciliae.

DISCUSSION

Some speculations on morphological adaptations seem relevant with regard to the observed allometry of growth of *E. mucronata*.

Changes in the size of the carapace with respect to telson, uropod and abdomen from calyptopis to juveniles can be related to differences in flotation and swimming activities occurring through these stages of the metamorphosis. The field data indicate (below) that juveniles and adults perform vertical diel migrations of a much greater extent than larvae. In the course of the ontogeny of euphausiids, swimming activity gradually shifts from the cephalic appendages (nauplius to calyptopis and to some extent furcilia) to the abdomen and abdominal appendages (furcilia), then to abdominal and thoracic appendages (juveniles and adults).

During the furcilia stages, a continuous functional trend from flotation to swimming and feeding is shown. The abdomen increases in length relative to the carapace (lower slope in fig. 6a), non-swimming, then swimming pleopods appear, and the cephalothorax changes shape and size, and progressively acquires biramous

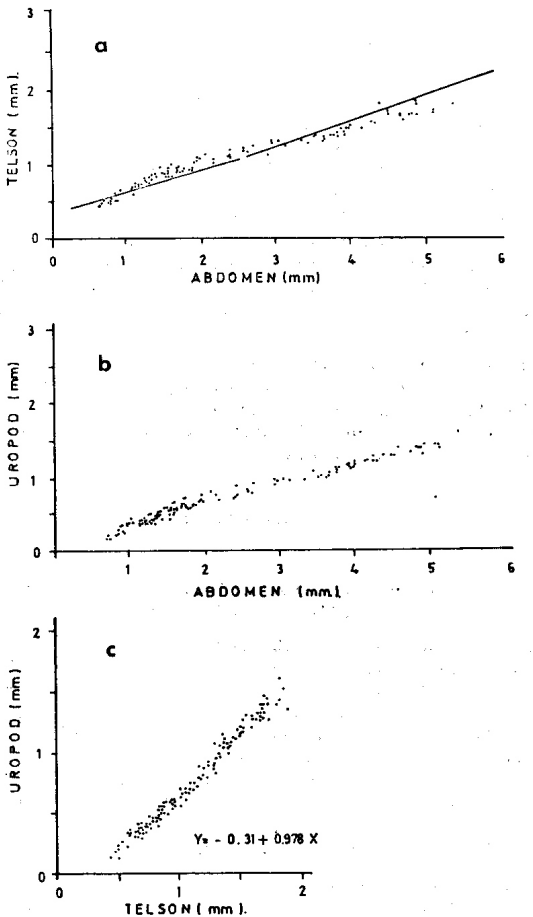

Fig. 7. Length relationships within the calyptopis-juvenile size range of *E. mucronata* reared in the laboratory (data points and grown in the ocean) (regression lines). a) Telson with terminal spines v/s abdomen length; b) External uropods v/s abdomen length; c) External uropods v/s telson with spines length.

thoracic legs.

At the furcilia-juvenile transition when all swimming pleopods have appeared and thoracic endopods and exopods are becoming more actively involved in swimming and feeding, the relative proportion of carapace to abdomen changes toward an enlarged carapace, which is probably related to accommodation of growing gonads and other internal organs.

On the other hand, telson and external uropod show an isometric growth with respect to abdomen throughout the calyptopis, furcilia, juvenile and adult development, with the only exception of the early furcilia stages reared in laboratory conditions.

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