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ABSTRACT

The present work provides morphological informations on two zoeal stages of the alpheid shrimp *Betaeus truncatus* obtained from plankton samples in the southwestern Atlantic Ocean. Larvae of *B. truncatus* were found in coastal waters of Argentina (47°-55°S) in autumn (April) and spring (October) mainly, reaching up to 846 ind.*1000^{-3} per station. Larval identification of the species was confirmed by the only known previous description of the second zoeal stage of this Caridean shrimp from shallow waters of central Chile. Differences in larval size, development of the appendages and telson indicate the present larval stages to be more advanced than that of previous work which are discussed as adaptations at latitudinal changes of the environment. Since the knowledge on life history and larval morphology in the Alpheidae is extremely scarce, we provide these descriptions in order to facilitate future ecological work on meroplankton, as well as these features could give more insights into phylogenetic relationships on the basis of larval characteristics.

Key words: larval development, Caridea, Alpheidae, Atlantic Ocean, morphology

RESUMEN

En este trabajo se entrega una descripción morfológica de dos estadios de zoea del camarón alpheido *Betaeus truncatus*, obtenidos en muestras de plánction tomadas en el Oceano Atlántico sudoccidental. Los estadios larvarios de *B. truncatus* fueron obtenido en aguas costeras de Argentina (47°-55°S) principalmente en otoño (Abril) y primavera (Octubre), con densidades que alcanzaron hasta 846 ind.*1000^{-3} por estación. La determinación a nivel de especie se basó en el único trabajo previo realizado sobre el segundo estadio zoeade este camarón con muestras de aguas someras de Chile Central. Las diferencias en el tamaño de las larvas, y desarrollo de los apéndices

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y el telson indican que los estadios larvales del presente trabajo están más avanzados que aquellos del trabajo previo, aspecto que fue considerado como una adaptación latitudinal a cambios ambientales. Dado que el conocimiento sobre las historias de vida ly morfología larvaria de Alpheidae es bastante limitado, esta información facilitará estudios ecológicos con el meroplancton. Asimismo, las descripciones morfológicas podrían aportar una mayor comprensión acerca de las relaciones filogenéticas basadas en caracteres larvales.

Palabras clave: desarrollo larvario, Caridea, Alpheidae, Oceano Atlántico, morfología

INTRODUCTION

Morphological descriptions of marine invertebrate larvae are the first step towards the understanding of life history, species ecology and plankton community assessment. The knowledge of Caridean decapod larvae is generally scarce, and this comes especially true for South American waters. The work on Caridean larvae is complicated by its great variability in developmental pathways (Knowlton 1974, Fincham 1979, Criales & Anger 1986), which was shown to occur in laboratory rearings as well as between larvae obtained from plankton catches and laboratory reared ones of the same species (e.g., Thatje & Bacardit 2000a).

Betaeus truncatus is the only alpheid shrimp of its genus known to be distributed in shallow coastal waters (0-50 m depth, see Spivak 1997, and references therein) of the cold temperate antiboreal southwestern Atlantic Ocean, the Falkland Islands/ Islas Malvinas and the adjacent channel and fjord system of the Subantarctic Magellan region (see, Boschi *et al.* 1992, Spivak 1997, Gorny 1999, and references therein). The second alpheid species of this genus known to occur in deeper waters off the Argentine continental shelf, *Betaeus lilianae*, is distributed north of about 42°S (Boschi *et al.* 1992). Only the first zoeal stage of this species has already been described by Boschi (1981).

Even now, only the second zoeal stage of *B. truncatus* is known from a population of central Chile, which was obtained from a laboratory rearing (Albornoz & Wehrtmann 1997). In the present work we describe the second and third larval stages of *B. truncatus* obtained from plankton catches sampled in the southwestern Atlantic Ocean (Fig. 1), in order to extend the knowledge on its larval development, larvae distribution and seasonality. In addition, we discuss morphological differences in comparison to previous work (Albornoz & Wehrtmann 1997) from an ecological point of view.

MATERIALS AND METHODS

The studied larval material of *Betaeus truncatus* was collected in Argentine waters in the southwestern Atlantic Ocean (37°35´S to 55°15´S; 53°40´W to 68°15´W, see Fig. 1) during expeditions carried out onboard the RV´s "Walther Herwig" and "Shinkai Maru" in 1978 and 1979, respectively (Ciechomski *et al.* 1979, Cousseau *et al.* 1979). Samples were collected monthly by means of a Bongo net of 330 μm mesh size and were preserved in 3% formalin solution buffered with hexamethylenetetramine. These samples were collected vertically from the seafloor to the surface or 100 m to the surface. Complete descriptions of the cruises and additional information on oceanographic measurements can be obtained from Ciechomski *et al.* (1979).

Carapace length (CL) was measured from the posterior edge of the orbital arch to the mid-dorsal posterior margin of the carapace; total length (TL) of the larvae was measured from the posterior margin of the orbital arch to the distal margin of the telson, excluding setae. The descriptions of larval stages represent an average of our observations. Nomenclature used for the differentiation of larval phases and morphology corresponds to that suggested by Williamson (1960, 1968, 1982), Gurney (1942), Boschi (1981), Haynes (1978, 1981, 1985), Thatje & Bacardit (2000a), and references therein. The description of zoeae of *Betaeus truncatus* is

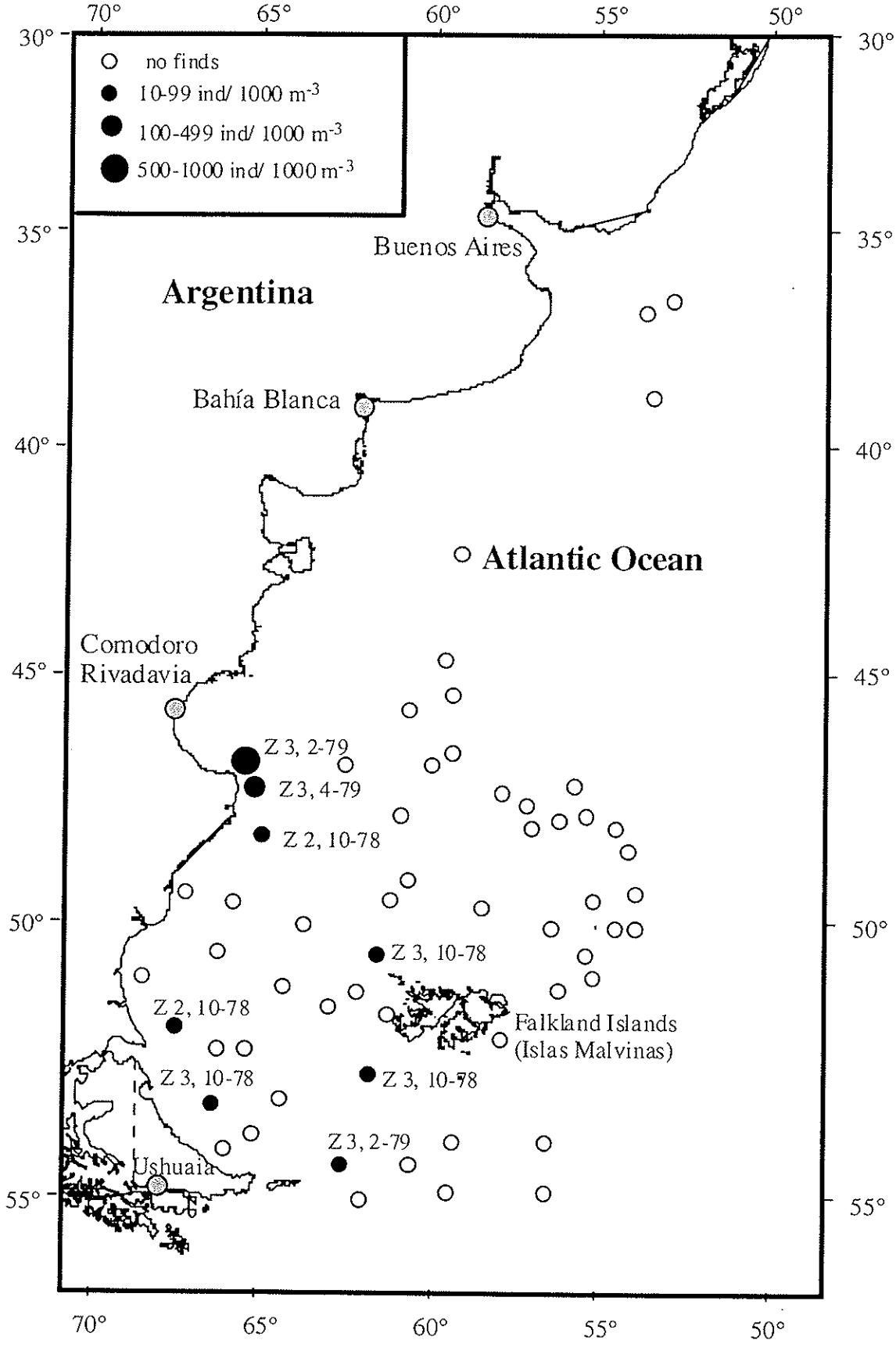

Fig. 1.- Sampling locations of larvae of Betaeus truncatus in the southwestern Atlantic Ocean (Argentina). Sampling month, year and distinguished zoeal stages as indicated at each station.

based and confirmed with previous work of Albornoz & Wehrtmann (1997), who described the second zoeal stages of this Caridean shrimp, obtained from shallow Pacific waters of central Chile.

RESULTS

Systematics
Crustacea: Decapoda: Caridea:

Alpheidae
Betaeus truncatus, Dana, 1854

Description of larvae

Zoea II (Figs. 2A-N)
CL = 0.82 ± 0.01 mm; TL = 3.5 ± 0.03 mm; N = 6

General characteristics (Fig. 2A, F): eyes pedunculate and extended laterally; carapace cylindricaly, narrow, with smooth margins; pterygostomic spines present; rostrum elongated, directing anteriorly; one dorsal protuberance present.

Antennule (Fig. 2D): antennal peduncle two-segmented; basal segment with slightly concave external extension; distal segment with one plumose internal seta; external flagellum represented by one segment, bearing two terminal and one subterminal aesthetascs and one apical plumose seta.

Antenna (Fig. 2I): exopodite with apical segmentation, without terminal external spine; one plumose subterminal seta on outer margin; distal inner margin (including tip) with 10 plumose setae, most external one reduced in size; endopodite with one plumose apical seta; one ventral internal spine at base of endopodite.

Mandible (Fig. 2C): incisor process with two sharp large setae at base; molar process well-developed, with multiple small teeth.

Maxillule (Fig. 2B): coxal endite with 7 plumose setae; basal endite with 4 spines and two plumose setae; palp unsegmented, with one strong terminal spine and one plumose seta.

Maxilla (Fig. 2G): coxal endite with 3 plumose setae; basal endites proximally and distally with 5 plumose setae each; palp unsegmented, with one plumose basal external seta and two apical ones; scaphognathite with 7 marginal plumose setae.

Maxilliped I (Fig. 2J): endopodite reduced, unsegmented, with 6 plumose setae; exopodite with 4 plumose apical setae and and two marginal external ones; coxa and basis with one and 7 short plumose setae, respectively.

Maxilliped II (Fig. 2H): basis with 4 small plumose setae; endopodite 5-segmented, with one short plumose seta in segments one to four, each; dactylus with one pronounced apical plumose seta and two plumose setae, one subterminal external plumose seta; exopodite with 4 plumose setae.

Maxilliped III (Fig. 2K): basis with three plumose setae; segments one to four of endopodite with 1, 1, 0 and 2 plumose setae, respectively; dactylus with one large strongly pronounced plumose terminal seta and one subterminal shorter one; exopodite with 4 plumose setae.

Pereiopods I+II (Fig. 2L): biramous, first one more developed than second; without setae and indications of chelae.

Pereiopods III+IV (Fig. 2M): reduced, uniramous.

Pereiopod V (Fig. 2N): uniramous, well developed; 1.5 times as long as endopodite of pereiopod I.

Abdomen (Fig. 2A): margins of somites smooth, without ornamentations; somite 6 fused with telson.

Telson (Fig. 2E): posterior margin with slight medial indentation, lateral margins almost parallel; posterior margin with 8+8 processes, central pair reduced in size, external pair being located at distal quarter.

Zoea III (Figs. 3A-J)
CL = 1.02 ± 0.01 mm; TL = 6.4 ± 0.02 mm; N = 25

General characteristics (Fig. 3A, B): eyes pedunculate, now shorter but wider than in previous stage; rostrum proportionally shorter than in previous stage; pterygostomic

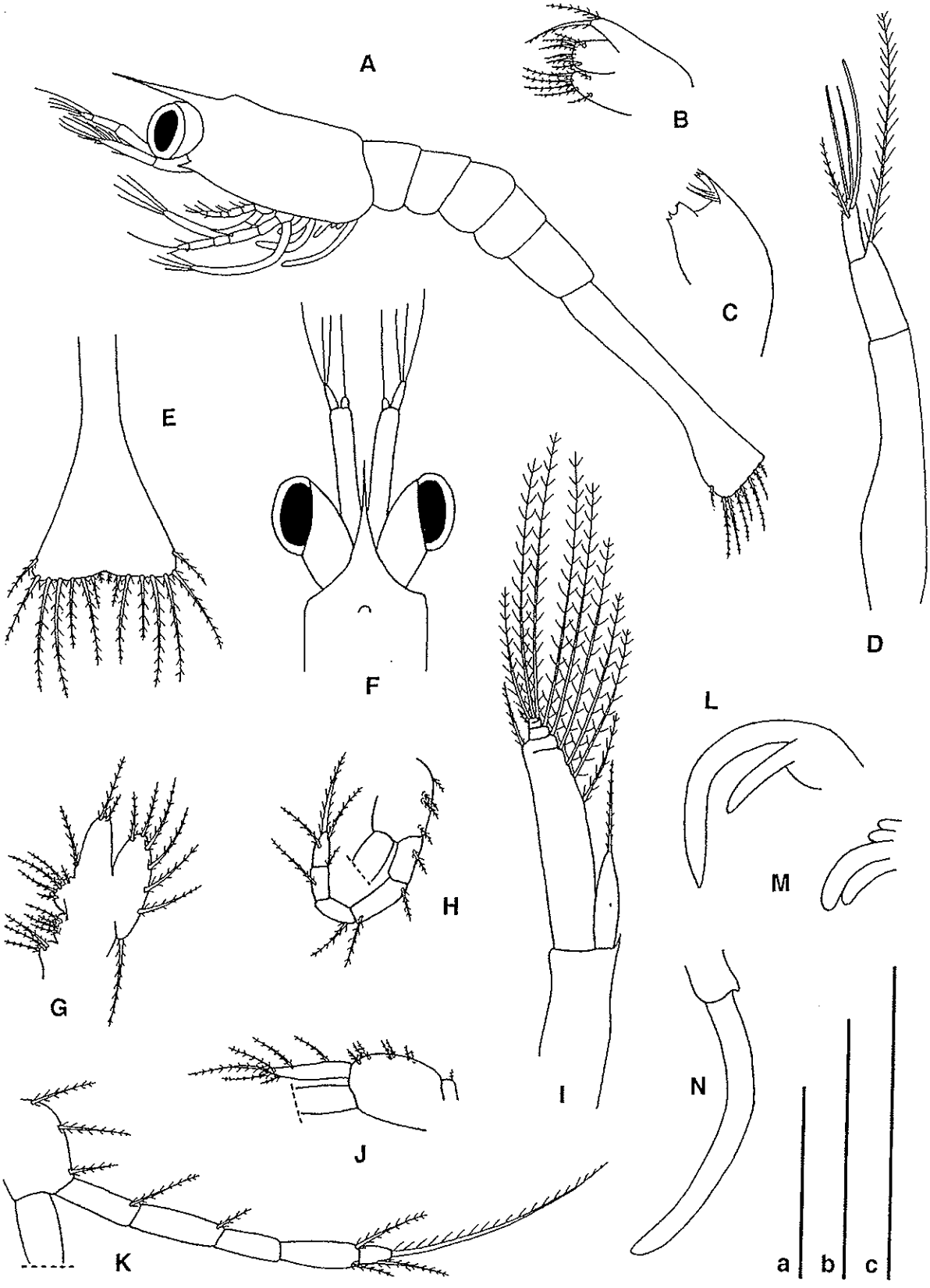

Fig. 2.- Zoea II. A: general aspect, lateral view; B: maxillule; C: mandible; D: antennule; E: telson; F: anterior part of carapace with cephalic appendages, dorsal view; G: maxilla; H: maxilliped II; I: antenna; J: maxilliped I; K: maxilliped III; L: pereiopod I; M: pereiopods I-IV; N: pereiopod V. Scale bars: a = 0.2 mm (B-C, G); b = 1 mm (A, E-F); c = 0.5 mm (D, H-N).

spines smaller; one dorsal anterior protuberance present; margins of carapace simple.

Antennule (Fig. 3F): antennal peduncle bisegmented; basal segment with stylocerite represented by one small protuberance, 4 distal setae; distal segment with 4 distal external setae and one large internal one; internal flagellum unsegmented, bearing one large apical seta; external flagellum with three aesthetascs and one seta.

Antenna (Fig. 3G): apical seta of endopodite more reduced; escama segmented, without external spine, with one marginal external seta and internal margin (including tip) with 15 plumose setae, of which most external one is reduced in size.

Mandible: without changes to previous stage.

Maxillule: without changes to previous stage.

Maxilla (Fig. 3D): without changes to previous stage.

Maxilliped I: coxa and basis with one and 6 short plumose setae, respectively; endopodite reduced, bearing 6 plumose setae, unsegmented; exopodite with 6 plumose setae.

Maxilliped II: exopodite with 6 plumose setae; without other changes.

Maxilliped III (Fig. 3J): exopodite with 6 plumose setae; without other changes.

Pereiopods I+II (Figs. 3H+I): endopodite with 2 apical setae, unsegmented; exopodite with 6 plumose setae..

Pereiopods III+IV (Fig. 3E): uniramous, more developed than in previous stage.

Pereiopod V (Fig. 3E): segmented, without setae; dactylus bearing large prolongation.

Abdomen: margins of somites smooth and without ornamentations, without pleopods; somite 6 free, with one lateral pair of short posterior spines.

Uropods (Fig. 3C): endouropod without setae; exouropod with 12 marginal posterior setae, without external spine.

Telson (Fig. 3C): posterior margin with slight medial indentation, less pronounced than in previous stage; lateral margins almost parallel; posterior margin with 8+8 processes, central pair reduced in size, external pair being located at distal quarter.

DISCUSSION

In the present work we described the 2nd and 3rd zoeal stage of the alpheid shrimp *B. truncatus* obtained from plankton samples taken in the southwestern Atlantic Ocean. Biogeographical separation to the second cogeneric species, *B. lilianae*, as well as morphological comparion with larval descriptions of previous works on both species occurring in Argentine waters of the southwestern Atlantic (Boschi 1981, Albornoz & Wehrtmann 1997), allowed the unambiguous identification of our larval material as the species studied.

Distinctive characteristics of larvae of the family Alpheidae (after Gurney 1938, 1942) are: (1) carapace without supraorbital spines, (2) rostral spine short, broadened at base and generally without dorsal spines; (3) abdominal somites without ornamentation and pleural or dorsal spines/setae; (4) antennal exopodite with apical segmentation, endopodite with apical seta and one small spine in first zoea; (5) mandible less developed in first stages; (6) palp of maxillule unsegmented, reduced; (7) maxilla with only three endites, endopodite small and unsegmented; (8) maxilliped 1 with reduced endopod and unsegmented; (9) maxilliped 3 bearing one long apical spine in 2nd zoea; (10) pereiopod 5 predeveloped, large and elongated, with apical spine; (11) exopodites in pereiopods 1 to 4 present.

Only one larval type, corresponding to the above summarized family characteristics in the Alpheidae, was distinguished from plankton samples which were obtained during our investigations in the southwestern Atlantic Ocean (Fig. 1). Albornoz & Wehrtmann (1997) distinguished almost all families of the Caridae (Hippolytidae, Alpheidae; Rhynchocinetidae) occurring in coastal waters of Chile, using differences in the telson shape of each family. Although the telson´s shape seems to be quite similar

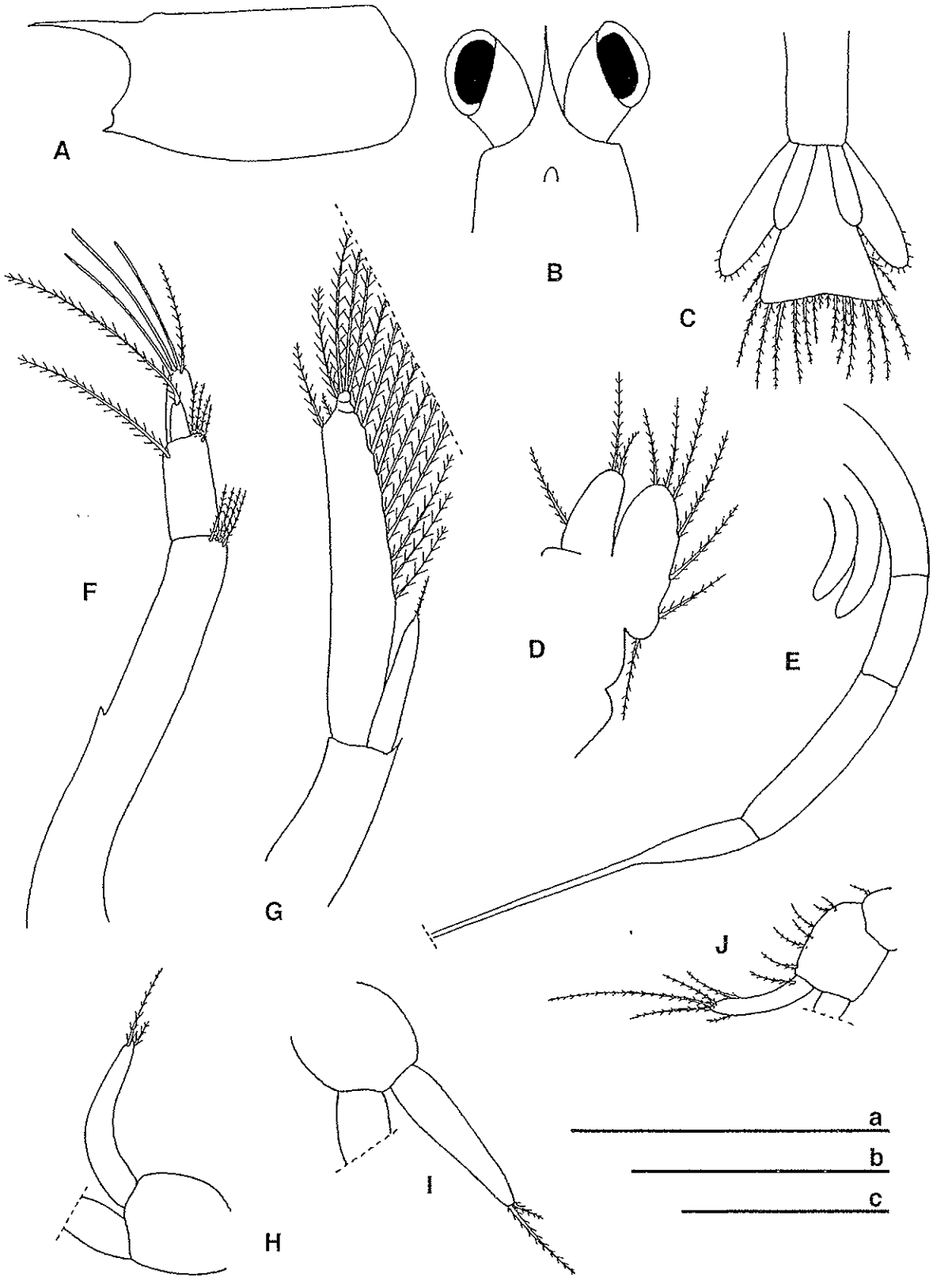

Fig. 3.- Zoea III. A: carapace, lateral view; B: anterior part of carapace, dorsal view; C: telson with uropods, ventral view; D: scaphognathite and palp of maxilla; E: pereiopods III-V; F: antennule; G: antenna; H: pereiopod II; I: pereiopod I; J: maxilliped III. Scale bars: a = 0.2 mm (B-C, G); b = 1 mm (A, E-F); c = 0.5 mm (D, H-N).

among families, its posterolateral margin clearly allows a classification of each family, and this method is also valid to distinguish from the Pandalidae which were not included into the work of the above authors, but occur in Patagonian waters too (e.g. *Austropandalus grayi* Cunningham, 1871, Thatje & Bacardit 2000b, see also: Williamson 1957, Haynes 1985). The genus *Betaeus* shows only a slight medial posterolateral indentation of its telson, which is lesser pronounced compared to other Alpheidae and in the presented hippolytid families (Boschi 1981, Wehrtmann & Albornoz 1997, Fig. 6).

Apart of the fact that only one species of the alpheid genus *Betaeus* is known to be distributed in the southwestern coastal waters of Argentina (e.g., Boschi *et al.* 1992, Spivak 1997), the distinguished larvae of the genus *Betaeus* obtained in our area of investigation have been clearly identified as *B. truncatus*, confirming the original description of the 2nd zoeal stage for this species by Albornoz & Wehrtmann (1997). However, some remarkable differences between the present and the original description of the above authors should be mentioned, (1) TL of larvae obtained from our investigation in the southwestern Atlantic Ocean are on an average about 0.3 mm larger in size than those from central Chile (Albornoz & Wehrtmann 1997). This could be explained as an adaptation to lower temperatures at high latitude (e.g., Clarke 1987) which was already reported to be especially conspicuous in Caridean development regarding eggs and larvae (Clarke 1993, Thatje & Bacardit 2000a); (2) the antennal exopod bearing 10 instead of 9 setae and (3) the endopod of Maxilliped 3 lacking one long apical spine in our description (compare with Wehrtmann & Albornoz 1997).

Morphological variability is known to occur within larvae of the Caridea (Thatje & Bacardit 2000a, Albornoz 1996)[1] and therefore setation does not always serve as an exact method for determination. Our comparison does not consider the possibility of larval instars and variability in developmental pathway, because other descriptions than those presented and cited do not exist for this species. Future lab rearing of alpheid larvae must be done, in order to complete the knowledge on the larval development of *B. truncatus*. This species probably shows an extended larval devlopment, since the pereiopods are not yet developed in the more advanced zoeal stage (Fig. 3) of our description, and pleopods are not yet visible. The absence of the first zoea in our samples, although monthly sampling was performed, was also assumed by Albornoz & Wehrtmann (1997) for their lab rearing, and could be explained as an extremely short occurrence in the culture as an intermediate stage. Due to the flexibility in Caridean larval development [1]Albornoz (1996) stated that especially early larvae in lab rearings can pass through more stages than those collected from the plankton and that this heterogeneity in the development is one reason for morphological variability (see also, Young & Chia 1987; Thatje & Bacardit 2000a).

Larvae of *B. truncatus* were found in coastal waters of Argentina (including the Falkland Islands/Islas Malvinas) (47°-55°S) in autumn (April) and spring (October) mainly, reaching up to 846 ind.*1000^{-3} per station, showing a strong seasonality in its occurrence. We did not catch more advanced larvae, which could be due to the more or less superficial sampling with Bongo nets, if more developed larvae become more demersal in its living and therefore are not capturable by vertical plankton hauls.

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1 Albornoz, L., 1996. Desarrollo morfológico en larvas de *Nauticaris magellanica* (A.M. Edwards, 1891) (Decapoda: Caridea: Hippolytidae), una comparación laboratorio-plancton. *Tesis, Esc. De Biología Marina, Fac. De Ciencias, Univ. Austral de Chile, Valdivia*: 1-104.

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