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THE LARVAL DEVELOPMENT OF A FRESH-WATER PRAWN, *PALAEMONETES ZARIQUIEYI* SOLLAUD, 1939 (DECAPODA, PALAEMONIDAE), REARED IN THE LABORATORY

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ABSTRACT

The larval development of the fresh-water prawn *Palaemonetes zariquieyi* Sollaud, 1939 is described and illustrated in detail. Egg and larval sizes are given. Three larval and one postlarval stages are distinguished, and their characteristics are compared with those of *Palaemonetes* species.

RÉSUMÉ

La développement larvaire de *Palaemonetes zariquieyi* Sollaud a été observé en laboratoire. La taille des oeufs et des larves est présentée. Quatre stades post-embryonnaires sont décrits et figurés en détail. Le développement larvaire de cette espèce est comparé à celui d'autres représentants du même genre.

INTRODUCTION

The caridean prawn genus *Palaemonetes* occupies a wide variety of habitats from marine conditions to fresh-water. Larval development has been described in some species: *P. vulgaris* Say, 1818 (see Broad, 1957), *P. paludosus* (Gibbes, 1850) (see Dobkin, 1963), *P. cummingi* Chace, 1954 (see Dobkin, 1971), *P. kadiakensis* Rathbun (see Broad & Hubschman, 1963), *P. argentinus* Nobili, 1901 (see Menú-Marque, 1973), *P. varians* (Leach, 1814) (see Gurney, 1924; Fincham, 1979), *P. pugio* Holthuis, 1949 (see Broad, 1957), *P. intermedius* Holthuis, 1949 (see Hubschman & Broad, 1974).

Palaemonetes zariquieyi Sollaud has been reported from fresh-water and oligohaline canals, pools and lagoons on the Mediterranean Spanish East Coast (Zariquiey, 1968).

Sanz (1980) studied the local distribution, population dynamics, biometry and physiological aspects, and described the first and second larval stage of *P. zariquieyi*.

However, complete larval development of the species has not been investigated. The present paper describes the abbreviated larval development of *Palaemonetes zariquieyi* as observed under laboratory conditions.

MATERIAL AND METHODS

Mature broodstocks of *P. zariquieyi*, were collected on 20 May 1992 from a freshwater canal in the Ebro delta (N. E. Spain, 40°37′N 0°36′E), by means of a push net swept through the vegetation. The animals mated under laboratory conditions. Ovigerous females were kept individually in small tanks (30 × 20 cm) supplied with recirculated water kept at 19°C. When the larvae hatched they were also kept in the same system and the females were removed. The larvae were reared at room temperatures, which varied from 19° to 22°C during the course of the study.

Newly-hatched nauplii of *Artemia salina* (L., 1758) were provided as food but were never accepted by the larvae. The small tanks were examined daily for exuviae. Daily examination of each larva was made by means of a binocular microscope. Exuviae and specimens of each developmental stage were preserved in 7% buffered formalin. All drawings were made with the aid of a projector-microscope. Measurements were taken by a binocular microscope with an ocular micrometer. Body length was measured from the posterior margin of the orbit to the posterior end of the telson (excluding setae). Each drawing was based on at least three specimens. Setules were omitted from the setae of the appendages in the lateral views of the various stages. These setules are more numerous and somewhat longer than the drawings indicate.

RESULTS

The egg size was found to vary from 1.44 × 1.18 to 1.7 × 1.27 mm depending upon stage of development. Mean incubation period was 36 days. *P. zariquieyi* has an abbreviated larval development. Three larval stages were observed before metamorphosis to post-larva. The first to third stages do not feed, subsisting only on stored yolk, and the first juveniles begin to feed. Major characteristics of the stages were as follows:

Stage 1 (figs. 1,2)

Six specimens of the first zoea measured 3.9 to 4.03 mm. Duration of the stage: 1.5-2 days. Upon hatching the larva assumes a benthic habit, lacking any free-swimming period. When disturbed, they move suddenly backwards through quick, anteriorly directed contractions of the abdomen and telson. When this movement stops, the larvae use the exopods of the maxillipeds much more for balancing and easing their descent rather than for influencing the direction.

The carapace (fig. 1A) lacks spines. The rostrum is straight and lacks spines. The eyes are sessile.

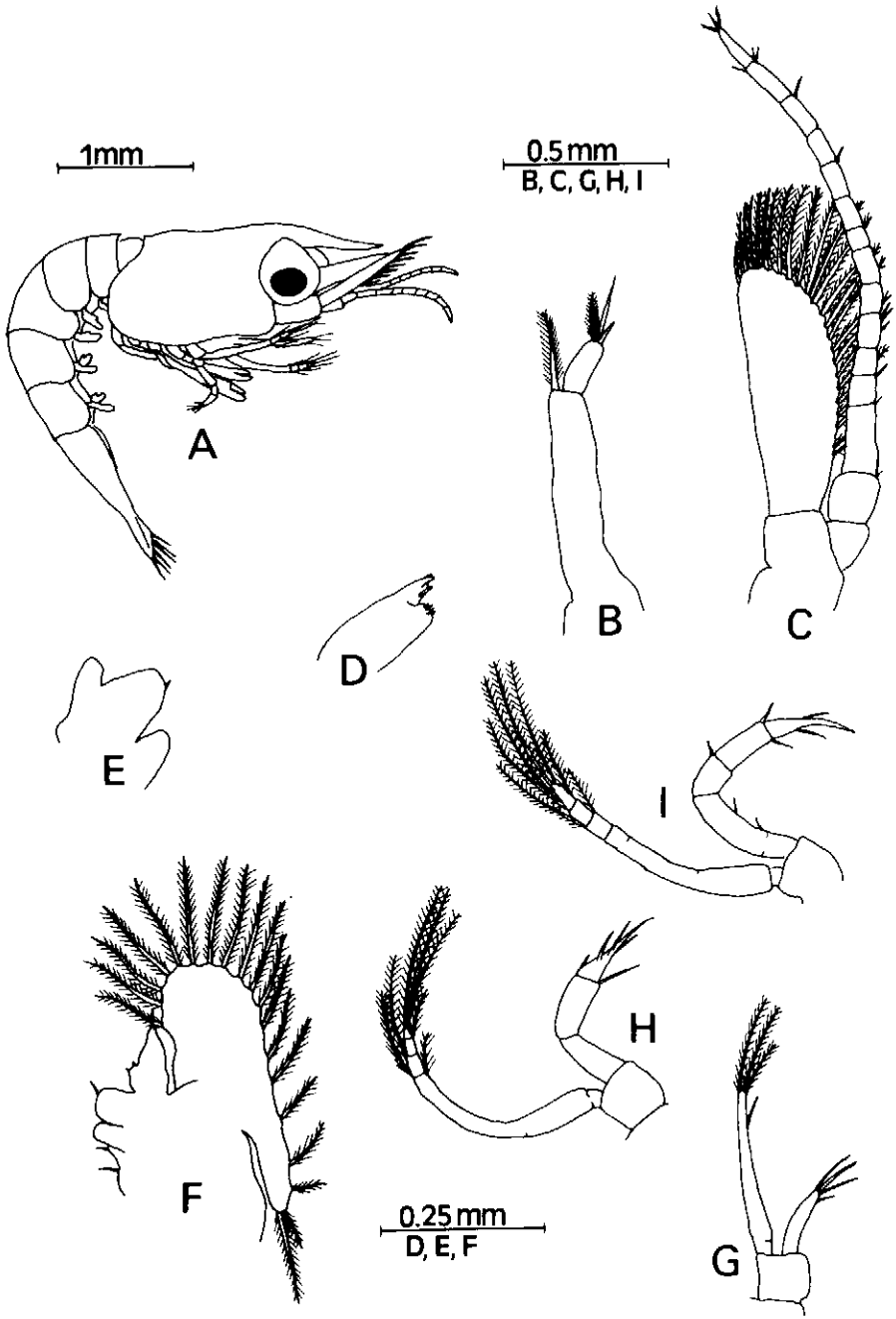

Fig. 1. *Palaemonetes zariquieyi* Sollaud, Stage I. A, lateral view; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped.

The antennule (fig. 1B) is uniramous and bears at the distal end of its unsegmented peduncle a lateral flagellum and a median plumose seta. The flagellum has three terminal aesthetes and a subterminal plumose seta.

The antenna (fig. 1C) is biramous, similar to adult shape. The protopod is unsegmented. The flagellum (endopod) is about twice the length of the scaphocerite with 15 segments. The scaphocerite (exopod) bears 25 or 26 plumose setae along the anterior-distal margin.

The mandible (fig. 1D) is rudimentary and lacks a palp. The incisor process has three rudimentary teeth. The molar process bears about seven small teeth.

The maxillule (fig. 1E) is rudimentary. The palp (endopod) is simple and unsegmented. The upper (distal) endite has one small tooth and is larger than lower (proximal) endite.

The maxilla (fig. 1F) is biramous, with three endites. The lower endite has two naked setae and the upper endite one naked seta. The unsegmented endopod has one naked seta at the tip. The scaphognathite (exopod) has 19 plumose setae on the entire margin.

The first maxilliped (fig. 1G) is biramous and simple. The unsegmented exopod, which is approximately twice the length of the endopod, has four plumose setae distally. The unsegmented endopod bears four terminal naked setae.

The second maxilliped (fig. 1H) is biramous, with a three-segmented endopod which is approximately two-thirds the length of the exopod. The endopod ends in a spine and bears three terminal setae on its distal segment and two setae on its penultimate segment. The exopod has seven plumose setae.

The third maxilliped (fig. 1I) is biramous. The endopod is four-segmented and longer than the exopod. The endopod ends in a spine and bears two terminal setae on its distal segment and two setae on its penultimate segment. The exopod bears seven plumose setae.

The first and second pereiopods (fig. 2A) are biramous, small and have rudimentary, non-functional chelae. The exopods are rudimentary and lack setae. The remaining three pairs of pereiopods are present, uniramous, unsegmented, glabrous and non-functional.

The uniramous pleopod buds (fig. 2B) are present but are non-functional.

The abdomen (fig. 1A, 2C) consists of six segments, the last being fused to a triangular telson which bears 22 plumose setae, the outermost two pairs of which are plumose on the inner margin only.

Stage 2 (figs. 3,4)

Five specimens of the second zoea measured 4.0 to 4.1 mm. Duration of stage: 1.5-2 days. The main differences between this and the preceding stage are the separation of the eyes from the carapace, the rostrum which has a single dorsal spine, the carapace with a pair of supra-orbital spines and another pair

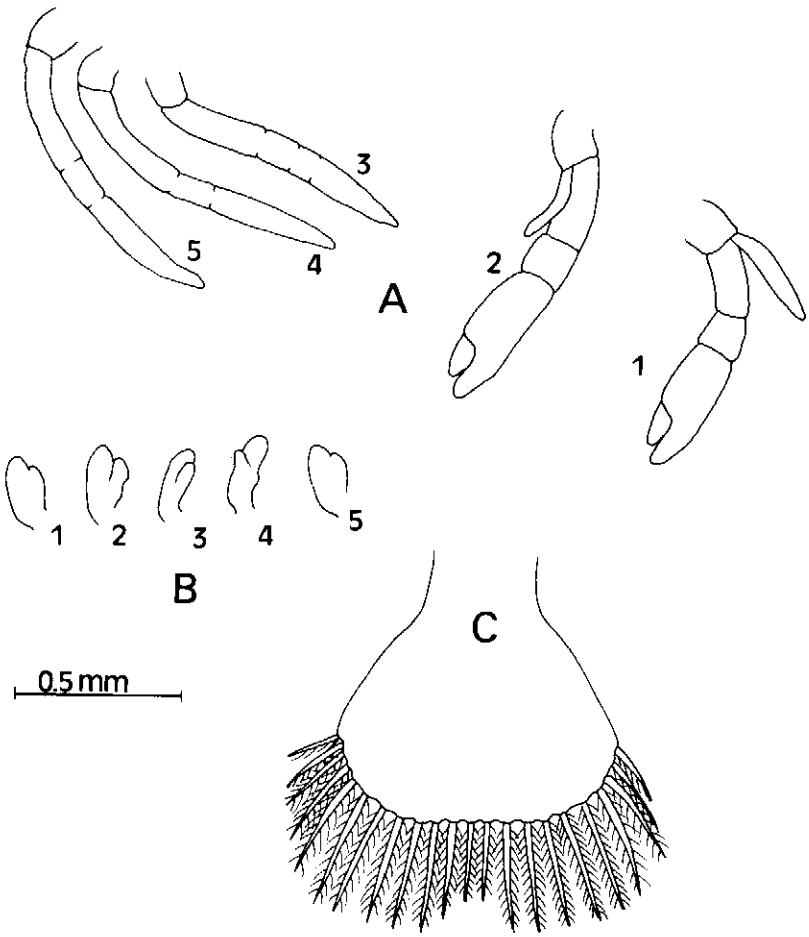

Fig. 2. *Palaemonetes zariquieyi* Sollaud, Stage I. A, (1-5) first to fifth perciopods; B, (1-5) first to fifth pleopods; C, telson.

at its antero-ventral corners; the last three pairs of perciopods are well developed and functional.

The antennula (fig. 3B) now has a three-segmented peduncle, the distal segment bearing two flagella. The stylocerite is located towards the base of the proximal segment on the lateral margin. The inner flagellum is unsegmented with two naked setae and is shorter than the outer flagellum. The outer flagellum is unsegmented with two terminal aesthetes. The three segments of the peduncle bear plumose setae.

The antenna (fig. 3C) has a scaphocerite with 22 plumose setae. The flagellum is more than twice the length of the scaphocerite with 17 segments.

The mandible (fig. 3D) is still rudimentary.

The maxillule (fig. 3E) is much the same as in the previous stage. The upper and lower endites have two and one small teeth, respectively.

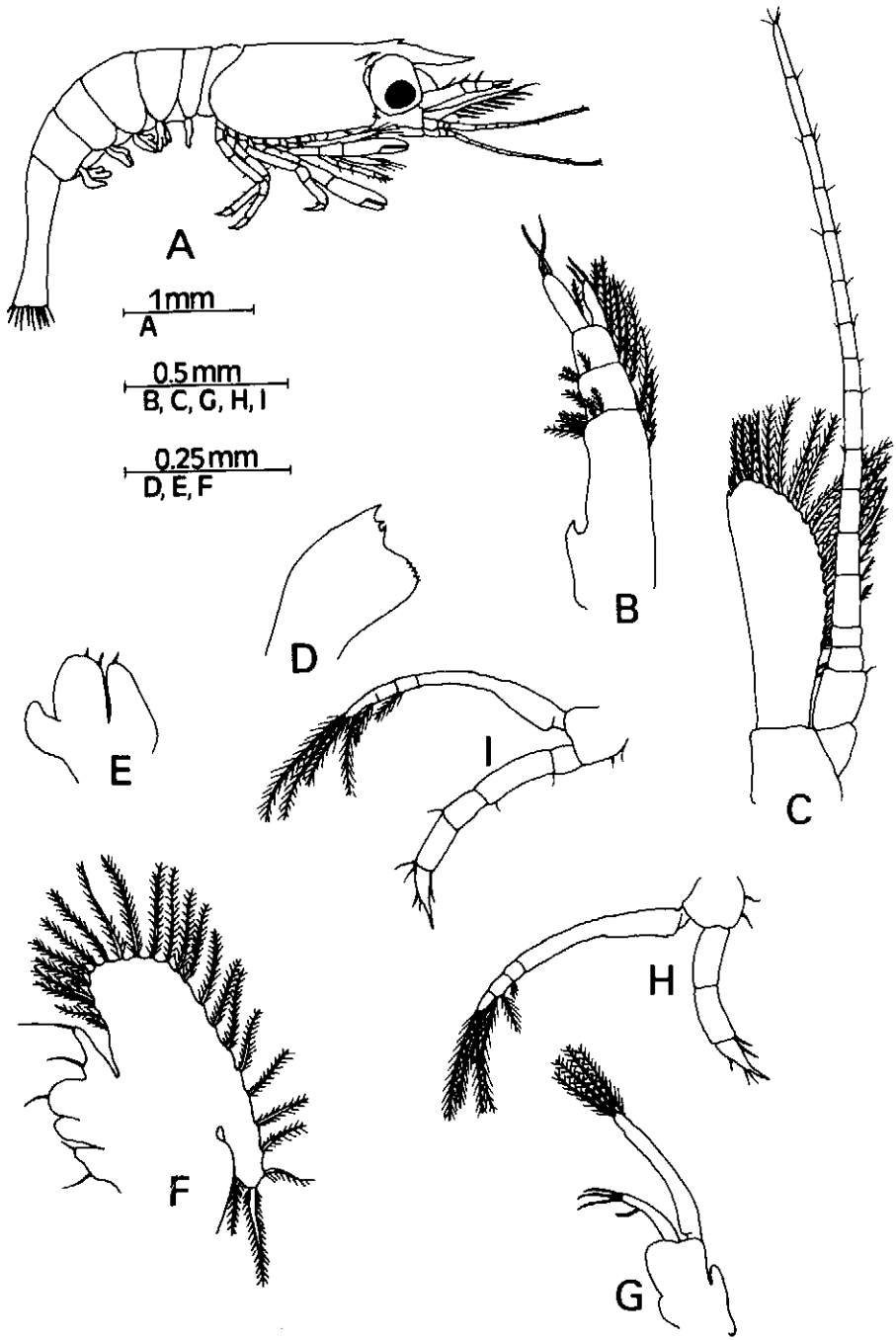

Fig. 3. *Palaemonetes zariquieyi* Sollaud, Stage II. A, lateral view; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped.

The maxilla (fig. 3F) is relatively unchanged, but the scaphognathite now bears 24 plumose setae. The endopod has gained a lateral naked seta. The upper and lower endite have one and two naked setae respectively.

The first maxilliped (fig. 3G) differs from that of the preceding stage in the apparition of a bilobed epipod.

The second and third maxillipeds (fig. 3H, I) are much the same as those of the first stage.

The first and second pereiopods (fig. 4A) have the endopods almost as in the first stage. The exopod of the first pereiopod has three terminal plumose setae.

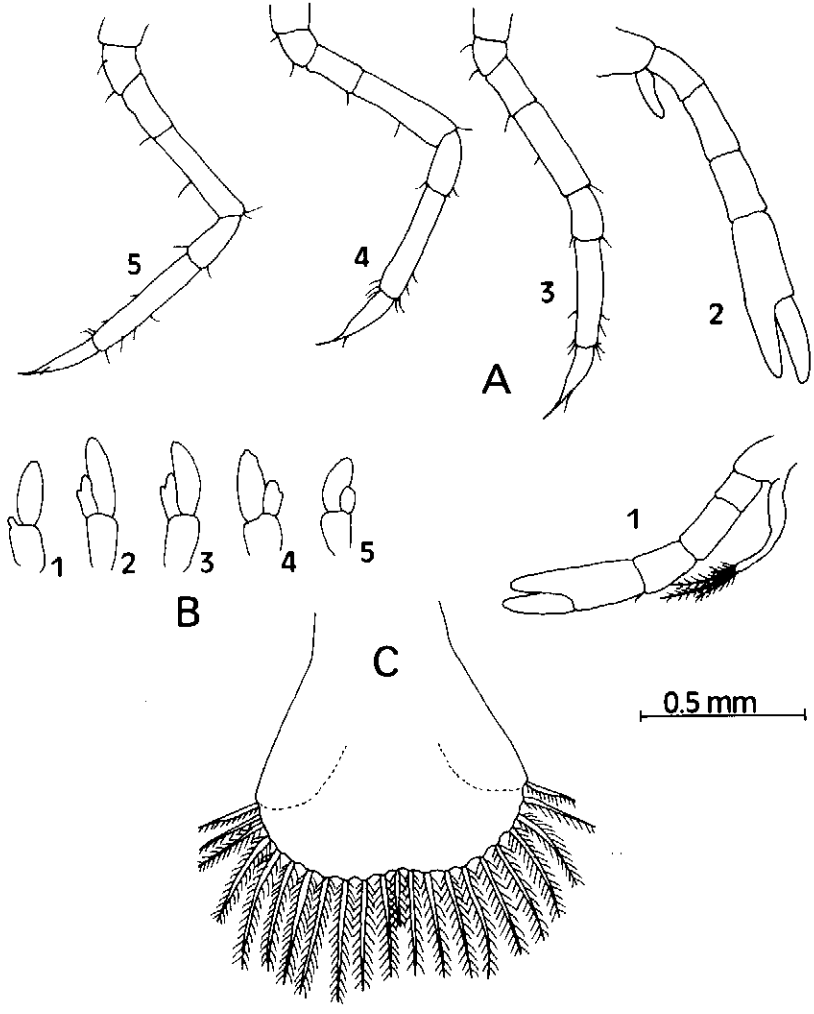

Fig. 4. *Palaemonetes zariquieyi* Sollaud, Stage II. A, (1-5) first to fifth pereiopods; B, (1-5) first to fifth pleopods; C, telson.

The fourth and fifth pereiopods are considerably better developed than they were in the previous stage and have assumed the adult segmentation.

The pleopods (fig. 4B) are larger than in the previous stage, but not functional and glabrous. The endopod of the second to fourth pleopods have rudimentary appendices internae.

The telson (fig. 4C) has 22 plumose setae. The developing uropods are seen beneath the cuticle of the telson in advanced second stages.

Stage 3 (figs. 5,6)

Seven specimens of the third zoea measured 4.06 to 4.3 mm. Duration of stage: 1.5-2 days. The chief differentiating characteristic of this stage is the presence of uropods.

The antennule (fig. 5B) has acquired additional setae and a small dorsal spine on its basal segment. The inner and outer flagella are almost equal in length and are both two-segmented.

The antenna (fig. 5C) has now developed an disto-lateral spine on the scaphocerite and about 26 plumose setae. The flagellum has 21 segments.

The mandible (fig. 5D) is better developed than in the second stage. The incisor process has three teeth. The molar process is obtuse, bearing many minute spines.

The maxillule (fig. 5E) is better developed than in the second stage. The palp is bilobed. The upper endite has four teeth.

The maxilla (fig. 5F) is mostly as in the second zoea, but the shorter endopod lacks setae. The scaphognathite has about 27 plumose setae.

The first maxilliped (fig. 5G) is about as in the second zoea. The endopod has 2 naked setae.

The second maxilliped (fig. 5H) now has the endopod five-segmented.

The third maxilliped (fig. 5I) is much the same as in the second stage.

The third to fifth pereiopods (fig. 6A) are the same as in the preceding stage. The first and second pereiopods are better developed than in the second stage, with numerous setae.

The pleopods (fig. 6B) are better developed than in the second stage, but are glabrous.

The telson (fig. 6C), which has 20 plumose setae, is now distinct and articulates with the sixth abdominal segment; it is more narrow posteriorly than in the preceding stage.

The uropod (fig. 6C) is biramous. The endopod articulates with the protopod, but the exopod is still fused to it. The endopod is rudimentary and naked. The exopod is well developed with about 19 plumose setae on its margins.

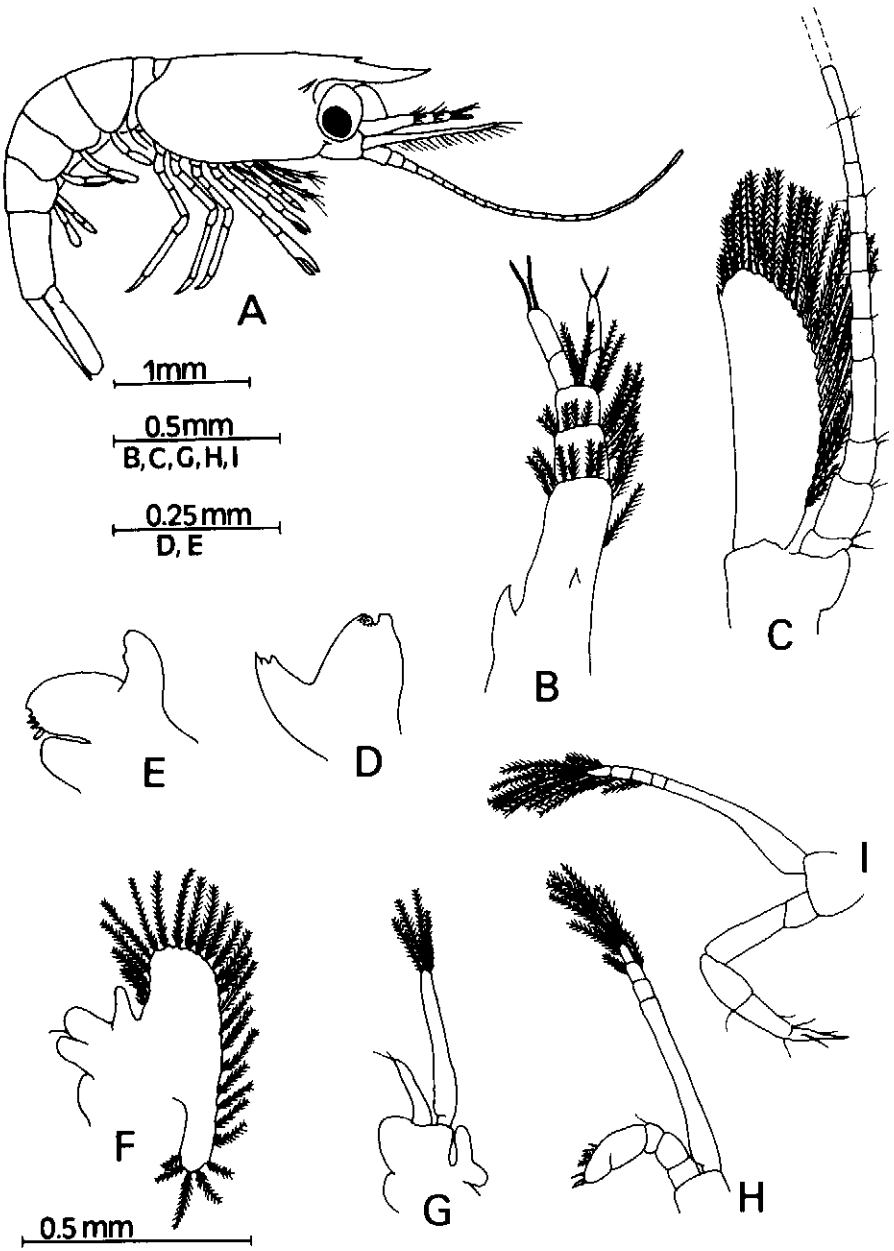

Fig. 5. *Palaemonetes zariquieyi* Sollaud, Stage III. A, lateral view; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped.

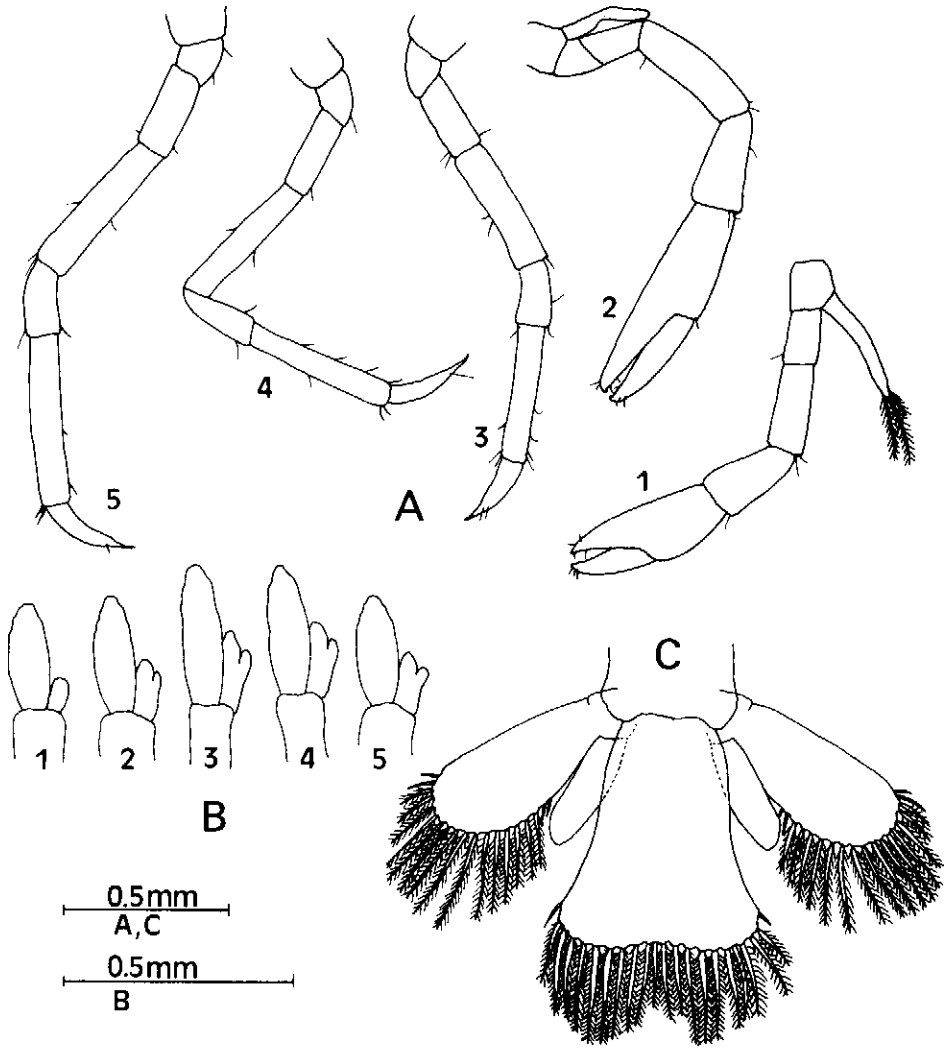

Fig. 6. *Palaemonetes zariquieyi* Sollaud, Stage III. A, (1-5) first to fifth perciopods; B, (1-5) first to fifth pleopods; C, telson and uropods.

Postlarva (figs. 7,8)

Seven specimens of the first postlarva measured 4.2 to 4.6 mm. Duration of the stage; 2-2.5 days. The main differences between this and the preceding stage are the loss of functional exopods on the thoracic appendages, the great elongation of the antennal flagellum, the rostrum which bears four dorsal spines and one or no ventral (fig. 7J), and the appearance of setae on the pleopods and the endopods of the uropods.

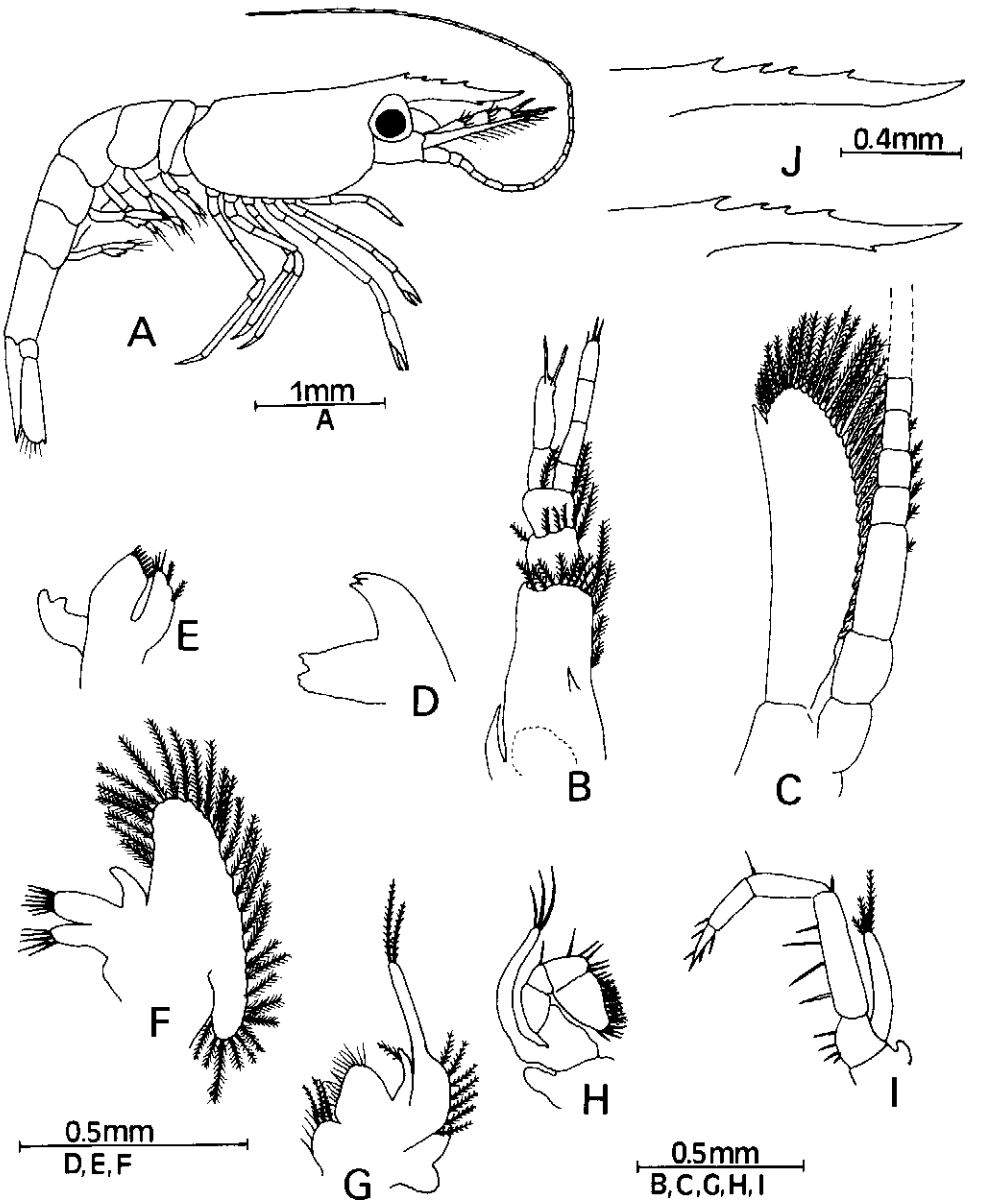

Fig. 7. *Palaemonetes zariquieyi* Sollaud, Postlarva. A, lateral view; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped; J, rostrum.

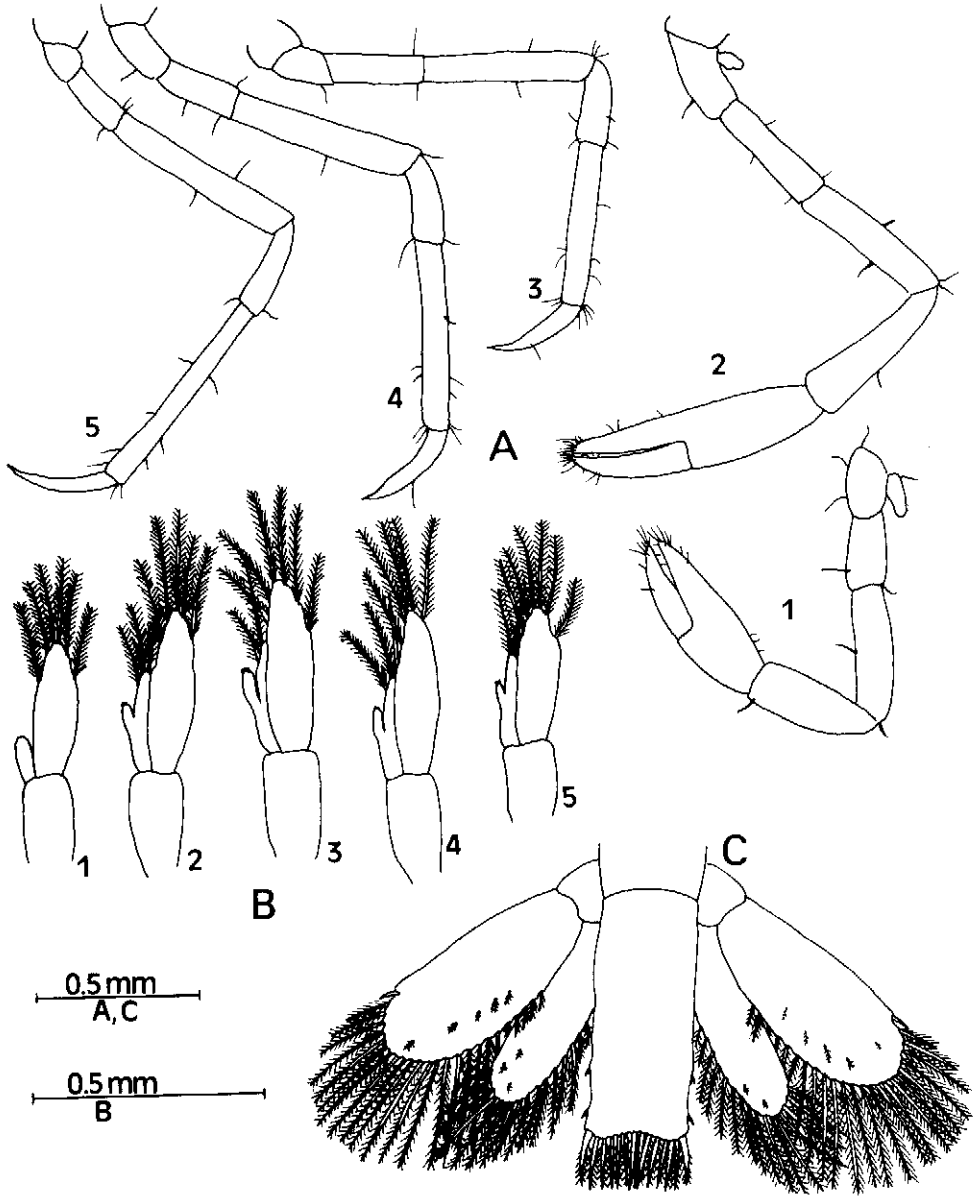

Fig. 8. *Palaemonetes zariquieyi* Sollaud, Postlarva. A, (1-5) first to fifth pereiopods; B, (1-5) first to fifth pleopods; C, telson and uropods.

The antennule (fig. 7B) now has an outer flagellum of two segments, which is slightly shorter than the inner flagellum which consists of four segments. The basal segment contains the statocyst.

The antenna (fig. 7C) has the flagellum as long as the body, with 33 segments. The scaphocerite has one anterodorsal spine and approximately 28 plumose setae.

The mandible (fig. 7D) has divided into a very definite molar and an incisor process. The incisor process is acute, with three teeth. The molar process shows marginal denticles.

The maxillule (fig. 7E) is well developed and functional, the upper endite has nine bristled setae; the basal endite has four bristles and two plumose setae.

The maxilla (fig. 7F) has an endopod which bears no setae. The basipodite resulting from the fusion of two basal endites has seven bristled setae. The coxal endite shows five bristled setae and the scaphognathite bears approximately 30 plumose setae marginally.

The first maxilliped (fig. 7G) shows a caridean lobe, which bears seven plumose setae. The exopod has two terminal plumose setae, the endopod a single sub-terminal plumose seta. The coxal and basal endites are well developed, their setae are as illustrated.

The second maxilliped (fig. 7H) has undergone a transformation. The endopod is five-segmented and the three distal segments are curved inwards. The ultimate and penultimate segments have widened, bearing many setae as illustrated.

The third maxilliped (fig. 7I) has a four-segmented endopod with numerous setae. The degenerate exopod bears three apical plumose setae.

The pereiopods (fig. 8A) are better developed than in the third zoea. The first and second pereiopods have the exopod greatly reduced and naked. The chela bears numerous short setae at its tip. The second pereiopod is considerably longer than the first.

The pleopods (fig. 8B) are well developed and fully functional, with plumose setae. An appendix interna is present on the endopods of the second to fifth pleopods.

The telson (fig. 8C) is rectangular; more than twice as long as broad. The posterior margin bears 14 plumose spines. The lateral margin has 2 pairs of small spines. The exopod of the uropods (fig. 8C) now articulates with the protopod and is longer and broader than the endopod. It usually has 24 plumose setae on its terminal and inner margins; a spine at its distolateral corner and five minute plumose setae on its dorsal surface. The endopod has 17 plumose setae on its margins. The protopod is naked.

DISCUSSION

Sollaud (1923) described three basic types of larval development in the palaemonids. The three types of development are present in *Palaemonetes*: the

TABLE I

Comparison of eggs size, larval stages, first larval and postlarva length of some *Palaemonetes* fresh-water species (in mm)

Species/reference	Distribution	Egg size	Larval stages	TL 1st instar	TL postlarva
P. paludosus (Gibbes) Dobkin, 1963	United States east of the Alleghenies	1.1×0.8 to 1.8×1.0	3	3.7-3.9	4.2-4.7
P. cummingi Chace Dobkin, 1971	United States northern Florida	1.4	3	4.8	5.5
P. kadiakensis Rathbun Broad & Hubschman, 1962	Central United States	1.4×1.1 (late eggs)	5-8	4.4	7.5
P. ivonicus Holthuis Magalhaes & Walker, 1987	Amazon basin	2.3×1.49	3	4.55	
P. mercedae Pereira, 1986 Magalhaes & Walker, 1987	Amazon and Orinoco River basins	2.01×1.13	1	4.68	–
P. argentinus Nobili Menú-Marque, 1973	South America		9	3.3	6.2
P. zariquieyi Sollaud Present paper	Eastern Spain	1.4×1.15 to 1.74×1.27	3	3.9-4.03	4.2-4.6

first is common among marine and brackish water forms, which bear many small eggs. The type of larval development of these species consists of five or more larval stages. The second is an abbreviated type, which consists generally of three larval stages prior to metamorphosis. Species showing this type of development are found in freshwater and have fewer and larger eggs than the first group. The third type of development is a complete suppresion of larval stages. *P. zariquieyi* belongs to the second type; its larval development is abbreviated and consists of three larval stages prior to metamorphosis. The eggs size, larval stages, and length of first and postlarval stage of some fresh-water *Palaemonetes* are exemplified in table I.

Sollaud (1938) reported that *P. varians* (Leach) was the putative parental species of *P. zariquieyi* and three mediterranean fresh-water prawns with abbreviated larval development: *P. mesopotamicus* Pesta, 1913, *P. antennarius* (H. Milne-Edwards, 1837) and *P. mesogenitor* Sollaud, 1912. Exopods occurred in the first two pairs of perciopods of the first stage of *P. zariquieyi* and *P. antennarius*, whereas the first stage of *P. mesogenitor* and *P. mesopotamicus* lack them. Such a difference could be a consequence of the more ancient colonization of freshwater by this species.

The larval development of *P. paludosus* and *P. cummingi* is similar to that of *P. zariquieyi*. However, morphologically the corresponding stages of the two American species are identical, but *P. zariquieyi* shows a greater tendency to reduce larval morphological features than the two other species. In the first stage of *P. paludosus* and *P. cummingi*, the endopod of the antenna is unsegmented, about

three-quarters the length of the scaphocerite, and bears a long terminal plumose seta. In *P. zariquieyi* it is better developed with 16 segments. The first larval stage of *P. ivonicus* Holthuis, 1950, also shows a multi-articulated endopod, longer than the scaphocerite. The third pereiopod of *P. zariquieyi* does not present an exopod in any larval stage, while in the third larval stage of *P. paludosus* and *P. cummingi* the third pereiopod is biramous with plumose setae.

A tendency toward abbreviated or direct development is common in fresh-water forms, but not all fresh water species show abbreviated development. *P. kadiakensis* and *P. argentinus* are more similar in their development to the marine and brackish-water species than to the fresh-water form. This difference may be related to the time the different species have inhabited fresh water. A tendency toward condensation of development would probably appear in forms which have been in fresh-water for a longer time (Dobkin, 1963; Strenth, 1976). In the Amazon basin, the palaemonid species with complete development inhabit areas rich in plankton, whilst those species with abbreviated development are found in plankton poor areas (Magalhaes & Walker, 1987).

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