The juvenile stages of *Parastacus brasiliensis* (von Martens, 1869) (Crustacea, Decapoda, Parastacidae)

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Abstract
The family Parastacidae consists of the freshwater crustaceans popularly known as crayfishes or crawfishes. Only the genus *Parastacus* occurs in Brazil, with *P. brasiliensis* (von Martens, 1869) endemic to the state of Rio Grande do Sul in southern Brazil. Parastacids have direct development, eclosing as juveniles. In laboratory-reared specimens, juvenile I stage is similar in morphology to the adult, with no setae on most appendages, absence of uropods and presence of a hook on the dactyl of pereiopods 4 and 5. The juvenile II retains juvenile I characteristics but has more setae, which are more varied in morphology. The juvenile III possesses setae as the adults, fully formed uropods and the hooks on pereiopods 4 and 5 are substituted by an apical rectilinear dactylus.

Keywords: Juvenile, morphology, Parastacidae, Parastacus brasiliensis, setae

Introduction
The freshwater crawfishes of the family Parastacidae are represented in South America by three genera, *Parastacus* Huxley, 1879, *Samastacus* Rieck, 1971 and *Virilastacus* Hobbs, 1991. Only the genus *Parastacus* is known to occur in Brazil, being present in Rio Grande do Sul and Santa Catarina states (Buckup and Rossi 1980). *Parastacus brasiliensis* (von Martens, 1869) is endemic to Rio Grande do Sul, occurring in the basins forming the Guaíba estuary in the central depression of the state (Buckup 1999). It can be found among plant detritus that accumulates in stagnant waters and shoals in small lotic systems (Buckup and Rossi 1980) and, like other species of the genus, it builds galleries in ravines in small brooks.

There are not many reports of the types and morphology of crustacean setae. There have been several attempts to categorize setae. Thomas (1970) detailed the setae of the appendages of the European crawfish *Austropotamobius pallipes* (Lereboullet, 1858), and Fish (1972) and Farmer (1974) described those of *Eurydice pulchra* Leach (Isopoda) and
Nephrops norvegicus (L.). General classification schemes for crustacean setae were proposed by Drach and Jacques (1977) for decapod crustaceans and by Jacques (1989), who suggested a classification system based on the functional morphology of the setae. The concept of setae homology as a basis for the classification of crustacean setae was adopted by Watling (1989). Setation of Brazilian decapods has been studied by Bond-Buckup et al. (1996) with Aegla prado Schmitt, 1942, Bueno and Bond-Buckup (1996) in A. violacea Bond-Buckup and Buckup, 1994, Bond-Buckup et al. (1998) in A. longirostri Bond-Buckup and Buckup, 1994, A. ligulata Bond-Buckup and Buckup, 1994, and A. platensis Schmitt, 1942. Calazanz and Ingle (1998) characterized the larval stages of Pleoticus muelleri Bate, 1888 (Solenoceridae) based on the morphology of the setae.

The post-embryonic development of Australian parastacids was described by Suter (1977) in Engaeus cisternarius Suter, 1977, and Hamr (1992) in Astacopsis gouldi Clark, 1936, A. franklinii (Gray, 1845) and Parastacoides tasmanicus Clark, 1936, among others. Studies on South American parastacids were undertaken by Ringuelet (1949) on the juvenile I of Samastacus spinifrons (Philippi, 1882) (as Parastacus agassizi Faxon, 1898); Rudolph and Zapata (1986) studied embryonic and post-embryonic development in Parastacus nicoleti (Philippi, 1882), Rudolph and Rios (1987) in Parastacus pugnax (Poeppig, 1835), and Rudolph and Iracabal (1994) in Samastacus spinifrons (Philippi, 1882). With the exception of P. nicoleti, the morphology of the appendices has not been described in other species of Parastacus.

Material and methods

Ovigerous females of Parastacus brasiliensis were collected from the regions around the cities of Taquara (29°46’S, 50°53’W) and Mariana Pimentel (30°20’S, 51°22’W), Rio Grande do Sul State, southern Brazil, in September 1998. Females were kept in aquaria, and eggs and the different developmental stages were monitored. Six individuals from each stage (juveniles I, II and III), were dissected; antennae 1 and 2, mouthparts, pereiopods 4 and 5, telson and uropods were mounted on glass slides, and drawn with the help of a camera lucida. Juveniles I (Figure 1A), II (Figure 1B) and III were also prepared with a technique adapted for photography by Scotto (1980) and Felgenhauer (1987) using a scanning electron microscope (Jeol-JSM 5.800), with critical point drying in a CO2 Baltec CPD 030, and gold coating in a Sputter Coater SCD 050 Baltec.

Figure 1. Parastacus brasiliensis von Martens. (A) First juvenile; (B) second juvenile.
The morphology, number and types of setae present were analysed. The scheme proposed by Thomas (1970) was adopted in order to classify the types of setae, using the presence or absence of a basal septum, presence or absence of annulation and the type of cuticular expansions of the setal shaft, for categorization.

Results

The post-embryonic development of *P. brasiliensis* consists of three juvenile stages. The juvenile I ecdoses with morphology already similar to that of the adult in having all appendages developed, except the uropods. It remains attached to the female pleopods by a double fixation mechanism, a thread originating from the embryonic cuticle and the hooks present on the dactyl of pereiopods 4 and 5. When the embryonic cuticle rips in the first stage, the juvenile remains attached to the pleopods only through pereiopods 4 and 5, which persists until the second moult, when the juvenile III loses the hooks and becomes independent of the female.

The setae of *P. brasiliensis* show remarkable variety in their morphology, the antennae, mouthparts, pereiopods 4 and 5, telson and uropods having 12 different types as follows.

1. **Simple setae** (corresponding to acuminate, rod and papillate types of setae in Thomas 1970; Figures 2A, 3A). Setae without setal wall outgrowths and very variable in length and width. The annulation is evident in the median shaft region or is situated in the first third from the base. There is no basal septum.

2. **Cuspidate setae** (Figures 2B, 3B). Stoutly built setae, with annulation in the basal region. There is no basal septum.

3. **Conate setae** (Figures 2C, 3C). Small setae, without setal wall outgrowths and with a distinct annulation in the basal third. There is no basal septum.

4. **Hamate setae** (Figures 2D, 3D). Hook-shaped setae without setal wall outgrowths and very small when compared to other setae. There is no basal septum.

5. **Aesthetasc setae** (Figures 2E, 3E). In this type of setae the annulation is very evident in the proximal third. There is no basal septum. Wall is thinner in the apical region.

6. **Toothed setae** (Figures 2F, 3F). These are robust setae inserted obliquely in the longitudinal axis of the segment. There is no basal septum and no annulation.

7. **Teazel setae** (Figures 2G, 4A). There is a prominent annulation halfway along the shaft, with no basal septum. Elongated denticles occur after the annulation.

8. **Plumose setae** (Figures 2H, 3A). These have setules arranged from the base to the tip in two opposed rows, at an angle of approximately 180°. There is a prominent basal septum. Annulation is present, but it is hard to see in the juveniles.

9. **Pappose setae** (Figure 2I, J). A type of seta in which the setules are disposed randomly around the shaft; it can bear a dense concentration of setules or setules can be very sparsely distributed. The length varies according to the placement of the setae. They have a thin shaft, the basal septum is present and the annulation is hard to see.

   - Pappose setae of the statocyst: these are restricted to the basal segment of antenna
     1. Two types: **type 1** (Figure 2L, M): robust seta, basal septum present with no annulation. **Type 2** (Figure 2N): robust shaft, no basal septum and no annulation.

10. **Serrate setae**. Setae having two opposed rows of denticles. The annulation is evident and the basal septum is present. The variations in size and form of the denticulation are as follows.

   - **Serrate type 1** (Figures 2O, 3F): the denticles occur after the annulation, are robust and grow gradually from the post-annular region until the middle of the shaft,
Figure 3. *Parastacus brasiliensis* von Martens, third juvenile. (A) Plumose seta (Ps) and simple setae (Ss) from the telson; (B) cuspidate setae from the basipodite of maxilla 1; (C) conate seta (Cns) and hamate setae (Hs) from the scaphognathite of maxilla 2; (D) hamate seta from the scaphognathite of maxilla 2; (E) aesthetasc seta from antenna 1; (F) tooth setae (Ts) and serrate seta (Srs) type 1 from pereiopod 5. an, annulation.

Figure 2. *Parastacus brasiliensis* von Martens. (A) Simple seta from the propodite of maxilliped 3; (B) cuspidate seta from the basipodite of maxilla 1; (C) conate seta from the exopodite of maxilla 2; (D) hamate seta from the epipodite of maxilliped 1; (E) aesthetasc seta from antennae 1; (F) toothed setae from the dactylopodite of pereiopod 4; (G) teazel seta from the basipodite of maxilla 1; (H) plumose seta from the antennal flag of antenna 2; pappose seta from antenna 1: (I) from the distal segment, (J) from the internal flagellum, (L–N) from the statocyst; serrate seta: (O) from the carpopodite of maxilliped 3, (P) from the propodite of maxilliped 3; (Q) multidenticulate seta from the basipodite of maxilla 1; plumodenticulate seta: (R) from basipodite of maxilliped 3, (S) from ischiopodite of maxilliped 3. Scale bar: 0.1 mm.
becoming smaller in the apical region. The annulation is in the median region of the shaft.

- **Serrate type 2** (Figures 2P, 4B): longer and thinner setae than type 1. The denticles begin shortly after the annulation, in the median region of the shaft, and are more numerous and less robust.

- **Serrate type 3** (Figure 4C): smaller than type 2. The denticles, of a uniform size, are on the distal third of the shaft, far from the annulation. The latter is found at around a third of the length from the base.

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**Figure 4. *Parastacus brasiliensis* von Martens. (A) Teazel seta from the coxopodite of maxilla 1 of the second juvenile; (B) serrate seta type 2 from the dactylopodite of maxilliped 3 from the third juvenile; (C) serrate seta type 3 from the coxopodite of maxilla 2 from the second juvenile; (D) multidenticulate seta from maxilla 1 of the third juvenile; (E) hooked spine at the apex of the dactylopodite of pereiopod 4 of the second juvenile; (F) setal precursors (sp) on the propodite of pereiopod 4 of the second juvenile. an, annulation.
11. *Multidenticulate setae* (Figures 2Q, 4D). Long setae with small denticles, away from the annulation and inserted in many rows. The denticles have projections in the distal part. An evident annulation is situated approximately in the median region of the shaft.

12. *Plumodonticulate setae* (Figure 2R, S). The setules are inserted both in the pre-annular and post-annular regions. There are denticles in the apical region of the shaft. The annulation is not visible for all setae. Basal septum present.

*First juvenile stage*

*Average cephalothorax length.* 2.87 mm SD 0.09 mm. The juvenile I is linked to the female by pereiopods 4 and 5 and by the embryonic cuticle, having a rounded and yellowish cephalothorax because of the presence of yolk, sessile eyes, short rostrum ventrally curved and with scarce hair cover (Figure 1A).

*Antenna 1 (Figure 5A).* Protopodite three-segmented, with distal segment biramous. Basal segment globose, with a depression on the aboral face where the statocyst is. There are no setae in this stage. External flagellum (exopodite) with six segments, with the apex of the last segment having three to four setal precursors. Internal flagellum (endopodite) with four to five segments, with the last segment having three to four setal precursors.

*Antenna 2 (Figure 5B).* The protopodite and the biarticulate endopodite do not show any setae. Antennal flagellum formed by 28–30 segments and three setal precursors at the apex of the last segment. Antennal scale (scaphocerite) with seven setal precursors along the margin.

*Mandible (Figure 5C).* Without setae and with molar and incisor processes without cutting ends. Mandibular palp with three segments. Distal segment with approximately 12–15 setal precursors distributed in the apical and sub-apical regions.

*Maxilla 1 (Figure 5D).* Biramous appendage and without setae. Protopodite with two unequal lobes, coxopodite and basipodite, and endopodite with beginning of segmentation. Distal margin of the coxopodite with 9–10 apical and sub-apical setal precursors. Basipodite more developed than the coxopodite with 18–19 apical and sub-apical setal precursors.

*Maxilla 2 (Figure 5E).* Biramous appendage, composed of the exopodite, endopodite and bilobed endites. Proximal endite of the coxopodite with four setal precursors and distal endites with three setal precursors. Endite of proximal basipodite with six setal precursors and distal endites more developed than previous ones, with 12–15 apical setal precursors. Unisegmented endopodite with four pappose basal setae and one sub-apical seta on the internal margin. Exopodite (scaphognathite) well developed and elongated with 50–55 pappose setae inserted along the margin and, in the inferior region, approximately six setal precursors. On the median surface there are three conate setae and in the basal region there are several hooked setae.

*Maxilliped 1 (Figure 5F).* Bilobed protopodite, with the basipodite more developed than the coxopodite and with 13–15 apical setal precursors. Coxopodite without setae.
Unisegmented endopodite rudimental and without setae. Exopodite elongated and without visible segmentation. External margin of the basal segment with 10–11 pappose setae and distal segment (flagellum) with four apical setal precursors. Epipodite leafy and elongated, with hooked setae on its surface.
Maxilliped 2 (Figure 6A). Biramous appendage devoid of setae. Endopodite five-articulate. Dactylopodite sub-cylindrical with three to four setal precursors on the distal margin. Propodite with two precursors on the posterior margin. Carpopodite and protopodite smooth. Meropodite rectangular, with the larger segment having five setal precursors on the internal margin. Ischiopodite with one apical setal precursor. Exopodite the same size as the endopodite, with four apical setal precursors and without visible segmentation.
Maxilliped 3 (Figure 6B). Biramous appendage well developed and devoid of setae. Endopodite five-articulate. Dactylopodite sub-cylindrical with four setal precursors on the distal margin. Propodite with two precursors on the internal margin. Carpopodite with one precursor on the external distal margin and approximately six precursors on the internal margin. The meropodite still does not show its tetrahedral form, but has one precursor on the external distal margin and three precursors on the internal margin. Toothed crest of the ischiopodite with four to five teeth without sharp-pointed form on the internal margin. Protopodite smooth. Exopodite reaches the distal end of the meropodite, having no visible segmentation and four setal precursors in the apical region.

Pereiopods 1, 2 and 3. Without setae, five-segmented with structure similar to the adult.

Pereiopod 4 (Figure 6C). Uniramous appendage devoid of setae. Dactylopodite with a hook on the apical region and five to six spines on the internal margin, under the hook. Propodite, carpopodite, meropodite, ischiopodite and protopodite smooth, without visible setal precursors.

Pereiopod 5 (Figure 6D). Uniramous appendage devoid of setae. Dactylopodite with an apical hook and five to six spines on the internal margin, under the hook. Propodite, carpopodite, ischiopodite, and protopodite smooth, without visible setal precursors. Meropodite with three setal precursors on the inferior internal margin.

Telson (Figure 6E). Sub-rectangular, with rounded border. Devoid of setae or setal precursors.

Uropods. Absent.

Second juvenile stage

Average cephalothorax length. 3.01 mm SD 0.16 mm. The juvenile II is attached to the female only by the hooks of pereiopods 4 and 5. The cephalothorax loses its globose form, but retains a quantity of yolk. Pedunculate eyes, rostrum straighter than in the previous stage and a larger number of setae on the appendices (Figure 1B).

Antenna 1 (Figure 7A). Basal segment with approximately 12 setal precursors on the median region of the internal margin, seven to nine setal precursors on the distal margin and three on the external margin. Median segment with two sub-apical setal precursors on the internal margin and two on the external margin. Distal segment with one apical setal precursor and one on the median region of the external margin. External flagellum with eight segments. Penultimate segment with one antero-lateral aesthetasc and last segment with three aesthetascos on the median region and three to four setal precursors and no or one simple seta on the apex. Internal flagellum with six to seven segments, with the last segment having two to three apical setal precursors. Both flagella with setal precursors on the apical region of the segments.

Antenna 2 (Figure 7B). Protopodite without setae. Endopodite with two articles without setae. Antennal flagellum formed by 34 segments with few setal precursors on the distal margin. Antennal scale with 12 well-developed setal precursors on the internal margin.
Mandible. Incisor process with seven sharp-ended asymmetrical teeth and molar process toothless. Mandibular palp three-segmented. Basal segment without setae, median segment with one antero-lateral pappose seta and distal segment with 23–26 teazel setae on the distal region.

Maxilla 1 (Figure 7D). Distal end of the coxopodite with 13–15 teazel setae and no or one plumodenticulate seta on the median region. Basipodite more developed than the coxopodite with two plumodenticulate median setae on the internal margin and two
sub-apical on the external margin. On the distal end, 12–15 cuspidate setae and 8–10 teazel setae. Endopodite elongated and bilobed with three to four pappose setae on the basal region and one type 1 serrate distal seta.

Maxilla 2 (Figure 8A). Distal endite of the coxopodite with three to five teazel setae and one to two simple setae (distal third of the oral face with three type 3 serrate setae), proximal endite with five teazel setae, one pappose seta on the distal margin (distal third of the oral face with one type 3 serrate seta) and hooked setae on the inferior lateral margin. Distal endite of the basipodite more robust, with 26–30 simple setae on the distal end and proximal endite with 10–11 simple setae on the distal margin (distal third of the oral face with one type 3 serrate seta). Endopodite elongated with two plumodenticulate setae on the lateral margin and seven to eight basal pappose setae. Exopodite with 76–80 pappose setae placed along the margin and one to two multidenticulate setae and one plumodenticulate seta on the inferior margin. Median region of the surface with four conate setae and on the inferior region several hooked setae.

Maxilliped 1 (Figure 8B). Coxopodite with 6–10 apical pappose setae. Basipodite with 18–22 simple setae on the internal margin, three pappose setae on the distal margin, four to five on the inferior margin, and four to six plumodenticulate setae on the median surface. Endopodite small, devoid of setae or with one pappose seta on the apex. Flagellum with visible segmentation only on the basal region and the apex with six setal precursors. Basal segment of the exopodite with 18–23 pappose setae on the external margin, and on the internal margin one median pappose seta. Epipodite with hooked setae on the inferior surface.

Maxilliped 2 (Figure 8C). Dactylopodite with one simple seta and four cuspidate on the apical region, two cuspidate setae being denticulate. Propodite with six to eight simple setae on the superior margin and two type 1 serrate setae on the inferior margin. Carpopodite without setae. Meropodite with 10 simple setae and three type 1 serrate setae on the internal margin. Ischiopodite with five to seven simple setae. Protopodite with five to seven plumodenticulate setae. Exopodite without visible segmentation, surpassing the endopodite in length. On the basal region there is one pappose seta and at the apex three setal precursors.

Maxilliped 3 (Figure 8D). Dactylopodite with two simple setae and two to three type 2 serrate setae on the apical region. Propodite with two simple setae on the superior margin, six type 1 serrate setae on the median region of the oral face and six on the aboral face. Carpopodite with one to two simple setae on the superior margin and four to five type 2 serrate setae on the oral face and 10 on the aboral face. Meropodite with four simple setae, one type 1 serrate seta and seven to nine type 2 serrate setae on the internal margin. Ischiopodite with four to six simple setae, three pappose setae, 8–10 plumodenticulate setae on the internal margin and toothed crest with eight teeth. Protopodite with five to seven plumodenticulate setae and three pappose setae on the inferior region. Exopodite as in juvenile I, except on the posterior margin, where there are two to three pappose setae.

Pereiopods 1, 2 and 3. Structure as in the adult, setae present only on the dactyl.

Pereiopod 4 (Figure 9A). Dactylopodite with a hook on the apical region and six spines on the ventral margin (Figure 4E). Propodite with three to five setal precursors on the ventral
margin (Figure 4F). Meropodite with one apical setal precursor on the dorsal margin. Carpopodite, ischiopodite and protopodite smooth.

_Pereiopod 5 (Figure 9B)._ Dactylopodite with a hook at the apical region and seven spines on the ventral margin. Propodite with six apical setal precursors on the margin. Carpopodite, meropodite, ischiopodite, and protopodite with one setal precursor each.

Figure 8. _Parastacus brasiliensis_ von Martens, second juvenile. (A) Maxilla 2, aboral view; (B) maxilliped 1, aboral view; (C) endopodite of maxilliped 1; (D) maxilliped 2, aboral view; (E) maxilliped 3, aboral view. Scale bar: 0.3 mm.
Figure 9. *Parastacus brasiliensis* von Martens, second juvenile. (A) Pereiopod 4, ventral view; (B) pereiopod 5, ventral view; (C) telson, dorsal view. Scale bar: 0.3 mm (A, B); 1.0 mm (C).

**Telson (Figure 9C).** Sub-rectangular, without setae and without setal precursors along the margin.

**Uropods.** Absent. By transparency, the beginning of their formation can be seen near the telson.

**Third juvenile stage**

*Average cephalothorax length.* 3.66 mm SD 0.15 mm. The juvenile shows the typical aspect of the adult and is independent of the mother. The uropods are developed and with a large number of setae on their external borders.

**Antenna 1 (Figure 10A).** Internal margin of the basal segment with two long apical pappose setae and one median, external margin with six basal pappose setae, four pappose statocyst setae of type 2 and two to three multidenticulate median setae and, on the distal end, 12–14
pappose statocyst setae of type 2. There is a narrow spine on the oral face in the median region. Statocyst with pappose setae and pappose statocyst setae of types 1 and 2 on various planes. Median segment with two pappose setae on the internal distal margin and, on the external distal margin, 8–10 pappose setae and two simple setae. Distal article with two to three pappose setae on the internal distal margin, no or one pappose seta on the distal median region and two simple setae on the external median region. External flagellum with 10–12 segments, on the last segment three aesthetascs on the lateral median region, one simple seta on the external median lateral region, on the apex two pappose setae and seven

Figure 10. *Parastacus brasiliensis* von Martens, third juvenile. (A) Antenna 1, dorsal view; (B) antenna 2, dorsal view; (C) mandible, oral view; (D) maxilla 1, aboral view. Scale bar: 0.3 mm.
simple setae. There is one aesthetasc on each one of the five distal segments and in all segments (but the last) there are 22–33 simple setae and 5–10 pappose setae. Internal flagellum with 8–10 segments, apex of the last segment with four pappose setae and three simple setae and distal margin of the remaining segments totalling 12–16 simple setae and five to seven pappose setae.

Antenna 2 (Figure 10B). Protopodite with two to three pappose setae on the internal margin. Basal segment of the endopodite with four pappose setae on the internal margin and four on the external margin, on the ventral side. Distal segment with eight simple setae and seven pappose setae on the internal margin, and one simple seta and one to two pappose ones apical and sub-apical on the external margin. Antennal flagellum formed by approximately 60 segments, totalling 37–47 pappose setae and 133–176 simple setae. Antennal scale with 16–18 long plumose setae on the internal margin and five simple setae on the external margin.

Mandible (Figure 10C). Incisor process with seven asymmetrical sharp-ended teeth and molar process with three teeth. Basal segment of the mandibular palp without setae, median segment with one pappose seta on the median internal margin, six basal on the internal margin and three simple setae sub-apical on the external margin. Distal segment with 37–42 teazel setae on the anterior region.

Maxilla 1 (Figure 10D). Distal margin of the coxopodite with 20–24 teazel setae and three pappose setae. On the distal third there is no or one plumodenticulate median seta and on the basal region one multidenticulate seta. Basipodite with two to three plumodenticulate setae on the external lateral margin, and three plumodenticulate setae and three multidenticulate setae on the internal lateral margin. On the distal end 15–18 cuspidate setae, 11–13 teazel setae and one sub-apical plumodenticulate seta. Endopodite as in juvenile II, however, with five to seven pappose setae on the basal region and two distal type 1 serrate setae.

Maxilla 2 (Figure 11A). Proximal endite of the coxopodite with 10–12 teazel setae, two pappose setae, one to two type 3 serrate setae and hooked setae on the inferior lateral margin. Distal endite with six teazel setae, one to two simple setae, two pappose setae and three median type 3 serrate setae. Proximal endite of the basipodite with 16–20 simple setae (there is one type 3 serrate seta on the oral face), larger distal endite with 46–52 simple setae, two distal lateral plumodenticulate setae and two median plumodenticulate setae. Endopodite with three to four median plumodenticulate setae on the internal margin and 11–13 basal. Exopodite with 10–12 pappose setae, one or two multidenticulate setae and one plumodenticulate seta. On the surface there are approximately four conate setae and several hooked setae.

Maxilliped 1 (Figure 11B). Coxopodite with 10–16 long pappose setae on the distal margin. Basipodite with approximately 50 simple setae on the internal margin, two plumodenticulate setae and seven to nine pappose setae on the distal lateral margin, nine pappose setae on the inferior lateral margin and 10–12 median plumodenticulate setae. Endopodite with eight pappose setae. Flagellum with eight long plumose setae at the apex, and on the base three to five pappose setae on the internal margin. Basal segment of the exopodite with 42–46 pappose setae on the margin. Epipodite with several hooked setae.
Maxilliped 2 (Figure 11C). Dactylopodite with two simple setae and nine cuspidate setae on the apical region, and among these, six are cuspidate denticulate. Propodite with 14–16 simple setae and one type 1 serrate seta on the distal margin and two on the inferior margin. Carpopodite with one simple seta. Meropodite with 17–20 simple setae and six type 1 serrate setae on the internal margin. Ischiopodite with seven to nine simple setae and three to five plumodenticulate setae. Protopodite with eight to nine plumodenticulate setae. Exopodite bi-segmented, larger than in the previous stages, with 10 pappose setae on the external margin and flagellum with 10 plumose setae at the apex.

Figure 11. *Parastacus brasiliensis* von Martens, third juvenile. (A) Maxilla 2, aboral view; (B) maxilliped 1, aboral view; (C) endopodite of maxilliped 1; (D) maxilliped 2, aboral view; (E) maxilliped 3, aboral view. Scale bar: 0.3 mm.
Maxilliped 3 (Figure 11D). Dactylopodite with eight to nine simple setae and four to five type 2 serrate setae on the apical region. Propodite with 10–12 simple setae, three type 1 serrate setae on the median region and 13 type 1 serrate setae on the oral face. Carpopodite with six simple setae, three type 1 serrate setae, six to eight type 2 serrate setae, and 13 type 1 serrate setae on the oral face. Meropodite with 9–11 simple setae, three type 1 serrate setae, 14 type 2 serrate setae on the margin, and seven type 2 serrate setae on the oral face. Ischiopodite with 17 simple setae, eight pappose setae on the external margin and 12–15 plumodenticulate setae. Dentate crest with 21 teeth well chitinized. Protopodite with eight to nine plumodenticulate setae, two simple setae and two to three pappose setae. Exopodite reaches the distal end of the mere, has five to eight pappose setae on the posterior margin and 8–10 plumose setae at the apex, segmentation not visible.

Pereiopods 1, 2 and 3. As in the adult.

Pereiopod 4 (Figure 12A). Dactylopodite with one apical spine, 11 tooth setae on the ventral margin, 13–17 simple setae, three to five pappose setae. Propodite with 27–30 simple setae, 14–16 pappose setae, 15–20 type 1 serrate setae and three type 2 serrate setae. Carpopodite with 9–13 simple setae, four to six pappose setae. Meropodite with 25 simple setae, five to seven pappose setae. Ischiopodite 12–14 simple setae and three to five pappose setae. Protopodite with four to six simple setae and one to four pappose setae.

Pereiopod 5 (Figure 12B). Dactylopodite with one apical spine, 11 tooth setae on the ventral margin, seven to eight simple setae, two to three pappose setae. Propodite with 18–20 simple setae, 17–20 pappose setae, 21–34 type 1 serrate setae and six to eight type 2 serrate setae. Carpopodite with 10–13 simple setae, six to eight pappose setae. Meropodite with 16–20 simple setae, two pappose setae. Ischiopodite with 8–10 simple setae, one or two pappose setae. Protopodite with two to four simple setae and two to four pappose setae.

Telson (Figure 12C). Twenty-three to 28 long plumose setae, 17–19 long and thin simple setae along the posterior margin. Simple and pappose setae distributed all over the surface of the appendage. Median region with eight well-developed simple setae.

Uropods (Figure 12C). Biramous. Endopodites with rounded distal border with 26–28 plumose setae, 10–12 simple setae distributed on the posterior margin. Simple and pappose setae distributed all along the appendage. Exopodites with cuticular ornamentation on the distal third. Distal border rounded with 31–40 plumose setae, 8–10 simple setae on the posterior margin, two to five pappose setae, five to seven simple setae and 9–10 plumose setae on the lateral margin.

Discussion

Juvenile Parastacus brasiliensis eclodes with morphology similar to the adult, and stays attached to the pleopods of the female with special hooks present on the dactyl of pereiopods 4 and 5 (Huxley 1879; Gurney 1935; Ringuelet 1949; Suter 1977; Gore 1985; Rudolph and Zapata 1986; Rudolph and Rios 1987; Hamr 1992; Rudolph and Iracabal 1994). In contrast, crawfishes from the families Astacidae and Cambaridae use the chelae of the first pair of pereiopods to hold on to the mother (Gurney 1935; Thomas 1973; Felder et al. 1985).
The general morphology of the three juvenile stages of *P. brasiliensis* is similar to what was observed by Thomas (1970, 1973) in European Astacidae such as *A. pallipes*, in Chilean Parastacidae such as *Parastacus agassizi* (*Samastacus spinifrons*), *P. nicoleti*, *P. pugnax* and *Samastacus spinifrons* (see Ringuelet 1949; Rudolph and Zapata 1986; Rudolph and Ríos 1987; Rudolph and Iracabal; 1994) and Australian Parastacidae such as *Engaeus cisternarius* and *Parastacoides tasmanicus* (see Suter 1977; Hamr 1992). An important aspect of the morphology of juvenile III of parastacids is the substitution of a hook by a rectilinear dactylus on pereiopods 4 and 5, and also by the formation of the uropods that, like the telson, have long plumose setae on their external borders. However, observing juveniles of *Astacopsis gouldi* and *A. franklinii*, Hamr (1992) detected differences in the development of these species, noting the existence of four juvenile stages, the presence of uropods already
in the juvenile II, and dependence on the mother until the end of the third stage. The early development in the genus *Astacopsis* can be considered primitive because of a super-numerary juvenile stage and because of the premature development of the tail fan, which cannot be observed in other Parastacidae.

The average cephalothorax length of the juveniles of *P. brasiliensis* was shorter than that for juveniles of *Austropotamobius pallipes*, *Astacopsis gouldi*, *A. franklinii*, *Parastacoides tasmanicus*, and *Samastacus spinifrons* (Thomas 1973; Hamr 1992; Rudolph and Iracabal 1994). However, similar values for body length were seen in juveniles of other species of South American crawfishes such as *S. spinifrons* and *P. pugnax* (Ringuelet 1949; Rudolph and Rios 1987).

Differences in the morphology of the appendices were detected by Thomas (1973) for the juvenile I of *A. pallipes* and by Rudolph and Zapata (1986) for juveniles of *Parastacus nicoleti* in the smaller number of flagellum segments in antenna 1. In *P. nicoleti* a smaller number of segments in antenna 2 was also seen in the three juvenile stages; the endopodite of maxilliped 1 was bi-segmented and the exopodite of maxillipeds 2 and 3 in juvenile I was smaller.

The setae of *P. brasiliensis*, as observed by Thomas (1970, 1973) in *A. pallipes*, show a great variety of morphological types and distribution patterns on the surface of the appendages, a fact observed only from the second stage of development since in juvenile I most of the appendages are devoid of setae (Table I). There are setae widely distributed on the appendages showing variation in length according to location, such simple setae, serrate setae and pappose setae, and setae with a restricted distribution and uniform size, such as hooked setae, the aestethascs, toothed setae and conate setae. On the dactylopodite of maxilliped 2 there is a special type of cuspidate seta with denticles, associated with smooth cuspidate setae, as well as on the statocyst of antenna 1, where there are special types of pappose setae, corroborating the observations of Thomas (1970) in *A. pallipes*. Some differences can be observed between the setae of juveniles and adults of *P. brasiliensis*; for example in the young the tooth setae, although arranged in rows, are distinct and well spaced, and the tease setae have elongated and spaced denticles.

Although it is a European crayfish of the Astacidae family, the distribution pattern of the setae of *A. pallipes*, described by Thomas (1970), is similar to that found in *P. brasiliensis*. Differences were detected by the presence, in *A. pallipes*, of serrate setae, cited as serrulate setae by the author, in the basipodite and coxopodite of maxilliped 1 and maxilla 1, a large number of conate setae on the appendages, cuspidate setae on pereiopod 4, and absence of teazel setae and multidenticulate setae on the basipodite of maxilla 1. In the description by Thomas (1973), of the juveniles of *A. pallipes*, differences were identified in juvenile I of this species by the presence of pappose setae on the endites of maxilla 1 and 2, serrulate setae on the coxopodite of maxilla 2, pappose and plumodenticulate setae on the coxopodite of maxilliped 2, and well-developed setal precursors on the margin of the telson. The juvenile II is differentiated in antenna 1 by the presence of simple setae on the flagella and pappose setae on the protopodite, in antenna 2 by the presence of plumose setae on the antennal flagellum and simple setae on the flagellum, on maxilla 2 endites by the presence of conate setae, and in that pereiopods 4 and 5 already have all setae present in the adult.

The post-embryonic development pattern of *P. brasiliensis* does not differ from other Australian and South American parastacid species, with the exception of *Astacopsis gouldi* and *A. franklinii* studied by Hamr (1992), and the morphology of the appendages of the juveniles do not show significant differences from known South American species.
Table I. Setal scheme of the appendages for juveniles I, II and III of *Parastacus brasiliensis* von Martens.

| Appendage     | Seg a | Juvenile I b | Juvenile II | Juvenile III |
|---------------|-------|--------------|-------------|--------------|
| **First antennae** | exf   | --           | 0–1 (I); 4 (V) | 30–41 (I); 8 (V); 7–12 (IX) |
|               | inf   | --           | --          | 15–19 (I); 9–11 (IX) |
|               | dsg   | --           | --          | 2 (I); 3–4 (IV) |
|               | msg   | --           | --          | 2 (I); 10–12 (IX) |
|               | bsg   | --           | --          | 9 (IX); >10 (IX type 1); >10 (IX type 2); 16–18 (X type 3); 2–3 (XI) |
| **Second antennae** | fl    | --           | --          | 133–176 (I); 37–47 (IX) |
|               | dsg   | --           | --          | 9 (I); 8–9 (IX) |
|               | bsg   | --           | --          | 8 (IX) |
|               | exp   | --           | --          | -- |
| **Mandible** | dsg   | --           | 23–26 (VII) | 37–42 (VII) |
|               | msg   | --           | 1 (IX)     | 3 (I); 7 (IX) |
| **First maxillae** | cxp   | 13–15 (VII); 0–1 (XII) | 20–24 (VII); 3 (IX); 1 (X type 1); 0–1 (XII) |
|               | bsp   | 12–15 (II); 8–10 (VII); 2–4 (XII) | 15–18 (II); 11–13 (VII); 3 (XII); 6–7 (XII) |
|               | en    | 3–4 (IX); 1 (X type 1) | 5–7 (IX); 2 (X type 1) |
| **Second maxillae** | exp   | 1–1 (I); >3 (IV) | 1–2 (I); >4 (IV); 16–18 (VII); 4 (X type 3); 4–5 (X type 3) |
|               | bsp   | 66–41 (I); 1 (X type 3) | 62–72 (I); 1 (X type 3); 4 (XII) |
|               | en    | 5 (IX) | 14–17 (XII) |
|               | exp   | 3 (III); >4 (IV); 50–55 (IX) | 4 (III); >7 (IV); 110–112 (IX); 1–2 (XII); 1 (XII) |
| **First maxilliped** | cxp   | 6–10 (IX) | 10–16 (IX) |
|               | bsp   | 18–22 (I); 7–8 (IX); 4–6 (XII) | 50 (I); 16–18 (IX); 12–14 (XII) |
|               | en    | 0–1 (IX) | 8 (IX) |
|               | exp   | 10–11 (IX) | 19–24 (IX); 45–51 (IX) |
| **Second maxilliped** | p     | 6–8 (I); 2 (X type 1) | 14–16 (I); 3 (X type 1) |
|               | c     | --           | 1 (I)     |
|               | m     | 10 (I); 3 (X type 1) | 17–20 (I); 6 (X type 1) |
|               | i     | 5–7 (I) | 7–9 (I); 3–5 (XII) |
|               | pt    | 5–7 (XII) | 8–9 (XII) |
|               | exo   | 1 (IX) | 10 (IX) |
|               | fl    | --           | 10 (VIII) |
| **Third maxilliped** | d     | 2 (I); 2–3 (X type 2) | 8–9 (I); 4–5 (X type 2) |
|               | p     | 2 (I); 12 (X type 1) | 10–12 (I); 16 (X type 1) |
|               | c     | 1–2 (I); 15 (X type 2) | 6 (I); 16 (X type 1); 6–8 (X type 2) |
|               | m     | 4 (I); 1 (X type 1); 7–9 (X type 2) | 9–11 (I); 3 (X type 1); 21 (X type 2) |
|               | i     | 4–6 (I); 3 (IX); 8–10 (XII) | 17 (I); 8 (IX); 12–15 (XII) |
|               | pt    | 3 (IX); 5–7 (XII) | 2 (I); 2–3 (IX); 8–9 (XII) |
|               | exp   | 2–3 (IX) | 5–8 (IX) |
|               | fl    | --           | 8–10 (VIII) |
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| Appendage   | Seg\(^a\) | Juvenile I\(^b\) | Juvenile II | Juvenile III |
|-------------|-----------|-----------------|-------------|--------------|
| Fourth      | d         | –               | –           | 13–17 (I); 11 (VI); 3–5 (IX) |
| pereiopod   | p         | –               | –           | 27–30 (I); 14–16 (IX); 15–20 (X type 1); 3 (X type 2) |
|             | c         | –               | –           | 9–13 (I); 4–6 (IX) |
|             | m         | –               | –           | 25 (I); 5–7 (IX) |
|             | i         | –               | –           | 12–14 (I); 3–5 (IX) |
|             | pt        | –               | –           | 4–6 (I); 1–4 (IX) |
| Fifth       | d         | –               | –           | 7–8 (I); 11 (VI); 2–3 (IX) |
| pereiopod   | p         | –               | –           | 18–20 (I); 17–20 (IX); 24–30 (X type 1); 6–8 (X type 2) |
|             | c         | –               | –           | 10–13 (I); 6–8 (IX) |
|             | m         | –               | –           | 16–20 (I); 2 (IX) |
|             | i         | –               | –           | 8–10 (I); 1–2 (IX) |
|             | pt        | –               | –           | 2–4 (I); 2–4 (IX) |
| Telson      | –         | –               | –           | >17 (I); 23–28 (VIII); >10 (IX) |
| Uropods     | end       | absent          | absent      | >10 (I); 26–28 (VIII); >10 (IX) |
|             | exp       | absent          | absent      | >13 (I); 40–50 (VIII); >10 (IX) |

\(^a\)Segments of the appendices: bsg, basal segment; bsp, basipodite; c, carpodite; exp, coxopodite; d, dactylopodite; de, distal endite; dsg, distal segment; end, endopodite; exp, exopodite; exf, external flagellum; fl, flagellum; inf, internal flagellum; i, ischiopodite; m, meropodite; msg, median segment; p, propodite; pt, protopodite; pe, proximal endite. \(^b\)Setae: I, simple setae; II, cuspidate setae; III, conate setae; IV, hamate setae; V, aesthetascs setae; VI, tooth setae; VII, teazel setae; VIII, plumose setae; IX, pappose setae; X, serrate setae; XI, multiserrate setae; XII, plumodenticulate setae.
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