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MISIDENTIFICATION OF MYSIS STAGES OF *XIPHOPENAEUS KROYERI* (HELLER, 1862) AND *RIMAPENAEUS* PÉREZ-FARFANTE AND KENSLEY, 1997 (DECAPODA: PENAEIDAE) IN THE WESTERN ATLANTIC

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ABSTRACT

Studies in the western Atlantic have relied primarily on the key of Cook (1966) to identify and discriminate early life stages (ELS) of *Xiphopenaeus kroyeri* (Heller, 1862) and *Rimapenaeus* spp. Pérez-Farfante and Kensley, 1997, even though larvae had not been reared successfully past the zoea phase at that time. We surveyed the penaeid literature for descriptions of reared mysis stages of *X. kroyeri* and *Rimapenaeus*, compared characters with those of Cook (1966), and found that Cook had reversed illustrations and criteria to discriminate taxa. We also examined plankton-collected mysis stages and identified new characters and previously unrecognized differences between taxa. Mysis stages of *X. kroyeri* have a slender median spine laterally near the posterior margin of pleomere five, not those of *Rimapenaeus*, although some early first myses of *Rimapenaeus* may have a vestigial spine laterally on pleomere five. *Rimapenaeus* has single dorsomedian spines on pleomeres four through six with the spine on pleomeres five and six >40% (usually about 50%) of fifth pleomere length as measured along the dorsal midline. *Rimapenaeus* lacks a pterygiostomial spine, although a spine on the distal margin of the developing antennal peduncle near the ventrolateral border of the carapace can be confused with a pterygiostomial spine. *Xiphopenaeus kroyeri* has a pterygiostomial spine and single dorsomedian spines on pleomeres four through six with the spine on pleomeres five and six <35% (usually about 25%) of fifth pleomere length. *Xiphopenaeus kroyeri* also has a gap about the width of one spine between the longest and adjacent outer pairs of furcal spines along the posterior margin of the telson, whereas *Rimapenaeus* has contiguous furcal spines. Differences in spine length dorsally on pleomeres five and six, and the presence or absence of a pterygiostomial spine should be used to discriminate taxa because the low hepatic spine and median spine laterally on pleomere five can be difficult to detect in *X. kroyeri*, even with a biological stain applied. Likely misidentification of mysis stages and possible overexploitation of *X. kroyeri* and *Rimapenaeus* spp. stocks in the western Atlantic emphasizes the need to re-assess information on ELS and the necessity of accurate identifications.

KEY WORDS: discrimination, dorsomedian carina, Penaeidae, *Rimapenaeus*, *Trachypenaeus*, *Trachysalambria*, vestigial characters, *Xiphopenaeus*

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INTRODUCTION

The multi-species shrimp fishery of the western Atlantic primarily targets larger, commercially important penaeids in the genus *Farfantepenaeus* Burukovsky, 1997, and *Litopenaeus* Pérez-Farfante, 1969. Secondary species, like seabob, *Xiphopenaeus kroyeri* (Heller, 1862); roughneck shrimp, *Rimapenaeus* (formerly *Trachypenaeus*) *constrictus* (Stimpson, 1874); and roughback shrimp, *Rimapenaeus* (formerly *Trachypenaeus*) *similis* (Smith, 1885), are smaller and less abundant, but ecologically important members of coastal and shelf communities (Bauer and Lin, 1994). We follow the taxonomy of Pérez-Farfante and Kensley (1997) and McLaughlin et al. (2005) despite ongoing debate about the generic or sub-generic classification of some members of Penaeidae.

Xiphopenaeus kroyeri, *R. constrictus*, and *R. similis* are widely distributed throughout the western Atlantic. *Xiphopenaeus kroyeri* occurs from North Carolina to southern Brazil and supports a small commercial fishery in the northern Gulf of Mexico (Fig. 1), but it is heavily fished from Guyana through southern Brazil and is currently considered overexploited (Castro et al., 2005; Gusmao et al., 2006; de Francisco et al., 2008). A cryptic species of *Xiphopenaeus* Smith, 1869, occurs off Central and South America (Gusmao et al., 2006), but only *X. kroyeri* is currently recognized (McLaughlin et al., 2005). *Rimapenaeus constrictus* occurs from Nova Scotia through the Gulf of Mexico to southern Brazil, and *R. similis* from the northern Gulf to southern Brazil (Pérez-Farfante and Kensley, 1997). These two species of *Rimapenaeus* support a small fishery in the northern Gulf (Fig. 1), but are generally ignored elsewhere due to their small body size (Bauer and Lin, 1994; Castrejon et al., 2005). Continued exploitation of *R. constrictus* as by-catch in commercial fisheries, however, has significantly reduced stock size off Brazil (de Francisco et al., 2008).

Maintaining sustainable populations of *X. kroyeri* and *Rimapenaeus* spp. in the western Atlantic requires an understanding of larval biology (Anger, 2006) and information on how early life stages (ELS) respond to changes in structure and function of coastal ecosystems because populations depend on the annual supply of new recruits for stock

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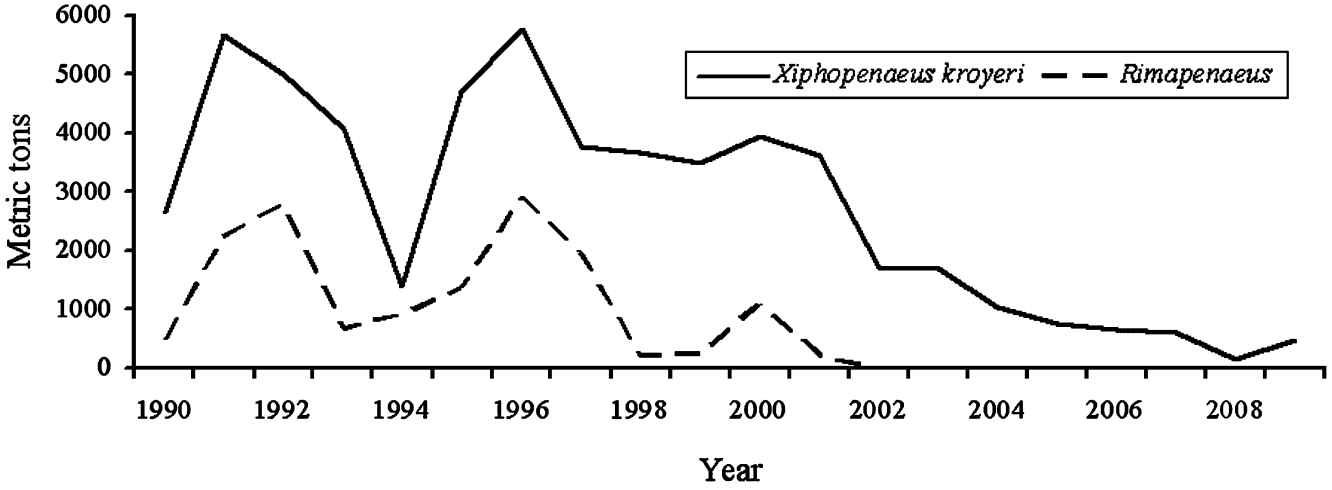

Fig. 1. Commercial landings of *Xiphopenaeus kroyeri* and *Rimapenaeus* along the Atlantic and Gulf coasts of the United States (source: NOAA, 2010).

replenishment. Fishery managers routinely use information on ELS to establish patterns of spawning and recruitment, distribution and abundance, and environmental and habitat preferences. Acquisition of reliable early life history information for stock assessment purposes, however, requires accurate identification and staging of targeted taxa because each stage has specific adaptations to the pelagic environment, and environmental fluctuations and perturbations may affect the behavior, dispersal, recruitment, and population dynamics of ELS differently (Anger, 2006).

Studies in the western Atlantic have relied primarily on the key of Cook (1966) to identify and discriminate ELS of *X. kroyeri* and species of *Rimapenaeus*. When Cook (1966) prepared his key, however, *X. kroyeri* had been reared successfully only to the first zoea (Renfro and Cook, 1963). Larvae of *Rimapenaeus* were partially described from plankton collections as *T. constrictus* (Pearson, 1939), but had not been reared. We surveyed the penaeid literature for descriptions of reared *X. kroyeri* and *Rimapenaeus*, and examined plankton-collected mysis stages to evaluate criteria Cook (1966) used to discriminate taxa. Our objectives were to: determine the likely number of mysis stages for *X. kroyeri* and *Rimapenaeus*; evaluate criteria Cook used to discriminate taxa and identify new characters, if possible; and, compare mysis stages of *X. kroyeri* and *Rimapenaeus* with those of related taxa from the Indo-West Pacific.

Materials and Methods

Use of subjective criteria to determine stage of development made comparisons within and across taxa difficult. We adopted the staging criteria and terminology of Dall et al. (1990a) to 'standardize' descriptions and illustrations of mysis stages in order to compare and evaluate characters to discriminate taxa. We defined stages as follows:

First mysis: carapace covers or nearly covers thorax; exopod of second antennae flattened to become antennal scale and with spine; pereopods biramous and segmented with or without rudimentary chela on first-three; pleopod buds absent or rudimentary.

Second mysis: chela on first-three pereopods distinct, but small; pleopod buds obvious, or pleopods biramous and segmented, but non-setose.

Third mysis: pleopods lightly to moderately setose, but propulsion remains thoracic.

A short, transitional 'megalopa' phase (Williamson, 1969; Kurata, 1970), also referred to as a postlarva (Gurney, 1942) or decapodid (first postlarva only; Felder et al., 1985), begins when the mode of propulsion changes from thoracic to pleopodal, and chela on the first-three pereopods become functional (Dall et al., 1990a).

We modified illustrations of *X. kroyeri* and *Rimapenaeus* from Kurata (1970) based on a consensus of characters compiled from the literature (Tables 1-2) and observations we made on plankton-collected mysis stages. Differences between taxa discussed here should be considered 'generic' because León Otero (1982) and Torres Virviescas et al. (1982) used adult *Xiphopenaeus* from waters where a cryptic species can occur as spawning stock for rearing studies. In addition, ELS described as *R. constrictus* by Pearson (1939) and Kurata (1970) were plankton-collected; therefore, species assignment is problematic. We photographed or illustrated other important characters to emphasize differences among stages and taxa. Mysis stages we examined were collected with a 0.5-m ring net (0.500-mm mesh) in a tidal pass into Galveston Bay, Texas and preserved in 70% non-denatured ETOH or 10% formalin.

Results and Discussion

Xiphopenaeus kroyeri and *Rimapenaeus* spp. likely have three mysis stages (Tables 1-2; Figs. 2-3). Kurata (1970) described several 'later zoea', i.e., mysis stages, and megalopa of *X. kroyeri*, and noted that the megalopa appears more larval than 'postlarval'. Based on criteria we applied and light to moderate pleopod setation, Kurata's (1970) megalopa is the third mysis stage of *X. kroyeri*. León Otero (1982) and Torres Virviescas et al. (1982) described three mysis stages for *X. kroyeri*, but illustrations and associated text depict only the first and second mysis stage based on our criteria (Tables 1-2). Actual number of stages can be dif-

Table 1. Characteristics of the first mysis stage of *Xiphopenaeus kroyeri* (Heller, 1862) and *Rimapenaeus* Pérez-Farfante and Kensley, 1997 from the western Atlantic, and *Trachysalambria fulva* (Dall, 1957) and *Trachysalambria curvirostris* (Stimpson, 1860) from the Indo-West Pacific. We adopted the staging criteria of Dall et al. (1990a) to 'standardize' descriptions and illustrations across taxa. All larvae were lab-reared, unless otherwise indicated under 'Comments'. NI indicates no information. [1]Absent or vestigial in some on third pleomere; [2]Character uncertain due to poor quality of illustrations; [3]Illustrated, but not mentioned in text; [4]Assumes all first myses possess or lack same characters with no variability; [5]Mysis stages originally described as *Trachypenaeus constrictus* (Stimpson, 1874), but species assignment is tentative; [6]Referred to only as a 'suborbital' spine in text; [7]Illustration of mysis designated as stage 5 is inconsistent with others and should not have a pterygiostomial spine; [8]Absent or vestigial; [9]Vestigial in some.

Taxon and reference	Dorsal rostral teeth	Spines on carapace				Pleomere with median spine dorsally			
		Supraorbital	Antennal	Pterygiostomial	Hepatic	1-3	4	5	6
Xiphopenaeus kroyeri									
Kurata (1970)	1-2	Yes	Yes	Yes	No	Some[1]	Yes	Yes	Yes
León Otero (1982)	1-2	Yes	Yes	Yes	No	Some[1]	Yes	Yes	Yes
Torres Virviescas et al. (1982)	1-2	Yes	Yes	Yes[3]	Yes	Some[1]	Yes	Yes	Yes
Cook (1966)[4]	NI	Yes	NI	NI	No	No	Yes	Yes	NI
Rimapenaeus[5]									
Pearson (1939)	1	Yes	Yes[6]	No	No	No	Yes	Yes	Yes
Kurata (1970)	1	Yes	Yes	No[7]	No	No	Yes	Yes	Yes
Trachysalambria fulva									
Chong (1991)	0-1	No	Yes	Yes	No	No	No	Yes	Yes
Trachysalambria curvirostris									
Ronquillo and Saisho (1995)	0-1	Yes	Yes	Yes	No	No	Yes[9]	Yes	Yes

Pleomere with median spine laterally				Applicable illustrations	Comments
1-3	4	5	6		
Xiphopenaeus kroyeri					
No	No	Yes	No	Stages 5-6 (Plate 12, Figs. B-C, E-F, H-I)	Illustrates hump along dorsal midline of carapace, but only mentions character as present in early zoea.
No	No	Yes	No[2]	Plates 8-9	Does not illustrate or discuss hump along dorsal midline of carapace.
No	No	Yes	No[2]	Fig. 9	Does not illustrate or discuss hump along dorsal midline of carapace.
NI	NI	No	NI		Mysis stages plankton-collected. Note that characters are consistent with first mysis of *Rimapenaeus* described below.
Rimapenaeus[5]					
No	No	No	No	Fig. 43	Mysis stages plankton-collected; three reared to 15 mm TL to 'confirm' identity.
No	No	Some[8]	No	Stages 5-6 (Plate 18, Figs. B, D, F; Plate 19, Figs. A, E)	Mysis stages plankton-collected. Illustrates, but does not mention hump along dorsal midline of carapace.
Trachysalambria fulva					
No	No	No	No	Figs. 7A-C and 8-10 are first mysis, not first, second and third mysis stages as labeled.	Illustrates, but does not mention hump along dorsal midline of carapace; rostrum shorter than in *T. curvirostris* of comparable stage.
Trachysalambria curvirostris					
No	No	No	No	Figs. 9A and C: Lacks spine on antennal scale, but possesses most other characteristics of first mysis stage.	Does not illustrate or mention hump along dorsal midline of carapace.

ficult to determine due to developmental plasticity in timing of ecdysis and duration of successive molts, intramolt growth of appendage buds, and because some taxa can skip a stage, especially during the first-two molts (Dall et al., 1990b; Anger, 2006). Number of stages can also vary seasonally based on feeding history and environmental conditions (Williamson, 1982) and between plankton-collected and reared larvae (Dall et al., 1990b) due to unrecognized developmental artifacts induced by rearing (Anger, 2006).

Comparison of our findings with those of Cook (1966) revealed that he reversed illustrations and criteria to discriminate taxa (Table 1). Couplet 4(3) in Cook (1966) should read:

Median spine laterally along posterior margin of fifth pleomere . . . . . *Xiphopenaeus*

Median spine laterally along posterior margin of fifth pleomere absent or vestigial . . . . . *Rimapenaeus*

Table 2. Characteristics of the second and third mysis stages of *Xiphopenaeus kroyeri* (Heller, 1862) and *Rimapenaeus* Pérez-Farfante and Kensley, 1997, from the western Atlantic, and *Trachysalambria fulva* (Dall, 1957) and *Trachysalambria curvirostris* (Stimpson, 1860) from the Indo-West Pacific. We adopted the staging criteria of Dall et al. (1990a) to 'standardize' descriptions and illustrations across taxa. NI indicates no information. All mysis stages were lab-reared, unless otherwise indicated under 'Comments'. [1]Counts include epigastric tooth; [2]After stage reassignment, hepatic spine appears in third mysis stage; [3]Short to vestigial; [4]After stage reassignment, supraorbital spine supposedly disappears in late second or early third mysis stage; [5]Absent or vestigial in some on third pleomere; [6]Character uncertain due to poor quality of illustrations; [7]Pterygiostomial spine illustrated, but not mentioned in text; [8]After stage reassignment, spine vestigial or absent on fourth pleomere in second mysis stage; [9]Character uncertain because text and figure title disagree as to location of bifurcate spine; [10]Mysis stages originally described as *Trachypenaeus constrictus* (Stimpson, 1874), but species assignment is tentative; [11]Second stage myses that we examined had supraorbital spine; [12]Spine illustrated, but never mentioned in text; [13]Not in second or third stage myses we examined, but acute terminal margin of sixth somite in Pearson's illustration of a second stage mysis may look like a median spine.

Taxon and reference	Dorsal rostral teeth[1]	Spines on carapace				Pleomere with median spine dorsally				Pleomere with median spine laterally				Applicable illustrations	Comments
		Supraorbital	Antennal	Pterygiostomial	Hepatic	1-3	4	5	6	1-3	4	5	6		
Xiphopenaeus kroyeri															
Kurata (1970)	3-4	Yes	Yes	Yes	Yes[2]	No	Yes[3]	Yes	Yes	No	No	Yes	No	Stage 7 (Plate 13, Figs. A and D depict a second mysis); Stages 8-9 (Plate 13: Figs. B-C and E-F depict an early third mysis); megalopa (Plate 15: Figs. A and E depict a third mysis based on moderately setose pleopods).	Author notes dorsal ridge along pleomeres 4-6 in third mysis stage and later.
León Otero (1982)	4	Yes[4]	Yes	Yes	Yes	Some[5]	Yes[3]	Yes	Yes	No	No	Yes	No[6]	Plates 10-11; Plates 12-13 depict a second mysis, not third mysis.	Spinules on carapace in third mysis stage and later.
Torres Virviescas et al. (1982)	3-4	Yes	Yes	Yes[7]	Yes	No	Some[8]	Yes[9]	Yes[9]	No	No	Yes	No[6]	Figs. 10-11 depict a second mysis, not a second and third mysis.	Spinules on carapace in third mysis stage and later.
Rimapenaeus[10]															
Pearson (1939)	3	No[11]	Yes[12]	No	No	No	Yes	Yes	Yes	No	No	No	No[13]	Fig. 44	Mysis stages plankton-collected.
Kurata (1970)	3	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	No	No	Stage 7 (Plate 19, Figs. B and F depict a second mysis); Stage 8 (Plate 19, Figs. C and G depict a third mysis).	Mysis stages plankton-collected.
Trachysalambria fulva															
Chong (1991)	2-3	No	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	Figs. 7D and 11 depict a second mysis, not fourth mysis; Fig. 12 depict a third mysis, not first postlarva.	
Trachysalambria curvirostris															
Ronquillo and Saisho (1995)	2-4	Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	Figs. 10-11; Fig. 12 depict a third mysis, not first postlarva based on lightly to moderately setose pleopods.	

Cook (1966) included a purported difference in rostrum to eye length as a supplemental character to discriminate taxa. The rostrum to eye relationship, however, can depend on eye orientation and preservation history (Dall et al., 1990b). Penaeids normally hold the eyes at about 70° to the median axis and any alteration in orientation or eye shrinkage during preservation can affect the rostrum to eye relationship (Dall et al., 1990b) and result in misidentification. Accordingly, placement of the rostrum tip relative to the distal margin of the first antennular peduncle segment, which provides a socket for the eye, provides a better estimate of rostrum length.

Cook's (1966) error requires corrections to his figures and tables, and to the work of other authors who relied on the key of Cook to identify and discriminate taxa (Subrahmanyam, 1971a; Boschi, 1981). Figure 6e in Cook (1966) should be *Xiphopenaeus*, and figure 6f should be *Rimapenaeus*. Likewise, the character entitled 'posteriolateral spines of abdomen' under the 'mysis' sub-heading of the 'Stage and Structure' column of Cook's Table 1 should be reversed for *Xiphopenaeus* and *Rimapenaeus*. Figure 11 and the associated description in Subrahmanyam (1971a) depict *X. kroyeri* and not *Rimapenaeus*, while figure 241-15 and the associated description in Boschi (1981) depict *Rimapenaeus* and not *X. kroyeri*.

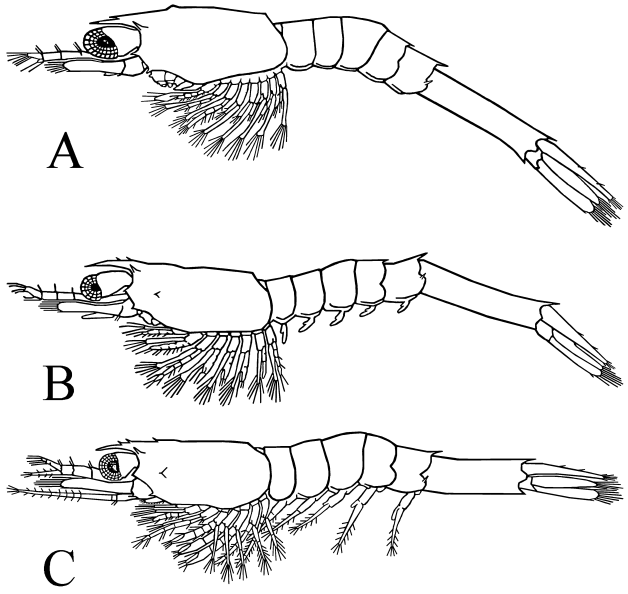

Fig. 2. Mysis stages of *Xiphopenaeus kroyeri*. Images were modified from Kurata (1970) to reflect a consensus of characters and our observations. A, first mysis; B, second mysis; C, third mysis (setae removed from along dorsal margin of pleomeres 5 and 6).

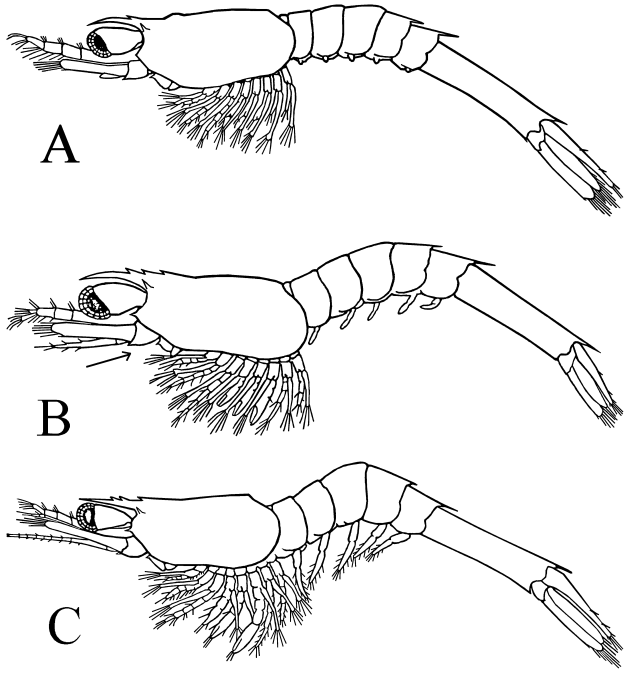

Fig. 3. Mysis stages of *Rimapenaeus*. Images were modified from Kurata (1970) to reflect a consensus of characters and our observations. A, first mysis; B, second mysis; C, third mysis. Arrow indicates location of spine anterior to ventrolateral border of carapace that can be confused with a pterygiostomial spine.

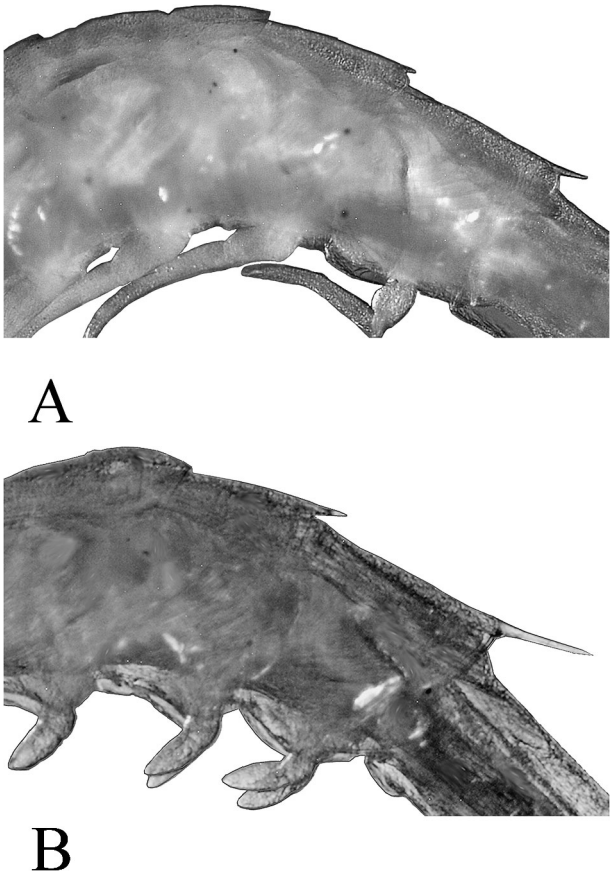

Fig. 4. Dorsomedian carina along pleomeres four and five. Dorsomedian carina begins as a low, thickened ridge midway along pleomere four in *X. kroyeri* and continues along pleomeres five and six. *Rimapenaeus* has a higher dorsomedian carina along pleomeres four through six, which is most pronounced along pleomere five. A, third mysis stage of *X. kroyeri*; B, second mysis stage of *Rimapenaeus*. The illusion of having a 'distinct' ridge in *X. kroyeri* is an artifact created by the separation of body musculature from abdominal terga. Note comparative length of dorsomedian spine on pleomeres four and five in each taxon.

Descriptions of reared *X. kroyeri* and observations we made on plankton-collected mysis stages of *X. kroyeri* and *Rimapenaeus* spp. revealed new information and previously unrecognized differences between taxa (Tables 1 and 2; Figs. 2 and 3). *Rimapenaeus* has single dorsomedian spines on pleomeres four through six with the spine on pleomeres five and six >40% (usually about 50%) of fifth pleomere length as measured along the dorsal midline. *Rimapenaeus* lacks a pterygiostomial spine, although a spine on the distal margin of the developing antennal peduncle near the ventrolateral margin of the carapace can be confused with a pterygiostomial spine (Fig. 3b). *Rimapenaeus* also has a dorsomedian carina along pleomeres four through six, which is most noticeable along pleomere five (Fig. 4). *Xiphopenaeus kroyeri* has single dorsomedian spines on pleomeres four through six with the spine on pleomeres five and six <35% (usually about 25%) of fifth pleomere length. *Xiphopenaeus kroyeri* also has a pterygiostomial spine and a slender mediolateral spine near the posterior margin of pleomere five (Fig. 2). In addition, mysis stages of *X. kroyeri* have a gap about the width of one spine between the longest and adjacent outer pair of furcal spines, whereas *Rimapenaeus* has contiguous spines (Fig. 5). *Xiphopenaeus kroyeri* has a low dorsomedian carina that begins as a thickened ridge midway along pleomere four and continues along pleomeres five and six, but is most conspicuous along pleomere five (Fig. 4). Kurata (1970) noted a dorsomedian carina in the late third mysis stage and megalopa of *X. kroyeri*, but not in *Rimapenaeus*. Torres Virviescas et al.

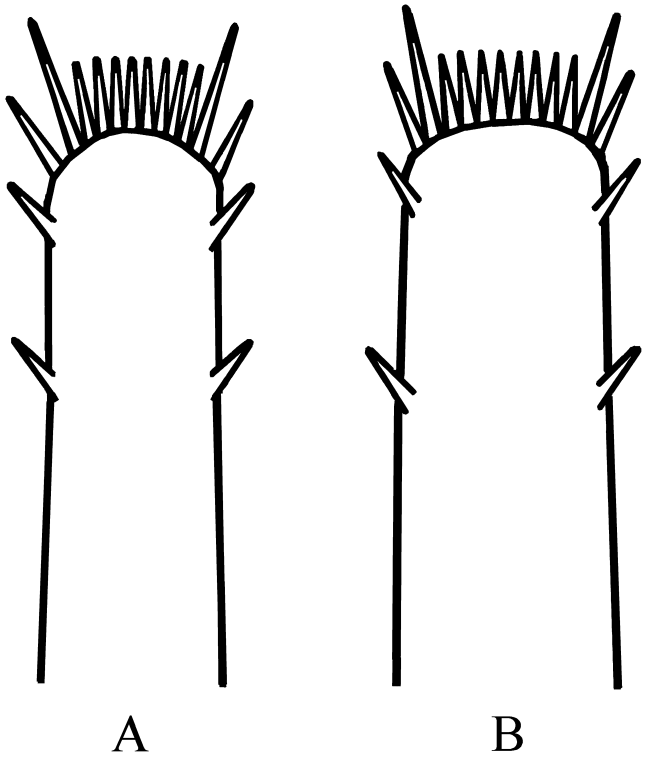

Fig. 5. Furcal spine placement along posterior margin of telson in mysis stages. A, *X. kroyeri*; B, *Rimapenaeus*.

(1982) reported that the second mysis stage of *X. kroyeri* has a bifurcate median spine dorsally near the terminal margin of pleomere six, but their figure 11 and associated caption places the spine on pleomere five. This discrepancy in spine placement and the fact that the second mysis stage of plankton-collected *X. kroyeri* we examined had a single, non-bifurcate median spine dorsally on pleomeres five and six makes this character problematic for discrimination purposes.

Vestigial characters, particularly in the first mysis stage, can complicate discrimination, especially when used in a dichotomous key. Keys require discrete criteria to reliably discriminate taxa and presume that all mysis stages possess the same characters, which they may not. For example, Calazans (1993) key to ELS of fifteen penaeid genera along southern Brazil discriminates mysis stages of *X. kroyeri* and *Rimapenaeus* by the presence of a dorsomedian spine on the third pleomere and hump-like structure or 'tubercle' along the carapace dorsal midline in *X. kroyeri*. While some *X. kroyeri* have a short to vestigial dorsomedian spine on the third pleomere in the first mysis stage, others do not, and both *X. kroyeri* and *Rimapenaeus* can have a dorsal hump on the carapace in the first mysis stage (Table 1; Figs. 2a and 3a). Second and third mysis stages of *X. kroyeri* and *Rimapenaeus* lack both characters. Kurata (1970) found that 14% of plankton-collected first myses of *Rimapenaeus* had a vestigial median spine laterally on the fifth pleomere similar to the spine found in *X. kroyeri*. Although Calazans (1993) does not use the presence or absence of a mediolateral spine on the fifth pleomere as a character in his key, illustrations of both taxa have a spine laterally (see figure 4D, E in Calazans, 1993).

Keys constructed from reared larvae of Indo-West Pacific penaeids (Jackson et al., 1989; Dall et al., 1990c) include *Trachypenaeus* Alcock, 1901, but not *X. kroyeri*, which do not occur in the area. After Jackson et al. (1989) and Dall et al. (1990c) prepared their keys to ELS, Pérez-Farfante and Kensley (1997) partitioned the *Trachypenaeus* complex into four genera: *Megokris* Pérez-Farfante and Kensley, 1997; *Rimapenaeus* Pérez-Farfante and Kensley, 1997; *Trachypenaeus*; and, *Trachysalambria* Burkenroad, 1934. Only *Rimapenaeus* occurs in the western Atlantic and eastern Pacific, whereas the remaining genera occur in the Indo-West Pacific. Descriptions of larvae of former members of the *Trachypenaeus* complex, however, have not been updated to reflect changes in nomenclature. Mysis stages described as *Trachypenaeus constrictus* by Pearson (1939) and Kurata (1970) should be *Rimapenaeus*, although the species assignment remains uncertain. Descriptions of *Trachypenaeus fulvus* Dall, 1957, by Chong (1991) should be *Trachysalambria fulva* (Dall, 1957), and those of *Trachypenaeus curvirostris* Stimpson, 1860, by Ronquillo and Saisho (1995) and Abdel Razek and Taha (2006) should be *Trachysalambria curvirostris* (Stimpson, 1860). The sternal spine pattern and antennal scale depicted for *Trachypenaeus* in Jackson et al. (1989: Figs. 15, 16), and sternal spine pattern for *Trachypenaeus granulosus* Haswell, 1879, in Dall et al. (1990c; Fig. 3.22) should be that of *Megokris granulosus* (Haswell, 1879).

Due to Cook's (1966) error, authors have mistakenly compared mysis stages of former members of the *Trachypenaeus* complex to *X. kroyeri* rather than to *Rimapenaeus* as intended. *Trachysalambria curvirostris* and *T. fulva* have a pterygiostomial spine that *Rimapenaeus* lacks, while *T. curvirostris* and *Rimapenaeus* have a supraorbital spine that *T. fulva* lacks (Tables 1 and 2). Mysis stages of *Rimapenaeus* have a dorsomedian spine on the fourth pleomere that *T. fulva* lack, whereas some *T. curvirostris* may have a short to vestigial spine on the fourth pleomere in the first mysis stage, but not thereafter (Tables 1 and 2). We did not include *T. curvirostris* from the Mediterranean reared by Abdel Razek and Taha (2006) in comparisons due to lack of spination normally found in mysis stages (Williamson, 1982), and what may be delayed development.

Paulinose (1982) described plankton-collected mysis stages of what he calls *T. curvirostris* based primarily on adult temporal and spatial distributions, an approach often criticized due to the higher probability for misidentification (Dall et al., 1990c; Calazans, 1993). As described by Paulinose (1982), mysis stages of purported *T. curvirostris* lack a hepatic spine and median spine laterally on the fifth pleomere, but have a short supraorbital spine (first mysis stage only), antennal and pterygiostomial spines, and, a single dorsomedian spine on the fifth and sixth pleomeres. Mysis stages also have a dorsally carinate third pleomere characteristic of adults of some species of *Trachysalambria* and *Metapenaeopsis* Bouvier, 1905 (Dall et al., 1990c). Mysis stages of *Metapenaeopsis*, however, have a serrate anterioventral carapace margin (Jackson et al., 1989; Chong and Sasekumar, 1994; Ronquillo and Saisho, 1997; Choi and Hong, 2001), which those described by Paulinose (1982) do not. While the identity of mysis stages described by Pauli-

Table 3. Comparison of mysis stages of *Xiphopenaeus kroyeri* (Heller, 1862); *Rimapenaeus* Pérez-Farfante and Kensley, 1997; *Farfantepenaeus* Burukovsky, 1997; and *Litopenaeus* Pérez-Farfante, 1969 from the western Atlantic. Characters for *Farfantepenaeus* and *Litopenaeus* are based on the descriptions of Cook and Murphy (1971), Kitani (1985, 1986, 1996), and observations we made.

Taxon	Rostrum[1]	Carapace spines				Pleomere with median spine dorsally			Pleomere with median spine laterally		
		Supraorbital	Antennal	Pterygiostomial	Hepatic	3	4	5-6	1-4	5	6
X. kroyeri	No	Yes	Yes	Yes	Yes[2]	Some[3]	Yes[4]	Yes	No	Yes	No
Rimapenaeus	No	Yes	Yes	No	No	No	Yes[4]	Yes	No	No	No
Farfantepenaeus and *Litopenaeus*	Yes	Yes	No	No[5]	Yes	Yes[6]	Yes[6]	Yes	No	Yes	Yes

[1]Tip exceeds distal margin of first antennular peduncle segment; [2]Low and poorly defined; [3]Absent or vestigial in some first stage myses; [4]Considerably shorter than spine found on pleomeres five and six; [5]Mysis stages have a spine along corner of carapace in 'pterygiostomial region' often referred to as the 'anterioventral' or 'anteriolateral' spine; [6]Distinct and slightly shorter than spine found on pleomeres five and six.

nose (1982) is consistent with a species of *Trachysalambria*, generic assignment remains uncertain because larvae of *Megokris* and the monotypic *Trachypenaeus anchoralis* (Bate, 1881) have not been described.

Several pronounced differences in elevation and length of body spines distinguish mysis stages of *X. kroyeri* and *Rimapenaeus* from those of *Farfantepenaeus* and *Litopenaeus* (Table 3). In *Farfantepenaeus* and *Litopenaeus*, the rostrum tip reaches to or extends beyond the distal margin of the first segment of the antennular peduncle. The long, slender but distinct supraorbital spine curves forward and extends well beyond the anterior margin of the carapace with the tip often above the dorsal margin of the rostrum. Mysis stages also have a slender, distinct hepatic spine about one-third of supraorbital spine length that projects away from the carapace, and single dorsomedian spines on pleomeres three through six with the spine on pleomeres five and six slightly longer than the spine on pleomeres three and four. *Farfantepenaeus* and *Litopenaeus* have single dorsomedian and mediolateral spines on pleomere five of similar length, whereas pleomere six has a longer dorsomedian than mediolateral spine. *Farfantepenaeus* and *Litopenaeus* lack an antennal spine, but have a spine along the anterior margin of the carapace in the 'pterygiostomial' region often referred to as an 'anterioventral' or 'anteriolateral' spine (Cook and Murphy, 1971; Kitani, 1985, 1986, 1996). By comparison, *X. kroyeri* and *Rimapenaeus* have a low, poorly defined hepatic spine, if present; the rostrum does not extend beyond the distal margin of the first segment of the antennular peduncle; and, the supraorbital spine generally extends dorsally to about the lateral midline of the rostrum only. Lab-reared *X. kroyeri* may have a vestigial dorsomedian spine on pleomere three in the first mysis stage, but not thereafter. *Rimapenaeus* has not been reared, but the first mysis stage of the closely related *Trachysalambria* lacks a dorsomedian spine on pleomere three (Table 1). Mysis stages of *X. kroyeri* and *Rimapenaeus* lack a median lateral spine on pleomere six and instead have a rounded lateral margin (Table 3).

Differences in dorsomedian spine length on pleomeres five and six, and presence or absence of a pterygiostomial spine should be used to discriminate *X. kroyeri* and *Rimapenaeus* because the low, poorly defined hepatic and slender mediolateral spine on pleomere five can be difficult to locate in *X. kroyeri* even with a biological stain applied. Differences in size, shape and number of appendage segments; number of setae per segment; and, other characters not reviewed here, including some body spination may also discriminate taxa. However, observations like number of setae per segment often require tedious, time-consuming manipulation and excision of appendages (Rothlisberg et al., 1983), which reduces the time needed to identify the large number of specimens often collected in routine monitoring surveys.

Misidentification of mysis stages of *X. kroyeri* and *Rimapenaeus*, and the existence of a cryptic species of *Xiphopenaeus* in the western Atlantic (Gusmao et al., 2006) have important implications for stock management. Since most studies used the key of Cook (1966) to identify and discriminate ELS, existing information on seasonality, distribution and abundance patterns, and environmental and habitat preferences are likely inaccurate (Temple et al., 1964; Subrahmanyam, 1971b; Bozada and Páez, 1987; Criales and McGowan, 1993; Castro, 1998; López and Garcia, 2001; Fehlauer and Freire, 2002). Uncertain identifications and a cryptic species of *Xiphopenaeus* may also account for the finding that juvenile *X. kroyeri* recruit to estuaries year-round in the western Atlantic (Fransozo et al., 2000; Castro et al., 2005). The fact that *X. kroyeri* and *R. constrictus* are currently considered overfished off Brazil (de Francisco et al., 2008) indicates a need to re-assess stocks because exploitation patterns differ and populations depend on the annual supply of new recruits for replenishment. If populations are recruitment limited, climate and other environmental changes that can affect the survival, dispersal and recruitment pathways of ELS may impact adversely stock dynamics and necessitate different management strategies, which emphasize the need to re-examine the abundance and distribution of ELS and the importance of accurate identifications.

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