Ontogenetic development and redescription of the whale louse Cyamus boopis *Lütken, 1870 (Crustacea: Amphipoda: Cyamidae), ectoparasite of humpback whale* Megaptera novaeangliae *(Mammalia: Cetacea: Balaenopteridae)*

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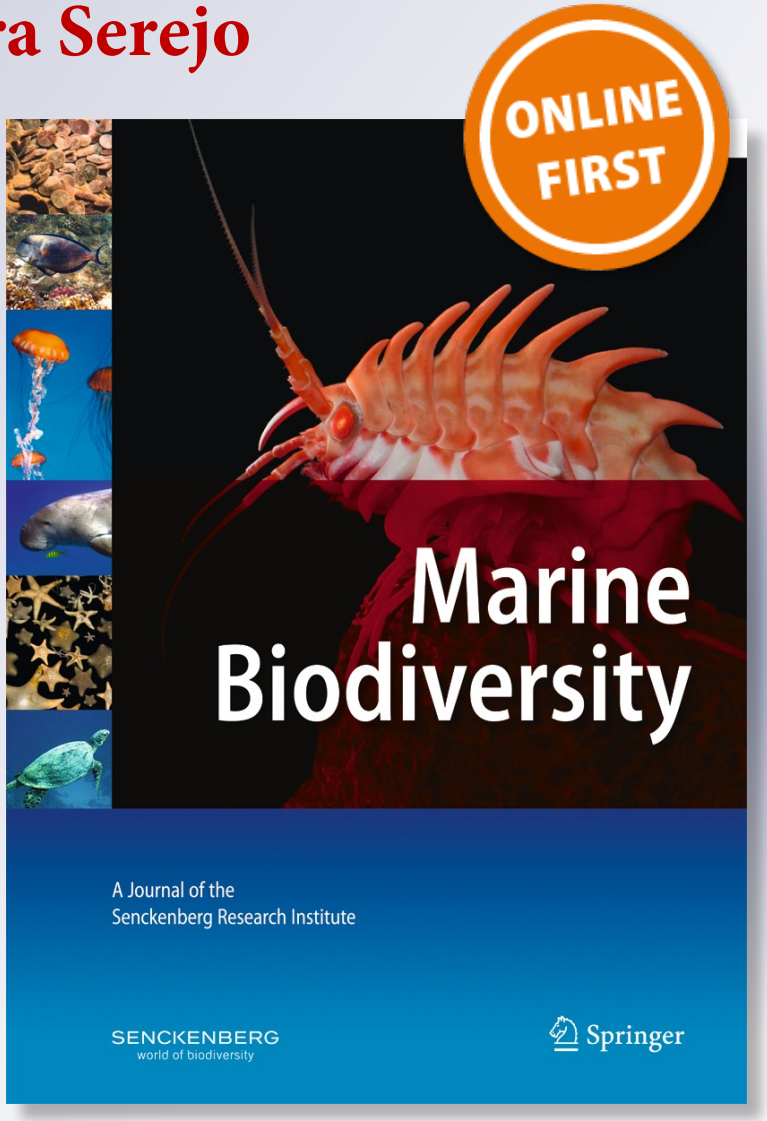

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ORIGINAL PAPER

Ontogenetic development and redescription of the whale louse *Cyamus boopis* Lütken, 1870 (Crustacea: Amphipoda: Cyamidae), ectoparasite of humpback whale *Megaptera novaeangliae* (Mammalia: Cetacea: Balaenopteridae)

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Abstract Crustacean amphipods known as whale louse parasitise cetaceans across the world. Taxonomy of the group is generally based on individuals collected during whaling periods and from fresh stranded cetaceans. The only known parasite of *Megaptera novaeangliae* is *Cyamus boopis.* Specimens collected from humpback whales stranded on the coast of Brazil were counted, measured, and identified by sex. As *C. boopis* show a high variation on some diagnostic characters, a redescription of *C. boopis* is given based on the type series material obtained from the Zoologisk Museum, Copenhagen. A lectotype and four paralectotypes are designated herein. Variation of characters as presence of maxilliped palps and number of acute ventral processes within the Brazilian material is discussed, and should be used with caution for species identification. The proportion of the lateral and accessory gills proved to be good characters to separate *C. boopis* from the similar species *C. catodontis* and *C. erraticus*. Ontogenetic variation of *C. boopis* is described and remarks on population ecology are provided for the Brazilian material.

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Keywords *Megaptera novaeangliae* · *Cyamus boopis* · Cyamidae · Southwestern Atlantic · Redescription · Ontogeny

Introduction

Necropsies of stranded cetaceans usually report ship strikes, anatomic anomalies and diseases, including ectoparasitisms. Among the ectoparasites, crustaceans are the only representatives, including copepods, that parasitise baleen plates and a single amphipod family—Cyamidae, commonly known as whale louse—that can be found in cetaceans of the two superfamilies, Mysticeti (the baleen whales) and Odontoceti (the toothed whales and dolphins) (Lincoln and Hurley 1980; Martin and Heyning 1999; Rohde 2005). Cyamids are considered generalists on odontocetes and host-specific on mysticetes (Leung 1970; Geraci and Aubin 1987; Carvalho et al. 2010). However, some species of mysticetes host more than one species of cyamid parasites (Leung 1967; Rowntree 1983; Kaliszewska et al. 2005).

Records of cyamids collected among cetacean mammals along the coastal waters of Brazil are composed of seven species, as listed in Table 1. The Abrolhos Bank, on the continental shelf off Brazil (Fig. 1), represents the main breeding area for humpback whale *Megaptera novaeangliae* (Borowski, 1781) in the southwestern Atlantic Ocean (Engel 1996; Siciliano 1997; Andriolo et al. 2006). However, this is one of the least studied areas worldwide (Andriolo et al. 2010). Humpback whales are known to host a single species of cyamid: *Cyamus boopis* Lütken, 1870 (Rowntree 1996). Acute ventral processes formulas and maxilliped palp characters are some of the diagnostic features used to identify cyamids (Margolis 1955; Leung 1967). Margolis et al. (2000) used the presence of the maxilliped palp as a

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Table 1 Cyamids found on stranded cetaceans along the Brazilian coast

Species	Host	Reference
Cyamus boopis Lütken, 1870	*Megaptera novaeangliae* (Borowski, 1781) (Humpback whale)	Carvalho et al. 2010
Cyamus erraticus Roussel de Vauzème, 1834	*Eubalaena australis* (Desmoulins, 1822) (Right whale)	Sawaya 1938
Cyamus ovalis Roussel de Vauzème, 1834	*Eubalaena australis* (Desmoulins, 1822) (Right whale)	Sawaya 1938
Cyamus gracilis Roussel de Vauzème, 1834	*Eubalaena australis* (Desmoulins, 1822) (Right whale)	Sawaya 1938
Isocyamus delphinii (Guérin-Méneville, 1836)	*Globicephala macrorhynchus* Gray, 1846 (Pilot whale)	Haney et al. 2004
Syncyamus ilheusensis Haney, De Almeida and Reis, 2004	*Globicephala macrorhynchus* Gray, 1846 (Pilot whale)	Haney, De Almeida and Reis 2004
Syncyamus pseudorcae Bowman, 1955	*Stenella clymene* (Gray, 1850)	Carvalho *et al.* 2010

subgeneric character. Variations in such characters has led to the wrong identification of some juveniles of *C. boopis* as a new species (Hiro 1938; Margolis 1955). Comments on morphology of *Cyamus* juveniles are scarce (Pfeiffer and Viers

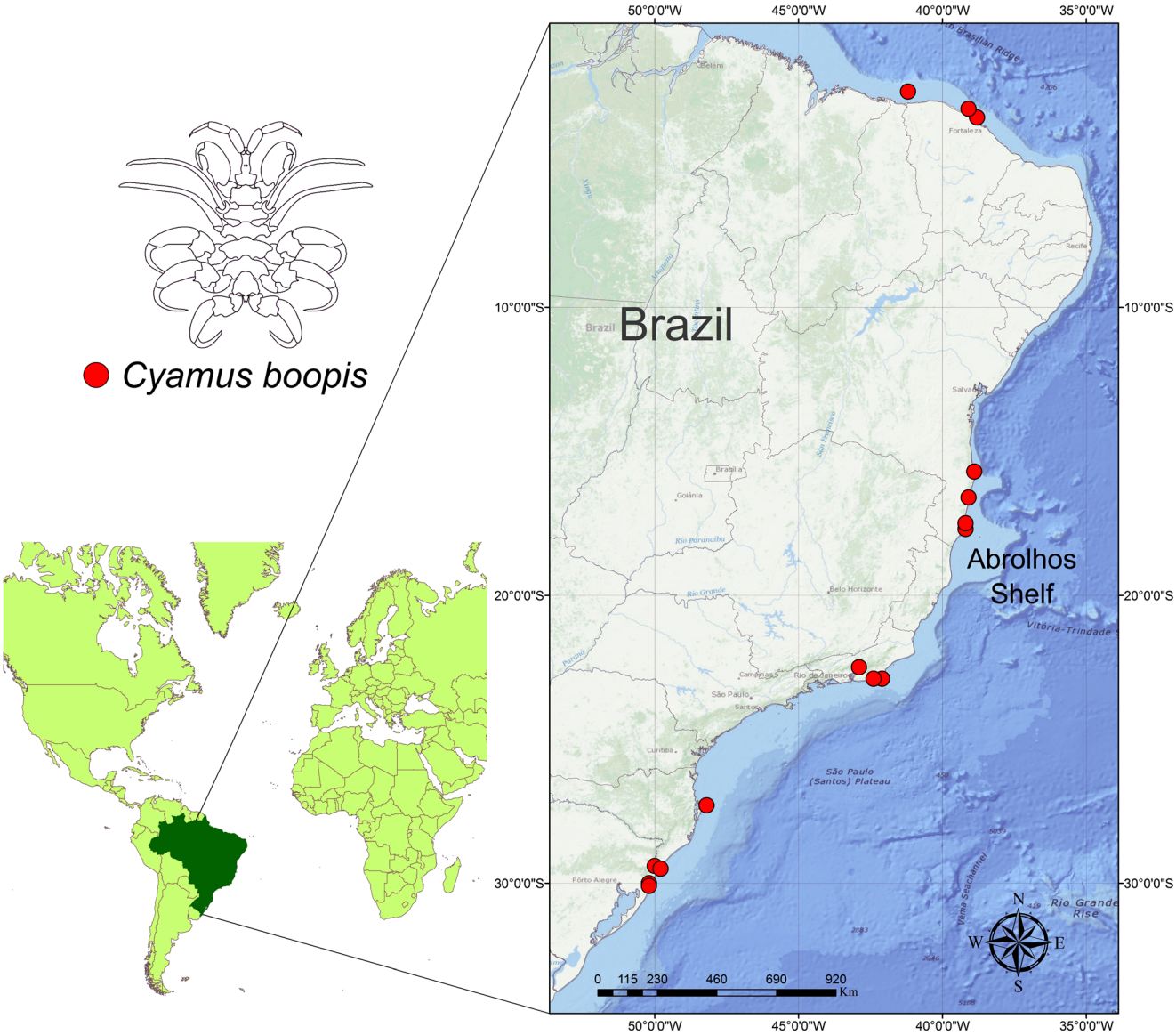

Fig. 1 Cyamid collection sites on humpback whales stranded during 2002 to 2015 along the Brazilian coast. States abbreviation: BA, Bahia; CE, Ceará; RJ, Rio de Janeiro; RS, Rio Grande do Sul and SC, Santa Catarina

1998; De Pina and Giuffra 2003), with a single previous study that described ontogenetic development of *C. scammoni* Dall, 1872 (Leung 1976).

Differences in the acute ventral processes were also observed in two species of Cyamidae from different genera (*Isocyamus deltobranchium* Sedlak-Weinstein, 1992 and *Syncyamus aequus* Lincoln and Hurley, 1981) (Raga 1988; Mariniello et al. 1994; Martínez et al. 2008).

In this study, we redescribe *C. boopis* based on the type material, and describe variation observed from specimens collected along the Brazilian coast and from Australia. Also, in order to better understand growth variations, the ontogenetic development is described for *C. boopis* based on the Brazilian material.

Material and methods

Brazilian cyamids were collected from carcasses of humpback whales stranded from 2002 to 2015 from a vast area of the Brazilian coast (02.5°S to 30.1°S), including the Abrolhos Bank (Fig. 1, Table 2). Material was fixed and preserved in ethanol 70 % and deposited at the Crustacean Collection of the Museu Nacional do Rio de Janeiro (MNRJ). Additionally, the typematerial of *C. boopis*, which is deposited at the Zoologisk Museum, Copenhagen (ZMUC) was examined and a lectotype and four paralectotypes are designated herein.

Specimens were observed, sexed and measured with Zeiss Discovery V12 AxioCam MRc stereomicroscopes. Measurements were made from head to pleon. Juveniles were measured and compared according with morphological variation in growth. Mouthparts were dissected and mounted in glycerol. Drawings were made with a camera lucida at a Zeiss Axioscope stereomicroscope, and digitally drawn with Adobe Illustrator CS6, according to Coleman (2003).

Specimen preparation for scanning electron microscopy (SEM) was made following the protocol adapted from Felgenhauer (1987), dried at critical point, and sputter-coated with gold or gold-palladium. Micrographs were taken with SEM JEOL JSM-6390LV at Laboratório de Microscopia Eletrônica (LCME/UFSC).

Abbreviations used: Pln, pleon; AG, accessory gill; Ant, antenna; Gil, Gill; Gn, gnathopod; LL, lower lip; Md, mandible; Mx, maxilla; Mxp, maxilliped; P, pereopod; Pn, penes; Pl, pleopod; UL, upper lip; l, left; r, right.

Results

Systematics

Infraorder Corophiida Leach, 1814 (sensu Lowry & Myers 2013)

Superfamily Caprelloidea Leach, 1814

Family Cyamidae Rafinesque, 1815

Cyamus boopis Lütken, 1870

Figures 2, 3, 4, 5, 6, 7 and 8

Cyamus boopis Lütken, 1870: 280. — Lütken 1873: 262, fig. 6. — Margolis 1955, 124—127, figs. 7—12. — Leung 1967: 287, figs. 1 and 5b. — Lincoln and Hurley 1974: 66. — Berzin and Vlasova 1982: 160. — Sedlak-Weinstein 1991: 95, figs. 3, 6, 11, 16. — Haney 1999: 92—100, figs. 28—30. — De Pina and Giuffra 2003: 55—59, figs. 90—118.

Table 2 Humpback whale stranding locations, dates and number of cyamids collected. The whale id corresponds to the collection reference number. Stranding location shows municipality and state of stranding

Whale	Stranding location	Lat., Long.	Date	# cyamids collected
IBJ 70	Maragogi, AL	9.0°S, 35.2°W	11-Aug-97	211
IBJ 122	Caravelas, BA	17.7°S, 39.2°W	6-Jun-02	265
IBJ 165	Canavieiras, BA	15.7°S, 38.9°W	30-Jul-04	142
IBJ 226	Trancoso, BA	16.6°S, 39.1°W	18-Aug-06	96
IBJ 364	Alcobaça, BA	17.5°S, 39.2°W	9-Jul-10	49
LCP 7615	Florianópolis, SC	27.3°S, 48.2°W	6-Jul-15	>1000
AQUASIS 198	Fortaleza, CE	03.4°S, 38.8°W	5-Sep-01	2
AQUASIS 349	Barroquinha, CE	02.5°S, 41.2°W	21-Aug-09	3
AQUASIS 594	Trairí, CE	03.1°S, 39.1°W	30-Aug-13	1
GEMARS 1409	Capão da Canoa, RS	29.4°S, 50.0°W	23-Aug-10	179
GEMM 115	Rio das Ostras, RJ	22.5°S, 42.9°W	14-Nov-06	202
GEMARS 1685	Nova Tramandaí, RS	30.0°S, 50.2°W	3-Jul-15	3
GEMARS 1684	Arroio do Sal, RS	29.5°S, 49.8°W	2-Jul-15	80
GEMARS 1683	Cidreira, RS	30.1°S, 50.2°W	11-Jun-15	33
GEMM 211	Arraial do Cabo, RJ	22.9°S, 42.1°W	5-Sep-10	65
GEMM 079	Saquarema, RJ	22.9°S, 42.4°W	16-Feb-05	31

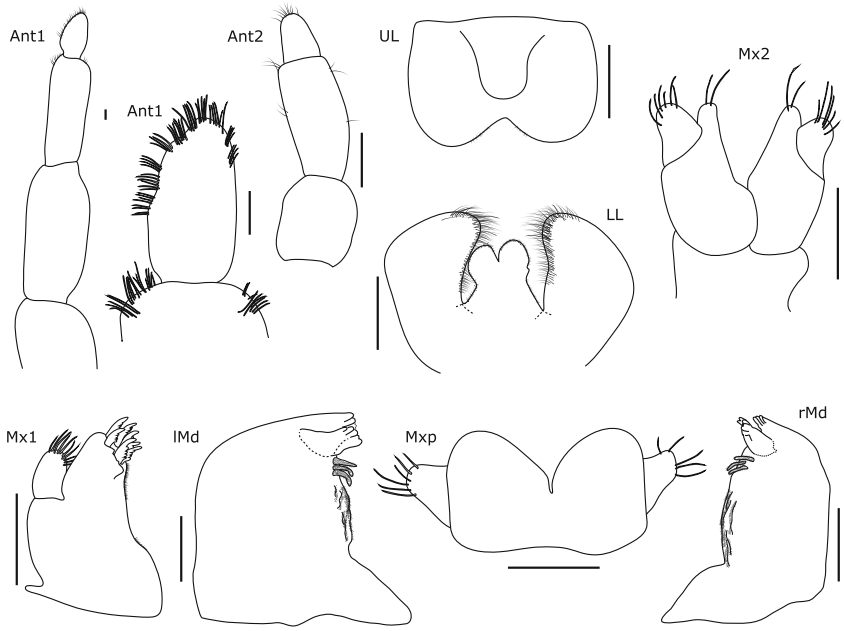

Fig. 2 *Cyamus boopis* Lütken, 1870. Lectotype, male, 9.2 mm, ZMUC CRU-8190. Scale bar: 100 μm

Paracyamus boopis — Sars 1895: 669. — Barnard 1932: 312. — Hurley 1952: 64—68, figs. 1—7. — Margolis 1954: 324.

Cyamus suffusus Dall, 1872: 281—283.

Cyamus pacificus Lütken, 1873: 264, fig. 7.

Cyamus elongatus Hiro, 1938: 71—77.

Cyamus (Paracyamus) boopis — Margolis et al. 2000: 80, figs. 8.

Material examined (host *M. novaeangliae*) Lectotype: One male, 9.2 mm, Iceland, ZMUC CRU-8190. Paralectotypes: four males, 6.3—8.2 mm, Iceland, ZMUC CRU-12. **Other non-type material:** five males, 9.5—12.3 mm, one female, 9.0 mm, Australia, Victoria, Bonbeach, Port Phillip Bay, NMV J20994; 47 males, 3.5—9.3 mm, 55 females (8 ovigerous females), 3.1—7.0 mm, 109 juveniles, 1.3—4.2 mm, Maragogi, Brazil, MNRJ 25979 (IBJ 70); 102 males, 3.3—9.8 mm, 105 females (10 ovigerous), 3.5—7.7 mm, 94 juveniles, 1.5—5.2 mm, Caravelas, Brazil, MNRJ 25980 (IBJ 122); 45 males, 4.2—10.1 mm, 66 females (10 ovigerous), 4.2—8.3 mm, 31 juveniles, 1.7—4.5 mm, Canavieiras, Brazil, MNRJ 25981 (IBJ 165); 51 males, 3.1—10.1 mm,

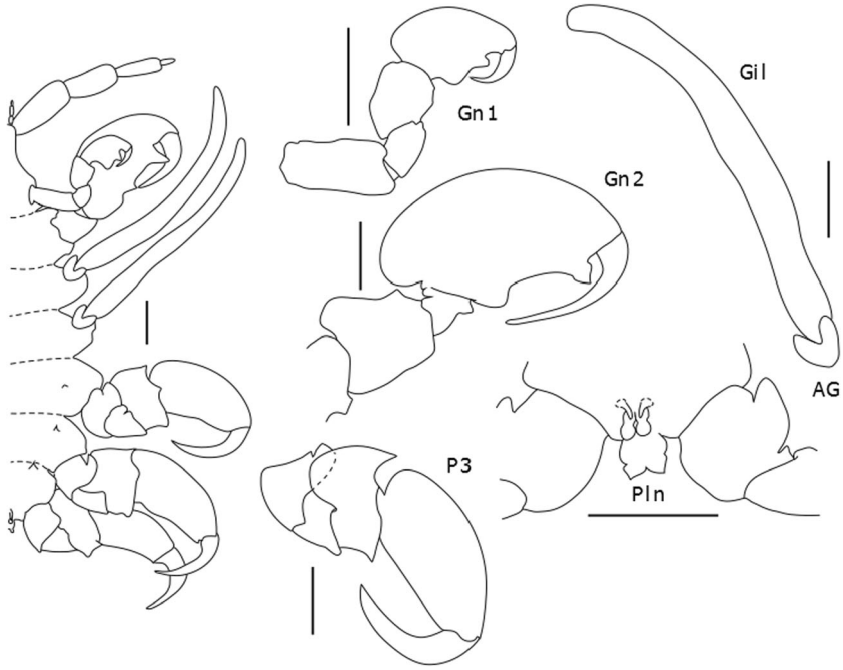

Fig. 3 *Cyamus boopis* Lütken, 1870. Lectotype, male, 9.2 mm, ZMUC CRU-8190. Ventral view. Scale bar: 1 mm

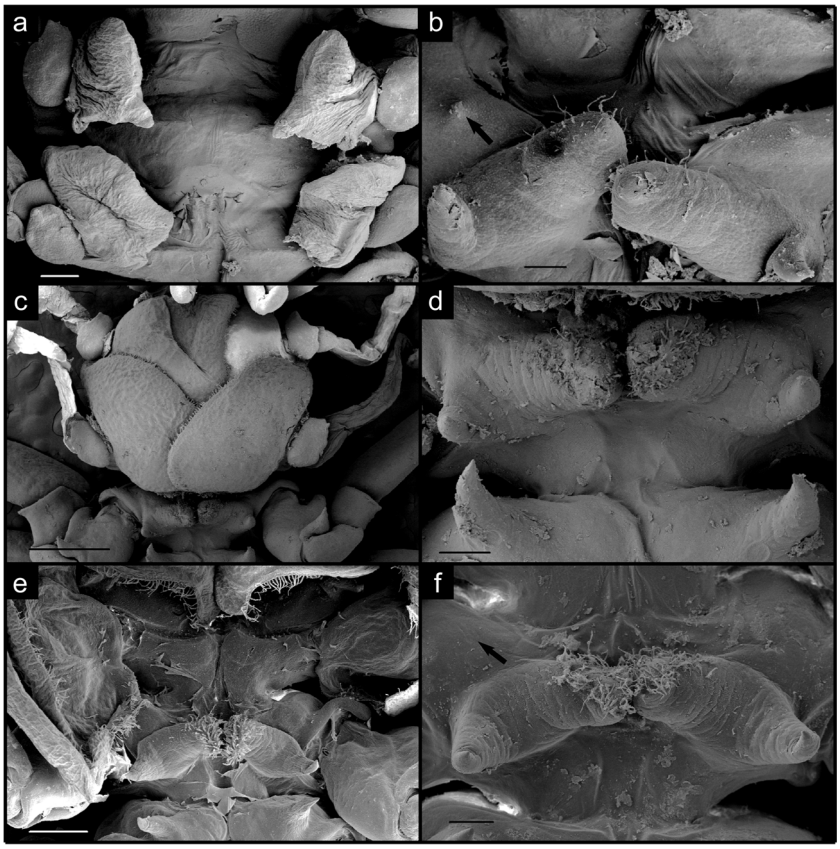

Fig. 4 Oostegite plates development in females of *C. boopis* Lütken, 1870. Females. MNRJ 25981. **a** Subadult female. Scale bar: 200 μm; **b** Acute ventral processes on pereonite 5 of subadult female. Scale bar: 100 μm; **c** Ovigerous female. Scale bar: 1 mm; **d** Acute ventral processes on pereonite 5 of ovigerous female. Scale bar: 200 μm; **e** Ovigerous female with posterior oostegite plates removed. Scale bar: 500 μm; **f** Pereonite 5 of ovigerous female. *Arrow* shows absence of the second pair of acute ventral processes. Scale bar: 200 μm

25 females (3 ovigerous), 4.5—7.0 mm, 20 juveniles, 1.0—3.6 mm, Trancoso, Brazil, MNRJ 25982 (IBJ 226); 19 males, 5.9—10.4 mm, 16 females (0 ovigerous), 5.6—8.0 mm, Praia do Forte, Brazil, MNRJ 25983 (IBJ 227); 12 males, 5.5—

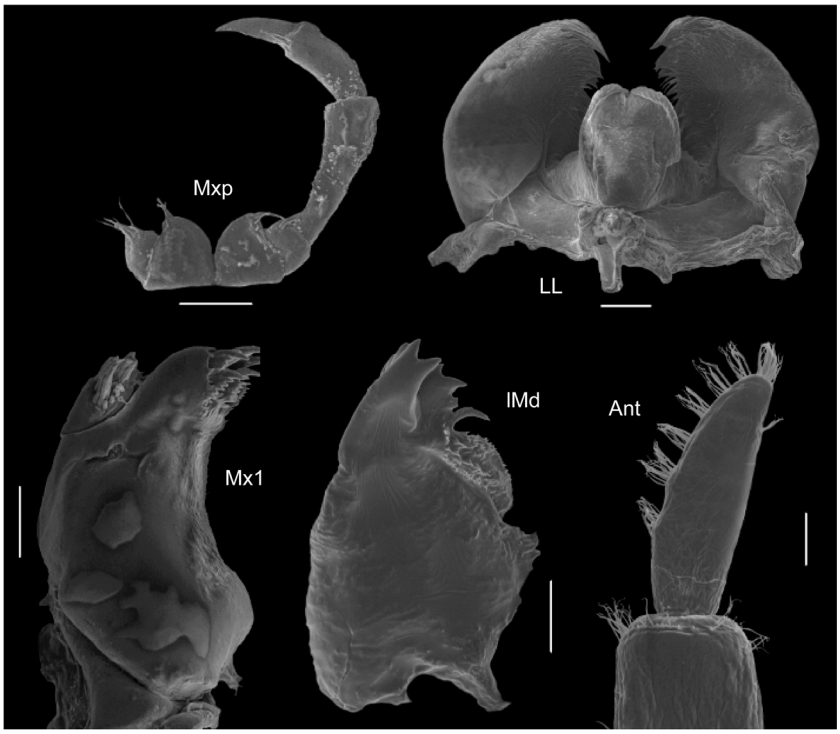

Fig. 5 *Cyamus boopis* Lütken, 1870. MNRJ 25995. Male, 8.3 mm. Antenna 1 and mouthparts. Scale bar: 100 μm

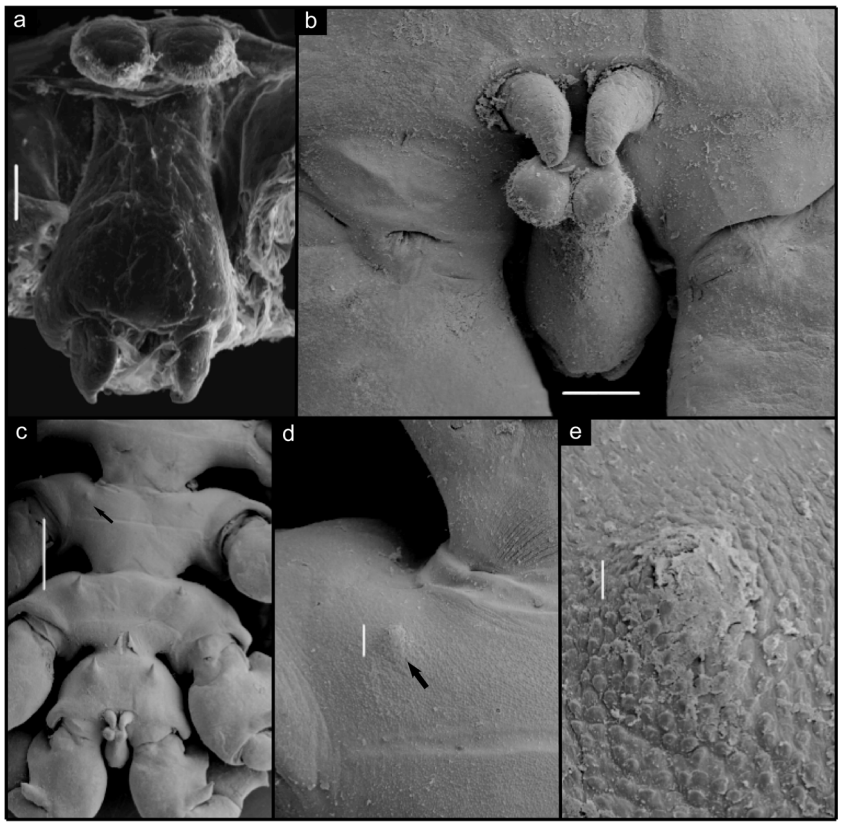

Fig. 6 *Cyamus boopis* Lütken, 1870. Male, 9.7 mm. MNRJ 25981. **a** Apical view of pleon and pleopods. Scale bar: 100 μm; **b** Ventral view of pereonite 7 with penes, pleon and pleopods. Scale bar: 200 μm; **c** Ventral view of pereonites 5–7 showing acute processes. *Black arrow* indicates pereonite 5 acute process. Scale bar: 1 mm; **d** Ventral view of acute process on pereonite 5. Scale bar: 100 μm; **e** Ventral view of acute process on pereonite 5. Scale bar: 20 μm

9.0 mm, 30 females (11 ovigerous), 3.0—7.4 mm, seven juveniles, 1.7—4.5 mm, Alcobaça, Brazil, MNRJ 25984 (IBJ 364); one male, one female (not measured), Fortaleza, Brazil MNRJ 25985 (AQUASIS 198); two males, 7.3—8.3 mm, one female, 4.4 mm, Barroquinha, Brazil, MNRJ 25986 (AQUASIS 349); one female, 6.5 mm, Trairí, Brazil MNRJ 25987 (AQUASIS 594); 96 males, 4.7—13.5 mm, 83 females, 3.1—7.4 mm, Capão da Canoa, Brazil, MNRJ 25988 (GEMARS 1409); 15 males, 5.0—9.5 mm, 18 females, 3.3—6.7 mm, Cidreira, Brazil, MNRJ 25989 (GEMARS 1683); 37 males, 5.4—9.1 mm, 43 females, 3.2—7.1 mm, Arroio do Sal, Brazil, MNRJ 25990 (GEMARS 1684); three males, 6.0—7.8 mm, Nova Tramandaí, Brazil, MNRJ 25991 (GEMARS 1685); 12 males, 4.5—9.2 mm, 19 females, 3.6—7.4 mm, Saquarema, Brazil, MNRJ 25992 (GEMM 079); 133 males (not measured), 69 females (not measured), Rio das Ostras, Brazil, MNRJ 25993 (GEMM 115); 45 males, 3.4—9.8 mm, two females, 3.7—7.2 mm, Arraial do Cabo, Brazil, MNRJ 25994 (GEMM 211); 100 males (not measured), 100 females (not measeured), 100 juveniles (not measured), Praia de Moçambique, Florianópolis, Brazil, MNRJ 25995 (LCP 7615).

Redescription Lectotype, male, 9.2 mm, ZMUC CRU-8190. Body compact and dorso-ventrally depressed. Eyes small and ovoid. Head long and quadrangular, partially fused with pereonite 1; lateral incision between head and pereonite 1 feebly present. Pereonite 1 with lateral expansion. Pereonite 2 with squared process on posterolateral margin. Pereonites 3 and 4 separate medially; and narrower than other somites, subequal width relative to pereonite 5, without pereopods, each bearing one pair of gills and one accessory gill. Pereonite 5 through 7 each bearing one pair of acute ventral processes, increasing in size from pereonite 5 to 7. Pereonites 6 and 7 separate medially. Pereonite 7 triangular. Penes large, stout.

Antenna 1 four-articulate, terminal article narrow and long, bearing apical tuft of setae, and brush-like setal groupings on the internal margin of terminal article; second article with sparsely setose. Antenna 2 four-articulate, with sparse setae; article 3 the longest.

Upper lip with distomedial invagination, producing distally rounded left and right subequal lobes, epistome moderate, not reaching distomedial invagination. Lower lip outer lobes longer than inner lobes; outer lobes broad, triangular; inner margin heavily setose; inner lobes partially fused, rounded distally. Left mandible with palp absent; incisor five-toothed; lacinia mobilis five-toothed; spine row of three or more setae; molar process absent. Right mandible with palp absent; right incisor six-toothed; lacinia mobilis five-toothed; spine row of three setae; molar process absent; submolar setae lacking. Maxilla 1 with seven denticulate setae on outer lobe; palp 1one-articulate, with long setae. Maxilla 2 with distomedial expansion of inner lobe bearing two setae. Maxillipeds with

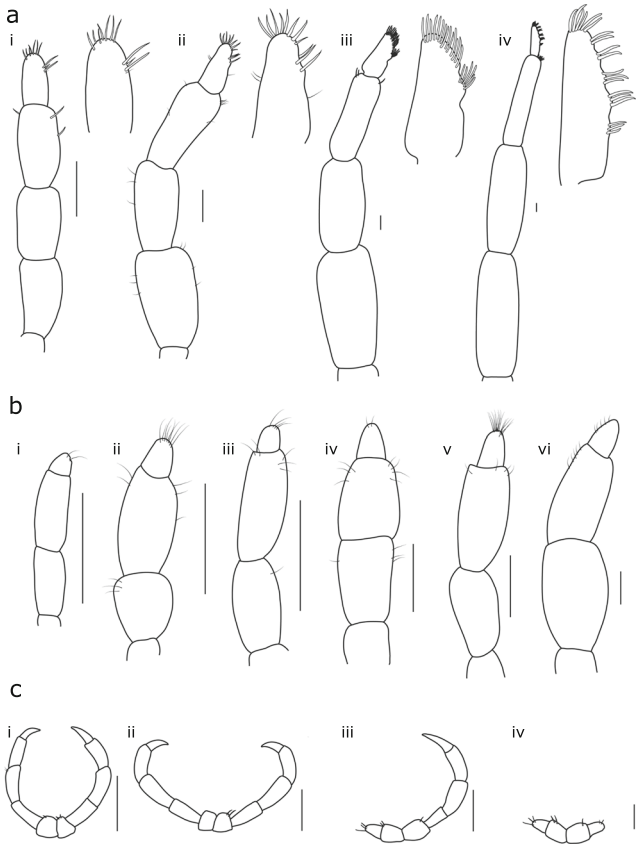

Fig. 7 *Cyamus boopis* Lütken, 1870. MNRJ 25995. **a** Antenna 1 development. **i** Juvenile, 1.8 mm, **ii** Juvenile, 3.7 mm, **iii** Female, 6.3 mm, **iv** Male, 9.2 mm. Scale bar: 100 μm; **b** Antenna 2 development. **i** Juvenile, 1.8 mm, **ii** Juvenile, 2.5 mm, **iii** Juvenile, 3.7 mm, **iv** Juvenile, 4.6 mm, **v** Female, 5.5 mm, **vi** Male, 9.2 mm. Scale bar: 100 μm; **c** Maxillipedal palps development. **i** Juvenile, 2.5 mm, **ii** Juvenile, 3.7 mm, **iii** Juvenile, 4.6, **iv** Female, 6.3 mm. Scale bar:100 μm

inner plate lacking setae; outer plate with 5–6 setae, palp absent (Fig. 2).

Gnathopod 1 approximately one-fourth size of gnathopod 2, coxa not fused with pereon, anterior margin of propodus with broad lunate expansion bearing distal notch, cuticular scales on inferior margin of propodus present (Fig. 3).

Gnathopod 2 coxa not fused with pereon; ventral face of basi-ischium with sharp process on anterolateral corner, large blunt process located proximally of sharp process; carpus and propodus fused; distal process of interior margin of propodus subtriangular, propodus with acute palmar tooth, dactylus large and unornamented, reaching propodus' subtriangular distal process (Fig. 3).

Pereopods 3 and 4 absent. Pereonites 3 and 4 bearing long, uniramous and outwardly directed lateral gill; lateral gill cylindrical, 11 times longer than wide. Pereonites 3 and 4 bearing biramous medial (accessory) gill; accessory gill much shorter than lateral gill, also arising as coxal epipod. Accessory gills lobes subequal in length (Fig. 3).

Pereopods 5—7 coxae not fused with pereon. Basi-ischium with large, acute spine, located distally on antero-ventral face; large triangular process located proximally on dorsal face; with acute depression at site of fusion between basis and ischium, giving posterior margin lobed appearance. Anterior margin of ischium uniform, unornamented. Inferior margin of merus uniform, lacking setal row. Ventral face of carpus with medium acute spine. Propodus subelliptical; with no teeth or spines. Dactylus acute, angle of recurve dactylus extreme, approximately 90° (Fig. 3).

Pleon reduced with one pair of pleopods, fused basally and separate distally; with each pleopod ending in a spherical lobe and bearing short seta along its lateral margins (Fig. 3).

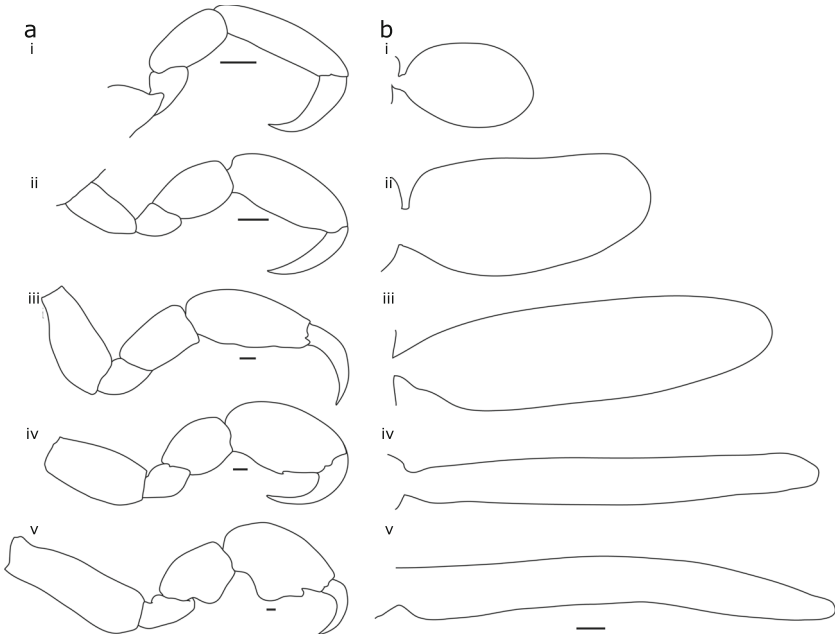

Fig. 8 *Cyamus boopis* Lütken, 1870. MNRJ 25995. **a** Gnathopod 1 development. **i** Juvenile, 1.8 mm, **ii** Juvenile, 3.7 mm, **iii** Juvenile, 4.5, **iv** Female, 6.3 mm, **v** Male, 9.2 mm. Scale bar: 100 μm; **b** Lateral gill development. **i** Juvenile, 1.8 mm, **ii** Juvenile, 2.5 mm **iii** Juvenile, 4.5, **iv** Female, 6.3 mm, **v** Male, 9.2 mm. Scale bar: 1 mm

Female, 7.2 mm, MNRJ 25995 — Pereonites 3 and 4 broader than those of male, subequal in width to pereonites 5 and 6, bearing leaf-shaped oostegite. Margins of oostegites lined with short, simple setae. Pereonites 3 and 4 bearing small round accessory gills, posterior margin serrate. Pereonite 5 with two pairs of ventral acute processes and genital valves; medial margin of genital valve well rounded, bearing cluster of short setae. Pereonites 6 and 7 with one pair of ventral acute processes; pleon lacking pleopods (Fig. 4).

Intraspecific adult variation

Specimens herein were compared with the types series of *C. boopis* deposited at the Zoologisk Museum of Copenhagen, Denmark, and other specimens from different localities and indeed showed a few morphological differences, especially the material from the Abrolhos Bank.

In the type material as well as specimens from other studies (Hurley 1952; Margolis 1955; Margolis et al. 2000), *C. boopis* is lacking the maxillipedal palps in adults. However, the Abrolhos population specimens generally had fully developed four-articulated maxillipedal palps in adult stages (Fig. 5 and Table 3). On the other hand, maxillipedal palp is absent in adults of *C. boopis* from other stranded whales in Brazil, Australia and the lectotype.

Adult specimens from Abrolhos are smaller when compared with material collected from whales of other localities (Table 4). Also, it is evident that there is a size reduction of the ventral acute processes on pereonite 5 of both males and females. Male processes are only visible on SEM pictures (Figs. 4 and 6), but females have a greatly reduced process on pereonite 5, and one pair of ventral processes on pereonite 5 are absent in ovigerous females (Fig. 4 and Table 3). These variations lead to problems in the identification of the species. However, characters such as maxilliped palp and the acute ventral processes of the pereonite 5 vary during ontogenetic growth, which indicate they are problematic in using them as diagnostic characters.

Ontogenetic development

Ontogenetic development was observed from cyamids collected from one humpback whale stranded at the coast of Santa Catarina state (MNRJ 25995). Here the maximum length of males was greater than Abrolhos Bank specimens, reaching 13.5 mm (Table 4).

Antenna 1 with brush-like setal groupings appeared only in adults. The development of this pattern is continuous, and juveniles present only the apical tuft setal grouping, and brush-like setal groupings becoming more conspicuous at size of more than 4 mm length (Fig. 7a).

Table 3 Morphological variations in adult males and females of *C. boopis* from the Abrolhos Bank

Males				Females				Ovigerous females			
n	Number of 4-articulated maxillipedal palps	Pairs of ventral processes	Size (mm)	*n*	Number of 4-articulated maxillipedal palps	Pairs of ventral processes	Size (mm)	*n*	Number of 4-articulated maxillipedal palps	Pairs of ventral processes	Size (mm)
115	2	1	3.1 – 10.1	61	2	2	4.1 – 7.0	21	2	1	5.5 – 7.9
38	1	1	3.9 – 9.1	20	1	2	4.1 – 7.9	9	1	1	6.0 – 8.3
21	2	0	4.1 – 10.1	58	2	1	4.5 – 7.4	4	0	1	6.3 – 6.9
7	1	0	6.6 – 9.2	20	1	1	4.5 – 8.3				
14	0	1	5.6 – 9.8	6	0	2	5.6 – 6.9				
5	0	0	8.4 – 9.3	12	0	1	5.7 – 8.1				

Table 4 Maximum length records of males and females *C. boopis* from the literature and present study

Sex	Maximum length	Reference
Male	13.5 mm	Argentina (De Pina and Giuffra 2003)
	13.5 mm	Brazil (present study)
	12.1 mm	Australia (present study)
	12 mm	British Columbia and South Africa (Margolis 1955)
	11.5 mm	New Zealand (Hurley 1952)
Female	9.5 mm	New Zealand (Hurley 1952)
	8.9 mm	Australia (present study)
	8.5 mm	Argentina (De Pina and Giuffra 2003)
	8.3 mm	Brazil (present study)
	6.8 mm	British Columbia and South Africa (Margolis 1955)

Antenna 2 showed different setae patterns in different body lengths; however, it does not seem to have a particular constancy (Fig. 7b).

Although maxillipedal palps reduction is already well known for *C. boopis,* it was not the rule for Abrolhos Bank populations. Individuals up to 10.1 mm had two fully developed maxillipedal palps, as well as most of the ovigerous females (Table 3). For southern Brazilian populations (Fig. 1, RJ, SC and RS), juveniles had fully developed palps, while adults from 6 mm up showed a palp reduction, as already observed by Hurley (1952) and Margolis (1955) (Fig. 7c).

Gnathopod 1 also showed a continuous transformation during development (Fig. 8a). Juveniles up to 4.45 mm showed a flat propodus palm, but individuals 6.3 mm or larger already had palm clippings.

Lateral gills continuously grew from juvenile to adult development. In juveniles up to 1.8 mm, lateral gills were as long as wide, and increasing in length in longer specimens (Fig. 8b). Accessory gills were not seen in individuals smaller than 4 mm. A bifurcated shape found in males, and knob-like shape in females were only seen in animals longer than 5 mm.

One pair of acute ventral processes is observed on the pereonites 5–7 in all juveniles, and a second pair of ventral acute processes on pereonite 5 in females is only seen in specimens longer than 3 mm.

The oostegite formation in females began around 4 mm body length, and grows from the accessory gills inwards (Fig. 4a and c). Genital valves are observed in subadult females around 3 mm length, together with a second pair of acute ventral processes on pereonite 5. Penes occurred in individuals longer than 2 mm, and they were larger than the pleon, which is still small in juveniles. Pleopods are only seen in males longer than 4 mm (Fig. 6).

Sexual dimorphism is noticed by the shape of accessory gills, the number of ventral processes, oostegite in females and penes and pleopods in adult males.

Discussion

C. boopis was originally described by Lütken (1870) based on material collected on *Megaptera novaeangliae* stranded in Iceland, North Atlantic Ocean. Sars (1895) transferred *C. boopis* to the new genus *Paracyamus*, distinguishing it from the older *Cyamus* on the basis of an uni-articulate maxilliped palp in adults of *Paracyamus*, in contrast to the five-articulate condition in *Cyamus*. Hurley (1952) agreed with the genus *Paracyamus*, and he noted the condition of palp reduction in specimens of *C. boopis* from New Zealand. Margolis (1955) returned *Paracyamus boopis* to *Cyamus* based on the palp reduction of individuals from British Columbia, Canada, once the juveniles of up to 3 mm body length had four-segmented palps. Margolis et al. (2000) considered *Paracyamus* as a subgenus including both *C. boopis* and *C. balaenopterae* Barnard, 1931, based on the absence of a

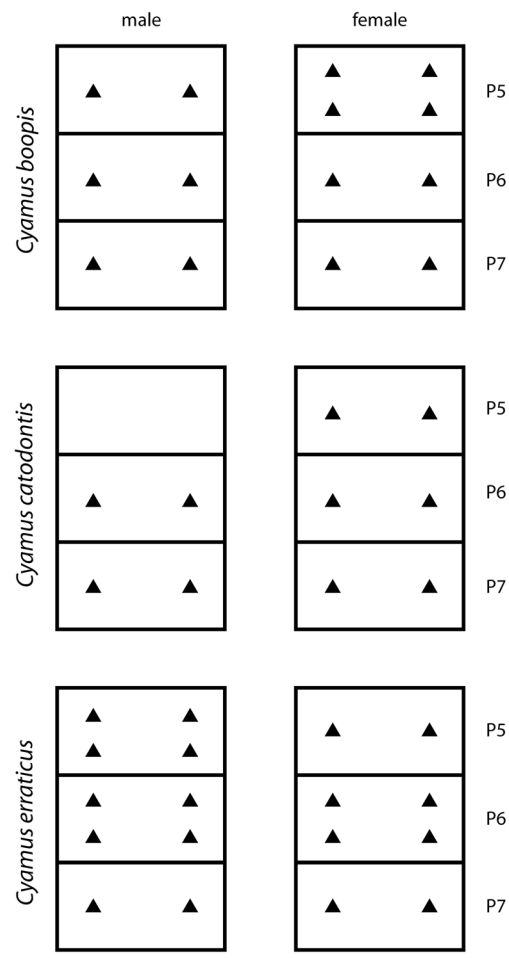

Fig. 9 Ventral process variation on pereonites 5–7 of adult males and females of *C. boopis*, *C. catodontis* and *C. erraticus*

maxilliped palp in adults, together with mouthparts and body features not clearly specified. De Pina and Giuffra (2003) redescribed *C. boopis* based on specimens deposited at the Museo Argentino de Ciencias Naturales Bernardino Rivaldavia, from humpback whales stranded at Argentinian beaches. Although it was the first attempt to describe the Southern Atlantic Ocean specimens, the description follows previous works without notice of morphological variation.

Among *Cyamus* species, *C. boopis* is similar to *C. catodontis* Margolis, 1954, parasite of sperm whales *Physeter macrocephalus* Linnaeus, 1758 and *C. erraticus* Roussel de Vauzème, 1834, parasite of right whales. All three species have biramous accessory gills on pereonites 3 and 4, and similar gnathopod 1. However, *C. boopis* differs from *C. catodontis* and *C. erraticus* by the number of ventral processes on pereonite 5 to7 on adult males and females (Fig. 9). Accessory gills are biramous in the three species, though they have small differences: the accessory gill lobes are subequal in *C. boopis*, the posterior lobe is slightly larger in *C. catodontis* and the posterior lobe is visibly longer in *C. erraticus. Cyamus erraticus* has a different shape of the accessory gills, more angular on the tips of each ramus, leaf-like, while *C. boopis* and *C. catodontis* have a sausage-like shape.

The genus level systematics is still controversial. Margolis et al. (2000) commented on the similarity of *C. boopis* and *C. balaenopterae*, and considered these species within the subgenus *Paracyamus* based on the follwing characters: broad outer lobes of the lower lip; the short deeply seperated inner lobes; head elongate; and maxilliped palp usually lost in adults. On the other hand, Haney (1999), based on a morphological phylogeny of *Cyamus,* stated that *C. balaenopterae* was distant from *C. boopis*, the latter placed in the same clade as *C. catodontis* and *C. erraticus,* due to: the gnathopod 2 propodus margin shape; female pereopods 3 and 4 accessory gills leaf-like; and pereopods 5 to 7 basis anterodistal margin process subacute and ventrally directed. *Cyamus boopis* and *C. catodontis* are suggested to be sister taxa, sharing the lack of ventral processes on pereonites 3 and 4, and smooth grinding surface on the right lacinia mobilis. Leung (1967) also pointed out the similarity of *C. boopis* and *C. catodontis*, and possibly previous authors might have confused both species.

Although one of the differences between *C. boopis* and *C. catodontis* is the presence of maxilliped palps in adults of *C. catodontis* (Margolis 1955), specimens of *C. boopis* collected at the Abrolhos Bank showed that this is a plastic character and should be used with caution for species identification. Some females from the Abrolhos Bank have one pair of ventral acute processes on pereonite 5, as observed in *C. catodontis*. However, characters related to the lateral and accessory gills can be used to distinguish these species as discussed above and the Abrolhos Bank material are herein identified as *C. boopis.* Recent molecular studies of Brazilian *C. boopis*, including the Abrolhos Bank material, confirm that all specimens of *C. boopis* parasitizing *M. novaeangliae* are a single species (Iwasa-Arai unpublished data).

Furthermore, records of *C. boopis* on other whales such as *P. macrocephalus* (Grüner 1975) may be to misidentifications of *C. catodontis* due to the similarity between these two species (Haney 1999). Thus, these small differences between *C. boopis*, *C. erraticus* and *C. catodontis*, together with the host specificity are sufficient to identify the species.

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