

Decapod crustacean associations with scyphozoan jellyfish (Rhizostomeae: Pelagiidae) in the Southeastern Brazilian coast

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Abstract In southeastern Brazil, decapod crustaceans were found living in association with the scyphozoan jellyfish. In total, 2002 specimens of the Scyphozoa *Lychnorhiza lucerna* were collected of which 511 were associated decapods that were identified as three species of the crab *Libinia ferreirae*, *Libinia spinosa*, and one Grapsoidea sp. and two species of caridean shrimps *Periclimenes paivai* and *Leander paulensis*. This is the first record of an association between the caridean shrimp *L. paulensis* and a scyphozoan and the first report of symbioses involving the crabs *L. spinosa* and Grapsoidea sp. on the Brazilian coast.

Keywords Brachyura · Crab · Caridea · Medusae · Symbiosis · Shrimp

1 Introduction

Associations of a benthic species with a pelagic organisms like the medusae of scyphozoan jellyfish can bring benefits such as greater mobility, shelter and food availability (Nogueira and Haddad 2005; Martinelli Filho et al. 2008; Sal Moyano et al. 2012; and Schiariti et al. 2012). Other potential advantages of symbiosis may include the exploitation

of new resources, the occupation of new ecological niches, refuges, and protection from predation (Thiel and Baeza 2001; Martinelli Filho et al. 2008; Sal Moyano et al. 2012).

Previous studies have documented associations of decapod crustaceans such as caridean shrimps (Palaemonoidea) (Marliave and Mills 1993; Moore et al. 1993; Martinelli Filho et al. 2008) and brachyuran crabs (Majoidea and Grapsoidea) (Nogueira and Haddad 2005; Sal Moyano et al. 2012; Schiariti et al. 2012) with scyphozoan in the medusoid-phase. On the southern and southeastern coasts of Brazil, jellyfish, are accidentally captured as bycatch during trawling for target species such as the seabob shrimp, *Xiphopenaeus kroyeri* (Heller, 1862) (Graça-Lopes et al. 2002; Schroeder et al. 2014). The capture of jellyfish, especially Rhizostomeae, potentially has an impact on any symbiotic species that are associated with them (Mianzan and Cornelius 1999). The community structure may thus be altered as a result of fishing influencing ability of symbionts to complete stages in their life cycle. The aim of the present study was to analyze and characterize the decapod species which live in association with scyphozoan medusae in southeastern Brazil.

2 Materials and methods

The medusoid-phase of scyphozoans and any associated crustaceans were sampled by trawling (30-min duration) using a shrimp boat outfitted with double-rig nets. The collections were done monthly in São Paulo state, Ubatuba (23°35'00"S - 45°12'30"W, July 2013 to August 2014) and Cananéia (25°04'43"S - 47°50'34"W, February 2013 to May 2014), and Rio de Janeiro state, Macaé (22°22'33"S - 41°46'30"W, September 2013 to June 2014), at depths between 5 and 15 m. A total of 216 trawls were executed (i.e., 48 in Macaé, 56 in

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Ubatuba and 112 in Cananéia). In order to standardize the results, the abundance of hosts and symbionts was estimated as the number of individuals caught per standard trawl set (catch per unit effort).

The bottom water was sampled using a Van Dorn bottle and the salinity was measured with an Atago S/1000 optic refractometer. The temperature (°C) was measured using a thermometer attached to the Van Dorn bottle. The medusa collected were examined for the presence of any symbionts and identified with the help of Morandini et al. (2005) and Nogueira and Haddad (2006). Medusa without any symbionts were counted and returned to the sea. Those that had symbionts were individually packed in plastic bags and transported to the laboratory.

In the laboratory, whole jellyfish in good condition were examined macroscopically to check the anatomical location of symbiotic crustaceans. Medusae were measured between two rhopalia (an accuracy of 0.01 mm) to assess the umbrella diameter (UD) (Nogueira and Haddad 2006) and were then grouped into 10 mm size classes. Umbrella diameters of medusae collected in the Cananéia region were compared with those from Macaé using the Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1995).

The decapod crustaceans were fixed in 70 % alcohol and identified using Williams (1984); Melo (1996) and Tavares and Santana (2012) for Brachyura, Machado et al. (2010) and Chace (1969) for caridean shrimps and Pohle et al. (1999) for larvae. As a result of the difficulty in determining *Libinia* species because of their great similarities during the juvenile phases, we utilized a specific character on the dorsal surface of the thoracic sternum. In *Libinia spinosa* H. Milne Edwards, 1834, the thoracic episternites of IV-VII is armed with strong, posterolateral-projecting, broad teeth, a feature that is absent in the teeth of *Libinia ferreirae* Brito Carpello, 1871 (Tavares and Santana 2012).

The Brachyura were separated by sex, based on the abdomen shape for adults (elongated pattern for males and oval for females) and on the number of pleopods on individuals (two pairs for males and four pairs for females) (Almeida et al. 2013; Melo 1996). Both sexes were assessed for maturity by abdomen adherence to the thoracic sternite. Individuals were considered immature if the abdomen was sealed and cementing substances were present in the abdomen contour. Individuals with an unlocked abdomen were considered adults (for more details, see Gonçalves et al. 2016).

The sex of the Caridea were determined based on the presence or absence of appendices on the base of the endopod of the second pleopod, present in males but absent in females (Bauer 2004). The state of female sexual maturity was determined by the presence or absence of embryos attached to the pleopods.

The carapace width in Brachyura (CW) and carapace length (CL) in the Caridea were measured with a digital

caliper to an accuracy of 0.01 mm. Specimens smaller than 5 mm were measured with a stereo microscope (Zeiss® Stemi SV6, fitted with a Zeiss® Stemi 2000-C image capture system) with accuracy within 0.0001 mm.

The proportion of jellyfish that had symbionts was estimated using an index: $P = \text{number of individuals with symbionts} / \text{total individuals} * 100$, and the density of symbionts per host was calculated as $IMS = \text{total number of symbionts} / \text{total number of hosts}$ (Bush et al. 1997).

3 Results

3.1 Abundance and richness of associated species

A total of 2002 *Lychnorhiza lucerna* Haeckel, 1880 specimens were collected which had 511 associated decapod crustaceans from the three collecting areas. The crustaceans belonged to the Majoidea, Grapsoidea, and Palaemonoidea superfamilies. They comprised two species of Brachyura crabs *Libinia ferreirae* ($N = 492$) and *L. spinosa* ($N = 1$), one species of Grapsoidea crab ($N = 1$) and two species of caridean shrimps *Periclimenes paivai* Chace 1969 ($N = 13$) and *Leander paulensis* Ortmann, 1897 ($N = 5$) (Table 1, Fig. 1). It was not possible to identify the Grapsoidea because it was a small juvenile. More than one species of crustacean was sometimes present on the same medusae in the Cananéia region. *Lychnorhiza lucerna* was host to an average number of 1.55 and 1.06 symbionts in the Cananéia and Macaé areas, respectively and the frequency of finding medusa with symbionts was 22 % and 19 % respectively.

With respect to crab maturity, juveniles of *L. ferreirae* were found associated with medusae from Cananéia (CW = 0.89 mm–36.8 mm) and Macaé (CW = 2.08 mm–4.97 mm) and adults in medusae from Cananéia (CW = 40.17 mm–49.59 mm). The specimens of *L. spinosa* and the Grapsoidea sp. were also juveniles (Table 1). With respect to shrimps, the majority of *P. paivai* were adult females carrying embryos ($N = 11$). Only one male was found. In contrast only males of *L. paulensis* were collected from Cananéia. In some cases, both caridean shrimp species were found sharing the same host in the Cananéia region. In two cases, two females of *P. paivai* carrying embryos (= ovigerous females) were observed sharing the same *L. lucerna* medusae. However no medusae was found to be host to a male–female pair.

A total of 1076 and 922 *L. lucerna* were collected in Macaé and Cananéia, respectively. Four *L. lucerna* from the Ubatuba region had decapod associates; but only one with an umbrella diameter (UD = 78 mm) was associated with *L. spinosa* (CW = 15.8 mm), 45 % of the associations in Cananéia region were in large medusae with UD 80–130 mm. In Macaé, the 42 % of the associations were found in medusae between 60 and 100 mm in size (Fig. 2). The sizes of *L. lucerna* in the two

Table 1 Number of crustacean decapod species associated by jellyfish species for each region sampled in Brazilian southeastern coast

| Region | Host | Decapod Sym | Sex of Sym | Size range of carapace Sym | | N° Sym | | |
|---|-------------------|---------------------|-------------------|----------------------------|-----------|--------|------|----|
| | | | | <CW/CL mm | >CW/CL mm | | | |
| Cananéia-São Paulo (25°04'43"S; 47°50'34"W) | <i>L. lucerna</i> | <i>L. ferreirae</i> | F | 4.23 | 48.25 | 101 | | |
| | | | M | 4.24 | 49.59 | 76 | | |
| | | | - | 0.89 | 4.3 | 134 | | |
| | <i>L. lucerna</i> | <i>L. paulensis</i> | M | 3.74 | 4.75 | 5 | | |
| | | | <i>L. lucerna</i> | <i>P. paivai</i> | F ovg | 2.08 | - | 12 |
| | | | | | M | 3.02 | 5.18 | 1 |
| | | | <i>L. lucerna</i> | Grapsidea | - | 1.3 | - | 1 |
| Macaé-Rio de Janeiro (22°22'33"S; 41°46'30"W) | <i>L. lucerna</i> | <i>L. ferreirae</i> | F | 4.59 | 32.03 | 87 | | |
| | | | M | 4.62 | 20.00 | 70 | | |
| | | | - | 2.08 | 4.97 | 23 | | |
| Ubatuba-São Paulo (23°35'00"S; 45°12'30"W) | <i>L. lucerna</i> | <i>L. spinosa</i> | F | 15.8 | - | 1 | | |
| Total of animals associated | | | | | | 511 | | |

Sym = symbionts; M = males; F = females; F ovg = ovigerous females (-) unsexed animals; CW = carapace width; CL = carapace length; N° = abundance of decapods by species/sex

regions was significantly different (Kolmogorov-Smirnov two-sample test; $d_{\max} = 0.27$, $P < 0.01$).

In Macaé, 16 % ($N = 169$) of medusae carried a total of 180 juveniles crabs (CW = 2.08 mm–32.03 mm) in association, of which 73 % were smaller than 10 mm CW. The highest incidence of medusae associated with crabs (134) was found in September 2012 (winter, temperature 21–22 °C; Figs. 3 and 4a). During this period, the mean salinity was 38. At this time there was the greatest abundance of *L. ferreirae* (85 % of the entire sample of associations). In January 2014 (summer, temperature 18.5–20 °C and a mean salinity of 36.7), the medusae were also abundant ($N = 329$), but no associations were found (Figs. 3 and 4a).

In the Cananéia region, 22 % of the captured medusae ($N = 205$, UD = 24–328 mm) had 330 associated decapods.

The most abundant crustacean species was *L. ferreirae* ($N = 311$), composed mainly of juveniles (CW = 1.38 mm–36.8 mm), with 76 % of individuals being less than 10 mm CW, and there were 4 megalopa larvae. Only 2 % of these crabs were adults (CW = from 40.17 to 49.59 mm). This region had medusae with up to 11 associated *L. ferreirae* as well as more than one species in the same host, for example, 1 *L. ferreirae* + 1 *L. paulensis*, 3 *L. ferreirae* + 1 *P. paivai* (females carrying embryos), and 6 *L. ferreirae* + 1 Grapsidae. The average CW of crabs that shared each medusae was 4.21 mm, which is smaller than the average CW of 7.8 mm for crabs captured alone in their host. The highest incidence of crabs associated with *L. lucerna* occurred during March 2014 (summer, temperature 25–26 °C and salinity 34): 179 medusae were associated with 206 crabs. Some had more than one

Fig 1 a. *Lychnorhiza lucerna* Haeckel, 1880 and *Libinia ferreirae* Brito Capello, 1871 dorsal view; b. *L. lucerna* dorsal view with *Periclimenes paivai* Chance, 1969 (female carrying developing embryos attached beneath the abdomen) within the subgenital space of the medusa; c. and d. *L. ferreirae* and *Libinia spinosa* H. Milne Edwards, 1834 dorsal pictures, respectively; e. *Leander paulensis* Ortmann, 1897 lateral view; f. *P. paivai* dorsal view; g. dorsal view of Grapsoidae MacLeay, 1838



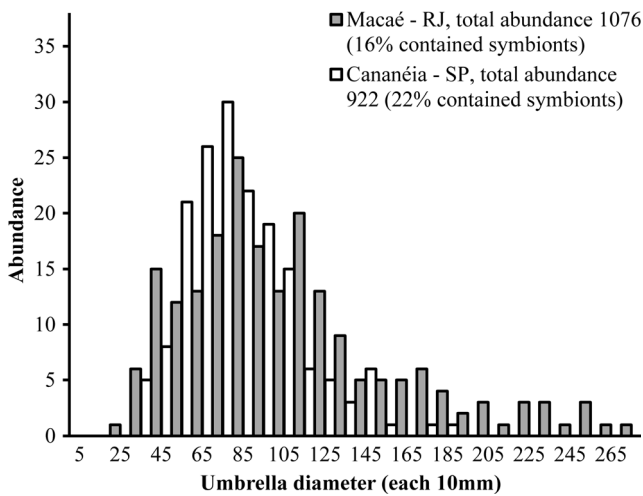


Fig 2 Size–frequency distributions for *Lychnorhiza lucerna* jellyfish with decapods associated from Cananéia, São Paulo, and Macaé, Rio de Janeiro, Brazilian southeastern coast. Intervals of 10-mm size class were used, ranging from 0 to 10 (class 5) to >270 (class 275)

symbiont in each host (Figs. 3 and 4b). The highest capture of 226 *L. lucerna* medusae was in August 2013 (winter, temperature 17.5–19 °C and salinity 29.2) (Figs. 3 and 4b) but only two medusae were host to four juvenile crabs (CW of 1.51 to 3.21 mm).

4 Discussion

Morandini (2003) studied juvenile *L. lucerna* medusae in the Cananéia region, and observed the jellyfish bloom during the spring season. The initial ephyra phases develops into the medusa phase during the following season and the life span is 5–6 months (Schiariti 2008; Sal Moyano et al. 2012). It is

after the ephyra phase, that the *L. lucerna* medusae becomes associated with decapod larvae (Sal Moyano et al. 2012).

The association of shrimps in the Palaemonidae family with Cnidarians has been reported previously, mainly with anemones (Omori et al. 1994; Fautin et al. 1995; Azofeifa-Solano et al. 2014) but occasionally with the scyphozoan medusae (Moreira 1961; Martinelli Filho et al. 2008). In the present study of associations with *L. lucerna*, there was a predominance of adult *P. paivai* females carrying embryos. This has been observed by others (Martinelli Filho et al. 2008 and Ohtsuka et al. 2010).

In the present study, it is possible that female *P. paivai* incubating embryos adopt a sedentary behavior after reproduction and use their scyphozoan host as a means of protection for their offspring (Martinelli Filho et al. 2008). The females may disassociate from the hosts when larval are to be releases as the offspring could be a food source for the medusae (Bauer 2004).

Although the abundance of the shrimp, *L. paulensis*, was low in this study, it is the first record of an association with *L. lucerna*. Furthermore, little is known about this species, except that it is found in shallow waters up to 16 m deep on sandy bottoms and algae. The occurrence of only males in this association with *L. lucerna* in Cananéia could indicate a difference in behavior between the two shrimp species (Ramos-Porto 1986; Zimmermann et al. 2015).

Libinia ferreirae was the most abundant brachyuran crab species associated with *L. lucerna*, and they were predominantly juveniles which are not found freely on the ocean floor. Larval and juvenile individuals may be associated with jellyfish because the latter provide a protected environment during this most vulnerable period of their lives (Nogueira and Haddad 2005). Probably, these crabs colonize the medusae

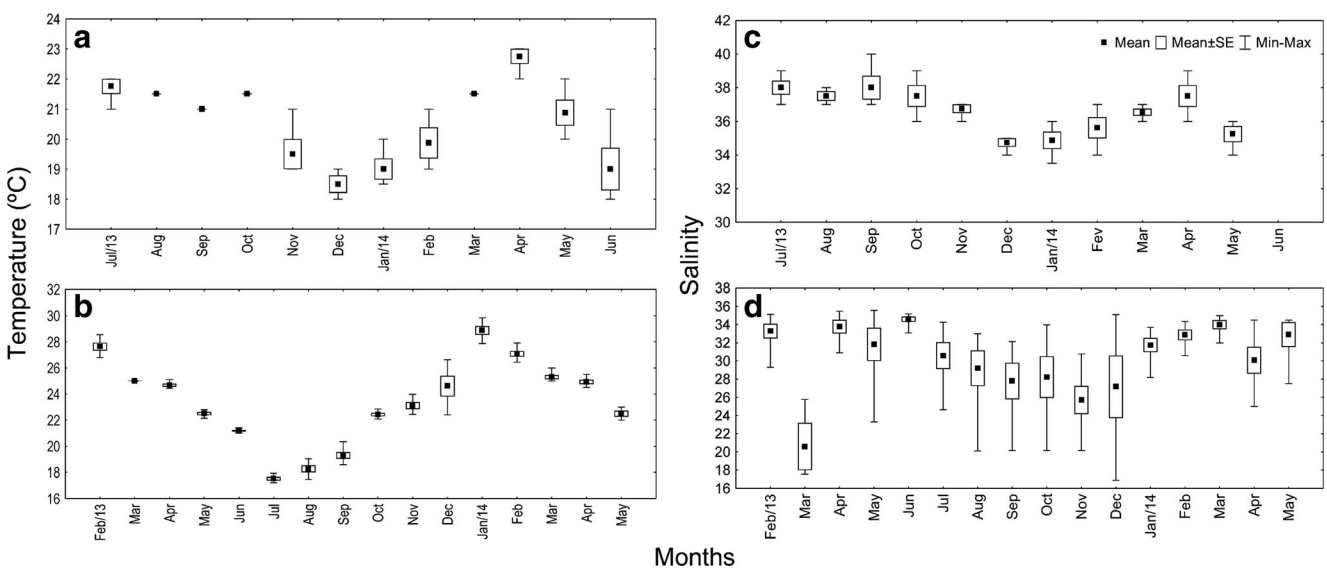
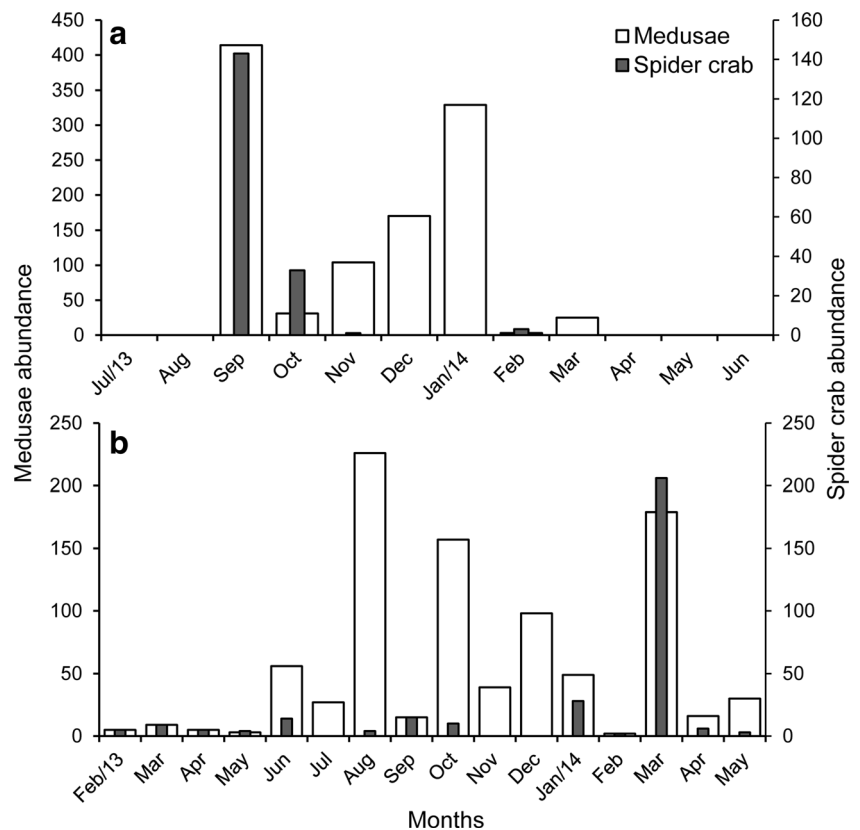


Fig 3 Monthly average temperature **a, b** and salinity **c, d**) variations. **a** and **c**. Macaé, Rio de Janeiro state; **b** and **d**. Cananéia, São Paulo state, Brazilian southeastern coast. SE: Standard error; Min-Max: the minimum and maximum ranges

Fig 4 Abundance of *Lychnorhiza lucerna* and *Libinia ferreirae* collected in Macaé **a**, Rio de Janeiro state, and Cananéia **b**, São Paulo state, Brazilian southeastern coast



during their larval phases, they do so from the plankton (Gutsell 1928; Nogueira and Haddad 2005).

Jellyfish are highly mobile animals and this can be a disadvantage as they may be moved by sea currents to areas where the environmental conditions are unsuitable for any symbionts (Berggren 1994). In the present study, a greater abundance of *L. ferreirae* associated with medusae occurred during periods with high water temperatures. The lower abundance of *L. ferreirae* in Macaé during summer can be explained by cooler water derived from the cold ocean currents from the South Atlantic (South Atlantic Central Water) and intensified by upwelling (Campos et al. 2000; Acha et al. 2004). Lower temperatures are likely not favorable for these crustaceans as suggested by other studies (Hartnoll 2001; Nogueira and Haddad 2005; Sal Moyano et al. 2012). It is interesting that the wide salinity variation found between the three sites in the present study appeared not to influence the ability of crabs to associate with medusae.

Schiariti et al. (2012) also found individuals of the Grapsoidea superfamily together with *Libinia* sp. while another Grapsoidea, *Planes major* (MacLeay, 1838), has been found in association with other hosts as turtles (Pfäller et al. 2014). It has been suggested that they use the host to complete the life cycle when associated in the megalopa phase.

Commensalism seems to be the most likely relationship between the decapod crustaceans and *L. lucerna*. This relationship benefits one of the members without harming the other

(Parmentier and Michel 2013). Commensalism was proposed for *L. ferreirae* (Nogueira and Haddad 2005). However, the deep sea shrimp *Notostomus robustus* Smith, 1884 associated with the medusoid-phase of *Atolla wyvillei* Haeckel, 1880 (collected at a depth of 790 m) feeds on the jellyfish umbrella so can be parasitic (Moore et al. 1993). Jachowski (1963) also considered the relationship between the crab *Libinia dubia* H. Milne Edwards, 1834 and the jellyfish *Aurelia aurita* (Linnaeus, 1758) to be parasitism, while Shanks and Graham (1988) suggested that crabs prey on jellyfish gonads.

Our results corroborate that *L. lucerna* provide protection during the medusoid-phase for their pelagic crustacean associates during the most vulnerable phases (larvae, juveniles, females carrying embryos and post-molt individuals). Further research is needed to understand these associations and their role in marine ecosystems.

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