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Ecological notes on *Actinostella flosculifera* (Le Sueur, 1817) (Cnidaria: Actiniaria: Actiniidae) in the South-western Atlantic, Brazil

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Abstract

Sea anemones have developed various strategies for interspecific interaction with other organisms and their own ability to obtain food, due to their coevolutionary history, ranging from mutualistic (e.g. clownfish, crustaceans, etc.) and symbiotic associations (zooxanthellae or zoochlorellae) to depredation (e.g. sea slug). This study aims to record some observations on feeding habits and interspecific interactions of *Actinostella flosculifera* (Le Sueur, 1817) in the locality of Pedra da Sereia in Vila Velha, Espírito Santo, Brazil, and to describe the hunting strategy of the sea slug *Spurilla braziliana* MacFarland, 1909 and the escape strategy of *A. flosculifera*. We found that the habitat of *A. flosculifera* is characterized by shallow pools ~10 cm deep at low tides, and this functions as a trap for many organisms and some biowaste (e.g. bones or fish drifting in from nearby populations) that fall into the oral disc. This is the first report of *S. braziliana* predated on *A. flosculifera*. We also report interspecific relationships between *A. flosculifera* with four species of crustaceans: *Omalacantha bicornuta* (Latreille, 1825), *Menippe* cf. *nodifrons* Stimpson, 1859, *Alpheus* cf. *angulosus* McClure, 2002, and *Alpheus* cf. *carlae* Anker, 2012.

Introduction

Sea anemones (order Actiniaria) are among the most diverse members of the class Anthozoa, subclass Hexacorallia. They can be found in any marine habitat and at all latitudes and depths (Rodríguez *et al.*, 2014), such as hydrothermal vents, oxygen minimum zones, high turbidity and sedimentation zones, abyssal whale carcasses, ice shelves, reef habitats, mangroves, seagrasses and anchialine caves (Aldred *et al.*, 1979; Fautin & Barber, 1999; López-González *et al.*, 2003; Daly & Gusmão, 2007; Ammons & Daly, 2008; Fautin, 2016; Durán-Fuentes *et al.*, 2022).

Furthermore, the sea anemones are considered polyphagous opportunistic predators, and it has been suggested that their diet reflects the structure of the community they inhabit (Ayre, 1984; Acuña & Zamponi, 1995; Kruger & Griffiths, 1996; Erralde & Acuña, 2020). Intertidal sea anemone species have developed various feeding strategies, ranging from the absorption of organic substances dissolved in seawater to the predation of vagile organisms or the association of a symbiotic relationship with unicellular organisms (zooxanthellae or zoochlorellae) (Erralde & Acuña, 2020).

The focus species of this study, *Actinostella flosculifera* (Le Sueur, 1817), has an anatomical structure called a marginal ruff or collar, which is richly provided with zooxanthellae – this favours it during the day. This structure is extended in the form of a ‘rug’ with retracted tentacles, ensuring maximum exposure to light. At night, the situation is the opposite: the tentacles are fully extended, and the marginal ruff can also be used to capture prey by the abundant presence of nematocysts (Ocaña, 1994; Häussermann, 2003).

This species is widely distributed in the western Atlantic, with reports from Bermuda to southern Brazil, including the south-eastern Gulf of Mexico (Verrill, 1869; Garesse *et al.*, 2009; González-Muñoz *et al.*, 2012, 2013, 2016; Durán-Fuentes *et al.*, 2022; Smithsonian’s National Museum of Natural History, accessed online 25 February 2022), but it also occurs in the Canary Islands (Ocaña & den Hartog, 2002) and the Gulf of Guinea (Wirtz, 2003; Wirtz *et al.*, 2020). However, little is known about the ecology of *A. flosculifera*, especially in the South-western Atlantic. Based on this scenario, this study focuses on recording the interactions of *A. flosculifera* with other species in tidal pools and thus advancing the knowledge of its ecology.



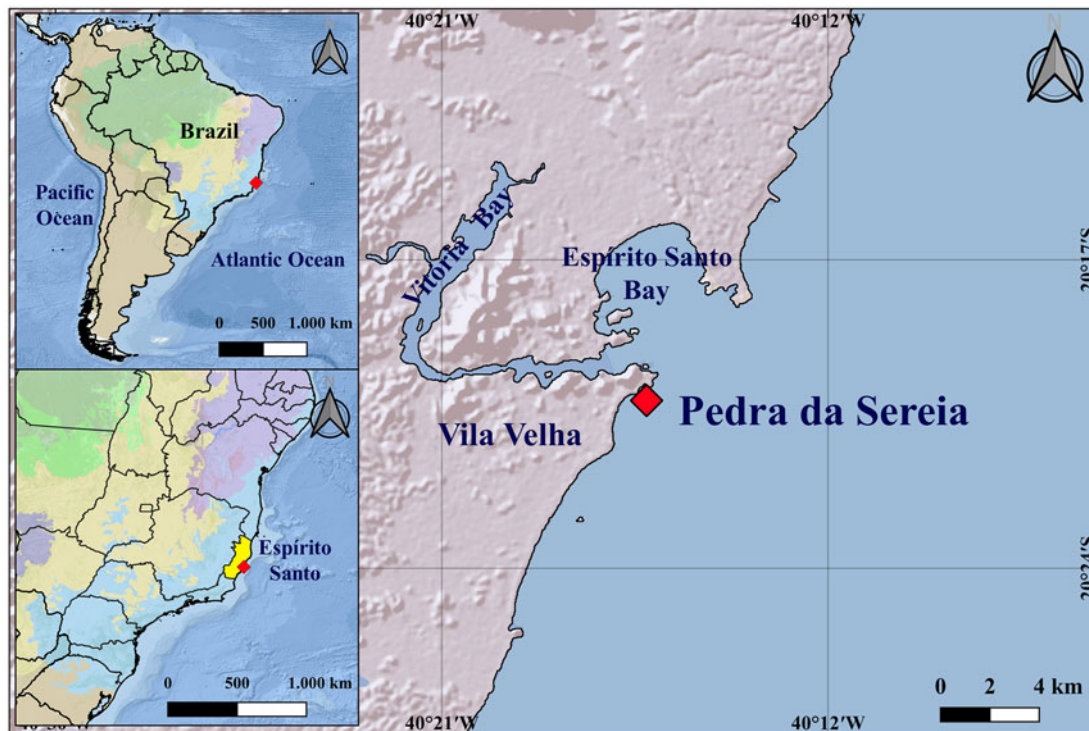


Fig. 1. Map of the study area on the shallow shore of the Pedra da Sereia (Costa beach) in Vila Velha (Espírito Santo, Brazil).

Materials and methods

Field observations of several specimens of *A. flosculifera* and their feeding and interspecific interactions were conducted at Pedra da Sereia (Costa beach) in Vila Velha, Espírito Santo, Brazil ($20^{\circ}20'03.1''\text{S } 40^{\circ}16'23.3''\text{W}$) (Figure 1). Specimens were recorded on 25 September 2014, and 1, 13 and 15 January 2022, mainly at night during low tide, using a Nikon D5300 camera and Albatroz 722b lighting. No individual was manipulated, and no human interference was observed. All specimens mentioned in this study were identified using specialized literature (e.g. Almeida *et al.*, 2008, 2018; Carmona *et al.*, 2014; Carmona-Suárez & Poupin, 2016).

The study area is part of a complex of rocky substrates on the coast of Vila Velha, which is associated with freshwater outflow from Vitória Bay, a complex of tropical estuarine systems located in the state of Espírito Santo. The system has two sea communications, the Passagem Channel and the Porto Channel, which comprise the southern part of Vitória Bay. In addition, this is formed by the mouths of several rivers, including the medium-sized Santa Maria da Vitória River, and the small-sized Formate-Marinho, Bubu, Aribiri, Córrego Piranema, and Canal da Costa rivers (Veronez-Júnior *et al.*, 2009). In this area, a large diversity of fishes, polychaetes, crustaceans, sponges, echinoderms, flatworms, molluscs, sea turtles and cnidarians have been recorded (Basílio *et al.*, 2020; Costa *et al.*, 2020; Santander *et al.*, 2020).

Results and discussion

This study reports the first record of interspecific interaction of *Actinostella flosculifera*, as well as some relevant observations in the study area. We observed a specimen of *A. flosculifera* feeding on a fish of the family Serranidae, class Actinopterygii (cf. *Diplectrum* Holbrook, 1855 or *Serranus* Cuvier, 1816) (Figure 2A, B). Based on the grey colouration and sparse scales on the caudal peduncle, it is possible to infer that the fish was

dead before being trapped by the anemone. Species of this family are not common in tidal pools. Therefore, this fish may have died due to a discard of selective fishing, as some artisanal fishers frequently work in the study area. In addition, another sea anemone had a relatively decomposed crab on its oral disc (Figure 2C, D), and a third specimen was observed with an avian bone partially inside its gastrovascular cavity (Figure 2E, F); evidently the anemone is not feeding on the bone, this results from the lack of selectivity in prey capture. Many other specimens of *A. flosculifera* were observed in the area but hidden by rocks or inside small holes in the rocks.

In general, sea anemones are polyphagous opportunistic predators (Ayre, 1984; Acuña & Zamponi, 1995; Kruger & Griffiths, 1996; Erralde & Acuña, 2020). Erralde & Acuña (2020) recently studied the feeding ecology of the sea anemone *Bunodosoma zamponii* Gomes, Schama & Solé-Cava, 2011 in the rocky intertidal zone of Punta Cantera, Mar del Plata, Argentina. The authors found 39 different prey items in the contents of the gastrovascular cavity of 154 specimens, mainly prey such as bivalves, amphipods, algae and other molluscs. Kruger & Griffiths (1996) detail the wide variety in the diet of eight species of sea anemones and the availability of resources at two localities on the Atlantic coast of South Africa. They highlight that the anemones, in addition to feeding on bivalves, gastropods, isopods, insects, platyhelminthes and crinoids, also ingested large amounts of non-digestible waste material, indicating that sea anemones can also be considered non-selective feeders, thus ingesting everything that touches their tentacles, from dead animals (Figure 2A, B), non-digestible organic waste (Figure 2E, F), to microplastic particles or other items of anthropogenic origin (Orte *et al.*, 2019; Morais *et al.*, 2020).

In the second case, a defence mechanism of *A. flosculifera* against the nudibranch *Spurilla braziliana* MacFarland, 1909 (Figure 3A–D) was observed. The nudibranch slowly approaches the sea anemone, and then, after the first contact, *A. flosculifera* responds by retracting the tentacles and column, then by inflating the column and slowly moving away using its pedal disc. In the

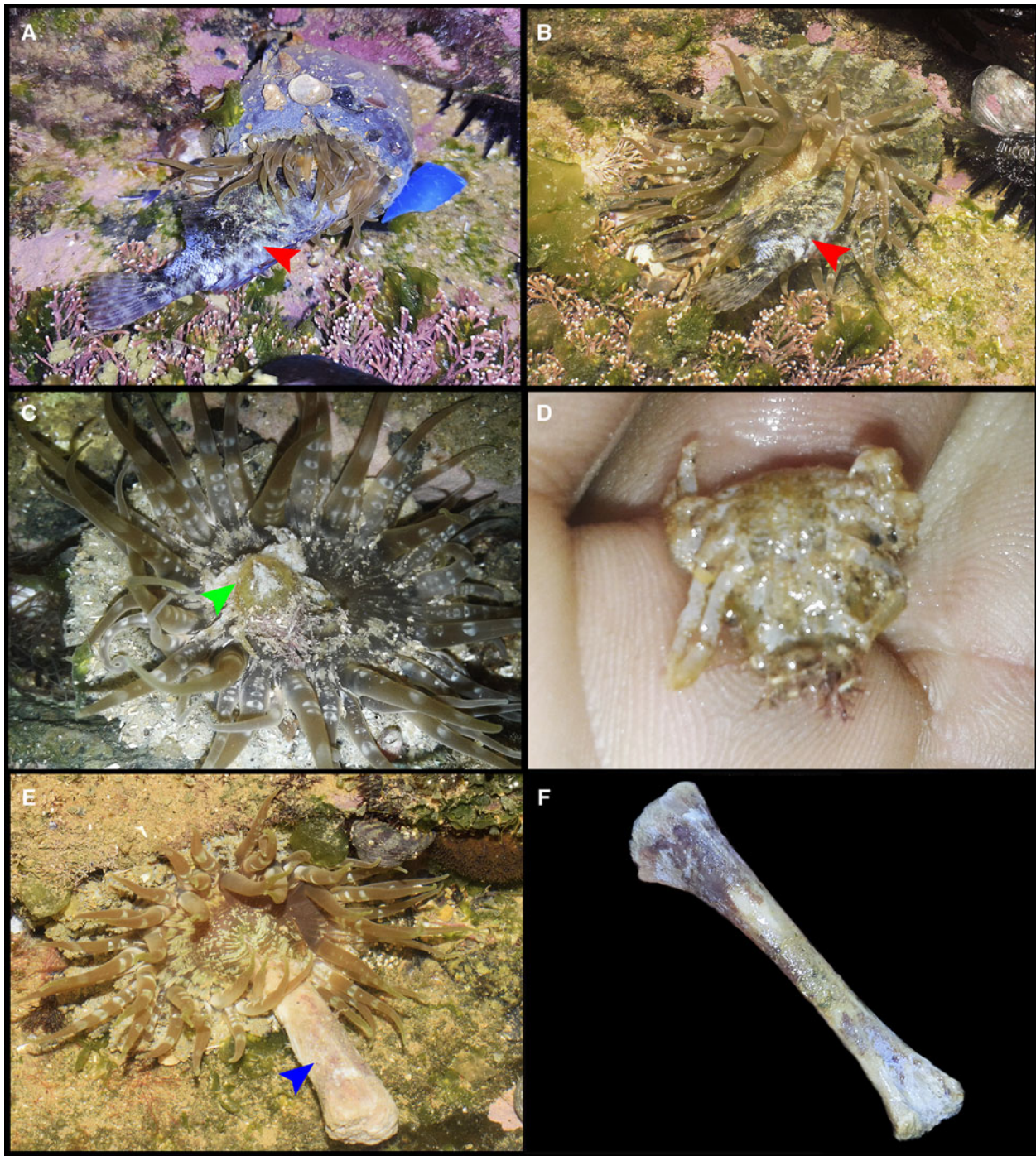


Fig. 2. *Actinostella flosculifera* (Le Sueur, 1817) feeding on: (A, B) a fish (possibly from family Serranidae) (red arrow); (C, D) a small crab (green arrow). And non-selective capture: (C–F) a bone (blue arrow).

end, the sea anemone did not detach from the substrate, and we estimated that the attack lasted between 30 and 35 min. After this time, the nudibranch stopped and remained next to the sea anemone. This behaviour can be explained based on the observations of Edmunds *et al.* (1976), where the authors mention the attack mechanism of the nudibranch *Aeolidia papillosa* (Linnaeus, 1761) and the response of the sea anemone *Actinia equina* (Linnaeus, 1758). Likewise, the nudibranch *A. papillosa* gets close enough to the column of the sea anemone, extends its buccal mass, and attaches it to the sea anemone over the column to begin feeding, causing tearing in the anemone's tissue, a process with intervals of 10–20 s. After a few minutes, the sea anemone shows signs of abrasion in the injured part by the bites. Feeding

is then interrupted for a few minutes and continues at the same side, as the nudibranch keeps feeding on the sea anemone, these pauses are longer and can last for several hours. In addition, *A. papillosa* continues to feed intermittently until it is satiated or *Actinia equina* escapes. However, when the anemone fails to escape, the nudibranch follows it wherever it goes and continues to feed on it.

Based on the above, this behaviour suggests that the sea anemone may have escaped from the nudibranch *Spurilla braziliiana* since *A. flosculifera* lives buried in sand or soft substratum fixed on some hard substrate with only the marginal ruff and oral disc protruding into the water column, with the marginal ruff extended in the form of a 'rug'. In addition,

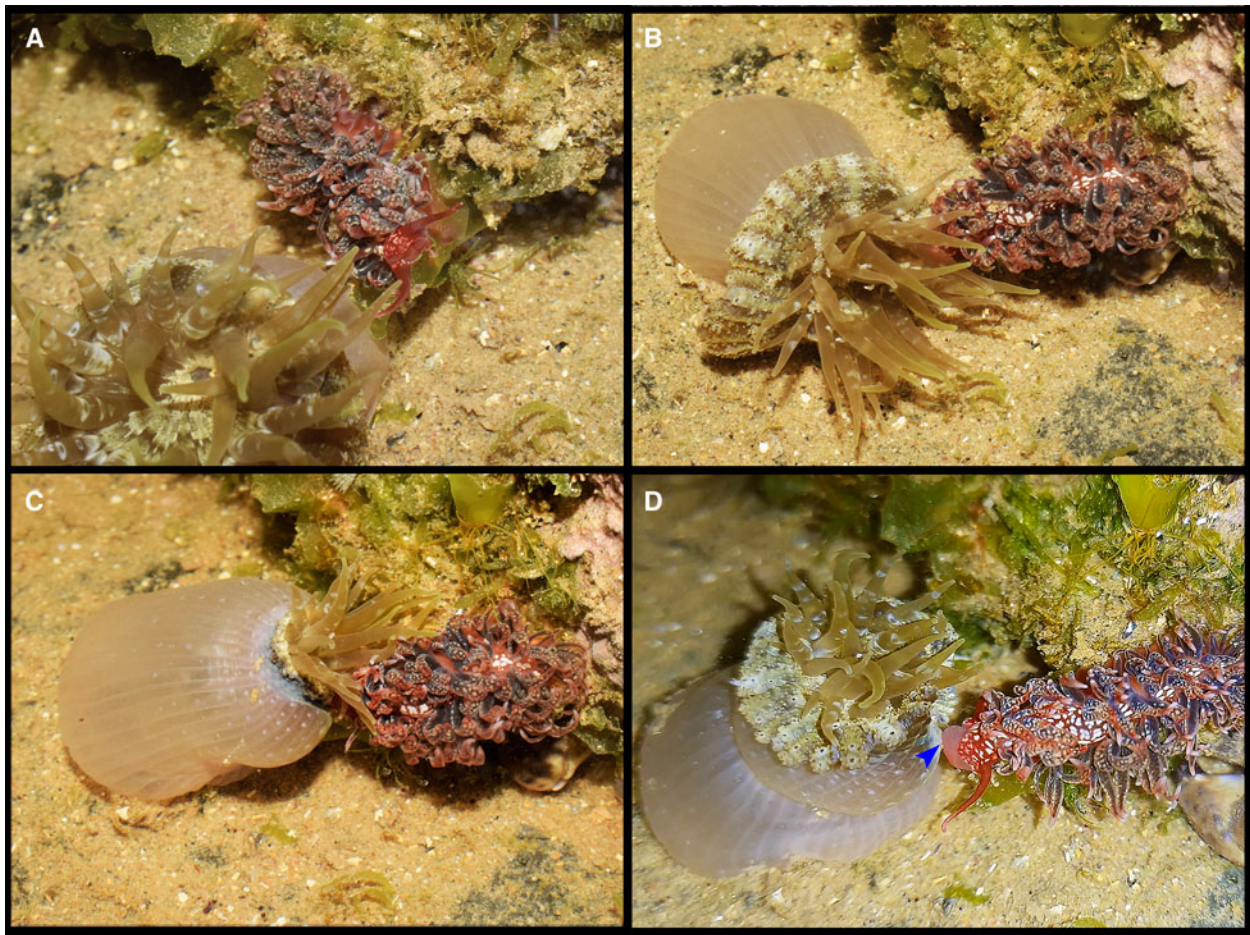


Fig. 3. (A–D) *Actinostella flosculifera* (Le Sueur, 1817) (left) being attacked by *Spurilla braziliana* MacFarland, 1909 (right). (D) Bite of the nudibranch on the sea anemone (blue arrow) with obvious column injury.

this species is characterized by the presence of verrucae in the distal region of the column next to the marginal projections, and these allow small rocks, shells or other material to adhere (Häussermann, 2003) (e.g. Figures 2A, 4E, F). In Figure 3, it is possible to observe a specimen with its column totally exposed and clean (without adhered material) and with traces of abrasion on the marginal ruff.

Moreover, some species of the genus *Spurilla* have been reported preying on sea anemones, as these nudibranchs are carnivorous and known to feed on them. They have the ability to secrete mucus to inhibit nematocyst discharge (Greenwood *et al.*, 2004), then extract nematocysts and store them in cnidosacs at the tips of their appendages (cerata) to use for defence against predators (Schlesinger *et al.*, 2009; Garese *et al.*, 2013; Bridle, 2017). However, this is the first report of *S. braziliana* showing signs of predation on *A. flosculifera*.

Finally, we observed four species of crustaceans associated with *A. flosculifera* (*Omalacantha bicornuta* (Latreille, 1825), *Menippe* cf. *nodifrons* Stimpson, 1859, *Alpheus* cf. *angulosus* McClure, 2002, and *Alpheus* cf. *carlae* Anker, 2012) (Figure 4A–F). In addition, five polyps of zoanthid *Zoanthus sociatus* (Ellis, 1768) associated with *O. bicornuta* (Figure 4A) were also observed. The interspecific relationships of sea anemones with crustaceans have been well documented (Wirtz & Diesel, 1983; Fautin *et al.*, 1995; Wirtz, 1997; Acuña *et al.*, 2003; Gusmão *et al.*, 2019, 2020; among others). Furthermore, many of these crustacean species associate with sea anemones to protect themselves against predators such as fish and octopus (Wirtz, 1997), they also feed on anemone regurgitates and mucus from the anemone's surface,

and even crops the tips of its host's tentacles (Wirtz & Diesel, 1983; Fautin *et al.*, 1995).

In contrast, the presence of alpheid (snapping shrimps) near *A. flosculifera* may be due to a mutualistic association (Figure 4C–F) between them. Smith (1977) and McCammon & Brooks (2014) evidenced that the association of *Alpheus armatus* Rathbun, 1901 with *Bartholomea annulata* (Le Sueur, 1817) showed defensive behaviour in the presence of an anemone predator, e.g. against the fire worms *Hermodice carunculata* (Pallas, 1766).

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Author contributions. JDF and SNS conceived and designed research. JDF wrote the manuscript and editing of figures. FM contributed to the field observation, and photographic evidence. All authors contributed to the writing, analysis of the document and approval of the manuscript.

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Conflict of interest. The authors declare that they have no conflict of interest.

Ethical standards. No animal testing was performed during this study.

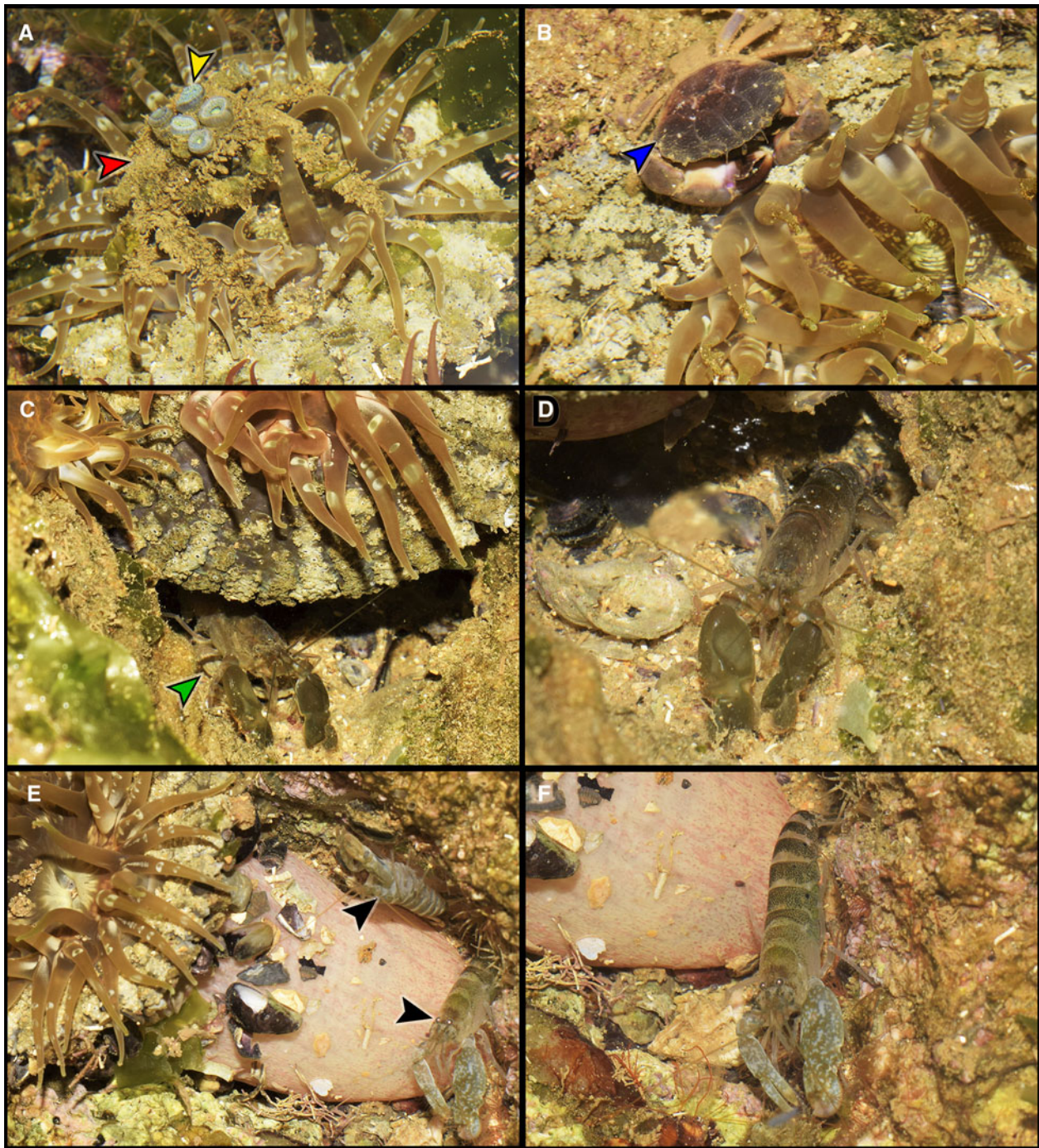


Fig. 4. Interspecific associations of *Actinostella flosculifera* (Le Sueur, 1817) with some species of crustaceans: (A) *Omalacantha bicornuta* (Latreille, 1825) (red arrow) was carrying five polyps of *Zoanthus sociatus* (Ellis, 1768) (yellow arrow); (B) *Menippe* cf. *nodifrons* Stimpson, 1859 (blue arrow); (C, D) *Alpheus* cf. *angulosus* McClure, 2002 (green arrow); (E, F) a heterosexual pair of *Alpheus* cf. *carlae* Anker, 2012 (black arrow).

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