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Caprellids in biofouling communities on aquaculture structures of the scallop *Argopecten purpuratus* (Lamarck, 1819) in northern coast of Peru, two new records

(Crustacea, Caprellidae)

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Caprellids are crustaceans belonging to the family Caprellidae (order Amphipoda). Worldwide, 447 species have been described. In Peru, the species diversity of these crustaceans remains unknown. Biofouling communities serve as habitats for colonizing caprellids. The objective of this study was to describe the species richness and biomass of caprellids on biofouling communities settle on aquaculture structures of the scallop *Argopecten purpuratus* at Sechura Bay, northern Peru. On December 08, 2020, 3 culture lanterns, 3 refloating buoys and 3 ropes were sampled. Four species of caprellids were identified: *Caprella scaura*, *C. penantis* f. *gibbosa*, *C. equilibra*, *C. penantis* [sensu lato]. High abundance of *C. penantis* [sensu lato] was recorded in buoys. *C. penantis* f. *gibbosa* was abundant in ropes, whereas *C. scaura* was abundant in lanterns. A high abundance of juveniles, males, mature and immature females was recorded in all species, regardless of the habitat. Biofouling community was different among the culture structures. Differences were driven by the contribution to the dissimilarity of the most dominant biofouling species. This study shows that caprellids use of aquaculture structures differentially, and *C. penantis* f. *gibbosa* and *C. penantis* [sensu lato] constitute 2 new records for Peru.

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Introduction

Caprellids "skeleton shrimps" are marine crustaceans belonging to the family Caprellidae (order Amphipoda) showing diverse feeding strategies; filter feeders, detritivores, carnivores and herbivores (Guerra-García & Tierno de Figueroa 2009, Alarcón-Ortega et al. 2012). Caprellids are brooders, juveniles emerge directly from the eggs deposited in the oostegites (Baeza-Rojano et al. 2011), thus, their dispersal could be assumed to be limited. However, caprellid species are widely distributed because their dispersal is assisted by rafting on artificial substrates or attached to fragments of algae or other invertebrates (Thiel et al. 2003, Guerra-García 2011).

Worldwide, 447 Caprellidae species have been reported (Horton et al. 2021). Most of these species have been described in Japan with a total of 115 species (Takeuchi 1999). On the coast of Peru (Southeast Pacific), studies on the diversity of caprellids are scarce and their presence has been recorded in a few sites together with other taxonomic groups. In the central coast of Peru, on the seabed between the San Lorenzo, El Frontón Islands and the La Punta

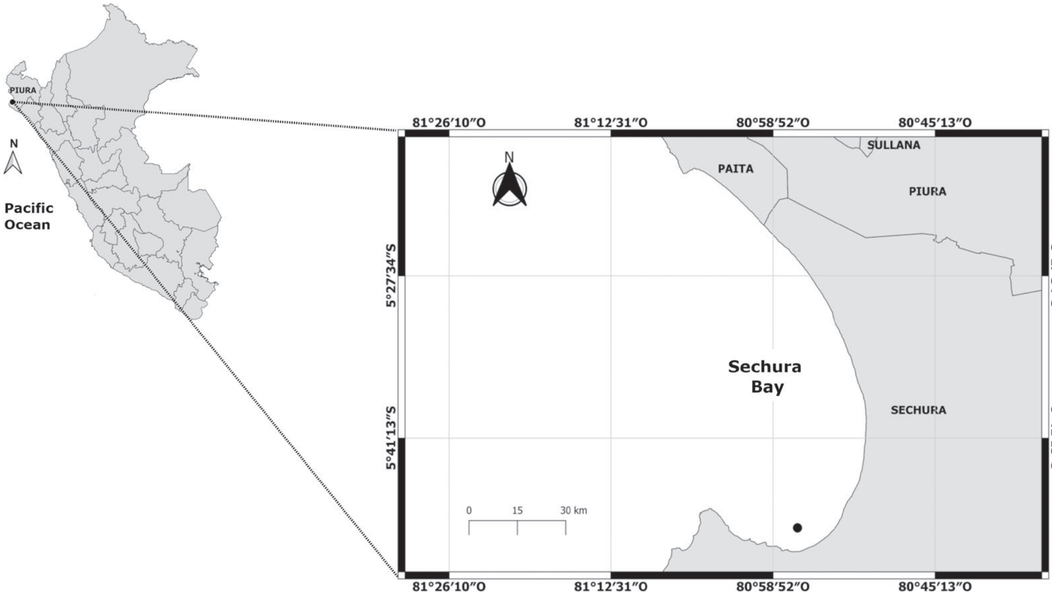

Fig. 1. Map of Peru showing the sampling area marked by a black dot in the interior of the Sechura Bay, Piura, Peru.

Peninsula (12°03'S, 77°15'W), high biomass of invertebrates including caprellids has been recorded (Argüelles et al. 2012). The presence of *Caprella* sp. has been recorded on the continental shelf of central-northern Peru (05°00'S, 81°30'W) at 90 m depth (Jiménez et al. 2018). In Paracas Bay (13°47'S, 76°14'W), a high abundance of *Caprella scaura* within the blades of the invasive macroalgae *Caulerpa filiformis* has been recorded (Pariona 2018). Caprellids have been also recorded in other localities in Paracas Bay but no detailed information on the species composition is provided (IMARPE 2010, Ibarra 2015). *Abyssicaprella galatheae* was also recorded in the abyssal zone off Paracas (McCain & Steinberg 1970). Apart from these reports, to our knowledge, no other studies are detailing the diversity of caprellids in marine habitats of Peru.

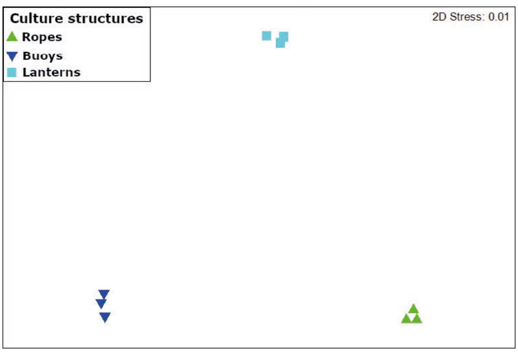

Fig. 2. nMDS ordination plot showing the dissimilarity of the biofouling community between the aquaculture structures of *Argopecten purpuratus*.

Biofouling is the community made by sessile and/or hemisessile algae and invertebrates that colonize artificial substratum submerged or in permanent contact with water (Inclán & Acosta 1989), e.g., buoys, boat hulls, ropes, among others. In Peru, the aquaculture of the scallop *Argopecten purpuratus* in suspended structures is increasing due to its high demand in international markets (Mendo et al. 2008). Some studies have revealed the diversity of biofouling organisms, including caprellids, living on the aquaculture structures of this scallop at Sechura and Samanco Bays (Pacheco & Garate 2005, Ayala 2016), being *Caprella equilibra* the most abundant species (Loayza & Tresierra 2014). Only 3 species of caprellids have been reported in Peru; *Caprella scaura*, *C. equilibra* and *A. galatheae*, however, due to the lack of research on this group, it is thought that the diversity of these crustaceans could be underestimated. The objective of this study was to determine the species composition and abundance of caprellids associated with biofouling communities colonizing aquaculture structures of *A. purpuratus* at Sechura Bay, on the northern coast of Peru.

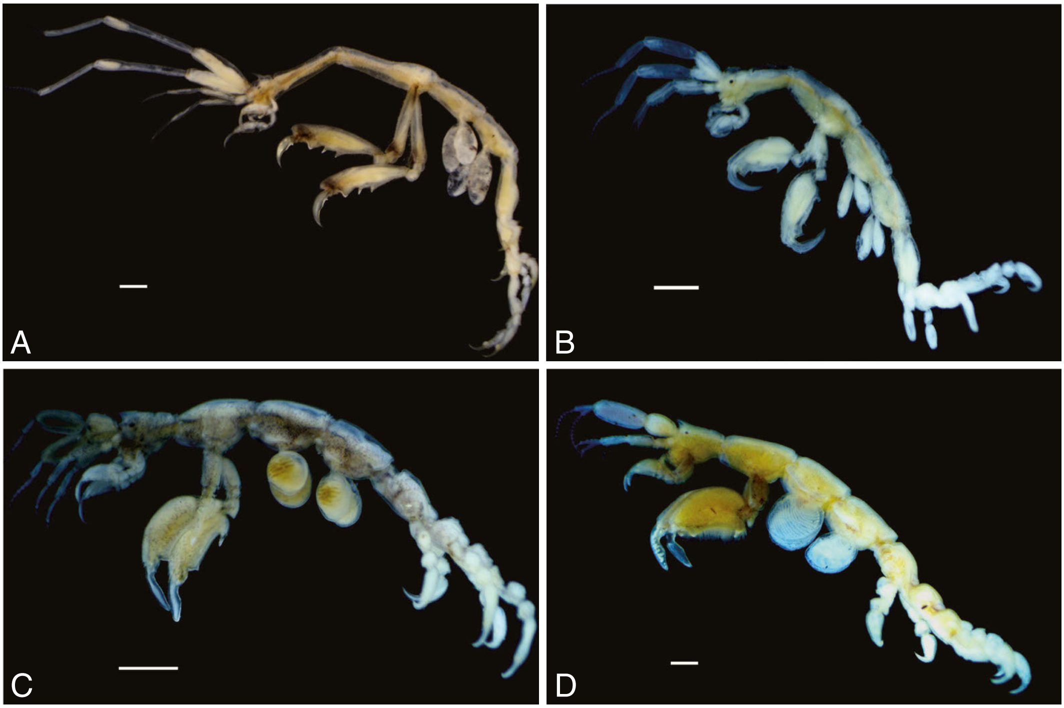

Fig. 3. Males of the caprellid species recorded in the present study. **A.** *Caprella scaura*. **B.** *C. equilibra*. **C.** *C. penantis* f. *gibbosa*. **D.** *C. penantis* [sensu lato]. Scale bars: 1 mm.

Material and methods

Study location and sampling

Sampling was conducted in the *A. purpuratus* aquaculture facility (05°48'46.8''S, 80°56'48.6''W) of the Asociación de Pescadores Extractores Artesanales "El Edén" located in the Sechura Bay, Peru (Fig. 1). On December 08, 2020, biofouling samples were collected from 3 culture lanterns, 3 buoys and 3 ropes. A 20 x 20 cm quadrat and a metal spatula were used for collection. Biofouling was collected in 3 replicated quadrats in each lantern, while at each buoy 2 replicated samples were taken. In addition, all biofouling was scraped from 3 ropes of 50 cm in length each. All the collected organisms were deposited in plastic jars and fixed with an 85 % ethanol solution.

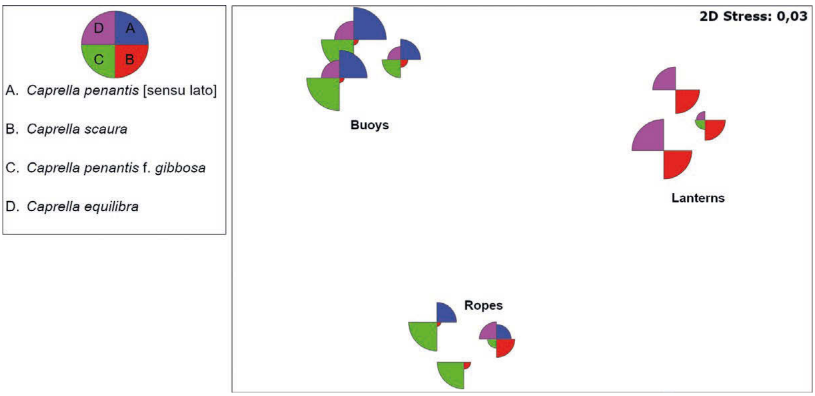

Fig. 4. nMDS ordination plot showing the average biomass (g/m²) of caprellid species on each aquaculture structure.

Sample processing

In the laboratory, all the biofouling was placed in a plastic container filled with fresh water and gently agitated to dislodge invertebrates and algae. The biological material was examined under a stereomicroscope and identified to the lowest possible taxonomic level using specialized taxonomic descriptions and keys (e. g. Moscoso 2013, Uribe et al. 2013, Arakaki et al. 2018, Carbajal et al. 2018). Thereafter, biofouling organisms were preserved in plastic jars with an 80 % ethanol solution. To collect caprellids, after removing the dislodged biofouling from the container, the material was sieved with 100 µm (Ros et al. 2013), and the retained organisms were deposited in small plastic jars, labeled, and preserved in 80 % ethanol for further detailed analysis. Caprellid individuals were classified as juveniles, males, immature females, and mature females. Females were considered mature when the oostegites were fully developed, and immature when the oostegites looked incipient (Guerra-García et al. 2015). Caprellid specimens were identified to the lowest possible taxonomic level using taxonomic keys provided in Guerra-García & Thiel (2001), Díaz et al. (2005) and Lacerda & Masunari (2011). Morphological descriptions were aided using a USAMED stereo microscope, with a Euromex digital camera. Since biofouling organisms were mostly colonial forms, biomass was estimated as an indicator of the abundance of each species in each sampling unit for further analyses (e. g. Zúñiga-Ríos et al. 2012, Martínez-Daranas et al. 2016). Biomass (g) of the organisms was obtained by recording wet weight (0.001 g), and each value was extrapolated to a square meter (m²) for each aquaculture structure.

Table 1. Taxa and average biomass (g/m²) of biofouling collected in aquaculture structures of Argopecten purpuratus.

Taxa	Culture structures		
	Lanterns	Ropes	Buoys
Rhodophyta			
Chondracanthus chamissoi	604.8	1467.2	139.8
Chlorophyta			
Bryopsis plumosa	0.0	0.0	391.2
Ulva lactuca	0.0	74.9	174.4
Bryozoa			
Bugula neritina	110.4	0.0	0.0
Hydrozoa			
Aglaophenia sp.	44.1	0.0	0.0
Tubularia sp.	72.7	725.4	36.1
Platyhelminthes			
Planariidae	0.0	0.1	0.5
Porifera			
Demospongiae sp. 1	705.4	85.4	365.3
Demospongiae sp. 2	216.5	0.0	0.0
Mollusca			
Semimytilus algosus	0.0	2192.5	81.5
Arthropoda			
Microphrys sp.	15.8	0.0	0.0
Acanthonyx petiverii	0.8	208.2	0.3
Pilumnoides perlatus	52.8	3.1	90.4
Pachycheles crinimanus	0.6	0.1	0.0
Penaeidae	0.0	3.9	0.0
Austromegabalanus psittacus	0.0	0.0	3155.6
Gammaridea	88.3	60.7	73.1
Caprella penantis [sensu lato]	0.0	2.6	24.8
Caprella scaura	277.9	27.9	1.1
Caprella penantis f. *gibbosa*	0.2	25.4	49.5
Caprella equilibra	8.6	0.6	1.8
Annelida			
Nereis callaona	7.4	210.7	10.5
Halosydna sp.	0.0	210.9	1.0
Chordata			
Ciona intestinalis	1624.6	0.0	0.0

Statistical analysis

Non-metric multidimensional scaling (nMDS) ordination analysis was used to examine community dissimilarity between buoys, ropes, and culture lanterns. A nMDS with the option "bubble plot" was used to visualize the biomass distribution of caprellid species and the sex and sexual maturity groups of these species between structures. Associations of biofouling biomass and caprellid species were also analysed using nMDS with bubble plot. It was considered as a good association when the biomass of both species (caprellid-biofouling) was similar or one of them was more than half the biomass value of the other. Finally, the contribution of biofouling species and associated caprellids to the differences between aquaculture structures was evaluated using Similarity Percentages Analysis (SIMPER). Statistical analyses were carried out using PRIMER 7 (Clarke & Gorley 2015).

Results

Biofouling community

A total of 24 taxa were recorded forming the biofouling community (Table 1). Barnacles (22.9 %), algae (20.7 %), sponges (9.9 %), bivalves (16.5 %), ascidians (11.8 %), hydrozoans (6.3 %), polychaetes (3.2 %), caprellids (3.0 %), decapods (2.7 %), gammarids (1.6 %), bryozoans (0.8 %) and planarians (< 0.1 %) composed the biofouling. An important dissimilarity in the biofouling community between the structures was observed (Fig. 2). The barnacle *Austromegabalanus psittacus* and the mussel *Semimytilus algosus* contributed most to the dissimilarity between ropes and buoys. Dissimilarity between ropes and lanterns was determined by *S. algosus* and the ascidian *Ciona intestinalis*, whereas *A. psittacus* and *C. intestinalis* were the species that contributed most to the dissimilarity between buoys and lanterns. Caprellid species contributed little to the dissimilarity between structures (Table 2).

Caprellids in biofouling communities

Four species of caprellids were identified: *Caprella scaura* Templeton, 1836; *Caprella equilibra* Say, 1818; *Caprella penantis* f. *gibbosa* Mayer, 1890 and *Caprella penantis* Leach, 1814 [sensu lato] (Fig. 3). The caprellid assemblages associated with biofouling were dissimilar between aquaculture structures, which contributed to the differential distribution in biomass. *C. penantis* f. *gibbosa* biomass was higher in ropes, whereas *C. scaura* together with *C. equilibra* were abundant in lanterns. *C. penantis* [sensu lato] was absent in lanterns, but its biomass was higher in buoys together with *C. penantis* f. *gibbosa* (Fig. 4). Biomass of juveniles, males, mature and immature females was high in all caprellid species, without showing a preference for a particular structure (Fig. 5). Syntype samples were deposited in the Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Lima, Peru, under the following accession codes: MUSM-INV 4729-4732 (*Caprella scaura*); MUSM-INV 4733–4736 (*Caprella equilibra*); MUSM-INV 4737-4740 (*Caprella penantis* f. *gibbosa*); MUSM-INV 4741-4744 (*Caprella penantis* [sensu lato]).

Dominant biofouling species and caprellids

Caprella scaura biomass was associated with *Bugula neritina*, *Ciona intestinalis*, *Chondracanthus chamissoi*, *Tubularia* sp., Demospongiae sp. 1 and Gammaridea in lanterns. In ropes and buoys, it was associated with *Acanthonyx petiverii*, *Halosydna* sp. and *Nereis callaona*. In buoys, it was associated with *Semimytilus algosus*. On the other hand, *Caprella penantis* [sensu lato] biomass was associated with *Austromegabalanus psittacus*, *Bryopsis plumosa*, *Ulva lactuca*, *Pilumnoides perlatus* and Planariidae in buoys. In ropes, it was associated with *Ch. chamissoi* and *S. algosus*. In buoys and ropes, it was associated with gammarids (Fig. 6). *Caprella equilibra* was associated with *B. neritina, C. intestinalis, Ch. chamissoi*, *Tubularia* sp. and Demospongiae sp. 1 in lanterns. In buoys, it was associated with *A. psittacus*, *B. plumosa*, *N. callaona*, *S. algosus* and *U. lactuca*. In lanterns and buoys, it was associated with the gammarids. On the other hand, *C. penantis* f. *gibbosa* was associated with *A. psittacus*, *B. plumosa*, *U. lactuca* and Planariidae in buoys. In ropes, it was associated with *Ch. chamissoi* and *S. algosus*. In buoys and ropes, it was associated with gammarids (Fig. 7).

Discussion

This study shows the presence of four species of caprellids in aquaculture structures of *A. purpuratus* in northern Peru, which showed a different distribution depending on the colonizing structure. However, when considering sex and sexual maturity, caprellids did not show clear differentiation in artificial structures. The biofouling community

Table 2. Results of SIMPER analysis showing the species contribution to the dissimilarity between structures. Abbreviations: DM, mean dissimilarity; BM, average biomass (g/m²); Cont (%), contribution percentage.

Structure 1–2 (DM)	Taxa	BM 1	BM 2	Cont (%)
Rope–Buoy (74.5)	*A. psittacus*	0	54.29	25.20
	S. algosus	42.24	6.38	16.05
	Ch. chamissoi	35.81	6.83	13.65
	B. plumosa	0	17.56	8.78
	Tubularia sp.	20.07	3.47	7.95
	Demospongiae sp.1	5.29	11.03	5.18
	U. lactuca	4.95	12.23	4.86
	N. callaona	8.95	3.09	3.25
	Halosydna sp.	8.83	0.63	3.10
	A. petiverii	8.60	0.51	2.88
Rope–Lantern (77.2)	*S. algosus*	42.24	0	18.36
	C. intestinalis	0	40.20	18.34
	Ch. chamissoi	35.81	17.33	10.95
	Demospongiae sp.1	5.29	21.66	9.04
	Tubularia sp.	20.07	6.84	7.12
	C. scaura	3.60	16.15	5.92
	B. neritina	0	10.5	4.77
	Demospongiae sp.2	0	8.50	4.12
	Halosydna sp.	8.83	0	3.00
	N. callaona	8.95	2.25	2.99
	A. petiverii	8.60	0.71	2.85
	P. perlatus	1.14	4.89	2.21
	C. penantis f. *gibbosa*	4.28	0.24	2.08
Buoy–Lantern (82.7)	*A. psittacus*	54.29	0	22.18
	C. intestinalis	0	40.20	16.95
	Demospongiae sp.1	11.03	21.66	7.84
	B. plumosa	17.56	0	7.70
	Ch. chamissoi	6.83	17.33	6.83
	C. scaura	0.96	16.15	6.29
	U. lactuca	12.23	0	4.96
	B. neritina	0	10.50	4.41
	Demospongiae sp.2	0	8.50	3.80
	S. algosus	6.38	0	2.84
	P. perlatus	6.86	4.89	2.81
	C. penantis f. *gibbosa*	6.49	0.24	2.75
	Tubularia sp.	3.47	6.84	2.52

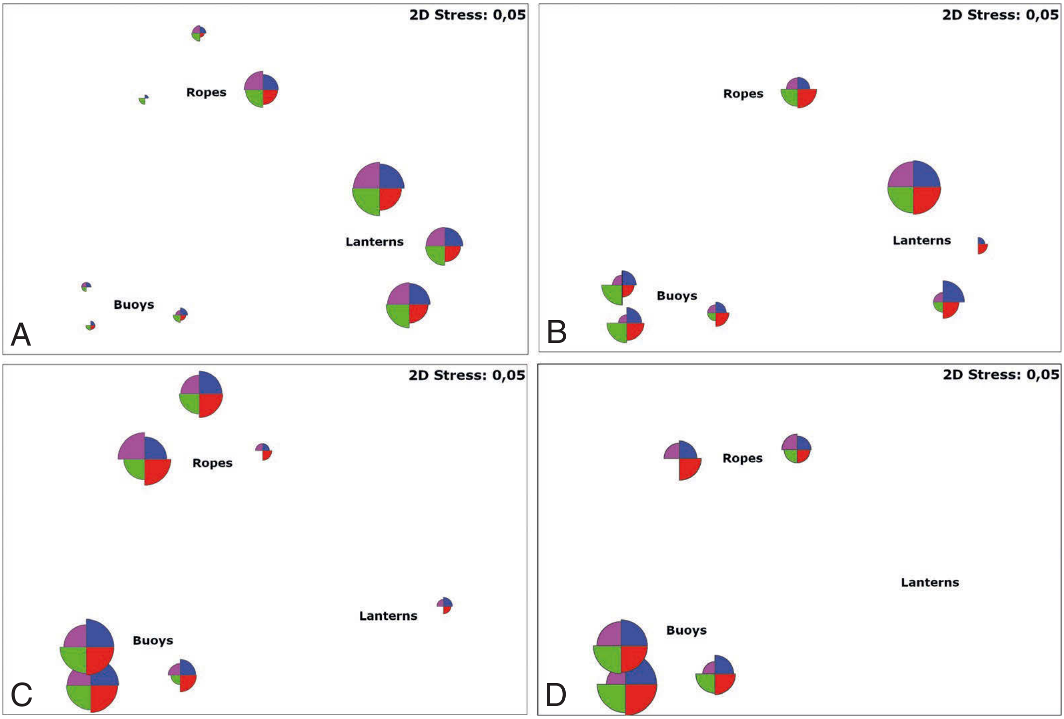

Fig. 5. nMDS ordination plot showing the average biomass (g/m²) of caprellid species by males (blue), mature females (red), immature females (green) and juveniles (pink) on each aquaculture structure. **A.** *Caprella scaura*. **B.** *C. equilibra*. **C.** *C. penantis* f. *gibbosa*. **D.** *C. penantis* [sensu lato].

structure consisted of 24 taxa and important dissimilarity between artificial structures was detected. The ascidian *C. intestinalis*, barnacle *A. psittacus* and mussel *S. algosus* contributed the most to this dissimilarity among aquaculture structures, while caprellid species contributed little to this dissimilarity. Associations between the biomasses of caprellids and biofouling organisms were also detected.

Caprella scaura is a species distributed in the Pacific Ocean (Thiel et al. 2003), Indian Ocean (Guerra-García 2004), Atlantic Ocean (Rodríguez-Aimaraz & Ortega-Vidales 2013), and Mediterranean Sea (Krapp et al. 2006). In the coast of Peru, *C. scaura* had been recorded in the central coast, specifically in the Paracas Bay (Pariona 2018), and at Melchorita beach (13°15.15′S, 76°18.5′W) (Tasso et al. 2018). On the north coast, this species was associated with the bottom culture of *A. purpuratus* at Sechura Bay (Vivar 2016). Thus, our study confirms the presence of *C. scaura* in Sechura Bay but in suspended aquaculture structures of *A. purpuratus*. *C. scaura* biomass was associated with bryozoan *B. neritina*. This association can be explained by morphological similarities of the two species; *C. scaura* mimics the morphology of *B. neritina* (Ros et al. 2013). In addition, *B. neritina* does not present defense structures called avicularia, which would allow *C. scaura* to live among the branches of *B. neritina* to avoid predation (Ros et al. 2013). Also, *C. scaura* was associated with hydrozoan *Tubularia* sp. Cunha et al. (2018) suggest that hydrozoans provide adequate structures for juvenile caprellids to attach themselves using their pereiopods.

Caprella equilibra was only reported in Peru at Samanco Bay, Ancash, located on the central-north coast (Loayza & Tresierra 2014). The present study extends the distribution range of *C. equilibra* northwards along the coast of Peru. Our results show that the biomass of *C. equilibra* was lower than *C. scaura* in lanterns. Ros et al. (2015, 2021) and Guerra-García et al. (2011) indicate that *C. equilibra* and *C. scaura* may compete for space, being *C. scaura* the dominant competitor thus displacing *C. equilibra* from the substratum. The results of the present study suggest that this may be happening in Sechura Bay. *C. equilibra* biomass was associated with *Tubularia* sp. The thin and translucid body of *C. equilibra* could allow camouflage within the hydrozoan (Keith 1971). Also, *C. equilibra* was associated with *C. intestinalis*. Mayer (1882) observed that many individuals of

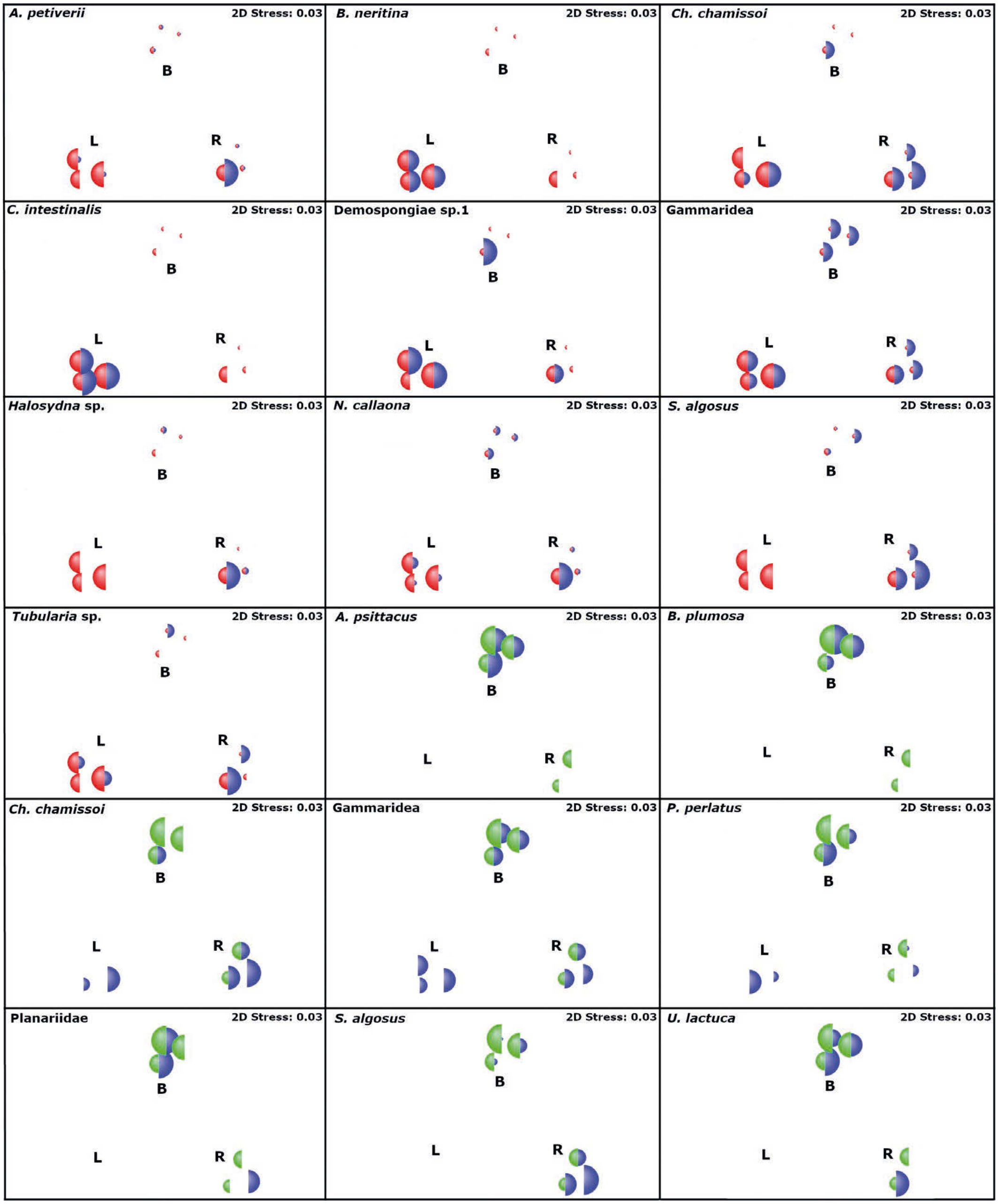

Fig. 6. nMDS ordination plot showing similar levels of biomass (g/m²) of *Caprella scaura* (red), *C. penantis* [sensu lato] (green) and the biofouling organisms (blue) in the culture structures of *Argopecten purpuratus*. **B** = Buoys, **R** = Ropes, **L** = Lanterns.

C. equilibra were located close to the inhalant siphon of *C. intestinalis*, suggesting that they benefited from the incoming water for feeding.

Caprella penantis f. *gibbosa* is recorded for the first time in Peru. Before this study, this species had been recorded only from Chile (Mayer 1890, 1903, Guerra-García & Thiel 2001). Thus, the specimens recorded in the present study are morphologically similar to those described in Chile, suggesting a northward extension in the distribution of this species along the southeastern Pacific coast. *C. penantis* f. *gibbosa* was important in colonizing ropes and buoys. On the coast of central Chile, this species was often found on buoys (Guerra-García & Thiel 2001). Thiel et al. (2003) suggest that anchored buoys would allow rapid development of caprellid populations, and detached buoys facilitate their dispersal over great distances. Also, *C. penantis* f. *gibbosa* did not show a particular association with other biofouling organisms, and dietary analyses of this caprellid species indicate feeding almost exclusively on detritus (Guerra-García & Tierno de Figueroa 2009).

Caprella penantis [sensu lato] is also recorded for the first time in Peru. *C. penantis* is a species complex (Cabezas et al. 2010, 2013). The specimens recorded in the present study partially resemble the morphology of *Caprella dilatata* and *C. penantis*. In male specimens, the palm of the propodus of the Gnathopod 2 (Gn2) has a trapezoidal process in the distal zone, and a robust tooth in the proximal zone (Fig. 8). The palm of the propodus of Gn2 in males of *C. dilatata* only has a spine and a trapezoidal process in the distal zone, while *C. penantis* only has a little spine in the proximal zone (Masunari & Takeuchi 2006, Lacerda & Masunari 2011). In female specimens, a projection in the ventral zone of Pereonite 2 (P2) was observed, and the palm of the propodus of Gn2 has a spine in the proximal zone, a protuberance in the medial zone, and a trapezoidal process in the distal zone (Fig. 8). In females of *C. penantis* and *C. dilatata* the ventral projection is absent in P2, and the palm of propodus of Gn2 has only a little spine in the proximal zone (Masunari & Takeuchi 2006). All these morphological characteristics allowed us to classify these caprellid specimens as *C. penantis* [sensu lato], and it may constitute a new species of caprellid. Further study is still required. *C. penantis* [sensu lato] biomass was associated with algae *U. lactuca*, *Ch. chamissoi* and *B. plumosa*. However, *C. penantis* has been found associated with more than 30 species of algae (Guerra-García et al. 2010). Therefore, it is suggested that this caprellid species colonizes a wide range of substratum types.

This study shows for the first time a detailed diversity of caprellids associated with biofouling on culture structures of *A. purpuratus* in the northern coast of Peru. Considering that the sampling was carried out at a single site and date, further sampling effort on artificial and natural habitats is recommended. The presence of one potential new species suggests that the diversity of caprellids in Peru is still underestimated.

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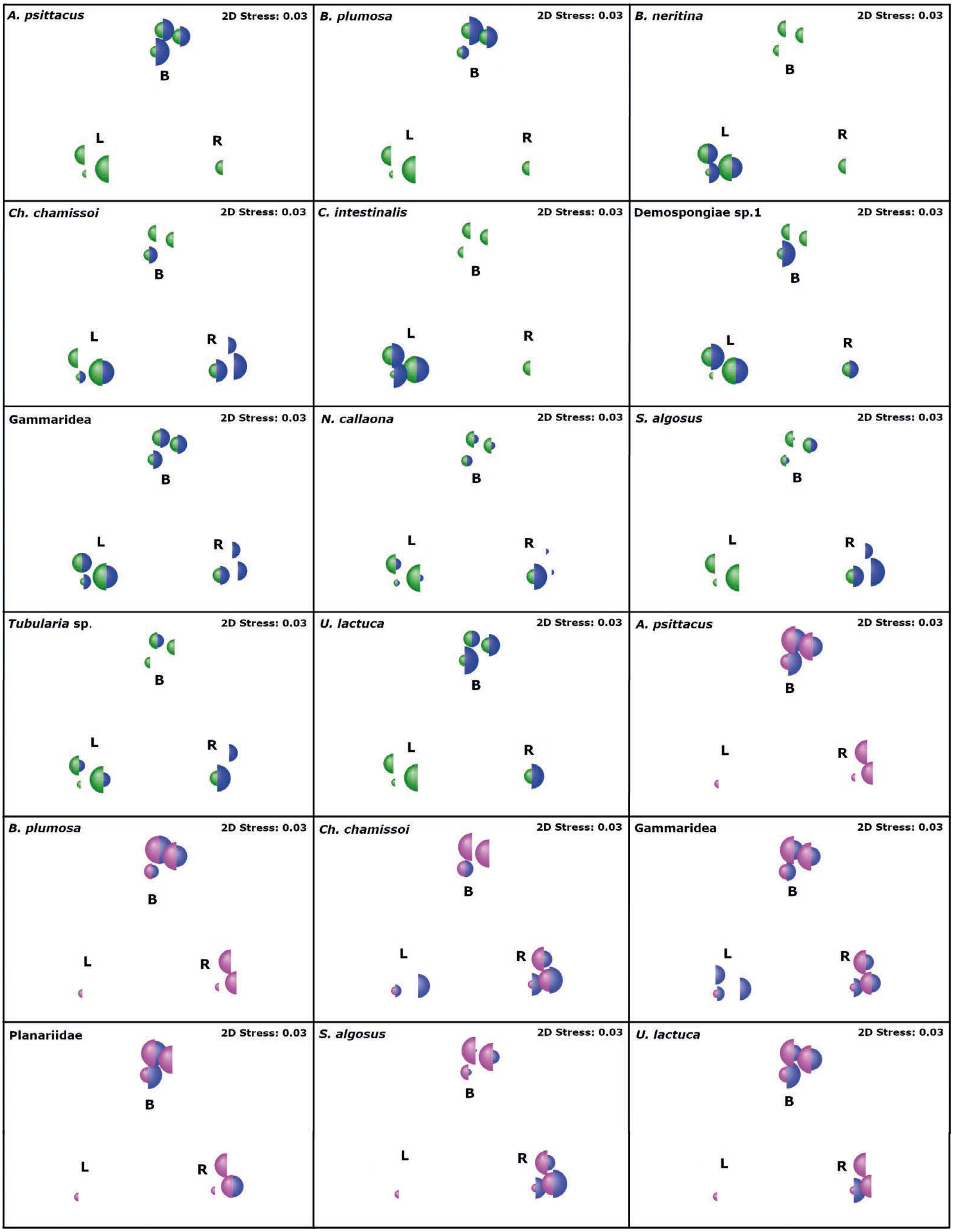

Fig. 7. nMDS ordination plot showing the average biomass (g/m²) of *Caprella equilibra* (green), *C. penantis* f. *gibbosa* (pink) and the biofouling organisms (blue) in the culture structures of *Argopecten purpuratus*. **B** = Buoys, **R** = Ropes, **L** = Lanterns.

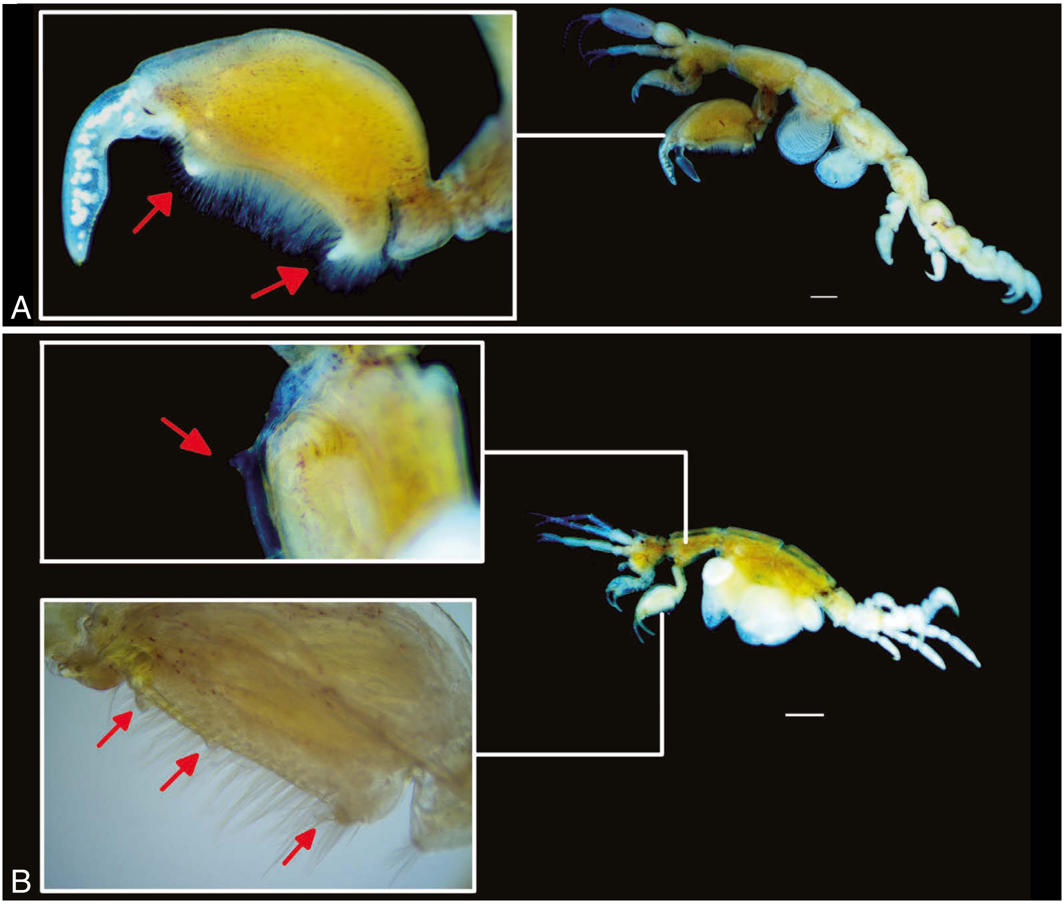

Fig. 8. Male and mature female of *Caprella penantis* [sensu lato]. Red arrows point to their main morphological characters. **A.** Male: palm of the propodus of Gnathopod 2 with a trapezoidal process in the distal zone, and a robust tooth in the proximal zone. **B.** Mature female: a projection in the ventral zone of Pereonite 2 (upper box), and the palm of the propodus of Gnathopod 2 with a spine in the proximal zone, a protuberance in the medial zone, and a trapezoidal process in the distal zone (lower box). Scale bars: 1 mm.

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