

Crabs associated with rhodolith seabeds: spatio-temporal variability in Gran Canaria Island

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Trabajo de fin de título presentado por Clara Sánchez Latorre para la obtención del Grado en Ciencias del Mar por la Universidad de Las Palmas de Gran Canaria.

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A handwritten signature in black ink, appearing to read 'CLARA SANCHEZ LATORRE'.

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Abstract

Rhodoliths are nodules of branching and unattached coralline red algae, which form relatively stable three-dimensional structures, providing a relevant habitat for associated invertebrates. Crustaceans are a key component of the fauna living in rhodolith beds, despite patterns in their distribution and abundance remain largely unknown. The overall objective of this study was to understand the spatio-temporal variability of crabs (Brachyura) associated with rhodoliths. In particular, rhodolith seabeds were seasonally studied at three depth strata (18, 25 and 40 m) through two successive years in Gran Canaria Island. Eight seasonal sampling campaigns were carried out, from December 2015 to October 2017. Samples were recolected using SCUBA at each of the three depth strata. Crabs were identified under a stereomicroscope, for a total of 808 individuals. The species *Nanocassiope melanodactylus* dominated the assemblage (*ca.* 80% of the total abundance), with more juvenile individuals living in deeper waters (40 m) than adults, which were more abundant at 18 m and 25 m depth. A higher richness of Brachyura was observed at 25 m, relative to 18 m and 40 m depth, where crabs found an ideal habitat. The species *Pilumnus* sp. followed this pattern, being more abundant at 25 m and almost absent at 18 m and 40 m. Nevertheless, *Pisa carinimana* and *Achaeus* sp. did not show any spatio-temporal pattern. This study has shown, therefore, that certain crab species associated with rhodolith seabeds are bathymetrically segregated. The larger abundance and richness of crabs at 25 m correlated with the biomass of epiphytic algae attached to rhodoliths, which therefore seem to provide food and refuge for crabs.

1. Introduction

Rhodoliths are nodules of individual, branching and unattached forms of non-geniculate (non-articulated) coralline red algae (Corallinaceae, Rhodophyta) with a calcified thallus, which form relatively stable three-dimensional structures and large heterogeneous beds of biogenic substrates on sedimentary benthos (Figure 1) (Steller *et al.*, 2003; Steller and Cáceres-Martínez 2009; Otero-Ferrer *et al.*, 2019). These beds are found worldwide, from the tropics to the poles, and from the intertidal zone to depths of over 200 m (Foster 2001; Nelson *et al.*, 2012). They have relatively slow growth rates and a perennial life strategy; some thalli can live >100 years (Hernandez-Kantun *et al.*, 2017).



Figure 1. Nodules of rhodoliths. Picture taken by Fernando Espino Rodríguez.

As they are not attached to a fixed surface, individual thalli are exposed to the action of waves and currents and have the potential to be rolled or moved on the seafloor. Hydrodynamic conditions, species, rhodolith nucleus and light are pivotal factors for their growth, morphology and, therefore, heterogeneity in rhodolith seabeds (Rebelo *et al.*, 2018; Otero-Ferrer *et al.*, 2019). It is possible that the natural patterns of disturbance in rhodolith beds affect the associated biodiversity (Hinojosa-Arango *et al.*, 2009).

In terms of area covered, rhodolith beds (Figure 2) may be one of the Earth's "Big Four" benthic communities that are dominated by marine macrophytes: kelp beds and forests, seagrass meadows and non-geniculate coralline reefs (Foster 2001). Rhodoliths seabeds occur in large extensions in the Canary Islands (Central-East Atlantic Ocean), despite few studies concerning basic ecological questions have been carried out (Rebelo *et al.*, 2018). These habitats can be found from 15 m all the down to 100 m depth in the Atlantic archipelago, so large variation in the spatial configuration is expected across a vertical axis (Riera *et al.*, 2012).

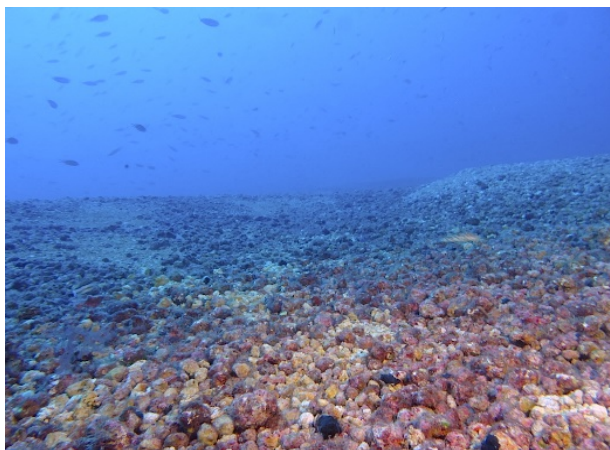


Figure 2. Rhodolith seabeds. Picture taken by Fernando Espino Rodríguez.

These structures have considerable ecological significance because they provide amounts of internal space in comparison to their total volume, representing a habitat for other algae and invertebrates, including abundant juvenile stages (Steller *et al.*, 2003; Hinojosa-Arango and Riosmena-Rodríguez, 2004; Kamenos *et al.*, 2004; Steller and Cáceres-Martínez, 2009; Otero-Ferrer *et al.*, 2019). Hence, rhodoliths are considered habitat modifiers or bioengineers due to their wide variety of ecological niches and resources, compared to surrounding habitats (Nelson *et al.*, 2012). In addition, rhodoliths provide a basal habitat for epiphytes (and fauna) to attach, which considerably increase the complexity of the entire ecosystem. These distribution patterns of marine benthic organisms can be seasonal or continuous throughout the year (García-Sanz *et al.*, 2014). Therefore, patterns of recruitment and growth are key structural elements in the marine benthos.

Typically, a higher biodiversity of epifauna is found in rhodolith ecosystems than over other common substrata (e.g. sandy substrates) (Steller *et al.*, 2003; Kamenos *et al.*, 2004; Amando-Filho *et al.*, 2007; Steller and Cáceres, 2009). Moreover, De Grave (1999); Hinojosa-Arango and Riosmena-Rodríguez (2004); Sciberras *et al.* (2009) and Otero-Ferrer *et al.* (2019) found crustaceans as one of the most abundant faunal group, in particular the order Amphipoda, which appeared to be the dominant fauna living in association with rhodolith beds. However, despite few studies mention the infraorder Brachyura (crabs) in these habitats (Bouzon and Freire, 2007; Herrera-Martínez *et al.*, 2013; Koettker and Lopes, 2013; Otero-Ferrer *et al.*, 2019), none explained the distribution of those animals living in these three-dimensional structures. In other words, there is a gap in our understanding of the magnitude of spatial and temporal variation in crustaceans living in rhodolith beds.

The Spanish crustacean fauna is one of the most known worldwide and, with polychaetes and molluscs, one of the most important zoological groups coastal waters. This subphylum is particularly interesting, beyond scientific investigation, being an

objective of global fisheries with high economic value. Decapods dominate the crustacean fauna, representing almost a third part (González, 1995). There are 73,141 crustacean species described in Spain and 6,500 of them belong to the infraorder Brachyura, the most diverse and rich group with 77 genera and 139 species, accounting for to a 31.8% of the whole marine Iberian fauna (García Raso and Mateo Ramírez, 2015).

Brachyuran crabs (Figures 3, 4 and 5), also known as true crabs, are found both in marine environments and fresh waters worldwide, from coastal shallow waters to the deep ocean. The carapace of Brachyuran crabs is usually wider than longer, and their abdomen is short, small and folded under the cephalothorax (Figure 4). The pleon is symmetric, small and triangular in males and wide and round in females, to facilitate the carrying of eggs (Thatje and Calcagno, 2014) (Figure 5).



Figure 3. Dorsal view of a Brachyuran crab (*Nanocassiope melanodactylus*).



Figure 4. Ventral view of a Brachyuran crab, including the abdomen (*Nanocassiope melanodactylus*).



Figure 5. Presence of eggs in a Brachyuran crab (*Nanocassiope melanodactylus*).

True crabs are found in all types of habitats and this has led to a very varied morphology. Their legs are laterally flattened; the length and form of legs change, depending on their habitat. For example, most of the species are unable to swim, but the family Portunidae own well developed oars on their last pair of legs, which allow them to swim (Thatje and Calcagno, 2014).

Brachyura have been historically a difficult group for taxonomists. The systematic classification has changed over time and will keep changing, as a result of new discoveries facilitated by the implementation of molecular tools. In brief, the classification of crabs follows this hierarchical scheme (Thatje and Calcagno, 2014):

Phylum Arthropoda

Subphylum Crustacea

Class Malacostraca

Order Decapoda

Suborder Pleocyemata

Infraorder Brachyura Linnaeus, 1758

Brachyura found in the Canary Island have been listed in some papers. After the work of González (1995), who compiled Canarian decapod crustaceans, Moro *et al.* (2014) published a list of decapods and *in situ* sightings, illustrated with color photographs. Moreover, some articles have been published with updated lists of Brachyuran decapod fauna from the Canary Islands (González, 2016; González *et al.*, 2017). However, few or scarce information is already published about the distribution of these faunal groups in rhodoliths seabeds (Riera *et al.*, 2012). The overall objective of this study was to understand the spatio-temporal variability of the fauna associated with rhodoliths, more specifically of Brachyuran crabs. In particular, rhodolith seabeds were seasonally studied at three depth strata through two successive years (i.e. eight times). Despite the effect of depth over the biology and morphology of rhodoliths has been widely studied, no study has analyzed whether the distribution and abundance of associated invertebrates change through bathymetrical gradients at varying seasonal scales. Specifically, this study tested the hypothesis that seasonal patterns in the distribution and abundance of Brachyuran crabs may vary over an annual cycle according to the different life traits of organisms (García-Sanz *et al.*, 2014).

In brief, this project first determined the species/genera in samples collected at varying depths and seasons, and then established spatial and temporal patterns for their distribution. We expected that depth and seasons affected the distribution, as well as abundances, of true crabs. Furthermore, we expected to find a discernible pattern for the breeding season of different genera or families.

2. Material and methods

2.1. Study area

The location of this study was the east coast of Gran Canaria Island (Canary Islands, eastern Atlantic Ocean), on a rhodolith bed near Gando Bay ($27^{\circ}55'54''\text{N}$, $15^{\circ}21'11''\text{W}$) (Figure 6). Rhodolith samples were taken, at each of the four seasons, during two successive years (2015 – 2017) at three different depths (18 m, 25 m and 40 m). In this area, the NE trade winds notably determine the Canarian coastal weather. The rhodolith beds are mainly composed by several genus of red calcareous algae, such as *Lithothamnion* sp. and *Phymatolithon* sp. (Haroun *et al.*, 2002; Pardo *et al.*, 2014).

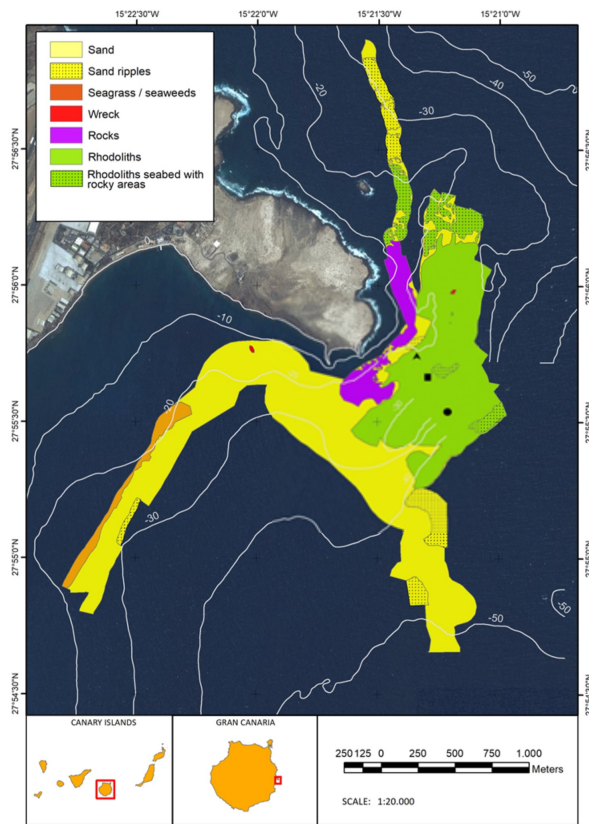


Figure 6. Location of the study area at Gran Canaria Island, showing the three sampling sites at 18 m (triangle), 25 m (square) and 40 m (circle) depth. The cartography was built upon side-scan sonar technologies.

2.2. Sampling design and collection of samples

During two years, eight seasonal sampling campaigns were carried out, from December 2015 to October 2017. Two seasonal samplings were taken during each season: autumn (December 2015 and 2016), winter (March 2016 and 2017), spring (July 2016 and 2017) and summer (October 2016 and 2017).

Samples were recolected using SCUBA at each of the three depth strata (Figure 7). On each stratum, $n=5$ random replicates (25 x 25 cm) were taken each time, by collecting all rhodolithic nodules up to 5 cm deep. SCUBA divers collected the samples by hand, which were enclosed within cloth bags and preserved in a freezer at -20°C until sorting.

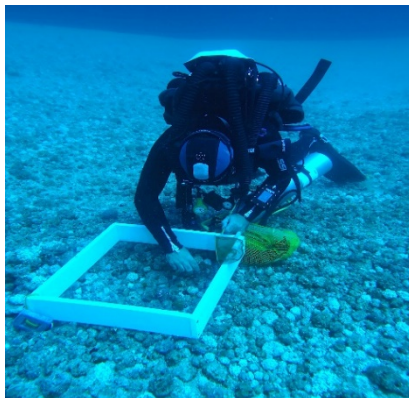


Figure 7. Sample recolection using SCUBA. Picture taken by Francisco Otero Ferrer.

2.3. Samples processing

In order to remove sand and debris from the rhodoliths, each sample was defrosted and filtered through a 0.5 mm sieve. All organisms retained by the mesh sieve, were identified under a stereomicroscope (Leica, EZ4W, Germany) in different taxonomic groups and preserved in alcohol. A total of 808 Brachyura were separated and observed with the same stereomicroscope connected to a computer in order to identify their lowest possible taxonomic level. Three dichotomous keys (Monod, 1956; Zariquiey, 1968; Manning and Holthuis, 1981) and three different lists (González, 1995; Moro *et al.*, 2014; González, 2016) were used. The WoRMS (World Register of Marine Species) was always taken as a reference to describe the taxonomy of the species. For their correct identification, pictures of each organism were taken with a computer program “Leica Microsystem LAS EZ”, which added a scale on the images.

2.4. Data analysis

To summarize the different taxa and abundance of crabs, a table was firstly created. Megalopae (Figure 8) were also considered, because they are the first post-zoea phase, which include the transfer of the locomotory role from the thoracic appendages to the abdominal pleopods. As their principal taxonomic characters were not defined yet, it was very difficult to identify the genus or species of these organisms, which remain therefore as unidentified. Differences in epibenthic algal biomass and Bachyuran richness were also represented, according to the three depth strata and sampled seasons. For the most abundant species, their distribution and abundance were analysed, using the average of the 5 replicas from each stratum and time. For each true crab species, a “Grouped Bar

Chart with Error Bars” was created, showing the abundance of organisms at 18 m, 25 m and 40 m, for each year and season, respectively. In order to shed light into potential recruitment season, the carapace width (Figure 9) was considered for the most abundant species, *Nanocassiope melanodactylus*, which accounted for *ca.* 80% of total crabs. A Chi-square test was used to evaluate differences in the size structure between the 3 bathymetrical strata.



Figure 8. Megalopa of a Brachyuran crab.

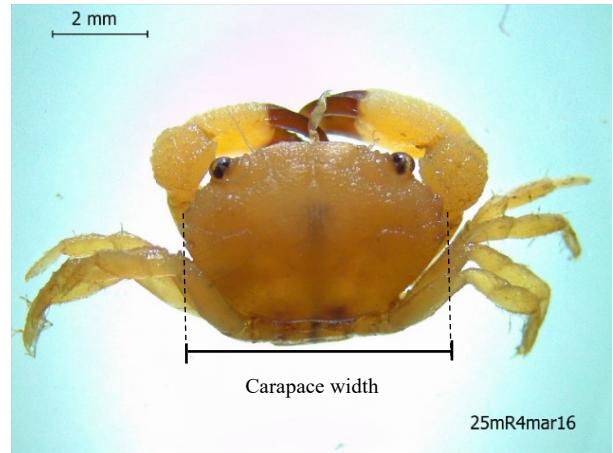


Figure 9. Carapace width of a Brachyuran crab (*Nanocassiope melanodactylus*).

Univariate responses (richness and abundance of the most abundant species) were analyzed by means of GLMs to test the effect of “Depth”, “Season” and “Year”. The first two factors were considered fixed, while year was typified as a random factor. A “negative binomial” family error structure was selected. In all cases, we assessed model performance (i.e. assumptions of linearity and homogeneity of variances) by visually inspecting graphical model diagnoses (QQ-plots, residuals histograms, residuals *versus* fitted values, and fitted values *versus* observed values). All modelling and testing was implemented in the R.3.6.0. statistical package, using the “lmerTest” library.

3. Results

3.1. General results

In this study, a total of 808 Brachyuran crabs, corresponding to 10 different taxa, were identified (Table 1). *Nanocassiope melanodactylus* (Figure 10) accounted for almost 80% of the total abundance. *Pisa carinimana* (Figure 11), *Achaeus* sp. (Figure 12), and *Pilumnus* sp. (Figure 13) contributed with another 10%.

Table 1. Total abundance (as a proportion of the total) and number of individuals of each taxon for the overall study (n=120 samples).

Brachyuran taxa	Abundance (%)	Number of individuals
<i>Nanocassiope melanodactylus</i>	78.6	635
<i>Pisa carinimana</i>	5.45	44
<i>Achaeus</i> sp.	4.83	39
<i>Pilumnus</i> sp.	1.73	14
<i>Acanthonyx lunulatus</i>	1.61	13
<i>Micropisa ovata</i>	0.87	7
<i>Paractaea</i> sp.	0.74	6
<i>Eurynome</i> sp.	0.37	3
<i>Ebalia</i> sp.	0.25	2
<i>Thalamita poissonii</i>	0.25	2
Megalopas	1.11	9
Others	4.21	34



Figure 10. Individual from the species *Nanocassiope melanodactylus*.



Figure 11. Individual from the species *Pisa carinimana*.



Figure 12. Individual from the species *Acheus* sp.



Figure 13. Individual from the species *Pilumnus* sp.

3.2. Epibenthic algal biomass

A higher epibenthic algal biomass was observed at 18 m and 25 m than at 40 m (Figure 14, Table 2, Estimate=8.7546367, P=0.0116).

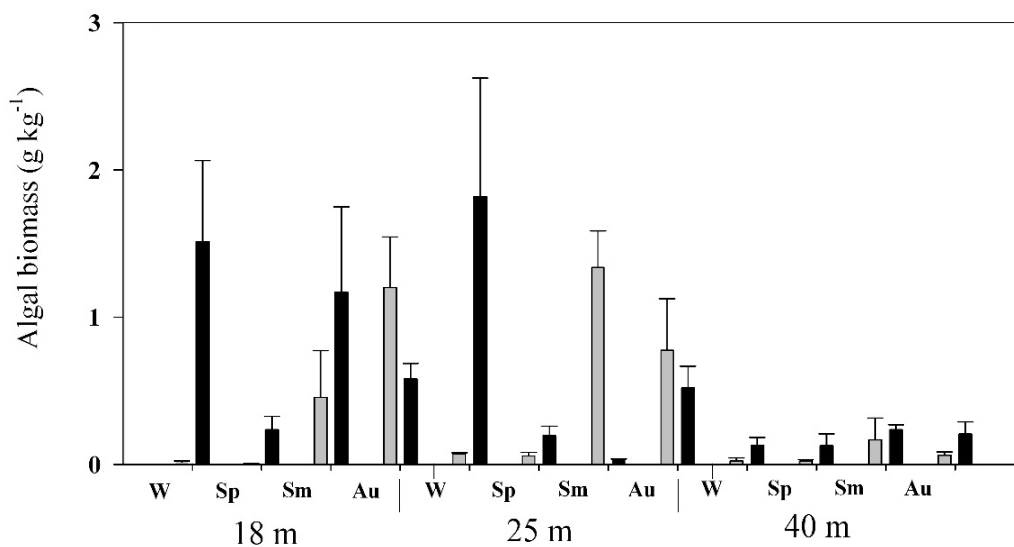


Figure 14. Total algal biomass (dry weigh) (+ SE of means) at each depth stratum and season (W: winter, Sp: spring, Sm: summer, Au: autumn) at 2015-2016 (grey bars) and 2017 (black bars).

3.3. Richness of *Brahyuran* taxa

At 25 m, the number of taxa was significantly higher than at 18 and 40 m (Figure 14, Table 2, Estimate=8.7546367, P=0.0116). A seasonal pattern was also observed; a higher richness of taxa was observed on summer (October 2016 and 2017, Figure 15, Table 2, Estimate=0.741928930, P=0.0443).

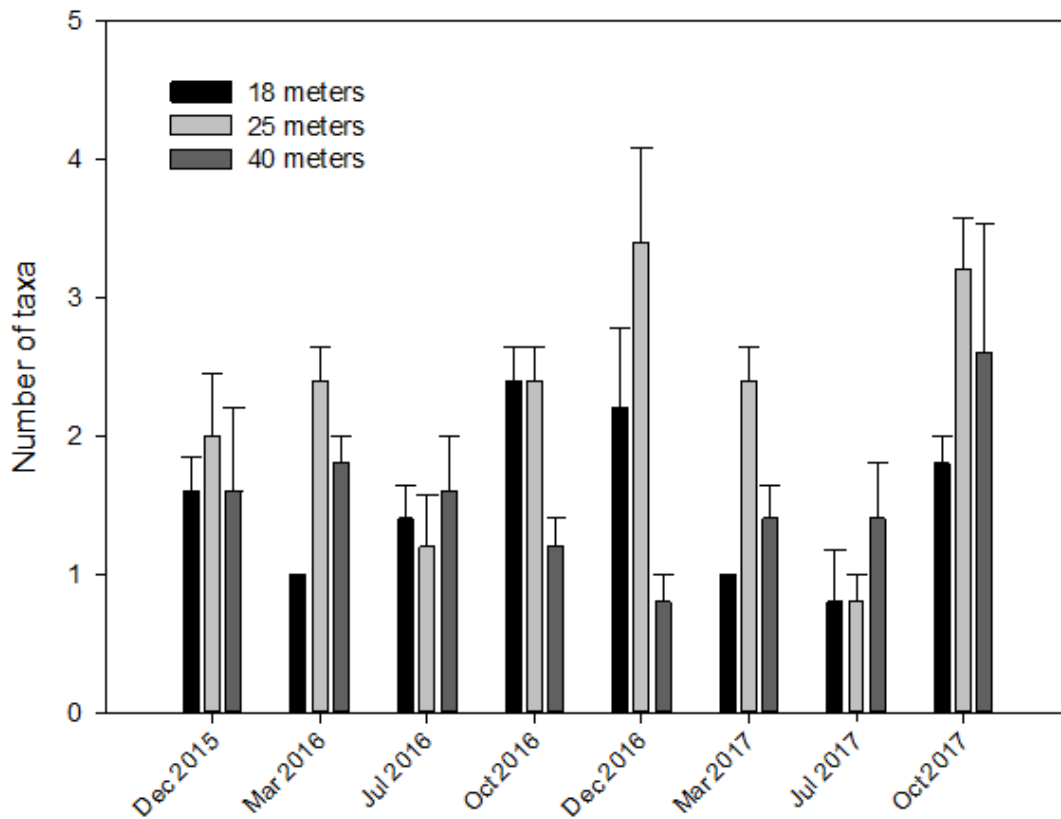


Figure 15. Richness (+SE of means) of Brachyuran taxa at different depths and seasons.

Table 2. Summary of the mixed GLM testing the effects of the fixed factors “Depth” and “Season” on the richness of Brachyuran taxa. The contribution of “Year” was not presented, as this was a random source of variation.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.000006235	0.292824959	0.000	1.0000
Depth [T.twenty five]	0.875463670	0.346976800	2.523	0.0116 *
Depth [T.forty]	0.469991719	0.388815914	1.209	0.2267
Season [T.Autumn]	0.641851478	0.362021943	1.773	0.0762 .
Season [T.Spring]	0.09530090	0.411632830	0.232	0.8169
Season [T.Summer]	0.741928930	0.368826235	2.012	0.0443 *
Depth [T.twenty five]:Season [T.Autumn]	-0.524069436	0.448036309	-1.170	0.2421
Depth [T.forty]:Season [T.Autumn]	-0.929531301	0.525575271	-1.769	0.0770 .
Depth [T.twenty five]:Season [T.Spring]	-0.970769772	0.538826818	-1.802	0.0716 .
Depth [T.forty]:Season [T.Spring]	-0.159832546	0.550836326	-0.290	0.7717
Depth [T.twenty five]:Season [T.Summer]	-0.587784918	0.452618664	-1.299	0.1941
Depth [T.forty]:Season [T.Summer]	-0.570068717	0.509029985	-1.120	0.2628

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

3.4. Abundance of individual *Brachyuran* species

The abundance of *N. melanodactylus* was lower in spring (July 2016 and 2017) than in other seasons (Figure 16, Table 3, Estimate=-1.0986, P=0.00957). This pattern was irrespective of depth (Figure 16, Table 3).

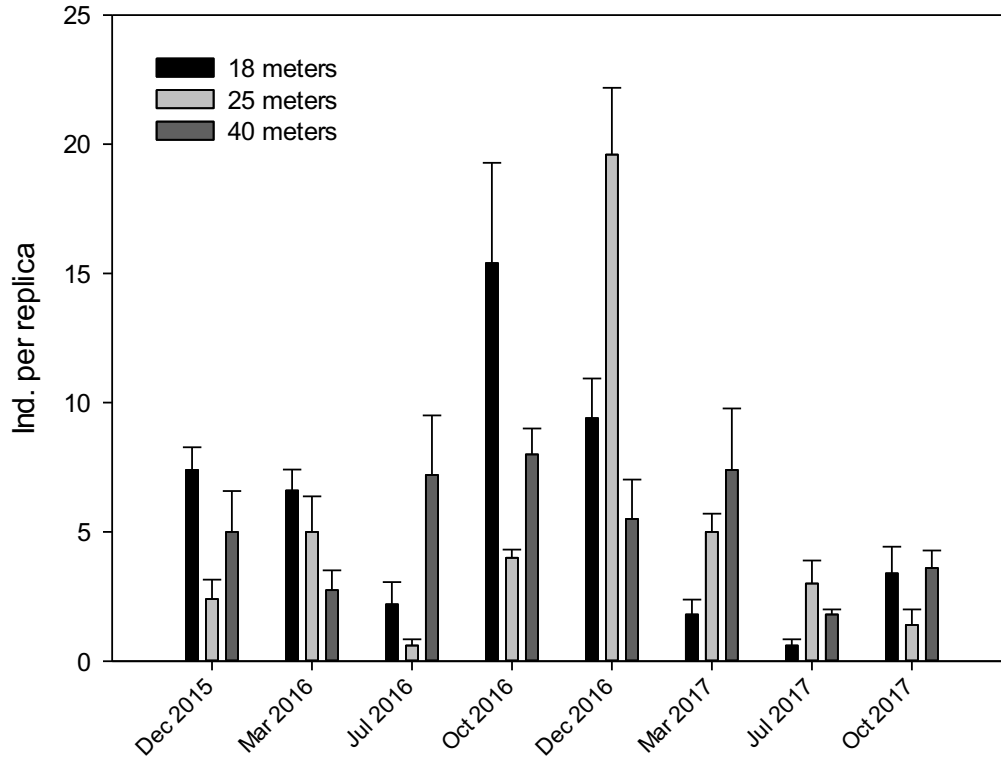


Figure 16. Abundance (+SE of means) of *Nanocassiope melanodactylus* at different depths and seasons.

Table 3. Summary of the mixed GLM testing the effects of the fixed factors “Depth” and “Season” on the abundance of *Nanocassiope melandactylus*. The contribution of “Year” was not presented, as this was a random source of variation.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	1.4351	0.2571	5.583	0.0000000237 ***
Depth [T.twenty five]	-0.1268	0.3679	-0.344	0.73048
Profundidad [T.forty]	0.1335	0.3594	0.372	0.71025
Season [T.Autumn]	0.6931	0.3468	1.999	0.04563 *
Season [T.Spring]	-1.0986	0.4240	-2.591	0.00957 **
Season [T.Summer]	0.8056	0.3449	2.336	0.01952 *
Depth [T.twenty five]:Season [T.Autumn]	0.3964	0.4908	0.808	0.41930
Depth [T.forty]:Season [T.Autumn]	-0.7142	0.4969	-1.437	0.15063
Depth [T.twenty five]:Season [T.Spring]	0.3781	0.5890	0.642	0.52094
Depth [T.forty]:Season [T.Spring]	1.0341	0.5544	1.865	0.06216 .
Depth [T.twenty five]:Season [T.Summer]	-1.1207	0.5173	-2.166	0.03028 *
Depth [T.forty]:Season [T.Summer]	-0.6164	0.4915	-1.254	0.20984

Signifi. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

The distribution of *P. carinimana* and *Achaeus* sp. was random, with no discernible spatio-temporal pattern (Figures 17 and 18, respectively; Tables 4 and 5).

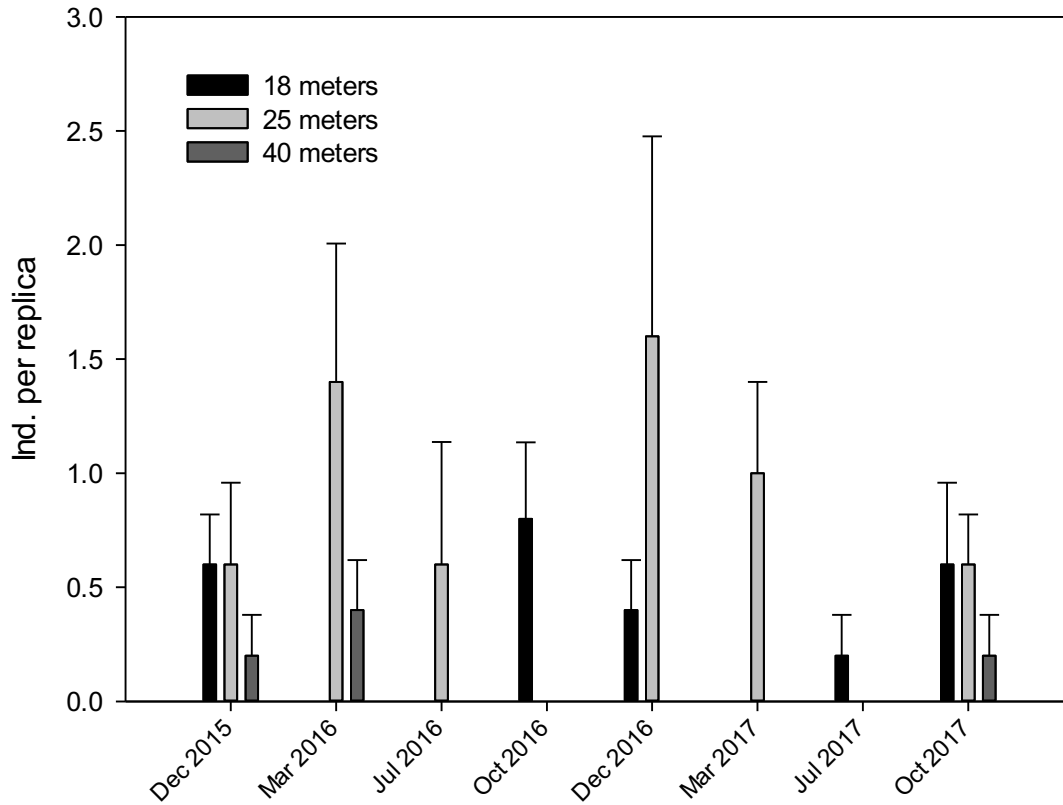


Figure 17. Abundance (+SE of means) of *Pisa carinimana* at different depths and seasons.

Table 4. Summary of the mixed GLM testing the effects of the fixed factors “Depth” and “Season” on the of abundance of *Pisa carinimana*. The contribution of “Year” was not presented, as this was a random source of variation.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	18.95	95.49	0.198	0.843
Depth [T.twenty five]	18.95	95.49	0.198	0.843
Profundidad [T.forty]	17.16	95.49	0.180	0.857
Season [T.Autumn]	18.07	95.49	0.189	0.850
Season [T.Spring]	16.46	95.49	0.172	0.863
Season [T.Summer]	18.41	95.49	0.193	0.847
Depth [T.twenty five]:Season [T.Autumn]	-18.16	95.49	-0.190	0.849
Depth [T.forty]:Season [T.Autumn]	-18.77	95.50	-0.197	0.844
Depth [T.twenty five]:Season [T.Spring]	-16.87	95.49	-0.177	0.860
Depth [T.forty]:Season [T.Spring]	-15.55	95.49	-0.163	0.871
Depth [T.twenty five]:Season [T.Summer]	-19.80	95.49	-0.207	0.836
Depth [T.forty]:Season [T.Summer]	-19.10	95.50	-0.200	0.841

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'.

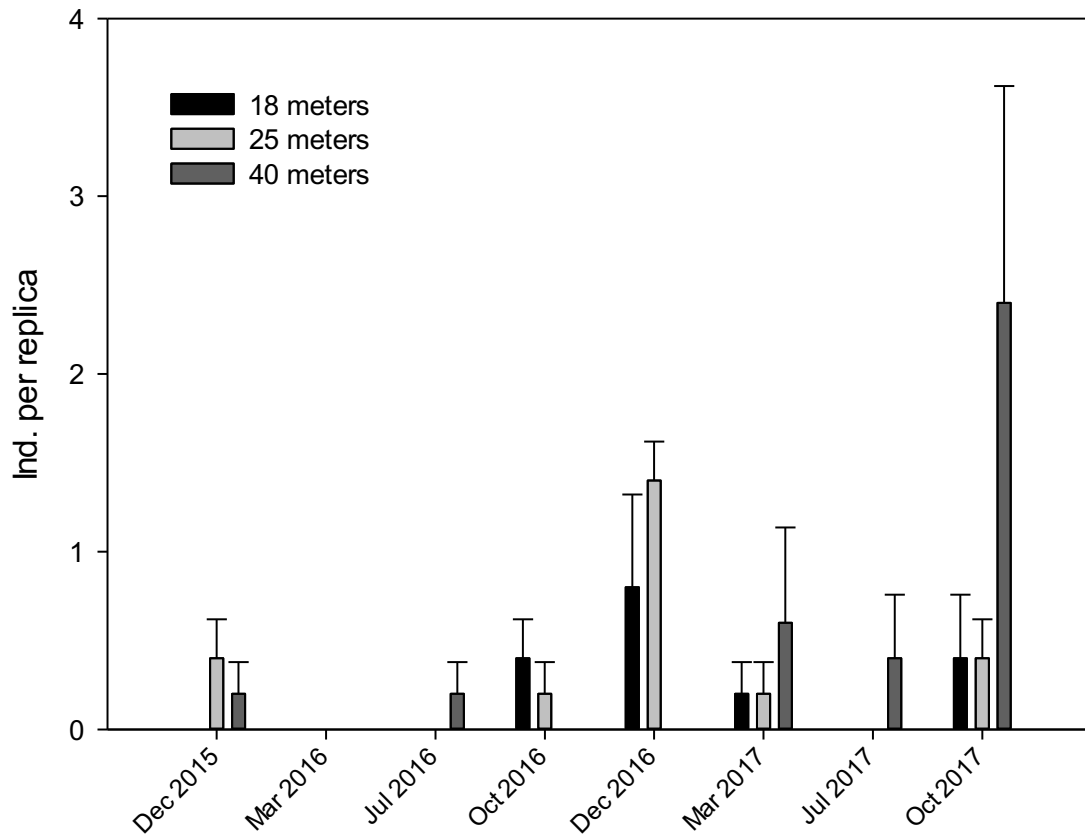


Figure 18. Abundance (+SE of means) of *Achaeus* sp. at different depths and seasons.

Table 5. Summary of the mixed GLM testing the effects of the fixed factors “Depth” and “Season” on the of abundance of *Achaeus* sp. The contribution of “Year” was not presented, as this was a random source of variation.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-2.5404435	1.1566001	-2.196	0.0281 *
Depth [T.twenty five]	-0.0001416	1.4623629	0.000	0.9999
Profundidad [T.forty]	1.0783950	1.2125483	0.889	0.3738
Season [T.Autumn]	1.3569902	1.1773806	1.153	0.2491
Season [T.Spring]	-17.3019973	241.8415869	-0.072	0.9430
Season [T.Summer]	1.4629584	1.1791669	1.241	0.2147
Depth [T.twenty five]:Season [T.Autumn]	0.8619360	1.6229437	0.531	0.5954
Depth [T.forty]:Season [T.Autumn]	-2.3767960	1.6908257	-1.406	0.1598
Depth [T.twenty five]:Season [T.Spring]	5.4694245	354.0188993	0.015	0.9877
Depth [T.forty]:Season [T.Spring]	16.2821626	241.8445020	0.067	0.9463
Depth [T.twenty five]:Season [T.Summer]	-0.3304714	1.6915675	-0.195	0.8451
Depth [T.forty]:Season [T.Summer]	0.1226274	1.3842303	0.089	0.9294

Signif. codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.'

Pilumnus sp. showed a larger abundance at 25 m than at 18 m and 40 m, where they remained almost absent (Figure 19, Table 6, $E=21.74687$, $P < 2e-16$).

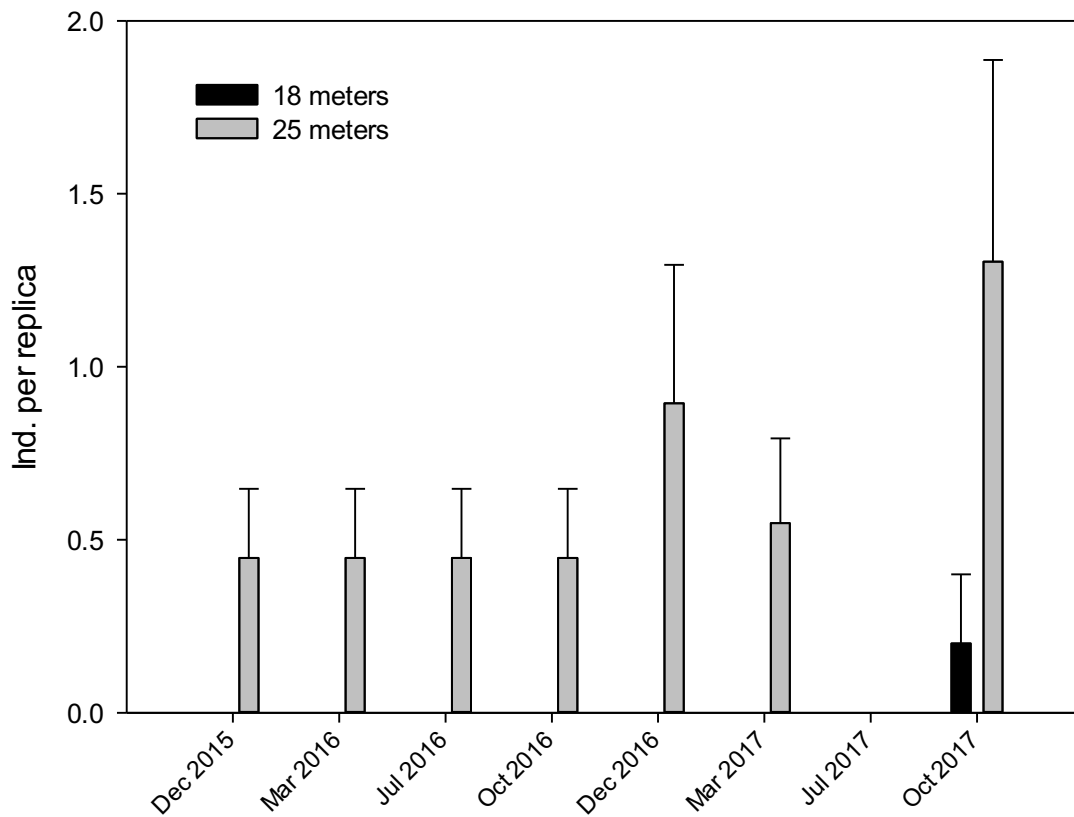


Figure 19. Abundance (+SE of means) of *Pilumnus* sp. at different depths and seasons.

Table 6. Summary of the mixed GLM testing the effects of the fixed factors “Depth” and “Season” on the abundance of *Pilumnus* sp. The contribution of “Year” is not presented, as this was a random source of variation.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-22.69305	0.03040	-746.368	< 2e-16 ***
Depth [T.twenty five]	21.74687	0.03043	714.605	< 2e-16 ***
Profundidad [T.forty]	0.16779	0.03049	5.504	0.000000037***
Season [T.Autumn]	0.08862	0.03050	2.906	0.00366 **
Season [T.Spring]	-0.26514	0.03051	-8.690	< 2e-16 ***
Season [T.Summer]	20.36078	0.03045	668.657	< 2e-16 ***
Depth [T.twenty five]:Season [T.Autumn]	-0.77404	0.03050	-25.379	< 2e-16 ***
Depth [T.forty]:Season [T.Autumn]	0.09359	0.03152	2.969	0.00299 **
Depth [T.twenty five]:Season [T.Spring]	-1.10894	0.03051	-36.348	< 2e-16 ***
Depth [T.forty]:Season [T.Spring]	0.45390	0.03152	14.399	< 2e-16 ***
Depth [T.twenty five]:Season [T.Summer]	-20.64478	0.03049	-677.07	< 2e-16 ***
Depth [T.forty]:Season [T.Summer]	1.20800	0.03049	39.625	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

3.5. Size of *Nanocassiope melanodactylus*

The size of the most abundant crab, *N. melanodactylus*, changed with depth: individuals at 40 m were smaller than those at shallower waters (Figure 19, Pearson's Chi-squared test, X-squared = 42.106, df = 18, p-value = 0.001069).

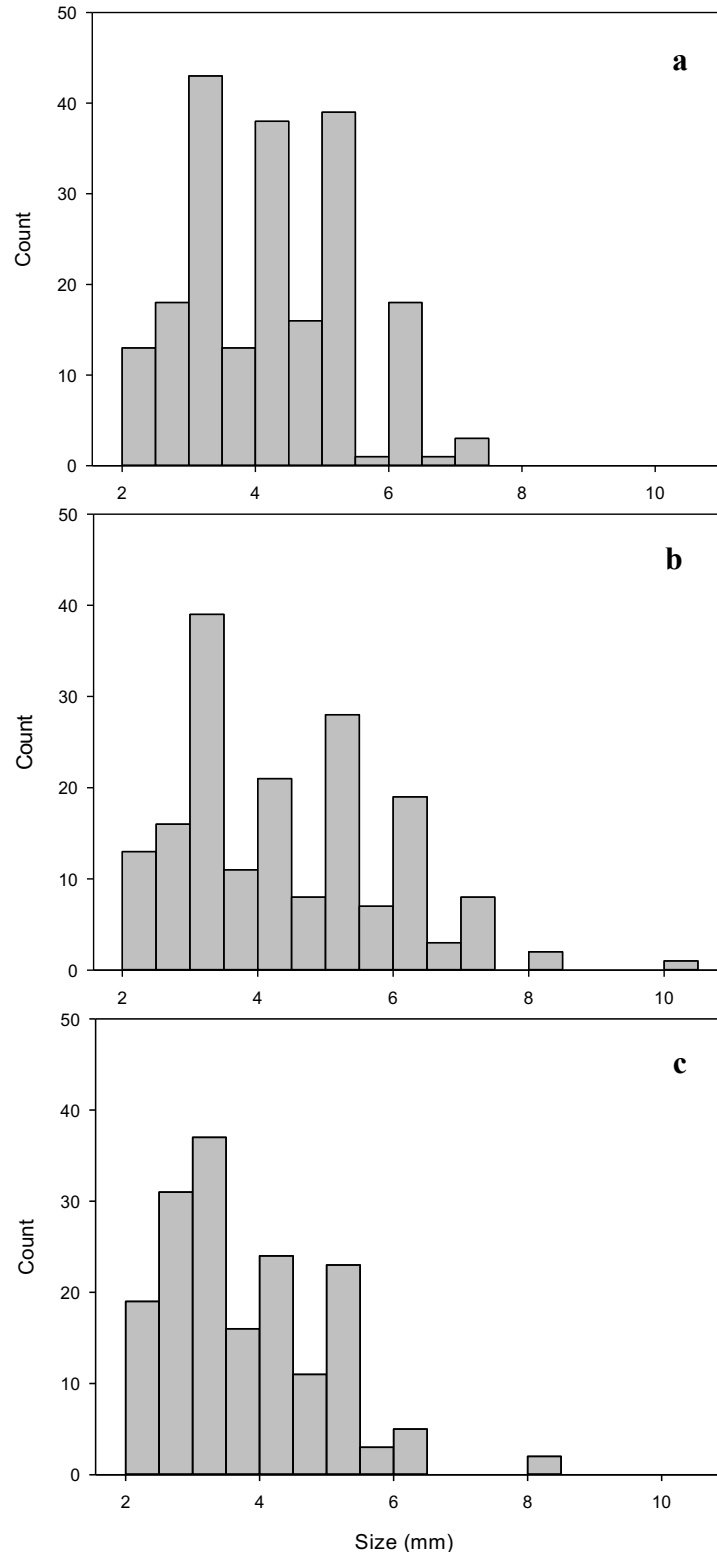


Figure 20. Histograms of the size (carapace width) of *Nanocassiope melanodactylus* at (a) 18 m (b) 25 m (c) 40 m depth.

4. Discussion

The present study has firstly evidenced that the assemblage of Brachyuran crabs associated with rhodoliths in Gran Canaria is dominated by just one species, *Nanocassiope melanodactylus*. Secondly, we demonstrated that the abundance of certain crab species depended on the sampling season and depth. In addition, this project pointed out that the smallest individuals of the dominant Brachyuran species, *Nanocassiope melanodactylus*, were majorly located on the deepest strata.

From the 10 taxa we found here, *N. melanodactylus* was the dominant crab, accounting for *ca.* 80% of the total abundance of Brachyuran crabs. Rhodolith seabeds in the east coast of Gran Canaria Island are exposed to different conditions, which seem to provide an optimal habitat for the development of this Xanthidae crab. Other studies (Hurley *et al.*, 2016) also defined Xanthidae crabs as generalists and suggested that they are omnivores. A basic premise of crustacean ecology states that the numerically dominant species within a biotope are generally those that are best adapted to efficiently exploit food and habitat resources (Abele, 1972).

An explanation for the low abundance of megalopae (1.11% of the total abundance) found in the present study is somehow provided by Landeira *et al.* (2009). They confirmed that the east coast of Gran Canaria Island has a low density of decapod crustacean larvae. This is an area exposed to strong currents and winds year-round (Landeira, 2010). Therefore, retention zones of megalopae are majorly located in the lee of Gran Canaria (downstream) and at the stagnation point (upstream). Larvae are majorly dragged to the south of the island, where recruitment is therefore enhanced.

At 25 m, Brachyuran richness was higher than in the shallower (18 m) or deeper strata (40 m). This distribution followed the most important factors for the optimal growth of rhodolith nodules: hydrodynamic conditions and light (Rebelo *et al.*, 2018; Otero-Ferrer *et al.*, 2019). The action of waves and currents are stronger at 18 m relative to deeper waters. At a depth of 40 m, even though the wave disturbance is reduced (Amado-Filho *et al.*, 2007), the conditions are not ideal for rhodoliths to grow, due to lower irradiance at this depth. Reduction in rhodolith density and epibenthic biomass with an increase in depth was observed in the study area, as in other studies worldwide (Steller and Foster, 1995; Riul *et al.*, 2009; Amado-Filho *et al.*, 2010; Pascelli *et al.*, 2013). Increasing depth, involves a reduction in irradiance and an increase in sedimentation rates (Otero-Ferrer *et al.*, 2018). These factors lead to a physiological limitation affecting rhodolith growth (Pascelli *et al.*, 2013). Therefore, at 25 m, rhodolith seabeds seem to reach an ideal balance between these trade-offs (i.e. hydrodynamics and light availability), to promote their fitness and performance and thus their structural complexity. Steller *et al.* (2003) showed that complex thalli of rhodoliths provide more space, refuge, and resources for associated epifauna through increased interbranch space.

Hence, rhodolith complexity appeared to be a good predictor of epifaunal species, abundance and richness. The results also showed a decrease in epifaunal algal biomass with depth; this idea supports the Weber-Van Bosse and Foslie's (1904) hypothesis that increasing structural complexity leads to enhanced species diversity.

Pilumnus sp. followed a similar bathymetric distribution, relative to the richness; almost all individuals were majorly found at 25 m. This fact confirmed that some crabs associated with rhodoliths were most likely to live where the conditions of light, temperature and hydrodynamic are optimal for their habitat. Hinojosa-Arango and Riosmena-Rodríguez (2004) demonstrated that rhodolith abundances may be responsible of the significant differences in faunal abundance.

Our data also agreed with Amado-Filho *et al.* (2007), who found a higher richness during summer. Species richness over the rhodolith bed was lowest in winter, which was likely the result of disturbances caused by typical winter storms. Pascelli *et al.* (2013) confirmed the fact that in summer, there was an increase in the rhodolith density. This seasonality could be also related to a lower water movement (Hinojosa-Arango *et al.*, 2009) due to the reduced frequency of storm conditions during summer, promoting sediment suspension (Pascelli *et al.*, 2013).

It is also noteworthy that *Achaeus* sp. and *Pisa carinimana*, both belonging to the superfamily Majoidea, accounted for 10.3% in terms of abundance and did not show any spatio-temporal pattern at all. In this sense, McConnico (2017) and García-Sanz *et al.* (2004) showed that invertebrate assemblages did not vary seasonally. These results apparently agreed with the fact that subtropical waters of Gran Canaria have a weak seasonal variation (García-Sanz *et al.*, 2014), which does not affect these Majoidea species living in rhodoliths. Contrary to these, *N. melanodactylus*, belonging to the superfamily Xanthoidea, had lower abundances in spring.

In the particular case of decapod crustaceans, their life cycle comprises an embryonic, larval (from early developed zoea to settlement decapodid stage) and a postlarval (juvenile-adult) phase (García-Sanz *et al.*, 2014). Our results showed a difference in the size of *N. melanodactylus* depending on the depth. Individuals at 18 and 25 m had similar sizes, while individuals at 40 m were apparently smaller. Therefore, juvenile crabs of *N. melanodactylus* lived in deeper waters. Although direct evidence is lacking, some studies explained this fact; Queiroga and Blancton (2004) suggested decapod crustaceans may perform vertical migrations to avoid predation and offshore currents and; Spivak *et al.* (2010) suggested a hypothetical spatial segregation of crabs, with recruitment taking place in a different habitat followed by migration episodes.

5. Conclusions

This study contributed to the understanding of the spatio-temporal variability of the Brachyuran fauna associated with rhodoliths. Here we demonstrated that the assemblage of Brachyuran crabs was dominated largely by *N. melanodactylus*, which seem to majorly recruit at 40 m. It turns out that at 25 m rhodolith seabeds find ideal conditions for the associated assemblage of Brachyura. *Pilumnus* sp. showed a spatial pattern, being more abundant at 25 m, while other crab species, such as *P. carinimana* or *Achaeus* sp. did not show any spatio-temporal pattern. As this is the first study of the spatio-temporal variability of Brachyura associated with rhodolith seabeds in Gran Canaria Island, further research is needed in this area.

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1. Descripción detallada de las actividades desarrolladas durante la realización del TFT.

Mi trabajo durante la realización del TFG (Trabajo de Final de Grado) consistió, en primer lugar, en identificar varios ejemplares de *Brachyura* hasta el nivel taxonómico más inferior posible en el laboratorio del Parque Científico Tecnológico Marino y posteriormente analizar su distribución espacio-temporal.

1.1 Trabajo previo: recolección de muestras

Desde diciembre del 2015 hasta octubre de 2017 investigadores de la empresa IU-ECOQUA estuvieron tomando muestras estacionales de rodolitos a diferentes profundidades en la bahía de Gando, Gran Canaria. Las inmersiones se realizaron en invierno (2015 y 2016), primavera (2016 y 2017), verano (2016 y 2017) y otoño (2016 y 2017), tomando en cada estación cinco réplicas de muestras a tres profundidades (18 metros, 25 metros y 40 metros), sumando un total de 120.

Una vez en el laboratorio, estas muestras se filtraron con un tamiz de 0.5 mm, para retirar la arena y los detritos de los rodolitos. Los organismos retenidos en el tamiz fueron identificados con un estereomicroscopio (Leica, EZ4W, Germany) en diferentes grupos taxonómicos y fijados con alcohol.

1.2 Identificación de individuos

Cuando yo me incorporé en el proyecto, ya tenía los *Brachyura* (un total de 808) separados del resto de organismos para su identificación. Cada organismo se colocó sobre un portaobjetos y, agregando alcohol cuando fuera necesario, con el estereomicroscopio conectado a un ordenador, se fotografiaron los diferentes ejemplares. Esto se pudo llevar a cabo gracias al programa “Leica Microsystem LAS EZ”, que también agregaba una escala a la imagen para su posterior medida.

Con ayuda de tres claves dicotómicas (Monod, 1956; Zariquiey Álvarez, 1968; Manning y Holthuis, 1981) tres listas (González Pérez, 1995, 2016; Moro *et al.*, 2014) y de Raúl Triay, colaborador del grupo BIOCON (Grupo de Biodiversidad y Conservación), se identificaron 10 diferentes géneros y especies, siendo los más abundantes: *Nanocassiope melanodactylus*, *Pisa carinimana*, *Achaeus* sp. y *Pilumnus* sp.

1.3 Análisis de los datos

Para cada especie, se creó un gráfico de barras con sus correspondientes errores, representando las tres profundidades (18m, 25m y 40m), mostrando la abundancia de organismos en cada año y estación. Como *N. melanodactylus* resultó ser la especie predominante con una abundancia del 78,6%, también se analizó el tamaño de estos

ejemplares, midiendo la anchura del caparazón para obtener la época y profundidad de reclutamiento.

Todas las representaciones de esta práctica se realizaron con el programa “SigmaPot” y el error estándar (SE), se calculó con la fórmula: $SE = \frac{\text{desviación estándar}}{\sqrt{n}}$, siendo “n” el número de réplicas de cada muestra (5 en este caso).

2. Formación recibida (cursos, programas informáticos, etc.)

Ambos programas informáticos requeridos para estas prácticas fueron de fácil manejo, pero aun así, tuve un gran apoyo por parte de mi tutor Fernando Tuya y de mi cotutor Francisco Otero, quienes me explicaron su funcionamiento, al igual que el del estereomicroscopio. También me resultó muy útil la bibliografía que me facilitaron para conocer todos los estudios previos realizados con relación a los cangrejos *Brachyura* en rodolitos. Para formarme en el ámbito de la identificación taxonómica de los mismos, fue necesario invertir numerosas horas buscando y leyendo información sobre el tema. La ayuda de Raúl Triay fue clave, puesto que él me pudo resolver todas las dudas y explicarme más detalladamente los caracteres taxonómicos importantes para diferenciar las especies.

3. Nivel de integración e implicación dentro del departamento y relaciones con el personal.

Dentro del departamento tanto el ambiente como el trato con el personal era muy agradable. Aun estando la mayor parte del tiempo completamente sola en el laboratorio, siempre tuve a mi disposición cualquier ayuda que necesitara, puesto que el despacho de mi cotutor Francisco Otero se hallaba al lado. Algunos días compartía el laboratorio con otros trabajadores de la empresa o con otros estudiantes que realizaban las prácticas en el mismo departamento, pero cada uno ocupaba otra zona de trabajo, por lo que no tuvimos problemas para organizarnos.

4. Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFG.

De estos seis meses de trabajo, destaco el hecho de empezar a usar el método científico en primera persona como aspecto positivo que nos proporciona la realización del TFG. Tener que analizar muestras por mi cuenta, identificar taxonómicamente a los *Brachyura* y luego obtener los resultados para ver si son coherentes, es una metodología que nunca había probado al 100% yo sola. He trabajado de manera totalmente independiente, es decir, mis tutores me explicaron en qué iba a consistir mi trabajo y el objetivo que tenía que lograr, dándome completa libertad de los horarios. De esta manera he podido compaginar perfectamente las horas de trabajo en el laboratorio con las que tenía que

pasar en la facultad de Ciencias del Mar por otra asignatura. Aunque me haya parecido muy positivo, es una forma de trabajar que precisa organización y constancia.

Como aspecto negativo señalo la dificultad que conlleva al principio familiarizarse con la taxonomía y la organización que se debe llevar con las muestras debido a su gran abundancia, teniendo cuidado de etiquetar todo debidamente. No obstante, estas dificultades me animaron aún más a aprender y a cumplir con las expectativas que tenía antes de empezar el semestre, puesto que he entendido como funcionan ciertos aspectos de la investigación. No dudaría en repetir o aconsejar realizar el TFG en el grupo BIOCON de la empresa IU-ECOQUA.

5. Valoración personal del aprendizaje conseguido a lo largo del TFG.

Valoro el aprendizaje conseguido a lo largo del TFG de manera muy positiva. He aprendido no solo de taxonomía y ecología de cangrejos, sino también a leer y entender publicaciones científicas. Ha sido el semestre de la carrera que más me ha aportado a nivel académico, puesto que he podido poner en práctica de forma independiente los conocimientos recibidos en asignaturas como Biodiversidad Marina o Estadística. La realización de este TFG me ha ayudado a aclarar mis ideas con respecto a mi futuro, queriéndome dedicar a la investigación en el campo de la biología marina.