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VARIABILITY IN THE ABUNDANCE OF THE ROCK CRAB *GRAPSUS ADSCENSIONIS* (DECAPODA: GRAPSIDAE) IN THE CANARY ISLANDS (EASTERN ATLANTIC)

RUBÉN RAMÍREZ* AND RICARDO HAROUN
Research Centre of Biodiversity and Environmental Management (BIOGES), Faculty of Marine Sciences, Universidad de Las Palmas de Gran Canaria, E-35017, Las Palmas, Spain

ABSTRACT The rock crab *Grapsus adscensionis* (Osbeck, 1765) is a common intertidal species in the eastern Atlantic. Little is known, however, about the status of its population because of its relatively recent taxonomic separation from *Grapsus grapsus*. Adult abundance of *G. adscensionis* was sampled throughout the Canary Islands (24 sites in total) in March and October 2003 and 2004. Abundance varied significantly at intermediate scales (sites spaced by tens of kilometers) but not at larger scales (islands separated by tens to hundreds of kilometers). Habitat complexity (measured as difficulty in walking and terrain variance) was the main source of spatial variability in abundance. In general, *G. adscensionis* was more abundant in sites of high complexity, mainly in cliffs. Abundance was greater in October (spring/summer) than in March in both sampling years. The frequency of black and red adults varied in time. Red individuals, which were larger than black ones, were very scarce.

KEY WORDS: rock crab, *Grapsus adscensionis*, abundance, spatial variability, temporal variability, habitat complexity, population structure, size class

INTRODUCTION

Despite being conspicuous, often abundant, and having a wide geographic distribution, the rock crab (*Grapsus adscensionis* [Osbeck, 1765]) has been poorly studied. Its taxonomic situation has been reviewed recently and showed some minor morphological differences with respect to *Grapsus grapsus* (Linnaeus, 1758) (Manning & Chace 1990, Freire et al. 2011). In particular, *G. adscensionis* lives in the intertidal zone of the eastern shores of the Atlantic, from the southwest of Portugal to Namibia, including the Azores, Madeira, the Salvage Islands, the Canaries, Ascension Island, and Saint Helena (Manning & Chace 1990, Espino et al. 2006).

There is limited knowledge about the populations of *Grapsus adscensionis* along its latitudinal range. Although some of its general features (e.g., morphology or threats) have been mentioned in several publications (e.g., Pérez & Moreno 1991, Carrillo & Cruz 1992, González 1995), only its reproductive biology has been addressed in depth as a result of an increase in the experimental use of its zoeae larvae in aquaculture (Carro et al. 2004, Shcherbakova et al. 2011). As a consequence, it has been revealed that its physiological and morphological maturation is profusely widespread among specimens of larger sizes (carapace width [CW], >50 mm) (Shcherbakova et al. 2011). Traditional exploitation as bait and human consumption has been reported in the Canary Islands (Pérez & Moreno 1991) and, similar with other shellfish (e.g., Lindberg et al. 1998), people collect larger specimens of *G. adscensionis* because they are more eye-catching.

Because *Grapsus adscensionis* is still apparently abundant at Canarian rocky shores and, at the same time, subject to exploitation, some experimental work was conducted to understand its ecological role and current status of its populations. The effect of habitat complexity on its abundance is described, and the spatial variability of this species along the Canarian archipelago at 2 spatial scales—between islands (separated by tens to hundreds of kilometers) and between sites on the same island (separated by tens of kilometers) is determined. Last, temporal variability was examined, with sampling in winter and summer for 2 consecutive years.

MATERIALS AND METHODS

Study Area

The study was carried out on the 7 main islands of the Canary Islands (eastern Atlantic) as well as on the small islets north of Lanzarote (designated as the "Chinijo Archipelago"; Fig. 1). The islands are located along the northwest African coastal transition zone, which implies the arrival of cold and nutrient-rich waters to the islands coming from the nearby African coast (Davenport et al. 2002). This event generates a gradient in water features (e.g., temperature and nutrient concentration) from the eastern islands to the western ones (e.g., Llinás et al. 1994). In addition, the age difference between islands (Fig. 1) has caused clear topographical differences, particularly on the coasts (e.g., length [Ramírez 2010]). Waves from the north dominate in frequency at the Archipelago (Haroun 2000). On the rocky shores, the marine assemblages are distributed in 3 zones: intertidal high zone, mid zone, and low zone (Ramírez et al. 2008). The high zone is characterized by a few cyanobacteria species, the mid zone is dominated by the cirriped barnacle *Chthamalus stellatus* (Poli, 1791), and the low zone is covered by a conspicuous canopy of turf-forming algae.

Sampling Design

Samplings were performed in March (oceanographic winter, 16–18°C sea surface temperature) and October (oceanographic summer, 23–25°C) 2003 and 2004, which roughly coincided with the broadest tides of the year (near 3 m in amplitude). At each island, spaced by tens of kilometers, 3 sites (24 sites for the entire study) exposed directly to swell were randomly selected. At each site, 10 plots 10 m in length and 5 m in width located in the low intertidal zone and parallel to the shore were used as sampling units. The number of adult crabs (differentiating black and red specimens; Fig. 2) and the search time (measured

*Corresponding author. E-mail: mailrubenramirez@yahoo.es
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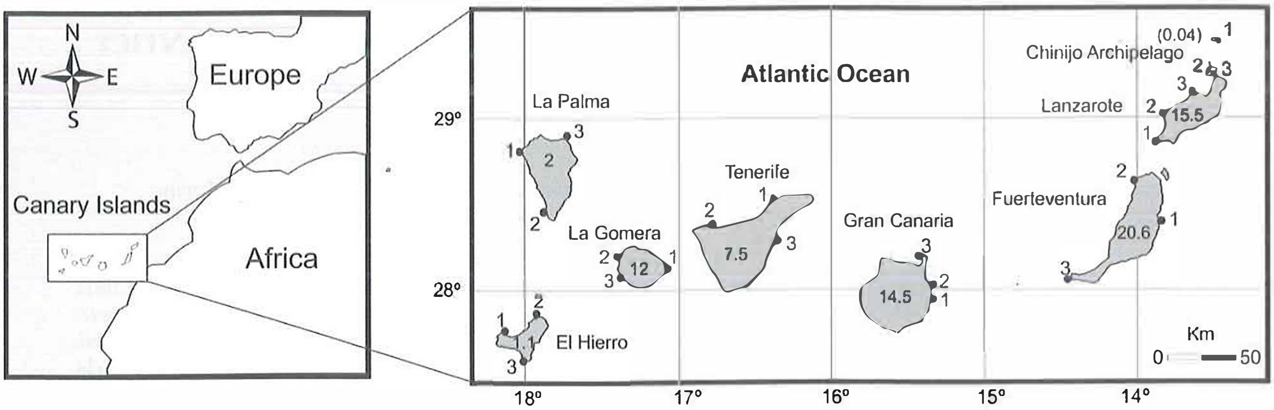

Figure 1. Map showing the study area and the sampling sites in the Canary Islands. Chinijo Archipelago: 1, Punta Abades; 2, El Corral; 3, Caleta de Arriba. Lanzarote: 1, Pechiguera; 2, El Cochino; 3, La Santa. Fuerteventnra: 1, Puerto del Rosario; 2, El Cotillo; 3, Punta Jandía. Gran Canaria: 1, El Cabrón; 2, Taliarte; 3, La Isleta. Tenerife: 1, Punta del Hidalgo; 2, Caleta de Interián; 3, Malpaís de Guimar. La Gomera: 1, Punta Llana; 2, Alojera; 3, Valle Gran Rey. La Palma: 1, Punta Gorda; 2, Punta Larga; 3, Punta Cumplida. El Hierro: 1, Arenas Blancas; 2 Charco Manso; 3, La Restinga. The numbers inside each island, except for Chinijo Archipelago — indicated in parentheses—indicate geological age in millions of years.

in seconds) was recorded in each plot. Particularly, whether black specimens were bigger or smaller (in terms of CW) than 50 mm was visually checked. This information gives an approximate number of adult specimens as well as those with an attractive human collection size. Physiological and morphological maturation of *Grapsus adscensionis* begins with a CW of 40 mm, which is profusely widespread among specimens larger than 50 mm (Shcherbakova et al. 2011). Juveniles (gray) were not analyzed because of the incompatibility of their behavior (i.e., they stayed hidden for a long time) with the sampling method used.

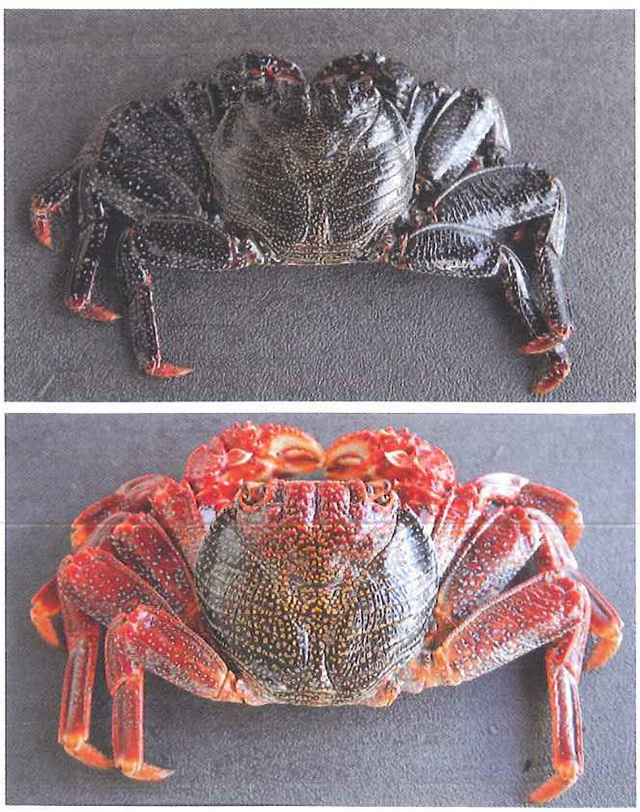

Figure 2. Black and red crab.

At each site, the habitat complexity was measured in 2 ways. The first established 3 complexity levels according to the difficulty sensed by researchers during the samplings: (1) low, the researcher can walk naturally (without disruption in walking), as he or she would do on a street; (2) medium, the researcher took caution when walking, although without reducing his or her pace excessively; (3) high, the researcher continuously monitored his or her steps, or stopped because of the complexity of the substrate (Fig. 3). In comparison with other sampling methods (e.g., presence of shelters), this one covers a greater surface area, which is an advantage when studying large crabs that show high ability of movement. The second method consisted of calculating a mean value of the terrain variance. To calculate the mean, a topographic profile was determined for the middle zone of each locality, in which the terrain height was measured every 3 m from the high intertidal zone to sea level. Specifically, the height differences between each measurement and the maximum recorded height was used. The topographic features of each sampling site are summarized in Table 1.

Data Analysis

The significance of differences in mean abundance of red and black crabs was tested using analysis of variance (ANOVA) (Underwood 1997). The model used incorporated the following factors: (1) time (fixed factor, with 4 levels corresponding to sampling dates), (2) island (fixed and orthogonal to time, with 8 levels corresponding to the 7 islands plus the Chinijo Archipelago), and (3) site (random factor and nested within island). Cochran's test was used to check for homogeneity of variance, and data were transformed to promote normality of variables. In addition, a significance level of $\alpha = 0.01$ (instead of $\alpha = 0.05$) was considered to avoid an increase in type I error (Underwood 1997). When ANOVA detected significant differences for time and/or island as a main effect or interaction, additional analyses were performed by using the

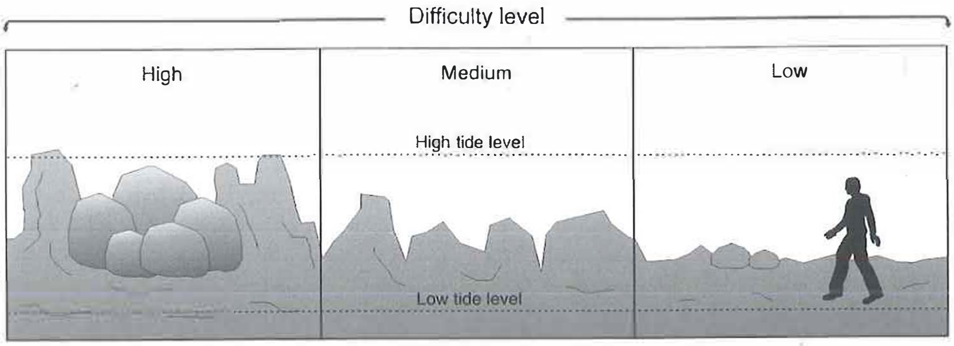

Figure 3. Diagram showing the 3 difficulty levels recorded by investigators during samplings.

SNK *a posteriori* test of multiple comparison for resolving differences.

Pearson's chi-square test was conducted to check whether the frequency distributions of (1) red and black specimens, and (2) black specimens divided by size (i.e., CW) were significantly different among sampling times. On the other hand, the Kruskal–Wallis test was used to prove the significance of the differences in abundance, length of time, and terrain variance among the considered difficulty levels (i.e., low, medium, and high). Then, the Mann-Whitney *U*-test was performed to know

TABLE 1.

Topographic features of each sampling site.

Island	Site	Orientation	Length, mean (m)*	Terrain variance, mean	Physical constitution†	Difficulty walking
Chinijo Archipelago	Punta Abades	NE 50°	81	636	b, c	High
	El Corral	NW 330°	89	447	c	Low
	Caleta de Arriba	SE 140°	60	262	c	Low
Mean			76.67	448.33		
Lanzarote	Pechiguera	SW 240°	63	1,367	a, b	Medium
	El Cochino	NW 310°	93	946	c	Medium
	La Santa	NW 330°	93	392	c	Low
Mean			83.00	901.67		
Fuerteventura	Puerto del Rosario	NE 44°	39	428	c	Low
	El Cotillo	W 270°	63	1,222	c	Medium
	Punta Jandía	SW 240°	72	134	c	Low
Mean			58.00	594.67		
Gran Canaria	El Cabrón	SW 210°	33	764	c	Low
	Taliarte	SE 150°	33	2,870	b, c	High
	La Isleta	NW 310°	57	1,778	b, c	High
Mean			41.00	1,804.00		
Tenerife	Punta del Hidalgo	NW 300°	42	2,778	c	High
	Caleta de Interián	NE 60°	63	774	c	Medium
	Malpaís de Guimar	SE 120°	51	401	c	Medium
Mean			52.00	1,317.67		
La Gomera	Punta Llana	NE 38°	128	473	c	Medium
	Alojera	SW 260°	33	2,302	a	Medium
	Valle Gran Rey	NW 300°	39	1,181	c	High
Mean			66.67	1,318.67		
La Palma	Punta Gorda	SE 160°	12	2,144	a	Medium
	Punta Larga	SW 260°	27	431	b	High
	Punta Cumplida	NE 20°	36	1,097	a	High
Mean			25.00	1,224.00		
El Hierro	Arenas Blancas	NE 80°	54	844	c	Medium
	Charco Manso	NE 3°	30	548	b	High
	La Restinga	SE 158°	27	566	b, c	Medium
Mean			37.00	652.67		

* Distance from the top limit of the high intertidal zone (i.e., the limit of tides) to sea level at low tide.
† a, high cliff with a shelf at their feet; b, cliff of 2–20 m; c, low coast (classification according to the Canary Institute of Statistics, http://www.gobiernodecanarias.org/istac/).

TABLE 2.

Results of ANOVA testing for differences between time (fixed), island (fixed and orthogonal), and site (random and nested within island) in abundance of *Grapsus adscensionis* across the Canary Islands.

		Red specimens			Black specimens		
Source of variation	*df*	MS	F	*P* value	MS	F	*P* value
Time	3	4.10	0.41	0.74	7.34	4.40	<0.01
Island	7	42.75	0.84	0.57	5.41	0.86	0.55
Site (island)	16	51.16	11.20	<0.001	6.28	22.58	<0.001
Time × island	21	18.99	1.90	0.03	1.68	1.01	0.47
Time × site	48	10.00	2.19	<0.001	1.66	6.00	<0.001
Residual	864	4.56			0.27		
Total	959						

F, Fisher's F value; MS, mean square.

the specific differences among the 3 categories. The significance level was set at $P < 0.05$.

RESULTS

The abundance of *Grapsus adscensionis* was highly variable at the intermediate scale (i.e., sites separated by tens of kilometers), which showed an inconsistent pattern from 1 sampling time to another (Table 2). This variability could have masked the detection of significant differences at larger scales (i.e., islands separated by tens to hundreds of kilometers; Table 2), although some inconsistencies were observed between some islands (e.g., the lowest abundance was found in Fuerteventura and Lanzarote, whereas the highest was seen in Gran Canaria or any of western islands; Fig. 4). On the other hand, the abundance of black specimens was significantly variable between sampling times (Table 2). After using the SNK test, the following dissimilarities were recorded: March 2003 < October 2003 and 2004 ($P < 0.01$), October 2003 > March 2004 ($P < 0.05$), and March 2004 < October 2004 ($P < 0.01$), which shows that black specimens were much more abundant in October than in March.

A total of 1,373 specimens of *Grapsus adscensionis* were recorded from the entire Archipelago, which corresponds to a mean abundance of 0.74 ± 0.06 individuals/50 m^2 (mean ± SE). Of these specimens, 1,172 were black (~85% of the total) and 201 were red (~15%), with a mean of 1.28 ± 0.11 and 0.21 ± 0.02 individuals/50 m^2 (±SE), respectively. This frequency distribution varied among sampling times, except between October 2003 and March 2004 (Table 3, Fig. 5). Overall, the total proportion of black specimens was always greater than 70% (Fig. 5), with large variability among sampling times. Specimens larger than 50 mm in CW increased gradually in number with time, whereas the smaller crabs showed reduced abundance from 2003 to 2004 (Fig. 5). The red specimens, all of them larger than 50 mm in CW, showed a low proportion that decreased along sampling time.

In general, the abundance of *Grapsus adscensionis*, terrain variance, and crab detection time increased with the complexity of the substrate (Fig. 6). In particular, terrain variance was not significantly different between the medium and high levels, and the length of time was similar between low and medium difficulty (Fig. 6, Table 4). A positive relationship ($r = 0.5$) was found between mean abundance per island and mean terrain variance. The association was negative ($r = -0.4$) between mean terrain variance and length of rocky platforms. Moreover, the low level of difficulty walking was observed in the eastern islands only—those older geological age and therefore larger sections of smooth, low coasts (Table 1).

DISCUSSION

This study shows the spatial variability in abundance of *Grapsus adscensionis* along the Canarian coastlines is greater at local scales than that at regional scales. This observation is in concordance with the general pattern for communities of

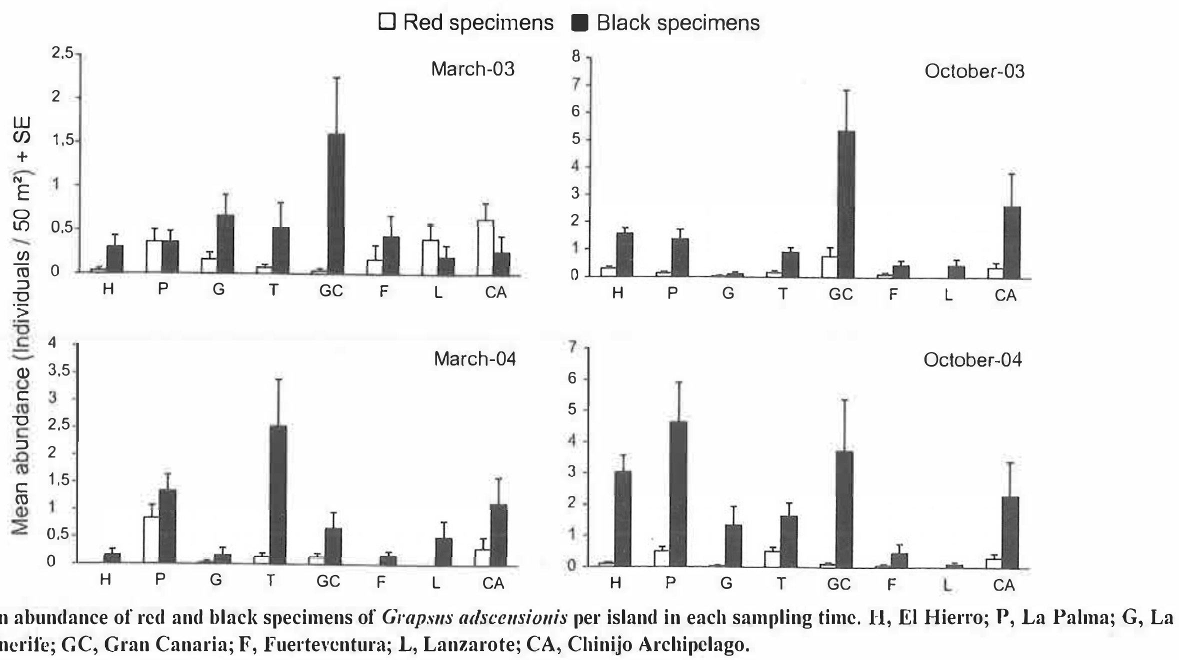

Figure 4. Mean abundance of red and black specimens of *Grapsus adscensionis* per island in each sampling time. H, El Hierro; P, La Palma; G, La Gomera; T, Tenerife; GC, Gran Canaria; F, Fuerteventura; L, Lanzarote; CA, Chinijo Archipelago.

TABLE 3.

Results of Pearson's chi-square test for comparison of frequency distributions among sampling times.

Comparison (sampling times)	Red specimens vs. black			Black specimens <50 mm vs. black ones >50 mm		
	χ^2	*df*	*P* value	χ^2	*df*	*P* value
March–October 2003	17.33	1	<0.001	22.38	1	<0.001
March 2003–March 2004	9.22	1	<0.01	78.65	1	<0.001
March 2003–October 2004	62.85	1	<0.001	98.19	1	<0.001
October 2003–March 2004	0.64	1	0.43	32.74	1	<0.001
October 2003–October 2004	14.13	1	<0.001	44.21	1	<0.001
March–October 2004	18.37	1	<0.001	0.44	1	0.51

X^2, value of Pearson's chi-square; *df*, degree of freedom.

benthic invertebrates (e.g., Fraschetti et al. 2005) and with previous work carried out along the Canary rocky shores (e.g., Ramírez et al. 2005, Ramírez et al. 2009b). Nevertheless, the inconsistency generated by large-scale environmental or geological gradients (island's age), such as those presented in the Canary Islands (e.g., Tuya et al. 2006), should be considered as a possible source of variability in abundance and distribution of this rock crab.

It was noted that the abundance of *Grapsus adscensionis* is governed greatly by habitat complexity. Thus, a larger substrate complexity means a greater number of crabs, which logically resulted in a longer sampling time. Cliffs are the favorite habitat of this rock crab. This type of shoreline offers multiple refuges for grapsid crabs that have an elusive behavior toward humans and birds (e.g., Rathbun 1918). Despite this, differences in abundance at regional scales were not statistically significant; some trends related to topographic features reinforced the importance of the habitat complexity. For instance, the characteristics of the coastal zone in Gran Canaria Island, with coastal areas that includes cliffs and has high terrain variance, seems to be ideal for the presence of *G. adscensionis*, whereas those in Fuerteventura Island, with long coastal areas with low terrain variance, are the opposite. Although the first type of coast is more common for the western islands of the Archipelago, rock crab abundance was not greater on these islands. In fact, a large variability was observed among sites within those islands. To be able to generalize about the major factors contributing to the abundance of this rock crab, the existence of other potentially influential biotic and abiotic factors should also be taken into account (Fraschetti et al. 2005, Tuya et al. 2006).

On the other hand, the low abundance recorded in March and the notable increments of black, smaller specimens in October seem to be the result of recruitment events during the

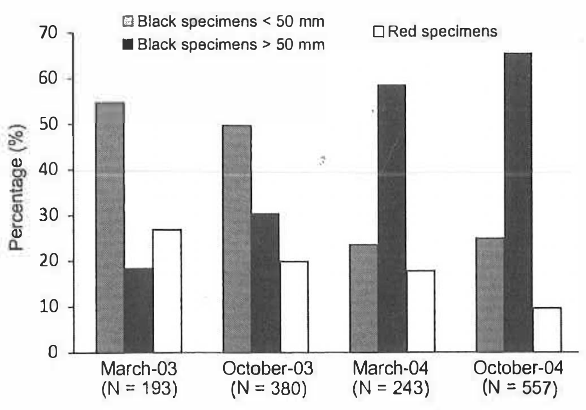

Figure 5. Percentage of red and black specimens of *Grapsus adscensionis* in each sampling time. The black specimens were divided according to carapace width. N indicates the total number of specimens per sampling.

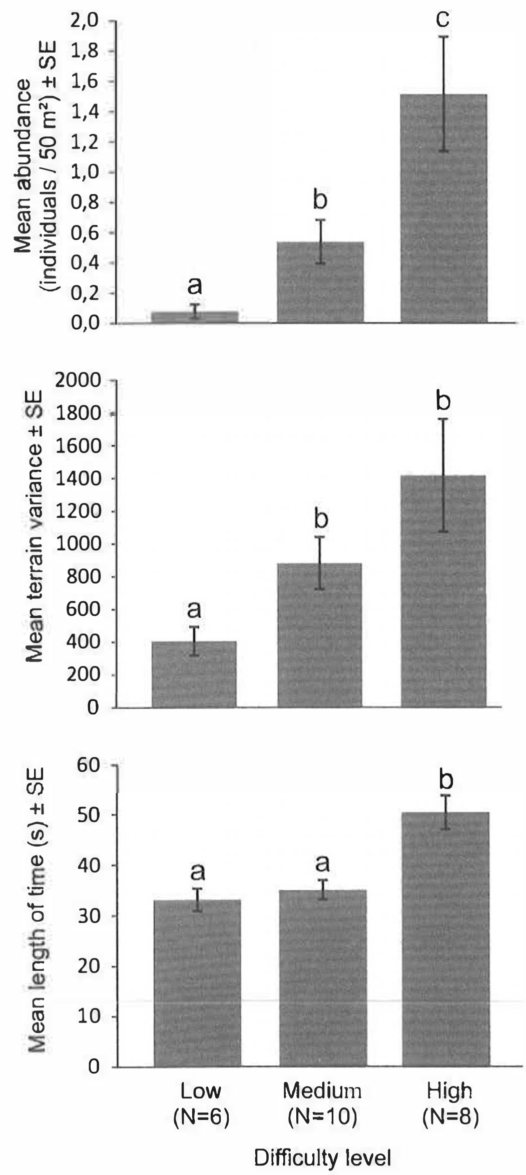

Figure 6. Distribution of mean values of abundance, terrain variance, and length of sampling time according to the level of difficulty (i.e., low, medium, and high) perceived by investigators. The same letter means similarity; different letters mean dissimilarity (see Table 4). N indicates the number of sites per level.

TABLE 4.

Results of the Mann-Whitney *U*-test for comparisons of abundance, terrain variance, and length of time among the 3 difficulty levels considered in the study; the Kruskal–Wallis test results are also included.

	Abundance		Terrain variance		Length of time	
Level of difficulty	U value	*P* value	U value	*P* value	U value	*P* value
Low–medium	9	0.02	9	0.03	23	0.48
Low–high	2	0.003	4	0.01	2	0.005
Medium–high	17	0.04	28	0.30	8	0.005
Kruskal–Wallis test	$H = 11.25$, $df = 2$, $P = 0.004$		$H = 8.32$, $df = 2$, $P = 0.01$		$H = 11.37$, $df = 2$, $P = 0.003$	

H, Kruskal–Wallis statistic; U, Mann–Whitney statistic.

previous months. Previous studies have determined this period occurs from December to September, showing maximum peaks of egg production in February and May/June (Shcherbakova et al. 2011), and even in August (Carro et al. 2004). It has been similarly recorded that the presence of ovigerous females is almost nonexistent in September, and is completely absent in October and November (Carro et al. 2004). The presence of larvae from January to September, as well as main peaks in March/April and August, also confirm this recruitment period (Landeira 2010).

The population structure of *Grapsus adscensionis* is variable in time. Taking into account that this rock crab can live for several years (up to 9 y [Madeira 2008]), the specimens accumulated from 1 y to another may explain the size changes observed, such as the size structure of the black specimens. Furthermore, the population was composed mostly of black specimens the second year. This result was similar to that noted by Freire et al. (2011), who found a population of *G. grapsus* dominated by green specimens. It is known that coloration patterns of semiterrestrial crabs are related to growth, seasonality, desiccation, or endogenous rhythms (Reid et al. 1997, Silbiger & Munguia 2008). For instance, the rock crab *Grapsus grapsus* changes its color gradually with increasing size (Veintimilla 1975). In our case, the red specimens were the bigger ones. Nevertheless, their low proportion could indicate that the change of coloration (i.e., from black to red) is, somehow, a "bottleneck" in the life history of grapsid crabs. Some factors such as predation or aggressive behavior may affect to their survival negatively. Predation (by humans and birds) may even be facilitated by their attractive color, their size, and their behavior (staying at higher levels along the coast for longer periods of time). In this sense, the great abundance of red crabs recorded in Chinijo Archipelago and Lanzarote in March 2003 could be the result of less human prevalence on these islands and the high level of environmental protection of its coastal areas, as is seen in other shellfish species (Ramírez et al. 2009a). In addition, local gatherers at these islands prefer to catch other crabs species, such as *Plagusia depressa* (J.C. Fabricius, 1775), because it is considered of higher quality and taste. In addition, aggressive behavior, such as that reported for *G. grapsus*, may cause mutilation, injuries to the abdomen or cephalothorax, and even death by cannibalism (Romero 2003, Freire et al. 2011).

In the future, understanding the influence of potential factors such as diet and human collection will be a key step toward clarifying the population dynamics of this species. For instance, diet composition affects important vital processes in crabs, such as growth and reproductive performance (e.g., Kennish 1996). In this sense, *Grapsus adscensionis*, similar to *Grapsus grapsus* (Romero 2003), seems to have a varied diet because it can live in different habitats of natural and artificial origin (e.g., rocky cliffs and breakwaters) and occupy diverse levels along the shore. Moreover, there are also differences in food availability between islands, as in those between eastern and western islands for mussels.

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