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Size composition and fecundity of the rock crab *Grapsus grapsus* (Linnaeus, 1758) in the islands of Navachiste Bay, Sinaloa, Mexico

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ABSTRACT

The present study analysed the size composition and fecundity of *Grapsus grapsus* (Linnaeus, 1758) in the intertidal regions of Guasayeye, La Ventana and San Lucas islands in Navachiste Bay, Sinaloa, Mexico. Samples were collected from November 2017 to October 2018 with a bimonthly periodicity and sampling stations were established in each island. Crab samples were collected randomly at nocturnal low tide. Sex of the crabs was determined and carapace width (CW), length (L) and height (H) in mm, and their weight (W) in g were measured. Biometric correlations were performed. Fecundity was estimated in gravid females. The highest percentage of capture for females was 53.3% whereas for males was 46.7% and the sex ratio was 1.15:1. The highest percentage was in San Lucas Island (41.4%) and the lowest in La Ventana (27.7%). Maximum CW (69.3 mm) and weight (137.5 g) were recorded in San Lucas Island, while the lowest CW (9.3 mm) and weight (0.5 g) were recorded in Guasayeye Island. No significant difference in size (CW and W) were observed between sexes or between islands. The average fecundity for female was 9,245 eggs. A high biometric correlation was obtained ($r^2=0.98$) between the morphometric variables and *G. grapsus* was found to have an isometric growth.

Keywords: Fecundity, *Grapsus grapsus*, Navachiste islands, Population, Rock crab, Size composition

The coast of Sinaloa and its natural resources have been insufficiently studied (Flores-Campana *et al.*, 2003). In this region, there are over 400 islands, which are classified as cliffs, cays, bars, points, reefs, rocks, islands and islets which represent almost 45% of the insular bodies that are within the Gulf of California (Flores-Campana *et al.*, 2003). The islands of Sinaloa are considered as continental due to their proximity to the coastal zone or within semi-enclosed coastal ecosystems of bays *viz.*, Topolobampo, Navachiste, Santa Maria, Altata-Ensenada del Pabellon and Mazatlan (Anonimo, 1988). Sinaloa islands are part of a protected natural area which is currently identified as the Flora and Fauna Protection Area of the Gulf of California Islands (DOF 07/06/2000). Therefore, adequate knowledge of the communities that inhabit these environments is necessary, especially in those where anthropogenic activities have not generated significant changes in their composition (Flores-Campana *et al.*, 2007). In these insular ecosystems due to their easy accessibility, some species of crustaceans are captured in

shallow waters or in the intertidal zones. One such species is the rock crab *Grapsus grapsus* (Linnaeus, 1758), which is used locally for human consumption (Arzola-Gonzalez and Flores-Campana, 2008) and as bait for fishing (Arzola-Gonzalez *et al.*, 2010; Gutierrez-Rubio *et al.*, 2018). *G. grapsus* is one of the most common intertidal species in the islands of Navachiste Bay, Sinaloa. This species, belonging to the Grapsidae family, is distributed in the Eastern Pacific in Cedros Island, on the west coast of Baja California, Rocas Alijos and the Revillagigedo islands, Mexico to the Talcahuano Bay, Chile; including the Galapagos islands, Clipperton, Malpelo and Juan Fernandez (Hendrickx *et al.*, 2005). In the equatorial Atlantic Ocean, it is distributed in the San Pedro and San Paul islands (Freire *et al.*, 2010).

Most of the work carried out on this species deals with taxonomic and distribution aspects (Hendrickx *et al.*, 2005, Arzola Gonzalez *et al.*, 2010). Recently, Barcenas-Gutierrez and Jauregui-Velazquez (2017) analysed the

social and reproductive behaviour of *G. grapsus* in the intertidal region of Puerto Vallarta, Jalisco. However, there are practically no studies on morphometric characters (Gutierrez-Rubio *et al.*, 2018) and fecundity (Teschima *et al.*, 2007) of *G. grapsus* from this area. This is a situation very different from that observed in other decapod crustaceans, where various biological aspects have been analysed, such as in lobsters, *Panulirus* spp. (Arzola-Gonzalez *et al.*, 2011); penaeid shrimps, *Penaeus* spp. (Aragon-Noriega *et al.*, 2017) and crabs, *Callinectes* spp. (Rodriguez-Dominguez *et al.*, 2012).

The present study is important because it provides basic information on the size composition and fecundity of *G. grapsus*, that may lead to implementation of fishing regulatory measures by the concerned authorities in Navachiste Bay, Sinaloa, Mexico.

The study area included different locations in the Guasayeye, La Ventana and San Lucas island system; which are located on the coastal area of the south-east of the Gulf of California, between 25° 22' and 25° 35' N and 108° 42' and 108° 56' E, in Navachiste Bay, Sinaloa, Mexico.

Surveys were carried out in the study area in order to identify topographic characteristics, exposure time and area of the coast during the tidal wave. In this way, collection strategies were established in each sampling station, preferably similar location in the rocky substrate were selected and general observations were made in each island. Bimonthly samples were collected from November 2017 to September 2018. Guasayeye Island has the largest rocky beach and La Ventana Island is characterised by a narrow beach and is difficult to access due to the huge size of the rocks. San Lucas Island has two rocky areas with a sandy beach in between with small rocks and a mangrove zone (Ortiz-Arellano and Flores-Campana, 2008).

The samplings were nocturnal during the tides of syzygy and in the low tide phase. A 2x20 m transect was used parallel to the coastline according to Freire *et al.* (2010), with the lower limit at low tide of each station. *G. grapsus* in intermoult stage were collected and deposited in plastic bags with seawater and ice and then transported to the laboratory in a cooler. Subsequently, the crabs were sexed based on the shape of the abdomen (which is wide in females and narrow in males), in addition to the presence of biramous pleopods in females and uniramous in males.

Carapace width (CW), length (L) and height (H) of the crabs were measured with a digital vernier caliper (0.01 mm) and their respective fresh weight (W) using a digital scale (0.1 g sensitivity) in intermoult stage. The form of

growth was verified based on the relation between the length of the cephalothorax and weight, and also between the lengths. Moreover, the coefficient of determination (r^2) between the morphometric relationships was calculated, by means of the following equations:

$$y = a + bx, y = axb, \text{ (Ricker, 1975).}$$

where, y = corresponds to CW, L or W; a = ordered to the origin; b = slope; x = CW, L or W

The Student's t - test was applied to the value of the exponent (b) of the equation obtained from the biometric relationship between length and weight. Once the values were transformed into logarithms and under the assumption that if " b " equals three (Zar, 2009), it was assumed that the *G. grapsus* organisms grow isometrically.

Fecundity was estimated by gravimetric method (Bagenal *et al.*, 1978; Escamilla-Montes *et al.*, 2013) in which all gravid females were used. Once the measurements and the corresponding weight of each specimen were recorded, the egg mass was removed. For each female, the eggs were weighed in preweighed aluminum dishes to get the wet weight of the egg mass.

For each roe, three subsamples of 0.001 g were taken at random and placed in petridishes and counted under a stereoscopic microscope. Then, the average of the three subsamples were calculated. Finally, this average was extrapolated with respect to the dry weight of the roe, thus obtaining the total estimate of eggs (fecundity) for each gravid female.

Normality tests (Kolmogorov-Sminorv test) and homoscedasticity (Bartlet test) were performed on the CW and W data, and Kruskal-Wallis test was performed by ranges. To estimate the difference between the width and weight between sexes, Student's t test was conducted. Student's t test was used to estimate the value of the slope (b) of the biometric relationship of length and weight. In all cases, a significance level of (α) 0.05 was used (Zar, 2009) and the statistical package, StaSoft V7.0 (StaSoft, 2004) was used.

In total, 198 organisms were analysed, out of which 106 were females (53.3%) and 92 males (46.7%), with female to male ratio of 1.15:1. Among the study loations, the highest catch percentage was in San Lucas (41.4%) and the lowest in La Ventana (27.7%). The population of *G. grapsus* reached a maximum width of 69.3 mm and maximum weight of 137.5 g which was recorded in San Lucas Island, while the lowest size in terms of width was of 9.3 mm and weight of 0.5 g was recorded in Guasayeye Island (Table 1).

Table 1. Maximum, minimum, mode, mean and standard deviation (S.D.) of carapace width (CW), length (L) and height (H) and weight (W) of *G. grapsus* in the islands of Navachiste Bay

	CW (mm)	L (mm)	H (mm)	W (g)
Max.	69.3	61.1	35.4	137.5
Min.	9.3	8.4	3.9	0.5
Mode	15.0	12.3	6.2	0.9
Mean	18.0	14.6	8.1	4.9
±S.D.	8.4	7.4	4.6	13.8

No significant differences were found in CW and W between males and females (t-Student test, $p > 0.05$). Among the islands, when comparing the sizes in terms of CW of *G. grapsus*, they did not follow a normal distribution (Kolmogorov-Sminorv, $p < 0.05$). Hence the nonparametric test, Kruskal-Wallis test by ranges was carried out, where the sizes of *G. grapsus* in terms of CW did not indicate significant difference between the rock crabs of Guasayeye, La Ventana and San Lucas islands.

For comparative purposes, W (g) of the rock crabs between the islands were also statistically analysed. They did not present a normal distribution (Kolmogorov-Sminorv, $p < 0.05$), except for the population from Isla La Ventana (Kolmogorov-Sminorv, $p > 0.05$). So the homoscedasticity test was omitted, opting for a

nonparametric test (Kruskal-Wallis test by ranges), resulting in nonsignificant differences in weight between the organisms in the three islands. Linear equations were obtained when correlating the morphometric variables of width, length and height. In all cases, the correlation coefficients (r^2) were above 0.98, which indicated high dependence on the morphometric variables of the rock crabs in the islands of Navachiste Bay. When analysing correlation between the width of cephalothorax and weight, a slope (b) of 2.79 was obtained ($p = 0.95$), which reveals that the population of *G. grapsus* presents an isometric growth (Fig. 1).

The estimation of fecundity per female of *G. grapsus* in the islands, recorded an average 9,245 eggs, with a maximum and minimum variation of 122,287 and 511 eggs, which coincided in San Lucas Island (Table 2).

The organisms were collected above the rocks or between craters among the rocks during night, which corroborates with the observations of Freire *et al.* (2010) who indicated that *G. grapsus* are most active during night. Rock crabs with larger sizes were always located above boulders and usually when they are caught by other crabs of the same species; they enter the coastal lagoon as a defense mechanism (Romero, 2003b). In addition, larger *G. grapsus* exhibit colour variations from olive green to

Table 2. Maximum, minimum and average of total weight of female (TW), wet weight of egg mass (EW) and fecundity (FEC) of *Grapsus grapsus*

Island		TW (g)	EW (g)	FEC (No. of eggs per female)
Guasayeye	Max.	8.6	0.169	16,135
	Min.		0.024	648
	Average		0.069	4,201
La Ventana	Max.	8.3	0.070	2,800
	Min.		0.011	519
	Average		0.038	1,326
San Lucas	Max.	87.5	2.505	122,287
	Min.		0.014	511
	Average		0.551	22,208

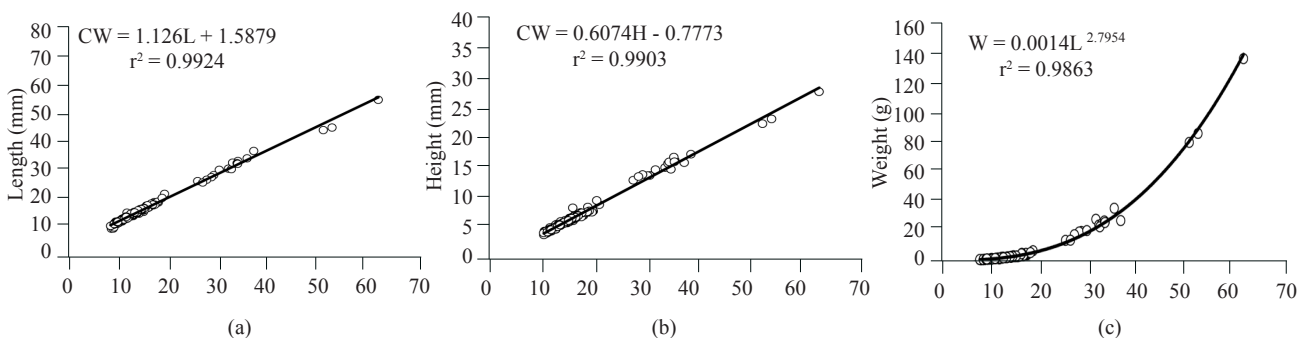


Fig. 1. Biometric relationships of (a) width-length, (b) width-height (mm) and (c) length-weight (g) of *G. grapsus* in the islands of Navachiste Bay

red orange, as reported by Romero (2003a), Fernandez Sanchez (2012) and Freire *et al.* (2010), who attributed the colour variations to reproductive stages and aggressive nature.

The larger sized rock crabs were collected in San Lucas over rocky habitats with abundant bivalve molluscs species *viz.*, *Crassostrea corteziensis*, *Magallan gigas* and *Saccostrea palmula*, while in Guasayeye Island, smaller sized juvenile *G. grapsus* were dominating which were found associated with the gastropod *Cerithium stermuscarum*. Crabs of small sizes were found on the island La Ventana, which has smaller areas of rocks. Furthermore, it was observed that rock crabs were associated with crustacean cirripedes (barnacles) and macroalgae, which according to Romero (2003b) and Arteta-Bonivento (2009) are constantly depredating both groups.

The size of *G. grapsus* in terms of carapace width recorded in the present study was found to be lower than those reported by Brusca (1980), who recorded *G. grapsus* between 40 to 90 mm width. However, this author's collection of rock crabs corresponded to a very specific collection area *i.e.*, islands of Navachiste Bay in the intertidal area of the Gulf of California. The islands Guasayeye, La Ventana and San Lucas covered in the present study are located within Navachiste Bay in the southern centre of the Gulf of California.

Gutierrez-Rubio *et al.* (2018), recorded average size of 41.4 mm CW and 31.5 g weight for *G. grapsus* in the intertidal zone of islands of Mazatlan Bay located south of Sinaloa, which is well above those registered during the present study. It is evident that the size and weight of the population of rock crab in Navachiste Bay could be related mainly to salinity, since this bay is located in a semi-enclosed area that is connected to the Gulf of California by two permanent openings, where salinity varies throughout the year due to precipitation (Flores-Campana *et al.*, 2012) and by the flow of marine currents to the lagoon system or *vice versa* (Sanchez-Lindoro *et al.*, 2017). On the other hand, the islands that are located in Mazatlan Bay are completely connected to the Gulf of California, that is to say, completely marine water, where salinity of the bay are not influenced by precipitations. However, the presence of the rock crab in the intertidal region of the Guasayeye, San Lucas and La Ventana islands (Navachiste Bay) is of particular interest for studies related to these ecosystems, due to the fact that some authors have indicated greater incidence of *G. grapsus* in an intertidal rocky marine habitat (Brusca, 1997; Freire *et al.*, 2010; Gutierrez-Rubio *et al.*, 2018) than in a lagoon ecosystem.

In crustaceans of commercial interest, the use of length-frequency models allows analysing the structure of a population through the distribution of frequencies of mode in length and weight as in the spiny lobsters (Puga-Lopez *et al.*, 2015), penaeid shrimps (Felix Ortiz *et al.*, 2014) and brachyuran crabs (Guerrero and Arana, 2009; Peiro and Mantelatto, 2011; Rivera-Velazquez *et al.*, 2018). Sometimes, it is convenient to use mode rather than the average for population analysis of fishery resources. As it is acknowledged that the standard measure is more common than the average; however, sometimes the mode and the average do not coincide, hence mode is a better representative than the average for any fishery evaluation.

In this study, the values of the means and mode of width, length and height of *G. grapsus* were very similar which imply that the morphological interpretation of the population of rock crab can be used for their fishery evaluation. Although, with respect to weight, both variables (mean and mode) were not similar. Therefore, a better population analysis of this resource in this area would be more advisable using the average than the mode in terms of weight in *G. grapsus*.

Estimation of fecundity per female of *G. grapsus* showed that the maximum and minimum sizes coincided with the crabs collected in San Lucas Island. The female with highest body weight (137.5 g) and egg mass weight (2.5 g) was observed in this island. The relationship between the lower body sizes and lower fecundity as observed in the present study in the Guasayeye, La Ventana and San Lucas islands, corroborates with the findings by Teschima *et al.* (2007) in *G. grapsus* females and in females of *Macrobrachium amazonicum* by Aya-Baquero and Velasco-Santamaria *et al.* (2013), indicating that there is a direct relationship between the size of the female and the number of eggs.

Estimation of fecundity in fishing populations is of special interest in terms of the relationship between the reproductive potential of the species and the capacity for renewal of populations. In addition, it represents a basic aspect in the biological knowledge of the reproductive strategy and evolution of the population. Fecundity represents the potential reproductive capacity of an adult female, that is, the number of eggs produced during spawning; furthermore, it is closely related to the population survival capacities (Bagenal, 1978; Escamilla-Montes *et al.*, 2013). It is an important parameter for estimating the reproductive capacity and size of "future recruitment" of different crustacean species or populations (Hattori and Pinheiro, 2001). Fecundity observed in this study, was well below the one recorded by Teschima *et al.* (2007) for the same species and in Western Atlantic with an average fecundity of 23,873 eggs per female, as well as

Gutierrez-Rubio (2015) in females of *G. grapsus* with an average of 23,354.8 eggs in the islands Lobos, Venados and Pajaros of Mazatlan Bay. The size of the abdomen recorded in the present study were also found lower than those indicated in the above studies.

In contrast to the present finding in *G. grapsus*, Escamilla-Montes (2013) estimated average values above one million eggs per female for commercial crabs *Callinectes arcuatus* and *Callinectes bellicosus*, which indicates that females with larger sizes have higher fecundity. Ramirez Llodra (2002) and Clores and Ramos (2013) have indicated that variations in fecundity of females are directly related to the fact that a female is spawning for the first time. The variations in fecundity of crustaceans have been attributed to the size of females, with their latitudinal distribution and with the habitats (Teschima *et al.*, 2007; Guerrero and Arana, 2009; Freire *et al.*, 2010; Clores and Ramos, 2013).

Results of the present study provides basic information on the size composition, morphometric relationships and fecundity of *G. grapsus* which can be useful for setting fishing regulatory measures for this important resource in the islands of Navachiste Bay.

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