Research Article

The growth of *Callinectes arcuatus* (Ordway, 1863) in the El Colorado Lagoon, Ahome, Sinaloa, Mexico

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ABSTRACT. The size structure of *Callinectes arcuatus* was determined from 2,786 ind (1,956 males and 830 females) of *C. arcuatus*, which were collected from March 2012 to March 2013 in El Colorado Lagoon, Sinaloa, Mexico. Sampling was random in grid form considering five stations located within the study area. Measurements of length (CL), the width of the carapace (CW) and total weight (TW) were registered. The average carapace width of *C. arcuatus* was 9.4 ± 0.03 cm with a minimum of 5.3 cm and a maximum of 19.5 cm. For the length of the carapace (CL) the mean was 4.8 ± 0.02 cm with a minimum of 2.8 cm and a maximum of 9.2 cm, while the total weight varied between 16 and 416 g with an average of 54.0 ± 0.71 g, in both sexes (juveniles and adults).The morphometric relationships between CL-CW were adjusted a linear model. The equation is describing the relation TW-CW, which was adjusted to a potential model with a coefficient of determination of $R^2 = 0.71$. The growth parameters estimated using the model of von Bertalanffy, for males was $K = 0.84$ yr^{-1} y $CW_\infty = 14.0$ cm while for females $K = 0.55$ yr^{-1} and $CW_\infty = 15.6$ cm. According to the results obtained, it is observed that the organisms with sizes and maximum weights were presented in juvenile and adult males in *C. arcuatus*, being slightly larger and heavier than females in similar sizes and according to the growth curves the organisms, this species reaching is the maximum length between 3-4 years old.

Keywords: *Callinectes arcuatus*, size, crab, fishery, Sinaloa, Mexican Pacific coast.

INTRODUCTION

It is of primary importance to get knowledge and characterize the individual growth of those species whose populations are under exploitation. Moreover, knowledge about growth efficiency is determined by the extent of resource availability (Munro & Pauly, 1983; Sparre & Venema, 1997). Thereupon it is clear that by obtaining a detailed comprehension about the growth pattern of a species, more accurate estimates will be obtained about the population size and how available it will be for exploitation, or at least with better-known variability margins (Arreguín-Sánchez *et al*., 1991).

Crabs (Portunidae) represent a highly important fishing resource due to the increase in their demand as an export resource, basically in the presentation of "soft crab." A total of 14 species of the genus *Callinectes* have been identified on both coasts of America, from which 11 are found in tropical and subtropical waters (Fischer & Wolff, 2006). On the coasts of Sinaloa, Mexico a total of 13 species and subspecies have been identified, being the most important ones for the fishing industry the arched swimming crab *Callinectes arcua*-

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tus (Ordway, 1863), the Cortez or warrior swimming crab *C. bellicosus* (Stimpson, 1859) and the giant swimming crab *C. toxotes* (Ordway, 1863) (Rathbun, 1930; Hendrickx, 1984; Ramírez-Félix *et al*., 2003).

C. arcuatus is distributed from Los Angeles to Mollenda, Peru and the Galapagos Islands (Hendrickx, 1984), extending to the northern zone of the coasts of Chile during "El Niño" events (Fischer & Wolf, 2006). The arched swimming crab is a euryhaline species which tolerates a salinity interval of 1-65, and it can be found within a temperature interval of 17.5-34°C, living in depths of 0-40 m (Paul, 1982).

C. arcuatus is an important fishing resource on the Mexican Pacific coast, but there are not many studies about the species. Due to this fact it is necessary to increase the knowledge about its biology, population and fisheries aspects, in order to establish strategies that allow the proper management of this resource by virtue of its biological, commercial and economic importance, but mainly for representing a viable alternative to diversify the fishing activity in lagoon systems (Estévez, 1972; Ramos-Cruz, 2008). This current study aimed to estimate the individual growth parameters of *C. arcuatus* distributed in El Colorado lagoon, Ahome, Sinaloa, by implementing a grid sampling design which distributed five fishing lines in different points within the study area.

MATERIALS AND METHODS

Study area

El Colorado lagoon is a shallow body of water of 146 km^2, with water supplies from the El Fuerte River and the Colorado and Pascola agricultural drainages. It is located in the Ahome municipality, north of Sinaloa, Mexico (25º79'and 25º81'N, -109º28' and 109º45'W) (Fig. 1). It is semi-closed by the Lechuguilla Island at its western portion. It is connected to the sea on the southwest, and it is surrounded by a high amount of estuaries and mangroves. It is a shallow lagoon with an average depth of 3 m. Water temperature ranges from 21.5 to 32.7°C, with a summer and winter average of 32,1°C and 22,0°C, respectively. Salinity values fluctuate from 37 to 48, the pH ranged from 7.71 to 8.13 and dissolved oxygen from 5.43 to 8.53 mg L^{-1} (Diez-Pérez & Ramírez, 1976).

Sampling design

The organisms were collected on a monthly basis by using a grid sampling system, from March 2012 until March 2013, between 6:00 AM to 17:00 PM. Captures were made in five sampling stations (E1, E2, E3, E4 y E5), located by a GPS (Garmin45®, Av. Patria 600, Local A15 Plaza Amistad, Col. Jardines Universidad, CP. 45110, Zapopan, Jalisco, Mexico), taking into consideration the biological behavior of those species from the genus *Callinectes* (Palacios-Fest, 2002). Catches were performed covering the eastern (E1 y E2), southern (E3), and western zones (bocabarra-central part) (E4) and the northern zone (E5), so there could be representative samples from all the sites in the lagoon (Fig. 1).

Three lines of traps per station were set (120 crab rings). Each line contained 40 traps (crab rings with a diameter (Ø) of 50 cm and 1" mesh size) (Fig. 2). In total 600 traps were used each month. The traps matched those devices usually used by fishermen in their fishing activities. The trap line measured 400 m in length with a separation of 300 m between lines, and the distance between the crab rings was of 10 m (Fig. 3). Mullet was used as bait (*Mugil* sp.), and the working period given to each line was of 15 min, in a depth of 1.5 to 3 m, during the new moon cycle. The crabs that were caught were placed in plastic sacks and were kept on ice until they were sent to the lab. After that, the species was identified (*C. arcuatus*) (Maduro, 1974; Williams, 1974; Hendrickx, 1984).

Environmental parameters

Temperature (YSI 55®, HydroTech Service LLC, 4910 Ins Street Wheat Ridge, CO 80033, Central Region-USA), salinity (refractometer Atago®, 11811 NE 1st Street Suite 101 Bellevue, WA 98005, USA), depth and transparency (Sechii disk) were registered every month in each sampling station.

Catch per unit of effort (CPUE)

CPUE was obtained by registering on each operation of the fishing gear the number of captured organisms per trap (crab ring), expressed as ind $trap^{-1}$, being representative for each station and sampling month and sex (Aedo-Urrutia & Arancibia, 2003).

Biometric data

The width (CW) and carapace length (CL) were measured on each organism by using a digital vernier calibrator with 0.05 mm of precision (Mitutoyo® 500-197, 965 Corporate Boulevard Aurora, Illinois 6050, USA). Total weight (TW) was determined by using a digital balance (Ohaus®, Scout Pro SP 200 Balance, Pine Brook, NJ 07058, USA). The individuals were identified according to Williams (1974) and Hendrickx (1984), and the sex was recorded based on the shape of the abdomen and telson (Hendrickx, 1984) (Fig. 4).

Morphometric relationship

In order to evaluate the relationship between the CW and CL, the data were adjusted to a linear model with the following equation:

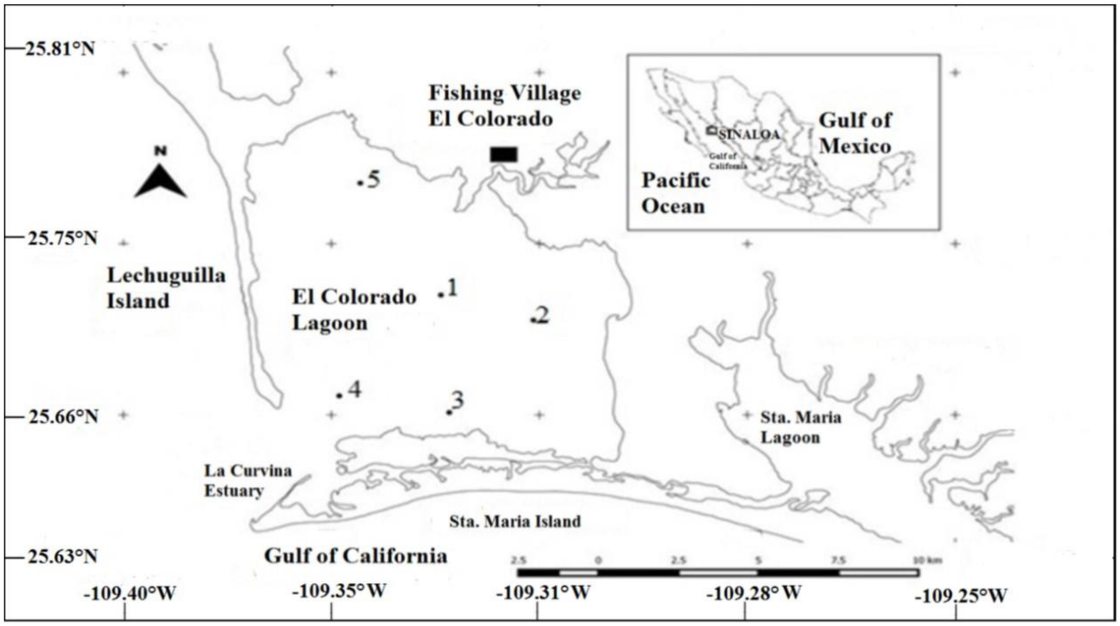

Figure 1. Study area El Colorado Lagoon, Ahome, Sinaloa, Mexico.

Figure 2. Fishing gear used in this study (crab trap).

$$\mathrm{CW} = a + b\mathrm{CL}$$

where CW: carapace width (cm), CL: carapace length (cm), *a*: intercept, *b*: slope.

Concerning the carapace width (CW) and total weight (TW), the values were adjusted to a potential type model through the following equation (Pauly & Munro, 1984):

$$\mathrm{TW} = a\ \mathrm{CW}^{b}$$

where TW: weight of organism, CW: carapace width. The *a* factor is the condition factor or individual robustness condition whereas *b* is an allometric factor, referring to the relative growth to carapace width (Salgado-Ugarte *et al*., 2005).

Size structure

The results from the carapace width (CW) were grouped in frequency histograms with amplitude intervals of 1 cm per age and sex class. In order to determine the age class, the criteria applied by Arreola-Lizárraga *et al*. (2003) was used (<7.5 cm of CW in juveniles, and >7.5 cm of CW in adults).

Growth

The CW data were used for the growth model which were grouped in frequency histograms and were analyzed by the modal progression method with the FISAT II program (FAO-ICLARM Stock Assessment Tools II, Roma, Italia) (Sparre & Venema, 1997). To determine the age, the L_∞ and K parameters were determined, and their dispersion from the traditional von Bertalanffy individual growth model through non-linear approximations by the use of the method of least squares from the data of length to the resulting age of the modal progression (Sparre & Venema, 1997; Escamilla-Montes, 1998). Once the values for each variable from the growth equation were obtained, they were projected through time, starting with the sizes from the smallest juveniles as the origin value. Except for the theoretical age of birth (t_0) the value proposed by other authors was used, which allowed the calculation of the absolute age of the species under study(Arreola-Lizárraga & Hernández-Moreno, 2007; Arciniega-Flores & Mariscal-Romero, 2013).

$$\mathrm{CW} = \mathrm{CW}\infty\ (1 - e^{-K\,(t - t0)})$$

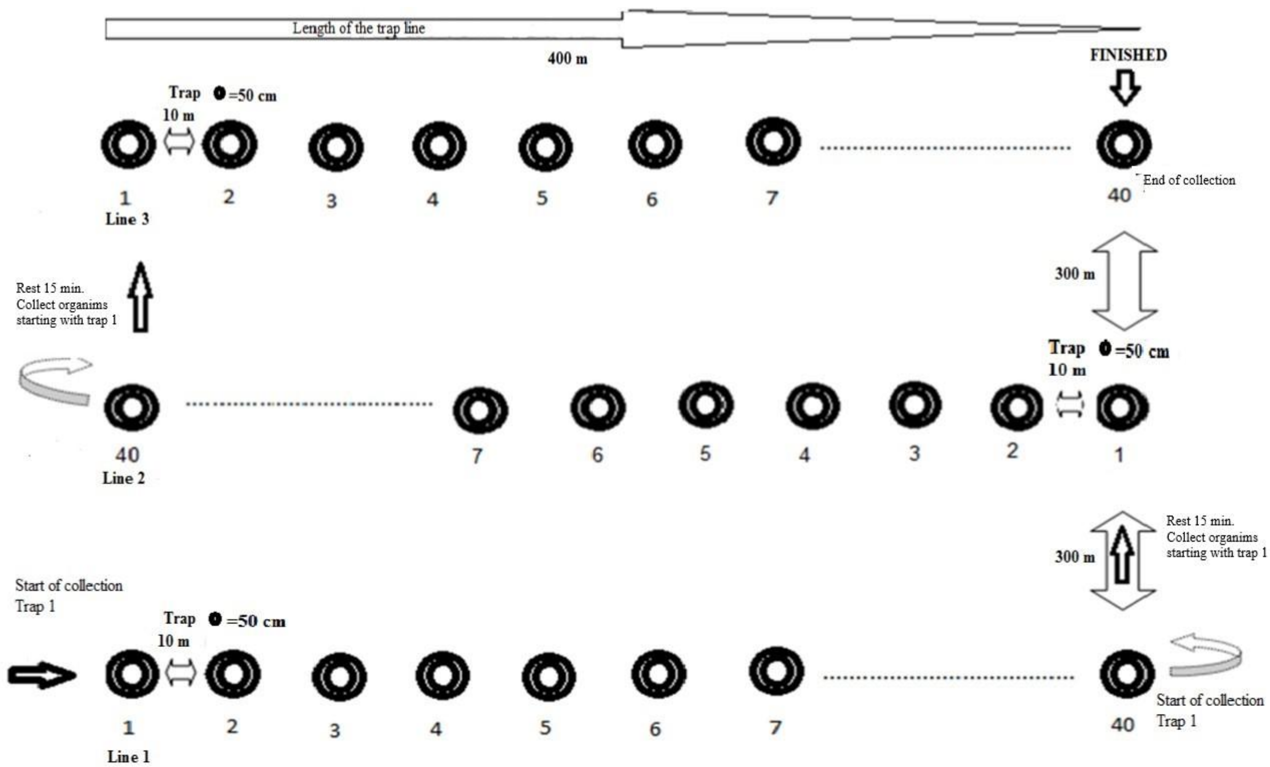

Figure 3. Experimental design by sampling station with crab traps in El Colorado, Ahome, Sinaloa.

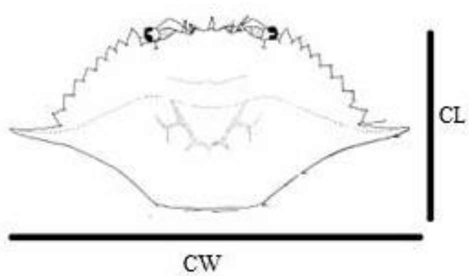

Figure 4. Carapace measurements of *Callinectes*; (CL) carapace length, (CW) carapace width considering lateral spines.

where CW: carapace width in cm, CW_∞: average asymptotic carapace width, K: growth coefficient, t: age of organism, t_0: theoretical age at which length is zero

The variation of growth efficiency was determined following the Phi Prima equation from Munro (Ǿ) (Pauly & Munro, 1984; López-Martínez *et al.*, 2014).

$$Ǿ' = \log10\,(K) + 2 \times \log10\,(CW\infty)$$

where Ǿ´: growth efficiency (Phi Prima from Munro), CW_∞: average asymptotic carapace width, K: growth coefficient.

By using the von Bertalanffy model, growth curves were estimated to get the total weight for both sexes. Modifications were made to these curves where the theoretical width was calculated from the data corresponding to the carapace width-total weight relationship (TW = a CW^b), by using the values of a and b, and the total weight observed values (TW) (Diarte-Plata *et al.*, 2013).

Statistical analysis

A one-way ANOVA analysis was applied to the CPUE between the sampling stations and the months. In order to determine if there were statistically significant differences *a posteriori* multiple comparisons, Tukey test was used (α = 0.05). In the case of the morphometric relationships to evaluate the regression coefficient value of the potential model (b), the *t*-Student test was applied to determine the type of growth exhibited by the species, where $b = 3$ represents an isometric growth, whereas $b \neq 3$, depicts an allometric growth (Ricker, 1975; Bagenal & Tesch, 1978; Zar, 2010).

A residual sum of squares analysis was used to compare the growth curves on both sexes (Chen *et al.*, 1992). The variation coefficient (CV) was used to calculate the significance of the growth efficiency, which is equivalent to the arithmetic average and the standard deviation of the Phi Prima ratio (Ǿ′) (Munro & Pauly, 1983; Sparre & Venema, 1997; Zar, 2010). Statistica 7.0 software was used for all these calculations.

RESULTS

The annual average water temperature registered in the El Colorado Lagoon was 25 ± 0.64°C, with the lowest values recorded in January and March 2013 (18.4°C) and the highest for August 2012 (31.8°C). The mean salinity value was 35 ± 0.30. The lowest was registered in August and September 2012 (32) and the highest in January 2013 (38). Depth (1.74 ± 0.06 m) varied from 1.12 to 1.94 m, in March and August 2012, respectively. Transparency (0.99 ± 0.045 m) was recorded at its lowest in March 2012 at 0.6 m, while its highest was obtained in July with 1.34 m (Table 1).

Within the sampling period, a total of 2,786 crabs' *C. arcuatus* were captured. From this number, 1,956 were males (70.2%), and 830 were females (29.8%) (Table 2). Males were scarce in January 2013 (10 ind) and more abundant in August 2012 (1,381 ind). Females were less abundant in January 2013 (1 ind), and more abundant in August 2012 (644 ind). During the study period, the lowest CPUE for both sexes occurred in December 2012 (0.01 ind trap^{-1}) and the highest (1.66 ind trap^{-1}) in August 2012. Between July (0.771 ind trap^{-1}) and October 2012 (0.885 ind trap^{-1}), the highest CPUE values were observed and the lowest was recorded from December 2012 (0.052 ind trap^{-1}) to February 2013 (0.128 ind trap^{-1}).

The monthly average of CPUE for the crab *C. arcuatus* within the sampling stations was 0.578 ± 0.16 ind trap^{-1} during the entire study period. The highest CPUE value of 3.475 ind trap^{-1} was observed during September 2012 in station E1, whereas the lowest values were found in stations E1, E2 and E4 with 0.009 ind trap^{-1} in January 2013, September and November 2012, respectively. The months with higher CPUE values were April to November 2012, whereas the lowest occurred in December 2012. Significant differences were found in the CPUE for each month ($F_{60, 0.05}$ = 165.54, $P < 0.05$).

The average carapace width (CW) in *C. arcuatus* crabs was of 9.4 ± 0.03 cm with a minimum value of 5.3 cm and a maximum of 19.5 cm. The average value for the carapace length (CL) was of 4.8 ± 0.02 cm with a minimum of 2.8 cm and a maximum of 9.2 cm, while the total weight varied between 16 and 416 g with an average of 54.0 ± 0.71 g.

The size interval observed in juveniles (females and males) was of 5.0 to 7.5 cm of CW, and a unimodal distribution was seen being the size interval most frequent between 6.9 and 7.5 cm, during March, April, August and September 2012. In the case of adult crabs (females and males), the size interval was of 7.6 ta 19.5 cm of CW, where the most representative sizes were between 8.4 and 9.4 cm.

In males a size interval of 5.0 to 14.0 cm of CW was registered, the most frequent size was 9.0 cm of CW. Two main groups were observed, the first one comprised juveniles between 5.0 to 7.0 cm in March, April, August and September 2012, and the second group with adults that had an interval of 8.0 to 14.0 cm of CW were found in every month of the study period but with a main abundance in August and September of 2012 (Fig. 5). For females, sizes ranged from 5.0 to 15.0 cm of CW, being the most representative size of 9.0 cm of CW. Juvenile females were recorded on a monthly basis in March, April, August and September 2012, with sizes between 5.0 and 7.0 cm of CW. On the other hand, in adult females, the size interval ranged from 8.0 to 14.0 of CW, with individuals present during the entire sampling period. In August and September the highest amount of mature females was recorded (Fig. 6). Significant differences in the CW were only observed for juvenile females (F = 1.973, $P < 0.05$), and for the CW and CL of juvenile males (F = 2.015 and F = 1.989, $P < 0.05$).

The relationship between CW and CL was adjusted to a linear type model for males and females, as well as for juveniles and adults (Table 3) with determinant coefficients higher to R^2 = 0.40. The best fit was obtained for females (CL = 0.5541 CW-0.3977, R^2 = 0.8076, F = 3,572.63, $P < 0.001$), where the variation of carapace width (CW) explains 81% of the variability of carapace length (CL). The weakest fit was observed in juvenile males (CL = 0.3593 CW+0.8963, R^2 = 0.4051, F = 103.46, $P < 0.001$).

The model that better represented the relationship between the CW and total weight (TW) was the potential type by age and sex class with determination coefficients higher than 0.4759 (Table 4). A better fit occurred in the overall number of females (juveniles and adults) (TW = 0.159 CW $^{2.5322}$, R^2 = 0.7044, t = 8.31, $P < 0.05$), where variation in total weight (TW) explains 71% of the variability with regards to carapace width (Fig. 7). The slope values of $b \neq 3$ indicate that crabs *C. arcuatus* show a negative allometric growth, independently of sex and age class, with very similar b values (Table 4).

Table 1. Recorded annual averages (mean ± SE) of environmental variables per sampling station in El Colorado Lagoon, Ahome, Sinaloa. SE: standard error.

Station	Temperature (°C)	Salinity	Depth (m)	Transparency (m)
1	24.48 ± 1.51	36.33 ± 0.61	1.83 ± 0.11	0.94 ± 0.09
2	24.71 ± 1.51	35.92 ± 0.71	1.77 ± 0.11	0.94 ± 0.07
3	25.12 ± 1.40	34.92 ± 0.73	1.68 ± 0.07	1.08 ± 0.08
4	25.38 ± 1.54	34.67 ± 0.70	1.93 ± 0.20	1.13 ± 0.13
5	25.52 ± 1.42	35.00 ± 0.63	1.52 ± 0.14	0.83 ± 0.10

Table 2. Abundance-based on the number of males and females of *C. arcuatus* captured in El Colorado Lagoon, Sinaloa, México.

Females		Males	
Juveniles 192	Adults	Juveniles 155	Adults
n = 830	638	n = 1,956	1,801

Figure 8 shows the theoretical growth curves according to the estimated growth parameters from the von Bertalanffy equation at different ages. Male crabs of *C. arcuatus* showed values of CW_∞= 15.6 cm, K = 0.84 yr^{-1} and t_0= 0.09, whereas females had values of CW_∞ = 14.0 cm, K = 0.55 yr^{-1} and t_0= 0.09.

All the models fit correctly with determination values (R^2) higher to 0.90. The resulting equations for males and females are shown in Table 5. The estimated values from the growth equation revealed that males (CW_∞ = 9.4 cm) grow faster than female crabs *C. arcuatus* (CW_∞= 6.31 cm) within the first years of their lives, reaching a maximum length at 3 years of age for both sexes (males = 14.4 cm; females = 11.4 cm) (Fig. 8). An F residual sum of squares test was applied in each growth curve, showing a significant difference in the growth between both sexes (F = 3.85, P = 0.037).

Weight growth curves indicated that during the first year of age males reach a weight of 115.0 g, obtaining a maximum weight of 175.0 g during the 2.7 years of age, whereas females weight 50.0 g, reaching their maximum weight at three years of age (120 g). An F residual square of sums test was used in every weight growth curve where significant differences were observed in the increase of total weight for individuals of both sexes (F = 0.1824, $P < 0.05$) (Fig. 8).

The growth rate was of 6.84 mm $month^{-1}$ in males and 4.69 mm $month^{-1}$ in females. The performance estimate of the growth parameters in males and females using the Munro index (Ø´) was of 4.22 for males and 4.13 for females, while the variation coefficient (CV) for males was of 4.42% and 5.67% for females.

DISCUSSION

The percentages in males (70.2%) and females (29.7%) were higher to the values (60% males and 40% females) found by Estrada-Valencia (1999) in Cuyutlán, Colima. This author reports that male dominance in the catches could be related with their voracity, as well as to the reproductive behavior of females, who tend to group in areas with less variable temperatures and salinity and who leave the lagoon to spawn. Even though the number of males in this study is lower than that reported (80%) in La Paz, BCS, and the Delta of the Colorado River, Sonora, sometimes there are more females than males (Escamilla-Montes, 1998; Villarreal-Chávez *et al*., 2003). Contrary to what was observed by Chávez-Dagostino (1998) and Ramos-Cruz (2008) in Matanchén Bay, Nayarit, and in the lagoon system of La Joya-Buenavista Chiapas, where females were slightly dominant (53 and 74% respectively) than the males.

Arreola-Lizárraga *et al.* (2003) presented a conceptual model about the ecology of *C. arcuatus* y *C. bellicosus* in semi-arid subtropical lagoons from the Gulf of California, suggesting that the reproductive season takes place during spring and summer with the presence of juveniles and adults, and of males and females in the inner part of the lagoons. During autumn the abundance reaches its lowest level, and only adult males are present near the mouth of the lagoons. This tendency matches with what was recorded in El Colorado Lagoon, where the highest catch values per unit effort (CPUE) occurred from April to October for both sexes (1,66 ind $trap^{-1}$), in sites 1 and 2 which were located in the eastern zone, which corresponds to the entrance of the estuarine zone, with lower values from November (0.052 ind $trap^{-1}$). Similar to what was reported by Palacio-Fest (2002) regarding the behavior of juvenile crabs *C. arcuatus* in the lagoon system, based their life cycle and to the ecological function of these coastal bodies of water, which represent the ideal habitat for the growth and reproduction of the species (Williams, 1974).

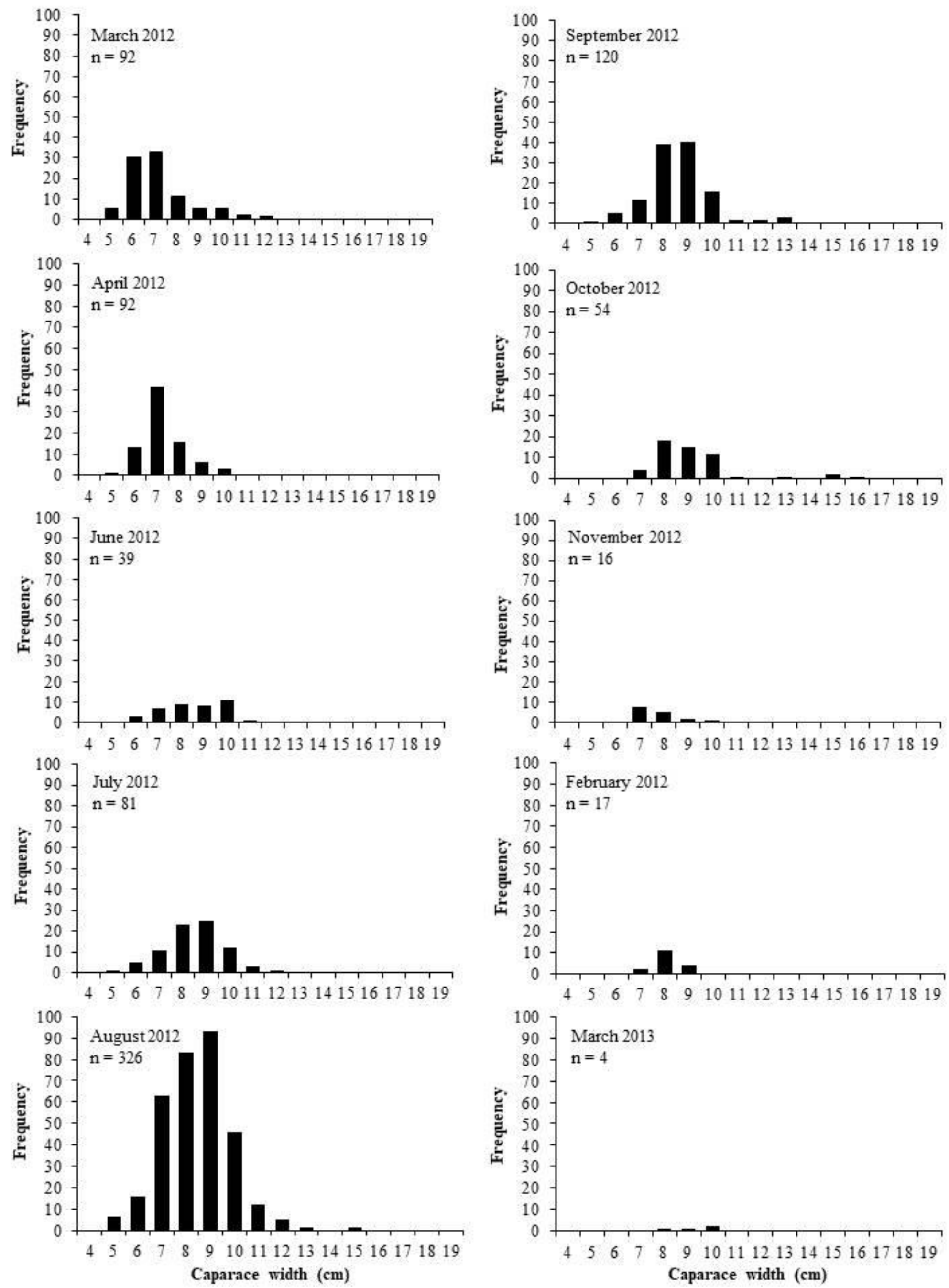

Figure 5. Monthly size structure for female swimming crab *C. arcuatus* in El Colorado Lagoon.

In this study, individuals of *C. arcuatus* showed average sizes of 9.4 ± 0.03 cm of CW, 4.8 ± 0.02 cm of CL and 54.0 ± 0.71 g of TW, being lower to what was reported by Quijano (1985) for the same species in the southern portion of Sinaloa, where the crabs measured in average 9.83 cm of CW and 6.23 cm of CL with an average weight of 77.7 g. Ortega-Lizárraga *et al.* (2016) reported a CW of 11.2 cm for this species in Santa María of La Reforma Lagoon, Sinaloa (central-north zone). According to the maximum size recorded for *C. arcuatus* in El Colorado Lagoon, Ahome, the male with the highest size measured 19.5 in CW and 10.0 cm in CL, which differs from what was reported by Paul (1977) and Hendrickx (1984), who mentioned that the biggest male crabs *C. arcuatus* found in the coastal lagoons of southern Sinaloa measured 14.6 and 12.3 cm, respectively. Those females found in this current study were also bigger in CW (14.0 cm) compared to what was reported by Ortega-Lizárraga *et al.* (2016) who found females with smaller sizes.

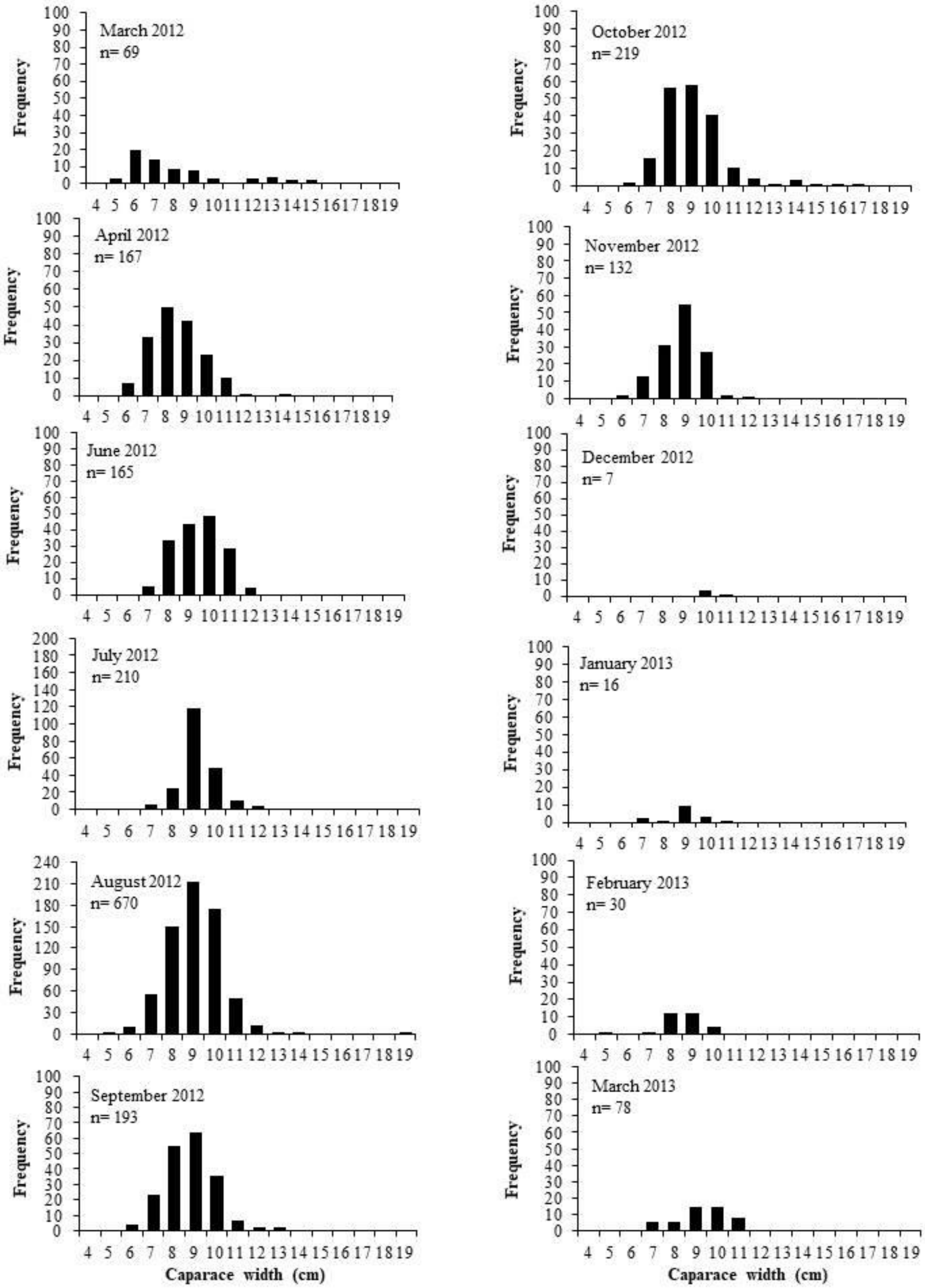

Figure 6. Monthly size structure for male swimming crab *C. arcuatus* in El Colorado Lagoon.

The population of *C. arcuatus* comprises two age classes: juveniles (5.0 to 7.5 cm of CW) being the most frequent sizes 6.9 and 7.5 cm and adults (7.6 to 19.5 cm of CW) where the most representative sizes were found within the range of 8.4 and 9.4 cm for both sexes (Figs. 5-6). In this case, the size structure for this species in the study area consisted of its majority of adult individuals and a lower quantity of juveniles. These results deviate from those reported by Molina-Ocampo (2001), Nevárez-Martínez *et al.* (2003) and Hernández-Moreno & Arreola-Lizárraga (2007), where size structure ranged from 1.8 to 9,8 mm of carapace length

Table 3. Summary of equations of the linear regression which explain the relationship between the carapace width (CW)-carapace length (CL) of *C. arcuatus* from March 2012 to March 2013 in El Colorado Lagoon, Ahome, Sinaloa, Mexico.

Parameters	Sex	Age class	Regression	R^2	*P*
CW (X)	Male	General	CL = 0.5668CW - 0.4944	0.6698	<0.05
		Juvenile	CL = 0.3593CW + 0.8963	0.4051	<0.001
VS		Adult	CL = 0.5732CW - 0.5499	0.6027	<0.05
	Female	General	CL = 0.5541CW - 0.3977	0.8076	<0.001
CL (Y)		Juvenile	CL = 0.4418CW + 0.3733	0.5716	<0.05
		Adult	CL = 0.5075CW + 0.1979	0.5223	<0.05

Table 4. Summary of the equations of potential regression that describe the relationship between carapace width (CW)-total weight (TW) of *Callinectes arcuatus* from March 2012 to March 2013 in El Colorado Lagoon, Ahome, Sinaloa, Mexico.

Parameters	Sex	Age class	Regression	R^2	b	*t*-Statistics	Growth
CW (X)	Male	General	$TW = 0.1852\ CW^{2.4993}$	0.6261	2.4993	11.264	Allometric
		Juvenile	$TW = 0.3309\ CW^{2.194}$	0.4752	2.194	4.310	Allometric
VS		Adult	$TW = 0.1807\ CW^{2.5105}$	0.5229	2.5105	5.900	Allometric
	Female	General	$TW = 0.159\ CW^{2.5322}$	0.7044	2.5322	8.3193	Allometric
TW (Y)		Juvenile	$TW = 0.2945\ CW^{2.2076}$	0.4887	2.2076	5.330	Allometric
		Adult	$TW = 0.1036\ CW^{2.7051}$	0.5243	2.7051	3.495	Allometric

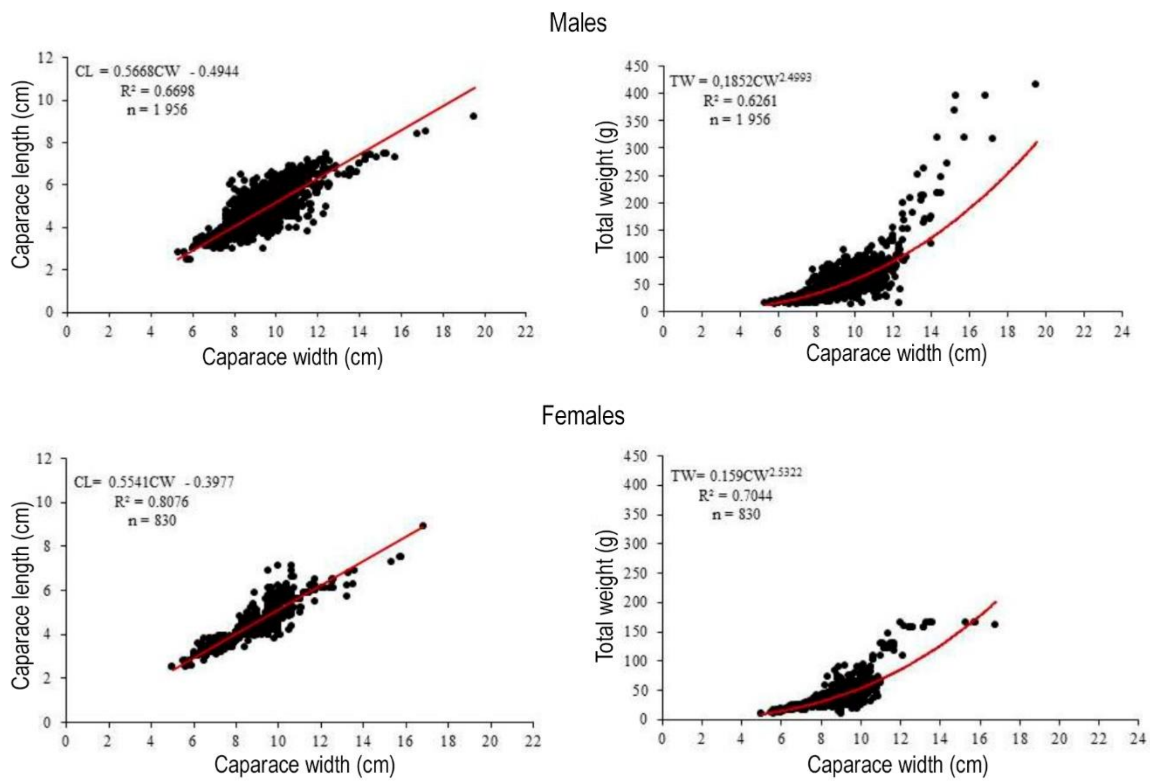

Figure 7. The morphometric relationship between carapace width-carapace length-total weight of male and female crabs *C. arcuatus* in El Colorado Lagoon, Ahome Sinaloa, Mexico.

(CL = CW) with measurements between 65 and 72 mm CL for *C. arcuatus* in Las Guásimas and Lobos bays, Sonora, Mexico. These differences can be explained because the data from these authors were obtained from commercial catches where crabs were taken by traps. This study´s data come from catches performed by different fishing gear like crab rings, as well as the sampling grid design which distributed the fish lines (5 stations) in different places within the inner portion of the study area. All these allowed the capture of smaller

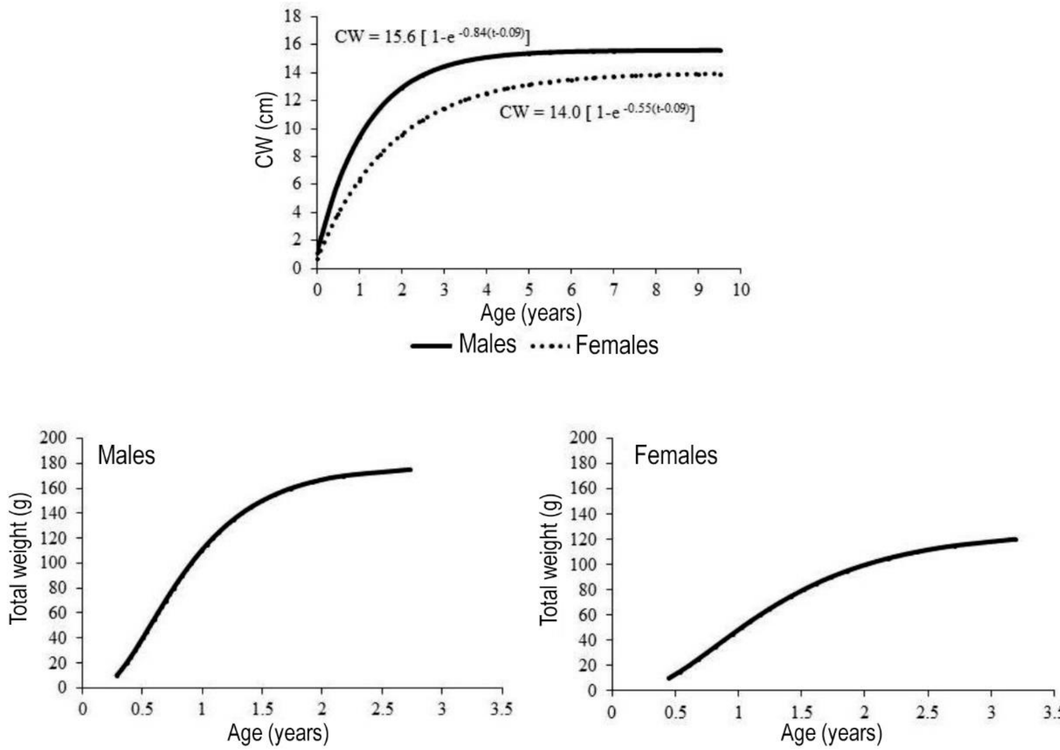

Figure 8. Growth curves from carapace width and total weight regarding the age of *C. arcuatus* obtained by the Von Bertalanffy growth model in El Colorado Lagoon, Ahome Sinaloa, Mexico.

Table 5. Parameters and growth equations calculated for the von Bertalanffy equations for *C. arcuatus* in El Colorado Lagoon, Ahome, Sinaloa, Mexico.

Sex	Growth parameters	Equation	Índex of Munro (Ø´)
Females	CW_∞ = 14.0 cm	CW = 14.0 [1-e $^{-0.55(t-0.09)}$]	4.13
	K = -0.55		
	t_0 = 0.09		
Males	CW_∞ = 15.6 cm	CW = 15.6 [1-e $^{-0.84(t-0.09)}$]	4.22
	K = 0.84		
	t_0 = 0.09		

organisms based on the assumption that each of the modal classes in the frequency distribution would correspond to a cohort representing different specific age classes in regular time intervals.

Nevertheless, the selectivity of the fishing gear could have influenced the distribution of the size frequencies by not capturing individuals smaller than 5 cm, due to the size mesh contemplated in the Norma Oficial Mexicana which refers to the fishing gear used for a sustainable catch of crabs in those waters of federal jurisdiction in the coast of the Pacific Ocean (Morales-Nin, 1991; NOM-039-PESC-2003). In the passive fishing gear that uses bait as an attractant, the catchability is influenced by the response to the bait´s scent. It has been proved that more prominent individuals are more likely to be caught rather than smaller ones (Miller & Addison, 1995).

The obtained morphometric equations in this study were similar to those proposed by Paul (1977) for *C. arcuatus* and *C. toxotes* in the Huizache-Caimanero Lagoon system, Sinaloa and in Oaxaca by Gil & Sarmiento (2001), where the relationship between CW-CL in *C. arcuatus* in the study area were adjusted to a linear model, where males were slightly bigger than females. Quijano (1985) determined that CW-CL relationship within crabs of this species adjusted to a linear model, where males are slightly bigger than females (Fig. 7).

For the CW-TW relationship, the values fit a potential model, showing differences between both 1982;

Table 6. *C. arcuatus*' growth efficiency (ϕ´) comparison between different coastal lagoons in Mexico. Average values of the Munro index ϕ´, standard deviation (SD) and coefficient of variation (CV) by sex.

Sex	L_∞(mm)	K(year)	ϕ´	Source	Locality
Males	140	0.84	4.22	This work	El Colorado, Ahome, Sinaloa
	106.33	3.2	4.56	Arciniega-Flores & Mariscal-Romero (2013)	Barra Navidad, Jalisco
	140	0.84	4.22	Arreola-Lizarraga *et al.* (2003)	Las Guásimas, Sonora
	152	1.9	4.64	Salazar *et al.* (2003)	Topolobampo, Sinaloa
	156	2.0	4.69	Salazar *et al.* (2003)	Navachiste, Sinaloa
	153	2.0	4.67	Salazar *et al.* (2003)	Santa María, La Reforma, Sinaloa
	154	1.9	4.65	Salazar *et al.* (2003)	Ensenada del Pabellón-Altata, Sinaloa
	151	1.9	4.64	Salazar *et al.* (2003)	Ceuta, Sinaloa
	153	0.63	4.17	Gil & Sarmiento (2001)	Mar Muerto Oaxaca- Chiapas
	181	0.8	4.42	Escamilla-Montes (1998)	El Conchalito, BCS
Mean ϕ´	4.49	SD	0.20	CV= 4.51	
Females	156	0.55	4.13	This work	El Colorado, Ahome, Sinaloa
	96.88	1.38	4.11	Arciniega-Flores& Mariscal-Romero (2013)	Barra Navidad, Jalisco
	142	2.0	4.61	Salazar *et al.* (2003)	Topolobampo, Sinaloa
	141	2.4	4.68	Salazar *et al.* (2003)	Navachiste, Sinaloa
	133	2.5	4.65	Salazar *et al.* (2003)	Santa María, La Reforma, Sinaloa
	139	2.2	4.63	Salazar *et al.* (2003)	Ensenada del Pabellón-Altata, Sinaloa
	134	2.3	4.62	Salazar *et al.* (2003)	Ceuta, Sinaloa
	153	0.63	4.12	Gil & Sarmiento (2001)	Mar Muerto Oaxaca- Chiapas
	231	0.5	4.43	Escamilla-Montes (1998)	El Conchalito, BCS
Mean ϕ´	4.43	SD	0.23	CV = 5.23	

Molina-Ocampo, 2001), as it has also been reported with other species from the genus *Callinectes* in the Atlantic coast (Tagatz, 1968; Olmi III & Bishop, 1983; García-Montes *et al.*, 1987). The above can be explained because in Brachyura crustaceans it seems to be an associated trait linked to the reproductive process, where females stop their growth to direct most of their energy to reproduction. Meanwhile, males keep growing even after they have reached their sexual maturity since mating happens after the female has shedded her shell and while she regenerates her exoskeleton, the male must be bigger to protect her for any possible predators (Sastry, 1983; Hernández-Moreno & Arreola-Lizárraga, 2007).

In this current study the slope values $b \neq 3$ reveal that crabs *C. arcuatus* show a negative allometric growth, independently of the age and sex class (Fig. 7), these results are similar to what has been found in other studies where *C. arcuatus* showed an allometric growth (Paul, 1982; Molina-Ocampo, 2001). Molina-Ocampo (2001) attributed this to an offset in their optimal biological condition particularly in females due to low feeding ratios and higher energy expenditure during the reproductive season. Nevertheless, these results do not correspond to what Nevárez-Martínez *et al.* (2003) and Hernández-Moreno & Arreola-Lizárraga (2007) reported. They observed isometry in the crabs that were captured in Las Guásimas and Lobos bays, Sonora, Mexico. It is important to point out that the data obtained by Paul (1982), Molina-Ocampo (2001), and Nevárez-Martínez *et al.* (2003), were based on commercial catches where the population consisted on adult males. While the data obtained in this present study corresponded to catches obtained by a different type of fishing gear (crab rings), being the population represented by juveniles and adults of both sexes.

According to Sparre & Venema (1997), the growth parameters in fish and aquatic organisms differ among species. In those water bodies with a subtropical climate regime and moreover a temperate one, growth will not remain constant throughout the year. It has been discussed that in warmer seasons, where food availability is higher, growth tends to be faster than when temperatures are lower. Also, these parameters can be different from one population to another one. Within the same species, different values can be observed during the life cycle. Subsequent cohorts can grow differently depending on the environmental conditions and the growing parameters usually vary based on the sex and reproductive conditions. Especially crustaceans are more affected by this due to the shedding processes (Petriella & Boschi, 1997; Sparre & Venema, 1997; Yi-Jay *et al.*, 2012). This could explain the remarkable differences between the calculated growth parameters and the Fi Munro index recorded for the same species in different places, where the values sexes. Where males reached bigger sizes and weights than females, as seen in others studies with the same species from other sites of the Mexican Pacific (Paul, are found within the known intervals (Table 6), so according to this a generalization about growth cannot be established and the observed differences are related to the environmental characteristics of each site.

The pattern of growth curves allows us to estimate the size that organisms will achieve until they reach a maximum asymptotic size in a given time. The estimated growth parameters for this study showed that the relative age in which organisms of the species *C. arcuatus* attain their maximum growth is between 3 and 4 years of age for both sexes. The former being similar to what was reported for the Mar Muerto Lagoon system in Oaxaca-Chiapas and in Las Guásimas Bay, Sonora, where crabs of the species *C.arcuatus* and *C. bellicosus* attain their biggest size between 3 and 4 years of age for both species (Gil & Sarmiento, 2001; Hernández-Moreno & Arreola-Lizárraga, 2007).

There are two different types of growth strategies in crustaceans, one which is called *dysecdysis*, the *intermolting phase* which is relatively short and *anecdyisis*, if there is a prolonged intermolting phase between two periods (Paul *et al.*, 1983; Petriella & Boschi 1997; Castillo *et al.,* 2011; Yi-Jay *et al*., 2012).

The growth curves calculated for *C. arcuatus* in El Colorado Lagoon, show a fast molting growth at the beginning of the development, whose duration extends without showing the terminal molting stage, in which males show a slightly faster growth than females during the first years of life (Fig. 8, Table 6).

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REFERENCES

Aedo-Urrutia, G. & H. Arancibia. 2003. Estimating attraction areas and effective fishing areas for Chilean lemon crab (*Cancer porteri*) using traps. Fish. Res., 60: 267-272.

Arreguin-Sánchez, F., J.A. Sánchez & O. Defeo. 1991. Análisis del crecimiento de la almeja amarilla (*Mesodesma mactroides*) de la costa uruguaya en base a datos de composición por longitudes. Frente Marí-timo, 9: 75-81.

Arreola-Lizárraga, J.A., L.G. Hernández-Moreno, S. Hernández-Vázquez, J. Flores-Verdugo, C. Lechuga-Devezé & A.A. Ortega-Rubio. 2003. Ecology of *Callinectes arcuatus* and *C. bellicosus* (Decapoda; Portunidae) in a coastal lagoon of Northwest Mexico. Crustaceana, 76(6): 651-664.

Arreola-Lizárraga, J.A. & L.G. Hernández-Moreno. 2007. Estructura de tallas y crecimiento de los cangrejos *Callinectes arcuatus* y *C. bellicosus* (Decapoda: Portunidae) en la laguna costera Las Guásimas, México. Rev. Biol. Trop., 55(1): 225-233.

Arciniega-Flores, J. & J. Mariscal-Romero. 2013. Estructura poblacional y crecimiento individual de *Callinectes arcuatus* en la Laguna Barra de Navidad, Jalisco. Cienc. Pesq., 21(1): 15-26.

Bagenal, T.B. & F.W. Tesch. 1978. Age and growth. In: T.B. Bagenal (ed.). Methods for assessment of fish production in freshwater. Blackwell Scientific Publications, Oxford, pp. 101-130.

Castillo, J., N. Eslava & L.W. González. 2011. Creci-miento del cangrejo *Callinectes danae* (Decapoda: Portunidae) de la Isla de Margarita, Venezuela. Rev. Biol. Trop., 59(4): 1525-1535.

Chávez-Dagostino, R.M. 1998. Contribución al estudio biológico de la jaiba *Callinectes arcuatus* Ordway, en el sur de Nayarit y norte de Jalisco, México. Tesis de Maestría, Universidad Autónoma de Nayarit, Nayarit, 80 pp.

Chen, Y., D.A. Jackson & H.H. Hervey. 1992. A comparison of von Bertalanffy and polynomial functions in modeling fish growth data. Can. J. Fish. Aquat. Sci., 49(6): 1228-1235.

Diarte-Plata G., R. Escamilla-Montes, G. De la Cruz-Agüero, S. Granados-Alcántar & P. Álvarez-Ruiz. 2013. Crecimiento y supervivencia del mejillón *Mytella strigata* (Bivalvia: Mytilidae) en cultivo suspendido en la Laguna Macapule, Sinaloa, México. Hidrobiológica, 23(3): 374-385.

Diez-Pérez, J.F. & G. Ramírez. 1976. Estudio de las bahías de Ohuira y Topolobampo mediante Landsat. Congreso Nacional de Fotometría, Fotointerpretación y Geodesi,. S.R.H., 120 pp.

Escamilla-Montes, R. 1998. Aspectos de la biología de las jaibas del género *Callinectes* en el Estero El Conchalito, Ensenada de La Paz, B.C.S. Tesis de Maestría, CICIMAR IPN, La Paz, Baja California Sur, pp.107.

Estévez, N. 1972. Estudio preliminar sobre la biología de dos especies alopátricas de cangrejos del Pacifico Colombiano. Bol. Mus. Mar, 4: 1-17.

Estrada-Valencia, A. 1999. Aspectos poblacionales de la jaiba *Callinectes arcuatus* (Ordway, 1863) en la laguna de Cuyutlán, Colima, México. Tesis de Maestría, Universidad de Colima, Colima, 77 pp.

Fischer, S. & M. Wolff. 2006. Fisheries assessment of *Callinectes arcuatus* (Brachyura, Portunidae) in the Gulf of Nicoya, Costa Rica. Fish. Res., 77: 301-311.

García-Montes, J.F., A. Gracia & L.A. Soto. 1987. Morfometría, crecimiento relativo y fecundidad de la jaiba del Golfo *Callinectes similis* Williams, 1966 (Decapoda: Portunidae). Cienc. Mar., 13(4): 137-161.

Gil, L.H. & S. Sarmiento. 2001. Algunos aspectos biológicos y pesqueros de las jaibas (*Callinectes* spp.) en el sistema lagunar Mar Muerto, Oaxaca-Chiapas. Doc. Técnico. SAGARPA. INP. CRIP Salina Cruz, Oaxaca, pp. 41.

Hendrickx, E.M. 1984. Estudio de la fauna marina y costera del sur de Sinaloa, México. III Clave de identificación de los cangrejos de la familia Portunidae. (Crustacea: Decapoda) An. Inst. Cienc. Mar Límnol., (1): 49- 64.

Hernández-Moreno, L. & J.A. Arreola-Lizárraga. 2007. Estructura de tallas y crecimiento de los cangrejos *Callinectes arcuatus* y *C. bellicosus* (Decapoda: Portunidae) en la laguna costera Las Guásimas, México. Rev. Biol. Trop., 55(1): 225-233.

López-Martínez, J., L. López-Herrera, J.E. Valdez-Holguín & C.H. Rábago-Quiroz. 2014. Population dynamics of the swimming crabs *Callinectes* (Portunidae) components of shrimp bycatch in the eastern coast of the Gulf of California. Rev. Biol. Mar. Oceanogr., 49(1): 17-29.

Maduro, Y.L. 1974. Contribución a la taxonomía de las jaibas de la familia Portunidae (Crustacea, Decapoda, Brachyura), de la costa del Pacífico Mexicano y procesamiento bio-estadístico de sus caracteres merístícos. Tesis de Maestría, Universidad Nacional Autónoma de México, México D.F., 81 pp.

Molina-Ocampo, R.E. 2001. Jaiba del Estado de Sonora *Callinectes bellicosus*. In: INP/SEMARNAP (eds.). Sustentabilidad y pesca responsable en México. Evaluación y manejo, Sonora, México, pp. 329-348.

Morales-Nin, B. 1991. Parámetros biológicos de *Mullus surmuletus* (L. 1758) en Mallorca. Bol. Inst. Esp. Oceanogr., 7: 139-147.

Miller, R.J. & J.T. Addison. 1995. Trapping interactions of crabs and American lobsters in laboratory tanks. Can. J. Fish. Aquat. Sci., 52(2): 315-324.

Munro, J.L. & D. Pauly. 1983. A simple method for comparing the growth of fishes and invertebrates. Fishbyte, 1(1): 5-6.

Nevárez-Martínez, M.O., J. López-Martínez, C. Cervantes-Valle, E. Miranda-Mier, R. Morales-Azpeitia & M.L. Anguiano-Carrasco. 2003. Evaluación biológica y pesquera de las jaibas *Callinectes bellicosus* y *Callinectes arcuatus* (Brachyura: Decapada: Portunidae) en las bahías de Guásimas y Lobos, Sonora, México. In: M.E. Hendrickx (ed.). Contribuciones al estudio de los crustáceos del Pacífico este 3. Instituto de Ciencias del Mar y Limnología, UNAM, México., pp. 143-151.

Norma Oficial Mexicana (NOM-039-PESC-2003), pesca responsable de jaiba en aguas de jurisdicción federal del litoral del Océano Pacífico. Especificaciones para su aprovechamiento. Diario Oficial de la Federación. México, D.F., pp.12.

Olmi III, E.J.O. & J.M. Bishop. 1983. Variations in total width-weight relationships of blue crabs, *Callinectes sapidus*, conrcerning sex, maturity, molt stage, and carapace form. J. Crustacean Biol., 3(4): 575-581.

Ortega-Lizárraga, G.G., G. Rodríguez-Domínguez, R. Pérez-González, N. Castañeda-Lomas & E.A. Aragón-Noriega. 2016. Estimation of growth parameters of male blue crabs *Callinectes arcuatus* (Brachyura: Portunidae) from the Gulf of California using the Schnute model. Lat. Am. J. Aquat. Res., 44(2): 371-379.

Palacios-Fest, M.R. 2002. La Jaiba: biología y manejo. AGT Editor, S.A., México D.F., 152 pp.

Paul, R.G.K. 1977. Bionomics of crabs of the genus *Callinectes* (Portunidae) in the lagoon complex on the Mexican Pacific coast. Ph.D. Thesis, University of Liverpool, Liverpool, 36 pp.

Paul, R.K.G. 1982. Observations on the ecology and distribution of swimming crabs of the genus *Callinectes* (Decapoda, Brachyura: Portunidae) in the Gulf of California. Crustaceana, 42(1): 96-100.

Paul, R.K.G., A.B. Bowers & F.J. Flores-Verdugo. 1983. Growth and ecdysis of the portunid crab *Callinectes arcuatus* Ordway (Decapoda, Brachyura), regarding the exploitation of soft-shell crabs in Sinaloa, México. Technical Report Overseas Development Administration, London, 50 pp.

Pauly, D. & J.L. Munro.1984. Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2(1): 1-21.

Petriella, A.M. & E.E. Boschi. 1997. Crecimiento en crustáceos decápodos: resultados de investigaciones realizadas en Argentina. Invest. Mar. Valparaíso, 25: 135-157.

Quijano, A.D. 1985. Fecundidad y crecimiento de la jaiba *Callinectes arcuatus* Ordway, 1863, en el sur de Sinaloa, México. Tesis de Licenciatura, Facultad de Ciencias, Universidad Nacional Autónoma de México, México D.F., 65 pp.

Ramírez-Félix, E., J. Singh-Cabanillas, H.A. Gil-López, S. Sarmiento-Nafate, I. Salazar-Navarro, G. Montemayor-López, J.A. García-Borbón, G. Rodríguez-Domínguez & N. Castañeda-Lomas. 2003. La pesquería de jaiba (*Callinectes* spp.) en el Pacífico Mexicano. In: E.

Ramírez-Félix & J. Singh-Cabanillas (eds.). Diagnóstico y propuesta de regulación. Comisión Nacional de Acuacultura y Pesca, Instituto Nacional de la Pesca, Mazatlán, Sinaloa, 54 pp.

Ramos-Cruz, S. 2008. Estructura y parámetros poblacionales de *Callinectes arcuatus* Ordway, 1863 (Decapoda: Portunidae), en el sistema lagunar La Joya-Buenavista, Chiapas, México. Pan-Am. J. Aquat. Sci., 3(3): 259-268.

Rathbun, M.J. 1930. The cancroid crabs of America of the families: Euryalidae, Portunidae, Atelecyclidae, Cancridae, and Xanthidae. Bull. U.S. Nat. Mus., 152: 609 pp.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can., 191: 382 pp.

Salgado-Ugarte, I.H., J.L. Gómez-Márquez & B. Peña-Mendoza. 2005. Métodos actualizados para análisis de datos biológicos-pesqueros. Facultad de Estudios Superiores Zaragoza, Universidad Nacional Autónoma de México, México D.F., 252 pp.

Sastry, A.N. 1983. Ecological aspects of reproduction. In: F.J. Vernberg & W.B. Vernberg (eds.). The biology of Crustacea 8. Environment adaptations. Academic Press, New York, pp. 109-177.

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Sparre, P. & S.C. Venema. 1997. Introducción a la evaluación de recursos pesqueros tropicales. Parte 1: Manual. FAO Documento Técnico de Pesca 306/1. Rev. 2, Roma, 420 pp.

Tagatz, M.E. 1968. Biology of the blue crab *Callinectes sapidus*, in the St. John River, Florida. Fish. Bull., 67: 17-53.

Villarreal-Chávez, G., P.G. González-Ramírez, F.A. García-Domínguez, E.F. Félix-Pico & O. Holguín-Quiñones. 2003. Population biology of *Callinectes bellicosus* (Stimpson, 1859) (Decapoda: Portunidae) in Bahía Magdalena Lagoon system, México. In: M.E. Hendrickx (ed.). Contributions to the study of east Pacific crustaceans Vol 2. Instituto de Ciencias del Mar y Limnología, UNAM, México, pp: 169-176.

Williams, A.B. 1974. The swimming crabs of the genus *Callinectes*. Fish. Bull., 72(3): 685-798.

Yi-Jai, C., S. Chi-Lu, Y. Chen & Y. Su-Zun. 2012. Modeling the growth of crustacean species. Rev. Fish Biol. Fish., 22: 157-187.

Zar, J.H. 2010. Biostatistical analysis. Prentice Hall, New Jersey, 662 pp.