

Research Article

Population structure and fecundity in *Uca virens* Salmon & Atsides, 1968 (Decapoda: Ocypodidae) in southern Tamiahua Lagoon, Veracruz, Mexico

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ABSTRACT. Fiddler crabs are common decapods of intertidal zones; thirteen species have been reported along the coast of the Gulf of Mexico, inhabiting different zones. For the southern region of the Tamiahua Lagoon, Veracruz, Mexico, five species have been identified: *Uca panacea*, *U. rapax*, *U. spinicarpa*, *U. virens* and *U. vocator* particularly in the southern region of the Tamiahua Lagoon, Veracruz, Mexico. Here we analysed the fecundity of *U. virens* in 25 ovigerous females out of 387 individuals collected between December 2008 and December 2009 during eight field trips and from five collection sites. Morphological measurements like carapace length (CL) and carapace width (CW), and total wet weight (TWW) for all individuals collected were taken, and total egg number was counted for ovigerous females. The total population was divided in nine size class intervals. Total egg number varied between 3,617 and 41,099. Egg number increased with CW (ranging from 9.0 to 18.6 mm CW) and TWW. Values of fecundity observed for *U. virens* in Tamiahua Lagoon vs other *Uca* species were similar to results reported in literature.

Keywords: *Uca virens*, morphological measures, fecundity, Tamiahua Lagoon, Mexico.

Estructura de la población y fecundidad en *Uca virens* Salmon & Atsides, 1968 (Decapoda: Ocypodidae) en el sur de la Laguna de Tamiahua, Veracruz, México

RESUMEN. Los cangrejos violinistas son crustáceos comunes de las zonas intermareales y en el Golfo de México, registrándose 13 especies que habitan diferentes zonas. En la región sur de la Laguna de Tamiahua, Veracruz, México, se identificaron cinco especies: *Uca panacea*, *U. rapax*, *U. spinicarpa*, *U. virens* y *U. vocator*. En este trabajo, se analizó la fecundidad de *U. virens* en 25 hembras grávidas de 387 organismos recolectados entre diciembre 2008 y diciembre 2009 en ocho fechas y cinco estaciones de colecta. Se midió la longitud (CL) y ancho del caparazón (CW), peso húmedo total (TWW) y se estimó el número total de huevos en hembras grávidas de todos los organismos de la población. La población total se dividió en nueve intervalos de clase de talla. El número de huevos varió entre 3.617 y 41.099 obteniendo una tendencia positiva en la relación. El número de huevos aumentó con el CW y el TWW de cada hembra ovígera, las cuales midieron entre 9,0 y 18,6 mm CW. Los valores de fecundidad observados para *U. virens* en la Laguna de Tamiahua vs otras especies de *Uca* son similares a los resultados reportados en la literatura.

Palabras clave: *Uca virens*, medidas morfológicas, fecundidad, Laguna de Tamiahua, México.

INTRODUCTION

The fiddler crab genus *Uca* is a well-known group of brachyuran crabs, characterized by having strong sexual dimorphism and male asymmetry (Rosenberg, 2001). They are common inhabitants of marshes, salt flats and mangrove swamps along tropical, neotropical,

and temperate coastlines (Crane, 1975; Mouton & Felder, 1995). Throughout most of the day these crabs reside within cool, humid burrows located in the higher intertidal zones that provide a stable microhabitat, presumably satisfying their moisture requirement and preference for a humid environment (Harris & Kormanik, 1981; Yoder *et al.*, 2005). The genus *Uca*,

one of the most important one with regard to number of species, density and total biomass in mangrove forests (Litulo, 2004a).

Crane (1975) listed 91 forms of *Uca*, including species and subspecies, but due to inconsistencies of her concept, most subspecies were treated as species by subsequent authors. Currently, 94 species have been recognized (Beinlich & Von Hagen, 2006).

Uca virens Salmon & Atsides, 1968 was originally reported only from Ocean Springs, Mississippi and Port Aransas, Texas, but subsequently was found in older collections from Mexico (Crane, 1975). Felder (1973), Crane (1975) and Von Hagen (1975, 1976, 1980) have all argued that the diagnostic morphological and behavioural traits described for *U. virens* fall within the range of variation reported for populations of *U. rapax* (Smith, 1870). Crane (1975) subordinated *U. virens* as a subspecies of *U. pugnax* (Smith, 1870), consequently extending the distribution range to Coatzacoalcos, Mexico. Barnwell & Thurman (1984) reported 15 species for the eastern of North America between Massachusetts, USA, and Quintana Roo, Mexico, and 13 from the Gulf of Mexico.

Information on the natural history and the reproductive biology of *Uca* species is limited (Rabalais, 1991). The species of *Uca* produce a variable number of eggs and fecundity is proportional to the size of ovigerous females. While few *Uca* species produce larger but fewer eggs, most species of *Uca* produce small and numerous eggs. Many species of *Uca* with extended planktotrophic larval development and an incubation period of 12-15 days produce small embryos (0.21-0.38 mm Ø; Yamaguchi, 2001). An exception within the genus is *U. subcylindrica* (Stimpson) with large embryos (1.06 mm Ø), lecithotrophic larval development, and an incubation period of 1-1.5 months (Rabalais, 1991; Litulo, 2004a, 2005a; Costa *et al.*, 2006; Lavajoo *et al.*, 2011).

Sastry (1983) observed that egg number and production periodicity were species-specific factors that reflected the reproductive strategy of each species. Fecundity analysis not only includes the estimation of egg numbers, but also the seasonal pattern of egg production. The reproductive aspects and fecundity in brachyurans have been treated for different families (Costa *et al.*, 2006; César *et al.*, 2007). Koga *et al.* (2000) analysed fecundity in different ocy podids and found that the production of large broods was not continuous (because of food scarcity, desiccation and egg vulnerability), while in species with small broods females tend to reproduce continuously.

Santos (1978) defined fecundity as the number of eggs laid by one female per spawning. However, Bond

& Buckup (1982) defined fecundity as the number of eggs per spawning that was found adhered to the female pleopods (Da Silva *et al.*, 2004). When estimating the reproductive potential and future stock size of a given species or population, the fecundity is an important parameter (Mori *et al.*, 1998; Hattori & Pinheiro, 2003). Moreover, the fecundity depends on female age, length and weight, as well as environmental conditions (Sivashanthini *et al.*, 2008). The number of eggs produced generally increases with female size (available cephalothoracic space) and decreases during embryogenesis (Hines, 1982, 1986), which is related to the embryo growth and water uptake during the incubation period. Numerous methods are available to estimate crustacean fecundity (Somers, 1991). The purpose of this study is to document the variation in size, fecundity, and egg size of *Uca virens* in Tamiahua Lagoon, Veracruz, Mexico.

MATERIALS AND METHODS

The Tamiahua Lagoon has a surface of 800 km², with dominant clayed soils, and is located in the northern Veracruz state between the rivers Panuco and Tuxpan, Mexico. Mangrove forest is the dominant ecosystem, conformed by *Laguncularia racemosa* (L.) C.F. Gaertn, *Avicennia germinans* L. (L.) and *Rhizophora mangle* L., however, salt marshes and tropical rainforest are also present in the area.

During eight field trips (16/12/2008; 31/1/2009; 9/5/2009; 4/7/2009; 5/9/2009; 2/10/2009; 1/11/2009; 15/12/2009) in five previously established sites in the southern Tamiahua Lagoon, the following fiddler crab species were collected: *U. panacea* Novak & Salmon, 1974, *U. rapax*, *U. spinicarpa* (Rathbun, 1900), *U. virens*, and *U. vocator* (Herbst, 1804) (Fig. 1). Collections were carried out during daylight (8.00 to 16.00 h) using a hand-net and covering an area of 20x20 m (400 m²). Collection sites included the beach area and the land flora zones. Specimens were preserved in ethylic alcohol 70%. To avoid egg loss, ovigerous females (females with eggs attached to pleopods) were individually stored in glass containers. In the laboratory, individuals were identified and separated by sex. The carapace length (CL), the carapace width (CW), and the total wet weight (TWW) of all individuals of *U. virens* were measured with the aid of an electronic caliper (± 0.05 mm) and an electronic balance (± 0.005 g), respectively. Rainfall levels (Fig. 2a) from Veracruz State published by Water National Commission (CONAGUA) were consulted. For each collection site, coordinates (Garmin GPS12), pH (Fig. 2b), and water temperature (Fig. 2c) at 50 cm under surface were registered.

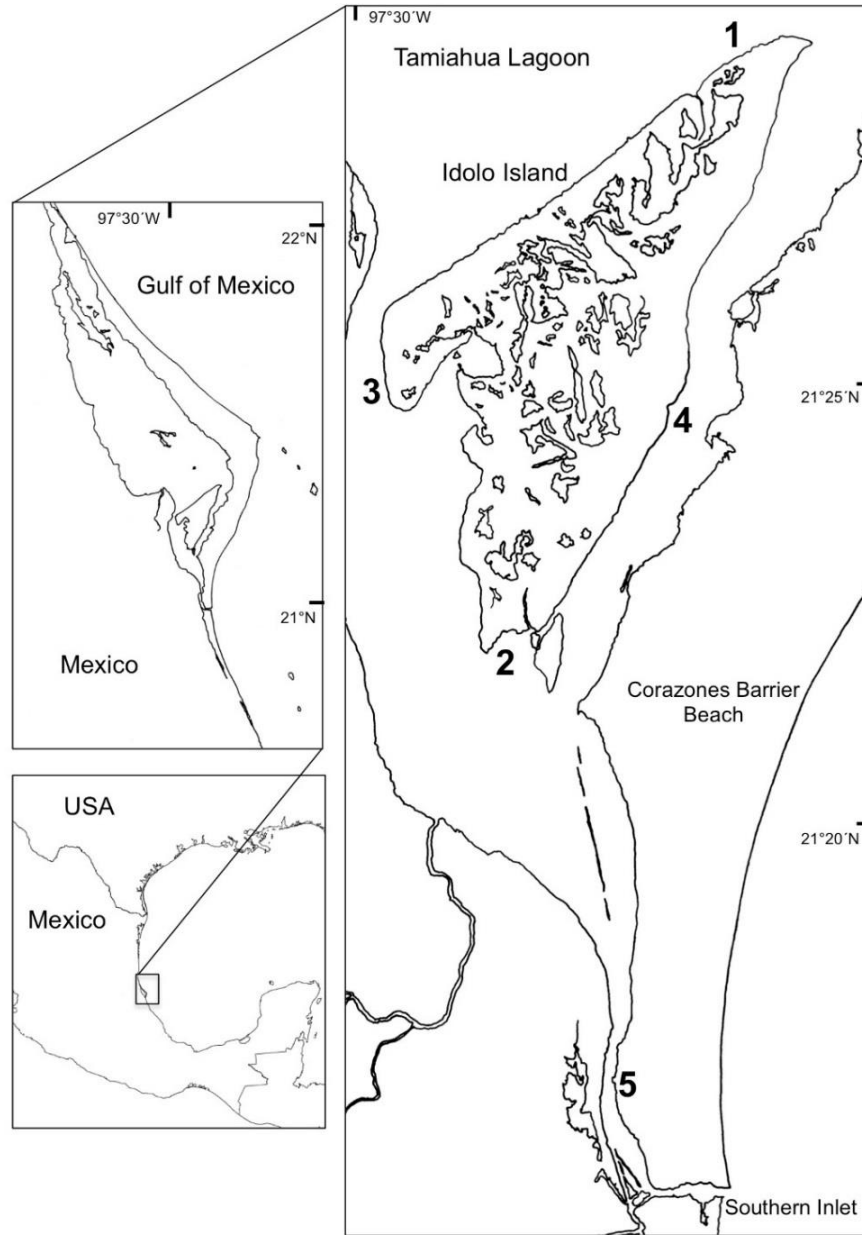


Figure 1. Collection sites around the Idolo Island in Tamiahua Lagoon, Veracruz, Mexico.

The egg mass of ovigerous female attached to pleopods was removed, weighed and stored in 5 mL vials. To obtain the average weight of an individual egg, an aliquot was weighed, and eggs were counted; the total egg number was estimated by weighing the remaining egg mass and dividing this value by the average egg weight. To calculate the average size of the eggs, the diameter of a total of 25 eggs from each ovigerous female was measured using a compound microscope. The ovigerous females obtained were separated in 2 mm size classes to generate size-frequency distribution graphs (Table 1). Correlation

and regression coefficients for CW, TWW and total egg number were calculated.

RESULTS

A total of 897 individuals of the genus *Uca* were collected, of which 387 (43.1%) were *U. virens* with 146 females and 241 males, distributed in nine size-class intervals (Table 1). The sex ratio was 1:1.6 (females:males). Minimum, maximum, mean, and standard deviation of CW for males, non-ovigerous females, and ovigerous females was 4.4-21.1, 14.18 ±

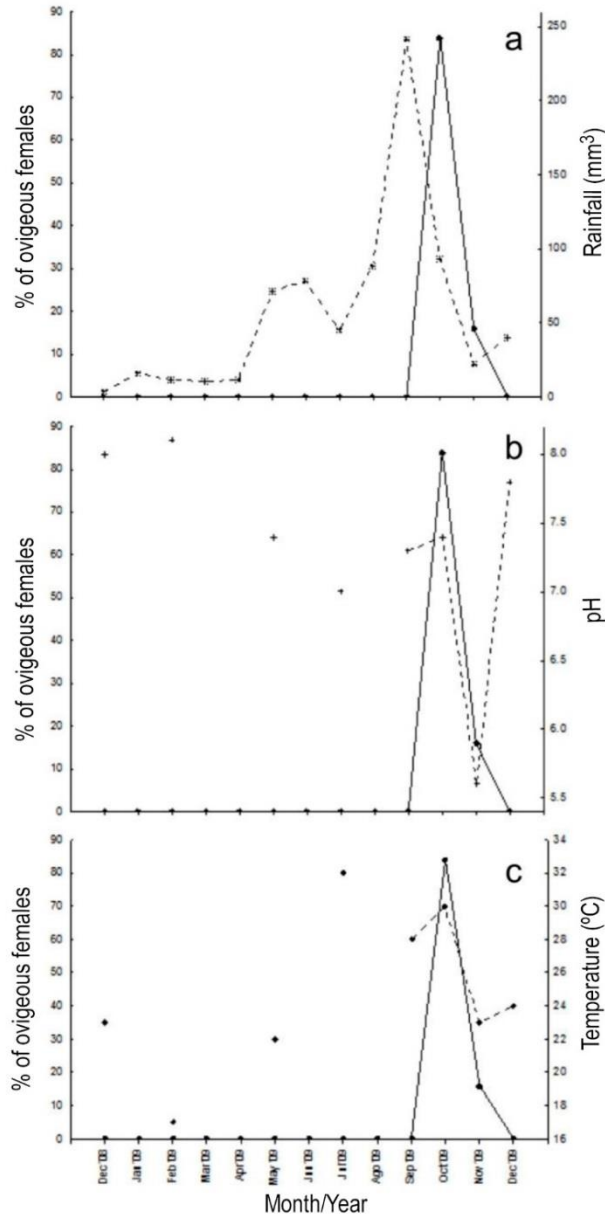


Figure 2. Physical and chemical parameters in relation to the presence of ovigerous females of *Uca virens* (expressed as percent of total individuals collected). a) Rainfall average data values for northern region of Veracruz state, (CONAGUA, 2008-2009), b) water pH values, and c) average temperatures at sampling sites (● Ovigerous females; * Rainfall; + pH; ♦ Temperature °C).

3.65; 4.3-23.0, 13.48 ± 2.81 , and $9.1-18.6$; 13.71 ± 2.29 , respectively. The size of ovigerous females varied between 9.0-18.6 mm CW. Most individuals (91.2%) were encountered in the class intervals between 8.0 and 18.0 mm CW (Fig. 3).

Uca virens was present during every month in the five collection stations with an increase in the number

of individuals from May 2009 to November 2009. Ovigerous females were observed only in October and November with mayor densities in October. These months coincided with the end of the rainy season, characterized by lower pH values, higher values of rainfall and relatively lower temperatures (Fig. 2) than during the remaining year.

Total egg number varied between 3,617 and 41,099, and increased with both CW (Fig. 4a) and TWW (Fig. 4b), with higher R^2 values for the relationship egg number/CW.

DISCUSSION

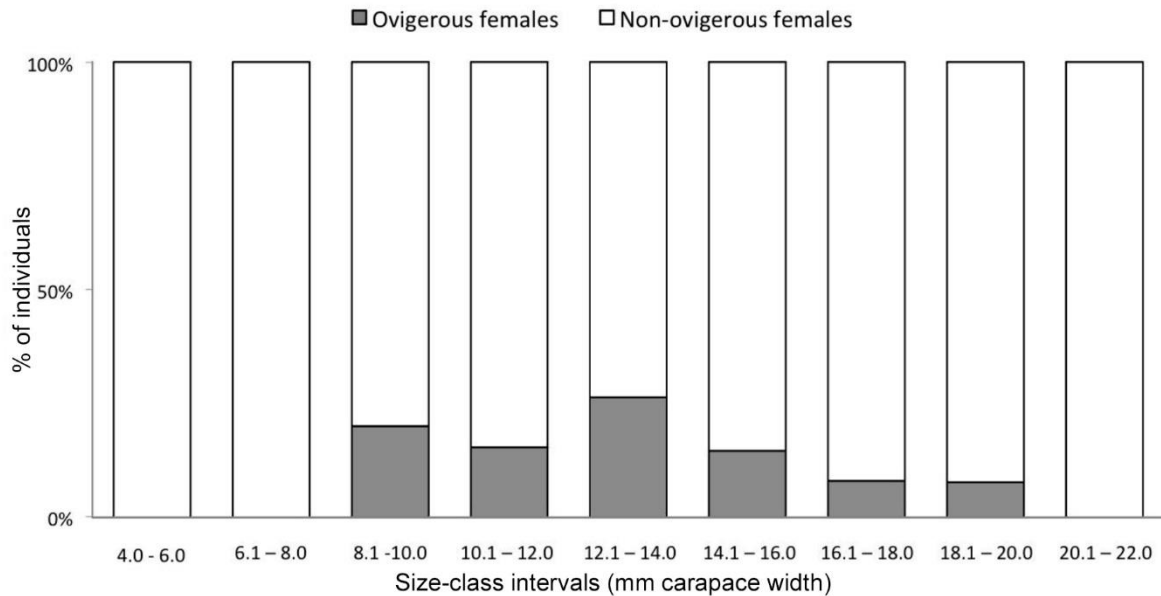
Barnwell & Thurman (1984) reported 13 species of *Uca* inhabiting the Gulf of Mexico, while Raz-Guzmán *et al.* (1992) and Raz-Guzmán & Sánchez (1996) mentioned only two species of *Uca* in Tamiahua Lagoon. In the present study, we encountered five species in southern region of Tamiahua Lagoon.

Several studies on decapods have mentioned environmental factors such as temperature, food availability, rainfall, and photoperiod, as the major modulators of reproduction (Zimmerman & Felder, 1991; Flores & Negreiros-Franzoso, 1998; Leme & Negreiros-Franzoso, 1998; Henmi, 2003; Litulo, 2004a, 2005a, 2005b; Hirose & Negreiros-Franzoso, 2008). Environmental pollution and fishing effort have shown important effects in the reproduction process too (Lauren & Weis, 2008). Moreover, endogenous factors, such as nutritional state of parental females (Delevati & Negreiros-Franzoso, 2003), gonad development period, and age of attaining sexual maturity (Tarso & Soares-Gomes, 2009), might play an important role in the reproductive process. Tarso & Soares-Gomes (2009) mentioned that different reproductive strategies of decapod crustaceans are the result of a coordinated action of exogenous and endogenous factors. Additionally, these factors exert influence on behaviour, maturity, fecundity, and reproductive period in fiddler crabs population (Sastry, 1983). Here we observed a short reproductive period associated to the end of the rainfall season, in agreement with the observations of Rabalais (1991). We consider that future work should include the above-mentioned variables to explain the fecundity for *U. virens* in the Tamiahua Lagoon.

The rainy season in the Tamiahua Lagoon ended in October with a peak in September, modifying pH and salinity values (Fig. 2). According to Conde & Diaz (1989) and Mantelatto *et al.* (2003), a spawning period in the rainy season provides a selective advantage to intertidal brachyuran populations, since those periods promote an increase of nutrient concentration favouring

Table 1. Size-class intervals of *Uca virens* from southern Tamiahua Lagoon, Veracruz, Mexico, separated in males, females, and ovigerous females (average size in mm with standard deviation, SD).

Class	n	Intervals CW (mm)	♂ $\bar{X} \pm SD$	N	♀ $\bar{X} \pm SD$	n	Ov.♀ $\bar{X} \pm SD$	n
1	2	4.0-6.0	4.40 ± 0.00	1	4.30 ± 0.00	1	-	-
2	17	6.1-8.0	7.47 ± 0.52	11	6.98 ± 0.46	6	-	-
3	43	8.1-10.0	9.17 ± 0.58	30	9.39 ± 0.51	12	9.00 ± 0.00	1
4	95	10.1-12.0	11.07 ± 0.52	64	11.21 ± 0.57	27	10.95 ± 0.26	4
5	86	12.1-14.0	13.03 ± 0.60	41	13.07 ± 0.44	35	13.01 ± 0.71	10
6	85	14.1-16.0	15.03 ± 0.58	57	14.78 ± 0.54	21	15.37 ± 0.56	7
7	45	16.1-18.0	16.74 ± 0.44	29	16.55 ± 0.60	14	16.85 ± 0.21	4
8	12	18.1-20.0	18.92 ± 0.50	7	18.40 ± 0.21	4	18.60 ± 0.00	1
9	2	20.1-22.0	21.10 ± 0.00	1	20.30 ± 0.00	1	-	-
Total	387			241		121		25

**Figure 3.** *Uca virens* from southern Tamiahua Lagoon, Veracruz, Mexico. Percentage of ovigerous females from all females collected per size-class interval.

the development of planktonic larvae, and resulting in an increased primary productivity of the seawater.

According to Sastry (1983), Thurman (1985) and Rabalais (1991), precipitation with associated changes in salinity and food availability can trigger reproduction in *Uca*. Particularly, Rabalais (1991) reported that peaks of reproduction of *U. virens* occur after maximum levels of rainfall. Our data coincided with these observations and revealed a two-month period peak (October and November) where ovigerous females of *U. virens* were present, indicating a well-marked breeding season (Fig. 5) that coincided with

low values of pH and temperature, and high values of rainfall (Table 1). These findings might differentiate *U. virens* from other species, which have been reported to have continuous breeding over the season (Sastry, 1983; Thorson, 1950; Litulo, 2005b). For example, Il *et al.* (2007) reported that populations of *U. uruguayensis* (Nobili, 1901) might exhibit at different locations a continuous or seasonal breeding pattern depending on food abundance in the plankton (Sastry, 1983; Ashton *et al.*, 2003).

Many studies demonstrated a direct relationship between female size and fecundity in brachyuran crabs

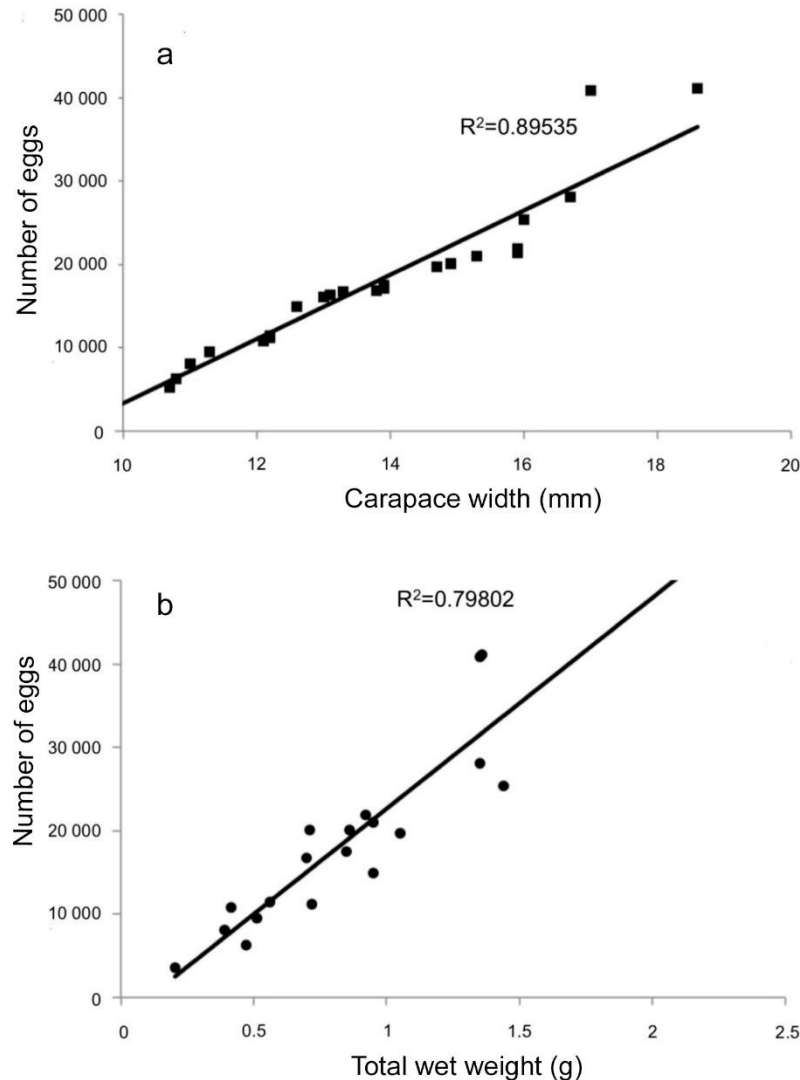


Figure 4. Relationship between a) number of eggs and carapace width, b) total wet weight in *Uca virens* from southern Tamiahua Lagoon, Veracruz, Mexico.

(Hartnoll, 1985; Thurman, 1985; Hines, 1986; Rodríguez *et al.*, 1997; Litulo, 2005a). Fecundity is species-specific, varying widely with latitude, habitat structure and food availability (Henmi, 2003). According to Figueiredo *et al.* (2008), CW of females in *Uca* is an adequate predictor of the number of eggs, with larger females producing significantly more eggs than smaller individuals. Our results confirm that *U. virens* exhibits this positive relationship (Fig. 4).

Although according to Thurman (1985) egg size is independent of female size, we observed in *U. virens* fecundity values of 3,617-41,099 eggs/female with sizes from 9.0-18.6 mm CW, while egg diameters fluctuated between 0.23-0.30 mm. However, our results did not reveal a direct relationship between the egg

diameter and the number of eggs laid per female. This suggests that the production of offspring by females of different sizes is independent of the egg size.

In comparing average CW and fecundity values of *U. virens* with other species of genus *Uca*, we found similar values, particularly with species inhabiting in the Gulf of Mexico (Rabalais, 1991; Yamaguchi, 2001; Litulo 2005a; César *et al.*, 2007). However, we observed larger sized non-ovigerous females than ovigerous females in breeding season. We assume that although there were potentially fertile, they were not fertilized or the eggs had been released from pleopods before its capture, as assumed by Thurman (1985). Few females appear to survive when they reach the larger size categories.

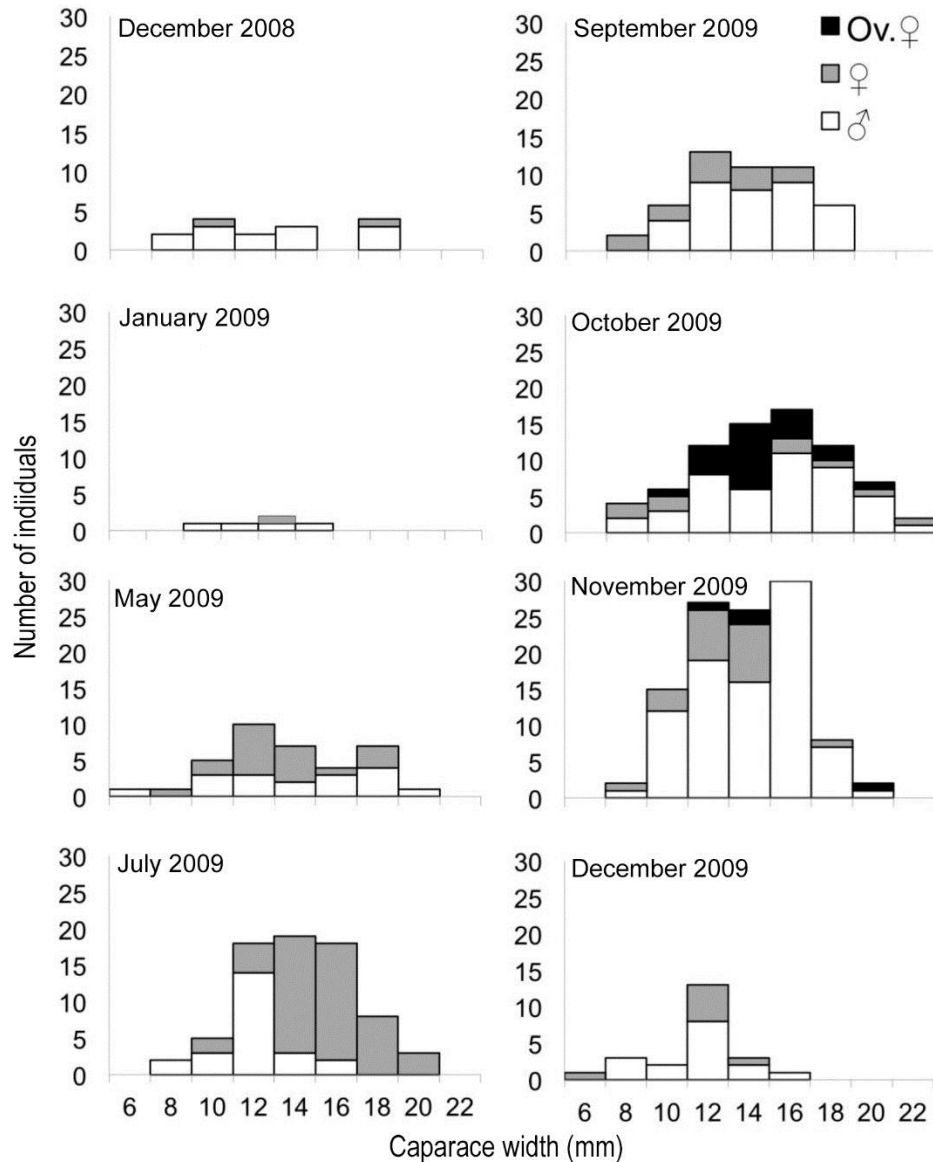


Figure 5. Frequency of males, females and ovigerous females of *Uca virens* collected between December 2008 and December 2009 in southern Tamiahua Lagoon, Veracruz, Mexico.

Using the determination coefficient, Litulo (2004b) demonstrated that the CW and the weight are good predictors of fecundity in *U. annulipes* (H. Milne Edwards, 1852), since they explained more than 90% of the total variance of data. In our analyses the determinant coefficient value of CW/egg produced was higher than TWW/egg produced; CW explaining 89% of the data variability and TWW accounts for 79% (Fig. 4). Although both values are good predictors of fecundity for *U. virens*, CW offers the best value, therefore we considered CW a better predictor than TWW.

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