ECOLOGY OF CALLINECTES ARCUATUS AND C. BELLICOSUS
(DECAPODA, PORTUNIDAE) IN A COASTAL LAGOON OF NORTHWEST MEXICO

BY

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ABSTRACT

Some ecological aspects of the swimming crabs, Callinectes arcuatus and C. bellicosus are presented. Specimens were collected with a trawl net, both day and night, on a monthly basis from March 1998 to February 2000 in a coastal lagoon in northwest Mexico. A total of 1235 specimens were captured, C. bellicosus (n = 878) with an abundance from 0 to 60 ind. ha⁻¹ was more abundant than C. arcuatus (n = 357) with an abundance from 0 to 38 ind. ha⁻¹ during the study period. Both species were more abundant at night and usually were found in conjunction with macroalgae. Salinity (32 to 40%) tended to favour the dominance of C. bellicosus over C. arcuatus (2.4 : 1) and the water temperature appeared to govern the breeding season (21 to 32°C). For both species, the breeding season runs from March until September (spring-summer), the recruitment of juveniles occurs during January and February (winter), and the lowest abundance of both species is found during October and November (fall). For both species, ovigerous females were observed in the mouth of the lagoon, and juveniles were found in the lagoon’s interior parts. The authors think that the observed ecological patterns of the species could be extrapolated to other coastal lagoons with a similar climate, oceanography, and geomorphology.
Quelques aspects écologiques des crabé pêcheurs *Callinectes arcuatus* et *C. bellicosus* sont ici présentés. Les spécimens étudiés ont été récoltés avec un filet-chalut aussi bien de nuit que de jour, approximativement mensuellement de mars 1998 à février 2000 dans une lagune côtière au nord-ouest du Mexique. Un total de 1235 spécimens ont été récoltés, *C. bellicosus* (*n* = 878) (abondance: 0 à 60 ind. ha−1) était plus abondant que *C. arcuatus* (*n* = 357) avec une abondance allant de 0 à 38 ind. ha−1 au cours de la période d'étude. Les deux espèces étaient plus abondantes la nuit et étaient habituellement trouvées conjointement avec des macroalgues. La salinité (32 à 40 pour mille) tendait à favoriser la dominante de *C. bellicosus* sur *C. arcuatus* (2.4 : 1) et la température de l'eau est apparue comme gouvemant la saison de ponte (21° à 32°C). Pour les deux espèces, la saison de ponte va de mars à septembre (printemps-été), le recrutement de jeunes survient de janvier à février (hiver) et l'abondance la plus faible des deux espèces a été observée pendant les mois d'octobre et de novembre (automne). Pour ces deux espèces, les femelles ovigères sont à l'embouchure de la lagune et les juvéniles ont été trouvées à l'intérieur de la lagune. Les auteurs pensent que les modèles écologiques observés pour ces espèces pourraient être extrapolés à d'autres lagunes côtières ayant un climat, une océanographie et une géomorphologie similaires.

**INTRODUCTION**

Three species of swimming crabs of the genus *Callinectes* are found in the Gulf of California, Mexico; (1) *C. arcuatus* (Ordway, 1863), a euryhaline species with a salinity tolerance from 1 to 65%, (2) *C. bellicosus* (Stimpson, 1859), a stenohaline species (30-38%), and (3) *C. toxotes* (Ordway, 1863), a euryhaline species (0-55%) (Paul, 1982). However, *C. arcuatus* and *C. bellicosus* are the most common species, the latter being the more abundant (Brusca, 1980; Hendrickx, 1995).

Knowledge concerning the biological and ecological aspects of *C. arcuatus* and *C. bellicosus* in the Gulf has been provided by Paul (1977, 1981, 1982), Loesch (1980), Salazar-Torres (1980), Villarreal-Chavez (1992), and Escamilla-Montes (1998). The results of such studies were based on representative samples taken over periods varying from six months to a year. Additionally, sampling and collection methods were quite different. Other contributions from this region have referred only to taxonomic aspects (Rathbun, 1930; Brusca, 1980; Hendrickx, 1995), geographical distribution (Garth & Stephenson, 1966; Rodríguez de la Cruz, 1987; Correa-Sandoval, 1991), or fisheries (González-Ramírez et al., 1996). The lack of systematized information over a period longer than one year and its limited integration have resulted in an incomplete understanding of these species' biology and ecology.

The life cycle of species of the genus *Callinectes* comprises two phases; (1) a planktonic phase offshore, during which the larvae develop, and (2) a benthonic phase of further growth and reproduction in coastal lagoons or estuaries (Williams, 1974). Our study focuses on the benthonic phase of *C. arcuatus* and *C. bellicosus* in a coastal lagoon in an arid zone. The objective of this work is to analyse
(1) population parameters, (2) seasonal occurrence, (3) sites of occurrence, and to establish (4) a conceptual model of these species' ecology in the arid coastal lagoons of the Gulf of California.

MATERIALS AND METHODS

Las Guásimas is a coastal lagoon on the east coast of the Gulf of California (27°49'–55'N 110°29'–45'W; fig. 1). The lagoon comprises an area of 37 km², with an average water depth of 0.7 m and a mouth of 2 km long, which remains open to the ocean (fig. 1). According to Kjerfve's (1986) classification system of lagoons (choked, restricted, and leaky), Las Guásimas qualifies as "restricted" because it (1) is permanently open to the sea by means of a wide mouth with two entrance channels, (2) has a well-defined tidal circulation, (3) is strongly influenced by winds, and (4) is well-mixed vertically. The tide mixes the lagoon water diurnally, with an average amplitude of 0.8 m. In this region the evaporation rate (2990 mm year⁻¹) exceeds the rainfall (290 mm year⁻¹) and rain and seasonal runoff are the only sources of fresh water to the lagoon.

The crabs under study were collected monthly both during the day and at night, from March 1998 until February 2000 at six stations located in the lagoon (fig. 1), using a trawl net of 3 × 1.5 m width at the mouth and 6 m long, with
2.5 cm mesh size. Ten-minute drags were made at each station, with simultaneous measurements of temperature and salinity by means of an autonomous Hydrolab Recorder. The presence of macroalgae was also recorded. The specimens captured were identified according to the criteria of Rathbun (1930) and Hendrickx (1995). Differentiation of the species was based on the form of the frontal spines, with gender being determined by the shape of the abdomen. Biometrics consisted in measuring the width of the carapace (the distance between the tips of the lateral spines) using Vernier callipers with 0.1 mm precision. The specimens were weighed on a College 300 Mettler scale with 0.01 g precision.

Data were entered and processed on an Excel 7.0 spreadsheet. Abundance values were standardized to ind. ha⁻¹ through division of the observed abundance by a conversion factor (0.165) obtained from the dragged area by multiplying the distance travelled by the vessel during a 10-minute drag (550 m) by the width of the net opening (3 m). Monthly and seasonal crab abundance data were analysed using one-way ANOVA, and a Student’s t-test was used to compare day and night values. All analyses were done to an α = 0.05 significance level.

RESULTS

A total of 1,235 crabs were collected; 357 were Callinectes arcuatus and 878 were C. bellicosus.

Water temperature and salinity

Water temperature and salinity showed no significant statistical differences between day and night or between the same seasons of the sampling period. Water temperature conformed to a seasonal pattern characterized by highs of between 30 and 33.9°C during the summer (July, August, and September) and lows of 13.7-20°C during winter (December, January, and February), with significant monthly differences \((F = 61.34, P < 0.05)\). Salinity was 31.2 to 40.6% and although there were significant monthly differences \((F = 8.8, P < 0.05)\), a definite seasonal pattern was not observed (fig. 2).

Occurrence of submerged vegetation

Of the 288 total net casts, 226 resulted in the collection of macroalgae in which 1061 crabs were found (86%), an average of 4.7 crabs per cast. Sixty-two samples not containing macroalgae were collected. These yielded 174 crabs (14%), for an average of 2.8 crabs per cast.
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Fig. 2. Seasonal variability of water temperature and salinity in Las Guásimas coastal lagoon.

Fig. 3. Seasonal variations in abundance of Callinectes arcuatus (Ordway, 1863) and C. bellicosus (Stimpson, 1859).

Seasonal variations in abundance and biomass

Both species were more abundant at night, Callinectes arcuatus (73%) and C. bellicosus (75%), with significant differences being found between day and night abundance (C. arcuatus $T = -5.10$, $P < 0.05$ and C. bellicosus $T = -6.05$, $P < 0.05$).

During the period of study, C. bellicosus was more abundant than C. arcuatus, but the pattern of abundance was similar for both species, with highest abundance during January and February and lowest abundance during October and November. From March to September there were fluctuations of abundance with intervals of 13-45 ind. ha$^{-1}$ for C. bellicosus and 0-13 ind. ha$^{-1}$ for C. arcuatus (fig. 3).

The abundance of C. arcuatus had an overall interval of 0-38 ind. ha$^{-1}$ with significant differences ($F = 1.99$, $P < 0.05$). The greatest abundance of 23-
38 ind. ha\(^{-1}\) was during January and February 1999 and February 2000. The periods of least abundance were in October and November 1998 and 1999 (0-1 ind. ha\(^{-1}\)). The abundance of *C. bellicosus* was 0.5-60 ind. ha\(^{-1}\) with significant differences (*F* = 1.57, *P* < 0.05), being most abundant in January 1999 and February 2000 (55-60 ind. ha\(^{-1}\)) and least abundant during October and November 1998 (0.5-1 ind. ha\(^{-1}\)) and in November 1999 (2 ind. ha\(^{-1}\)) (fig. 3).

Neither species exhibited a definite seasonal biomass pattern, with the monthly values of *C. arcuatus* having a range from 0 to 900 g and those of *C. bellicosus* between 0 and 2240 g.

Spatial distribution of abundance

The abundance of *C. arcuatus* was greatest at Station 6 (53 ind. ha\(^{-1}\)) and was significantly different from the other stations (*F* = 3.41, *P* < 0.05). *Callinectes bellicosus* appeared to be more abundant at Station 6 (50 ind. ha\(^{-1}\)) (fig. 4), although in this case no significant differences (*F* = 1.28, *P* = 0.27) were observed between this and the other stations.

Sizes, sex ratio, and occurrence of ovigerous females

Size data for both species were accumulated from both juveniles and adults. The size range of *Callinectes arcuatus* was 9.1-130 mm caparace width (cw) and showed no significant monthly differences (*F* = 10.44, *P* < 0.05), but the smaller specimens (< 50 mm cw) appeared to be more common in winter (January and
February 1999 and 2000), whereas the larger specimens (> 50 mm cw) appeared to be more common in autumn (October, November, and December 1998 and 1999) (fig. 5a). The size interval of *C. bellicosus* was 8.4-166 mm cw, showing no significant monthly differences ($F = 15.65$, $P < 0.05$), though the smaller organisms (< 50 mm cw) observed almost throughout the year, appeared to be more common in winter and spring (March, April, and December 1998; January, February, March, and December 1999; and January 2000), whereas the larger specimens (> 50 mm cw) appeared to be more common in autumn (October and November 1998 and November 1999) (fig. 5b).

The sex ratio in *C. arcuatus* was 1.17 : 1 (193 males and 164 females) ($X^2 = 1.82$, 24 g.l.), although characterized by a dominance of males both in summer
Fig. 6. Seasonal variations in sex ratios of: a, *Callinectes arcuatus* (Ordway, 1863); and b, *C. bellicosus* (Stimpson, 1859).

(July) and the autumn-winter months (November 1998 and September, October, and December 1999), and by the slight dominance of females in spring and summer (August 1998 and April 1999) (fig. 6a). The sex ratio in *C. bellicosus* was 1:1.23 (393 males and 489 females) ($X^2 = 34.4, 24$ g.l.), and characterized by the dominance of males during autumn-winter (from October 1998 to February 1999) and a dominance of females during spring-summer (May, June, and September 1998 and May, June, and August 1999) (fig. 6b).

Twenty out of 164 *C. arcuatus* females (12.1%) were ovigerous and these were found in spring and summer (April and August 1998 and March, April, and May 1999) and had a size interval of 54-122 mm cw. Of 485 *C. bellicosus* females, 62 were ovigerous (12.7%) and these were also found during the spring and summer (May, June, August, and September 1998 and March, April, May, July, August, and September 1999) and showed a size of 54.7-92 mm cw.
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DISCUSSION

In Las Guásimas lagoon, the slight annual variation in salinity (31-40%) is the result of a good interchange with the ocean and the scarcity of fresh rainwater. The dominance of Callinectes bellicosus over C. arcuatus (2.4 : 1) can be explained by the salinity, because C. bellicosus is a stenohaline species with optimal development potential in salinities of 30-38% (Paul, 1982) similar to those observed in this lagoon, whereas C. arcuatus is a euryhaline species (1-65%) with better development in coastal lagoons with large annual variations in salinity, especially where these fall significantly below 30% (Paul, 1982), which was not true for Las Guásimas.

The greater catch of both species of crab (75%) at night coincides with previous reports concerning their nocturnal habits (Williams, 1974), and shows the importance of designing the survey with sampling during the night.

The sex ratio of ≈ 1 : 1 observed contrasts with other studies in which males were dominant; e.g., C. bellicosus 4 : 1 (Molina, 1999) and C. arcuatus 4 : 1 (Villarreal-Chavez, 1992) and 3.4 : 1 (Escamilla-Montes, 1998). These differences could have been caused by the fact that the data of Villarreal-Chavez (1992) and Molina (1999) were gathered from commercial captures and composed of adult specimens only, and the data of Escamilla-Montes (1998) correspond to adult crabs captured with a harpoon exclusively during the day. Our data come from crabs captured with a trawl net, which captures crabs of all sizes both during the day and the night.

Seasonal occurrence

The seasonal occurrence of both species is fundamentally associated with water temperature, so deduced because ovigerous females are primarily found from March until September, when the lagoon water temperature is above 21°C (fig. 2).

The breeding season can be defined as the period with more ovigerous females. For both species this occurred during spring and summer (March-September). Juveniles were recruited in greater numbers for both species during the winter, primarily in January and February. This pattern of juvenile recruitment indicates that peak reproduction occurs in the summer, because it takes a swimming crab around six months to enter the benthonic phase (Tagatz, 1968; Sánchez-Ortíz & Gómez-Gutiérrez, 1992).

Specifically in southern Sinaloa, the breeding season of C. arcuatus was continuous throughout the year, with peaks occurring from March to June, and the greatest recruitment of juveniles occurred between April and August (Salazar-Torres, 1980). The climate in southern Sinaloa is wet and dry tropical, and in addition the coastal systems are influenced by rivers, whereas Las Guásimas is dry
subtropical (García, 1973) with implications of higher variations in temperature and lower rainfall rates, and the lagoon is not influenced by a river. It shows that climatic factors such as rainfall plus seasonal variations in temperature and salinity, and seasonal pulses in productivity, would be relevant in the reproductive strategy of the animals.

Sites of occurrence in the lagoon

In Las Guásimas lagoon, the spatial distribution of both species was not significantly correlated with water temperature or salinity, although in other locations it has been observed that the distribution of swimming crabs in the interior of coastal lagoons or estuaries is associated with changes in salinity, as for C. arcuatus in southern Sinaloa (Paul, 1982) and in the Colorado River delta (Villarreal-Chavez, 1992), as well as for other species of Callinectes (cf. Negreiroz-Fransozo & Franzozo, 1995; Calderón, 1996; Norse & Estévez, 1997). The last-mentioned studies were made in estuaries with well-defined salinity gradients, whereas in Las Guásimas lagoon no such gradient, that could have influenced crab distribution, was found. The homogeneity of the salinity and the average annual range (31-40‰) do not limit the distribution of both species throughout the lagoon, as C. bellicosus and C. arcuatus usually inhabit systems with salinities of 30-38‰ and 1-65‰ respectively (Paul, 1982), but this range apparently favoured C. bellicosus because C. arcuatus prefers lagoons with lower salinities.

The greater number of crabs of both species at one particular site in the lagoon (i.e., station 6, fig. 4) is attributed to the largest quantity of macroalgae in that location. These unattached macroalgae characteristically form masses, mainly composed of Spyridia filamentososa (Wulfen), Gracilaria pacifica (Abbott), Hypnea johnstonii (Setchell & Gardner), and Gracilariosis lemaneiformis (Dawson, Acleto & Foldvick), all of which are transported by tidal currents throughout the lagoon and eventually are concentrated in some places of the lagoon such as station 6 (fig. 1). This relationship between the macroalgae and the large abundance of swimming crabs coincides with the results of other studies (Orth & Van Montfrans, 1987; Denton, 1999), which have shown that even in the same location, sites with aquatic vegetation have a greater abundance of decapods than sites without vegetation. This information would suggest that the macroalgae in Las Guásimas lagoon provide substrate and sustenance for the swimming crabs, and also serve as a refuge, in particular for nurturing, a function performed by seagrasses in other locations (Orth et al., 1996).

Species of Callinectes make local migrations, leaving and reentering the coastal lagoons throughout their life cycle to find the appropriate environmental conditions for hatching, larval development, and moulting (Norse, 1977). In Las Guásimas
lagoon, the majority of ovigerous females of both species are found near the mouth of the lagoon. This behaviour coincides with that described in other studies and is attributed to the tendency of the females to leave the lagoons for the nearby sea to spawn, where they also find more stable conditions for hatching their eggs and releasing the larvae (Tagatz, 1968; Sánchez-Ortíz & Gómez-Gutiérrez, 1992; Negreiros-Fransozo & Fransozo, 1995; Tankersley et al., 1998). The juvenile organisms are found chiefly in the most interior parts of the lagoon, a behaviour previously noted by Ryer et al. (1997), who indicated that this spatial segregation according to size was possibly advantageous in that it prevented competition for territory and food between juveniles and adults and also protected the juveniles from being eaten by the adults, as the former moult more frequently and are thus more vulnerable.

A conceptual ecological model for *Callinectes arcuatus* and *C. bellicosus*

Based on the information provided in this work, we propose a conceptual model of the ecology of *Callinectes arcuatus* and *C. bellicosus* that might well
be applicable to the coastal lagoons between Guaymas and Agiabampo on the east coast of the Gulf of California (fig. 7), considering that they share similar climatic conditions (dry subtropical where the evaporation rate is about ten times greater than the precipitation), and are restricted lagoons (permanently open to the sea by one or two entrance channels, well-defined tidal circulation, strongly influenced by winds, and being well-mixed vertically) (Kjerfve, 1986).

This model shows (fig. 7) that the breeding season is during spring and summer with presence of ovigerous females in the mouths of the lagoons, and males, nonovigerous females, and juveniles in the inner zones of the lagoons. During fall the abundance is lowest and only adult males occur in the mouths. During winter the main recruitment of the juvenile crabs take place and these are mainly concentrated in the interior-most parts of the lagoons.

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LITERATURE CITED


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