Population structure and sexual maturity of the calico box crab Hepatus epheliticus Linnaeus (Brachyura, Hepatidae) from Yucatan Peninsula, Mexico
Short Communication

Population structure and sexual maturity of the calico box crab

*Hepatus epheliticus* Linnaeus (Brachyura, Hepatidae) from
Yucatan Peninsula, Mexico

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ABSTRACT. The calico box crab *Hepatus epheliticus* is an abundant species from shallow and continental
shelf waters of the Atlantic coast of USA and Mexico. Information about population structure and sexual
maturity is absent, even though this crab is caught to be used as bait for the octopus fishery in the Campeche
Bank, Mexico. In order to achieve such information, a total of 768 individuals were collected from January to
March 2010 through baited traps installed in the Yucatan Peninsula, Mexico. Our results showed that sex ratio
is biased towards more males than females (1:0.55), contradicting to that reported in other brachyuran crabs.
The absence of ovigerous females suggests that they did not enter into the traps during embryogenesis. Males
reached a larger maximum size than females (64.0 ± 6.15 and 58.4 ± 5.60 mm carapace width, respectively).
The general scheme of growth being positive allometric throughout ontogeny of both sexes. Males presented a
transition phase from juveniles to adult corresponding to the puberty moult. The estimation of the onset of
functional sexual maturity revealed a steady situation for the population, with 21.5 and 13.8% of males and
females, respectively, morphologically immature at the time of catch. This study constitutes the first report on
population structure and sexual maturity in a population of the calico box crab *H. epheliticus*.

Keywords: population structure, sexual maturity, biometry, *Hepatus epheliticus*, Yucatan Peninsula, México.

Estructura poblacional y madurez sexual en el cangrejo caja moteado

*Hepatus epheliticus* Linnaeus (Brachyura, Hepatidae) procedente de la
Península del Yucatán, México

RESUMEN. El cangrejo caja moteado *Hepatus epheliticus* es un abundante braquiuro perteneciente a la
familia Hepatidae, distribuido desde aguas someras hasta la plataforma continental en la costa atlántica de
Estados Unidos y México. La información sobre su demografía poblacional y madurez sexual es actualmente
inexistente, aun cuando esta especie es intensamente capturada como carnada en la pesquería del pulpo del
estado de Campeche, México. Entre enero y marzo de 2010, se colectaron 768 especímenes usando trampas
instaladas en la Península de Yucatán, México. Los resultados mostraron una proporción sexual
completamente inclinada hacia los machos (1:0,55), lo cual contradice el esquema general reportado en otras
especies de braquiuros. La ausencia total de hembras ovígeras, sugiere su resistencia a ingresar a las trampas
durante el periodo de incubación de los embriones. Los machos alcanzaron un tamaño promedio mayor que las
hembras (64,0 ± 6,15 y 58,4 ± 5,60 mm de ancho del caparazón, respectivamente), siendo el crecimiento de
tipo alométrico positivo a lo largo de la ontogenia de ambos sexos. Los machos presentaron una fase de
transición desde juveniles a adultos correspondiente a la muda de pubertad. La estimación de la madurez
sexual funcional mostró una situación normal para la población, con 21,5 y 13,8% de machos y hembras
The calico box crab *Hepatus epheliticus* Linnaeus (Hepatidae) is an abundant subtidal crab that lives buried in sandy substrate between depths of 2 to 91 m (Franks et al., 1972). This species occurs throughout the Chesapeake Bay to western Bay of Campeche, Mexico (Rickner, 1977), but it has also been reported from Cuba, Jamaica and Dominican Republic (Williams, 1984). In the Campeche Bank, Mexico, this crab is heavily fished and used as bait for the octopus fishery (*Octopus maya* Voss & Solís-Ramírez, 1966). In Mexico the octopus fishery is the third most important not only in volume, but also in value, and it is concentrated in the Campeche and Yucatan coastal states (Salas et al., 2009). From early August to mid December, the octopus fishery demands high numbers of crabs for bait, which are used tied at the end of slowly dragging lines over hard bottom, to which the octopus grabs (Arreguín-Sánchez et al., 1987, 2000). The calico box crab is also fished as by-catch in the baited crab traps set up for portunids (“jaibas”), popular year-round on the local seafood market. Although there are reports on the octopus fishery, little is known on the catch statistics of *H. epheliticus* and collateral effects of the octopus-jaibas fishing pressure on their populations. In fact, as far as we know, there is no report on neither size-frequency distribution, sex ratio nor on sexual maturity of this crab. Such lack of data on the population biology of this crab species impedes any attempt for ecosystem based management by the local authorities, as the species is a natural prey item of both octopus and other demersal fishes.

The present study examines for the first time the population structure and sexual maturity in the calico box crab *H. epheliticus* from the Yucatan Peninsula, Mexico. Such information provides valuable insights into the ecology of this crab and could facilitate future sustainable management of this species in the gulf of Mexico.

Specimens were collected between January and March 2010 from subtidal zone along the coast of Sisal, Yucatan Peninsula, Gulf of Mexico (21°10’N, 90°00’W). Crabs were collected using baited traps (2 cm diameter mesh) and identified according to Williams (1984). After collecting the crabs, each individual was sexed based upon macroscopic characters such as the morphology of the abdomen (Fig. 1), presence of gonopods (males) and number of pleopods. Specimens of each sex were grouped into 1 mm CW size classes (CW = carapace width); thereafter, data were plotted as length-frequency histograms to analyze the population structure of each morphotype (males, females without eggs, and ovigerous females). The normal component of each sex was separated using the Bhattacharya method and confirmed by Normsep routine, both included in FiSAT software (Gayanilo et al., 1996). This analysis, based on the identification of each cohort’s mean, allows the separation of each modal component. Sex ratio was estimated as the number of males divided by the number of females. Departures from the expected 1:1 ratio were tested statistically using a chi-square test (*P* < 0.05, Sokal & Rohlf, 1995). The data distribution was tested using a goodness of fit proof.

The following measurements were made with a precision vernier calipers (nearest 0.1 mm) on each specimen: carapace length (CL: from the anterior margin of the rostrum to the posterior margin of the carapace), carapace width (CW: measured between the base of the principal lateral teeth), and length and height of the propodus of the chelipeds (PL and PH, respectively; Fig. 1). Gonopod length (GL) and 6th abdominal somite width (A6) was measured on males and females, respectively (Fig. 1). To determine the growth pattern in *H. epheliticus*, the allometric equation (*Y* = a*X*^b^) was used to represent biometric growth constant “b” (see Somerton, 1980). The accuracy of each allometric equation was determined by the coefficient of determination (*r*^2^, *P* < 0.05), obtained for the log-transformed equations. To analyze the chelae symmetry, a comparison between PL of both chelae was realized (Student’s *t*-test, *P* > 0.05, Sokal & Rohlf, 1995). When *t*-test analysis was carried out, the Cochran tests were used to test for homogeneity of variances (Zar, 1996).

All biometric relationships were submitted to the MATURE software (Somerton, 1980; Somerton & Macintosh, 1983), and statistical data were confirmed by the program “R” Version 2.5.0 (Ihaka &
Gentleman, 1996), to identify break point(s) in the empiric point trend during ontogeny (puberty size). The MATURE program was developed to estimate the size at sexual maturity specifically for crustaceans, based on morphometric data. During postlarval development, brachyuran crabs can display body changes with the onset of the development of secondary sexual characters (Hartnoll, 1974), with two phases (juvenile and adult) separated by a critical molt (puberal or pubertal molt). Each phase is represented by a mathematic equation (power function) following one of four patterns described by Somerton (1980). In a simpler pattern (e.g., chelar variables in males) there is no overlap between phases, where dependent variable (y) grows better of the independent one (x), where pubertal molt occurs. The MATURE program requests a size (CW) range that contains a “visible” inflection in data trend (size at maturity) established by a smaller “x” value (only juveniles) and a greater one (only adults). A linear regression (log-transformation of $Y = a^b$) was fitted to each subset and established an initial intersection value. The data were grouped according to each ontogenetic phase, and regression lines were obtained interactively until the best one with a minimum residual sum of square was found. After this interactive process, a statistical test was performed to determine if the resulting two lines fit the data better than a single one. If the fit was not significantly better, there was little justification for using two lines to describe the data, revealing the need for other procedures to estimate maturity.

Maturity size can be estimated using different criteria (Hernández & Wehrtmann, 2007). In our study, the size at morphological sexual maturity (MSM) was estimated by biometric analysis of males (GL $\times$ CW and PL $\times$ CW) and females ($A_6$ $\times$ CW and PL $\times$ CW). The constant “$b$” of the power function provides information concerning the increment of one biometric dimension in relation to another. We considered growth to be isometric when “$b$” ranged between 0.90 and 1.10, negative allometric when $b < 0.90$, and positive allometric when $b > 1.10$ (Pinheiro

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**Figure 1.** Morphometric variables measured in the a) carapace, b) gonopod, c) chela, d) abdomen of the adult male, and e) female. Where CL: carapace length; CW: carapace width; PL: chelar propodus length; PH: chelar propodus height, GL: gonopod length; $A_6$: width of sixth abdominal segment. Scale measurement is valid for all structures.

**Figura 1.** Variables morfométricas medidas en los individuos: a) caparazón, b) gonópodo, c) quela, d) abdomen masculino y e) femenino de ejemplares adultos. Donde CL: longitud del caparazón; CW: ancho del caparazón; PL: longitud del propodio de la quela; PH: altura del propodio de la quela, GL: longitud del gonópodo; $A_6$: longitud del sexto segmento abdominal. Escala de mediciones válida para todas las estructuras.
Population biology of Hepatus epheliticus, México

A total of 768 individuals of *H. epheliticus* (497 males = 65%; and 271 females = 35%) were analyzed. Males captured ranged from 48.4 to 82.7 mm CW, and females from 40.3 to 73.3 mm CW. Average CW of males was significantly larger than females (64.0 ± 6.2 mm vs 58.4 ± 5.6 mm CW, *t* = 12.46, *P* < 0.05). The size structure in both sexes was polymodal, and the majority of males (59%) and females (58%) were registered in the range of 61.0 to 70.0 mm CW and 51.0 and 60.0 mm CW, respectively (Fig. 2). The cohort analysis revealed the presence of five and four cohorts in males and females, respectively (Fig. 2). Males were significantly more abundant than females (*χ*² = 66.5, *P* < 0.05). No ovigerous female was caught during the study period.

The empirical points in each biometric relation analyzed were well aligned and fitted the power function (Table 1). MATURE and “R” routines revealed in the relations PL x CW (males) and A₆ x CW (females), a similar growth pattern throughout the ontogeny (Table 1). In males, two break points were indicated for the relationship PL x CW (Fig. 3) between 59.3 and 67.3 mm CW (Fig. 3), where the puberty molt occurs. In contrast, in females the biometric analysis of A₆ x CW (using “R”) did not reveal a distinction between line phases; however, at the last one was observed two regression lines (juvenile and adults) with an overlap registered at 51.3 mm CW (Fig. 3).

A comparison of the PL of both chelae revealed that males and females (*n* = 30 each) have symmetric chelae (paired Student’s *t*-test, males: *t* = -0.61, *P* > 0.05; females *t* = 0.45, *P* > 0.05). Therefore, data from the left chelae was used to estimate MSM. A comparison between the left and right GL revealed significant differences of this variable in males (paired Student’s *t*-test, males: *t* = 8.37, *P* < 0.05).

Crabs used as bait (e.g. Callinectes spp., Libinia dubia, Cardisoma guanhumi, and *H. epheliticus*) are normally sold at around US$ 2.00-2.25 per kg depending on the availability of crabs and time passed since the beginning of the octopus fishery period, with higher prices towards the end of the fishing season. The bait-crabs are supplied by local fishermen, fishing with baited traps close to the shore, but crabs are also imported from other states of Mexico (e.g. Tabasco, Chiapas and Veracruz). In average, each small fishing boat uses 5-10 kg of bait-crabs per fishing day which accounts to nearly 20% of operation costs of the fishery (CONAPESCA, 2009). According to the Mexican Carta Nacional Pesquera (2010, data from 2004), there are two main states fishing octopus in the south coast of gulf of Mexico: Campeche and Yucatan. This adds up to 16 and 418 large and 1,617 and 3,300 small fishing fleet vessels in Campeche and Yucatan, respectively. Data corrected to Yucatán during 2008 (CONAPESCA, 2009) reports 2,731 small boats fishing in Yucatan. A simple projection using this last fleet figure fishing for 90 days (75% of the fishing period) and using minimum bait-crab volume per boat (5 kg) would totalize more than 1 million metric tons of bait-crab used. Information obtained in 2011 from local Yucatan markets reveals that each kilogram price of bait-crabs reached an historical peak above US$ 3.5 (N. Simões, pers. comm.). This high price during 2011 can be explained by reduced crab catches due to fishery demand. This may be the first sign of alert for a possible overexploitation of the crab population in Yucatan.

In many species of brachyuran crabs, the apparition of secondary sex characters allows to estimate the onset of functional sexual maturity (Hartnoll, 1974, 1978; Hines, 1982). These traits include the release of abdominal somites from the thoracic sternites and opening of gonopods (Guinot, 1979), the conspicuous growth of certain cheliped segments (mainly the propodus) (Hartnoll, 1982; Pinheiro & Fransozo, 1993), and colour pattern...
Table 1. Regression analyses by biometric relation evaluated for the calico box crab *Hepatus epheliticus* from Yucatan Peninsula, gulf of Mexico. All relations were significant ($P < 0.01$), where: GL: gonopod length; PL: major chelar propodus length; 6th abdominal somite width and CW: carapace width; JM: juvenile males; AM: adult males; TM: total males; JF: juvenile females; AF: adult females; TF: total females. *The best equations to represent the relative growth: allometric levels related to isometry (0), negative allometry (-) and positive allometry (+).

<table>
<thead>
<tr>
<th>Relation</th>
<th>Sex/Stage</th>
<th>N</th>
<th>Equation</th>
<th>$R^2$</th>
<th>Allometric level</th>
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<td>GL x CW</td>
<td>JM</td>
<td>155</td>
<td>GL = 0.13 CW$^{1.15}$</td>
<td>0.83</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>AM</td>
<td>100</td>
<td>GL = 0.35 CW$^{0.91}$</td>
<td>0.76</td>
<td>0</td>
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<tr>
<td></td>
<td>TM</td>
<td>255</td>
<td>GL = 0.19 CW$^{1.05}$</td>
<td>0.92*</td>
<td>0</td>
</tr>
<tr>
<td>PL x CW</td>
<td>JM</td>
<td>55</td>
<td>PL = 0.12 CW$^{1.33}$</td>
<td>0.75</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>122</td>
<td>PL = 0.05 CW$^{1.53}$</td>
<td>0.67</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>AM</td>
<td>79</td>
<td>PL = 0.19 CW$^{1.22}$</td>
<td>0.54</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>TM</td>
<td>256</td>
<td>PL = 0.10 CW$^{1.37}$</td>
<td>0.93*</td>
<td>+</td>
</tr>
<tr>
<td>A$_6$ x CW</td>
<td>JF</td>
<td>10</td>
<td>PL = 4·10$^{-10}$ CW$^{0.15}$</td>
<td>0.54</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>AF</td>
<td>128</td>
<td>PL = 0.10 CW$^{1.23}$</td>
<td>0.66</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>TF</td>
<td>138</td>
<td>PL = 0.05 CW$^{1.40}$</td>
<td>0.71*</td>
<td>+</td>
</tr>
</tbody>
</table>

Enhancement of cheliped propodus and dactylus (Hopkins, 1963; Ryan, 1967). The general scheme of growth in crustaceans is confirmed by our data. The growth pattern of *H. epheliticus* was characterized by allometric body symmetry, with slight changes in the biometric relations through ontogeny. However, an analysis of $A_6$ x CW did not reveal a distinction between line phases. It seems necessary to obtain a greater number of points to achieve a better approximation of the size of the morphological sexual maturity, mainly for females smaller than 60 mm (CW).

Only 35% of the total individuals analyzed were females. The major percentage of males observed in the population of *H. epheliticus* contradicts the scenario reported in other crab species (including hepatid crabs), where females predominate in all habitat types from shallow waters (Wolff & Cerda, 1992; Mantelatto *et al*., 1995; Jesse & Stotz, 2003). The deviation from the expected 1:1 sex ratio is very common in decapods (Wenner, 1972), and may be attributed to spatial segregation (Jesse & Stotz, 2003) and/or temporal variations in sexual composition of the population (Wenner, 1972; Bas *et al*., 2005). However, when the capture method involves baited traps, it is common that ovigerous females do not enter (Howard, 1982; Smith *et al*., 2004). This suggests that ovigerous females of *H. epheliticus* may concentrate in other locations to incubate their eggs, which explains the disparity of the sex-ratio observed during study period. The total absence of ovigerous females during the study period supports this hypothesis. However, we do not discard temporal migrations of the females to other areas away from the fishing area. Long-term studies are necessary to answer this question.

This is the first evaluation concerning the population structure and sexual maturity of the calico box crab *H. epheliticus*. The antecedents compiled in this study reveal a stable situation for the population studied, with 21.5% and 13.8% of males and females, respectively, morphologically immature at the time of catch (Fig. 4). Finally, our results suggest that the breeding cycle and spatial distribution of each population component are aspects that require a more thorough revision, especially considering the development of management strategies for a future sustainable fishery of this resource in the waters of Mexico and neighboring countries.
Figure 3. Chelar propodus length (PL) versus carapace width (CW) scatterplot in males (n = 256) and females (n = 138) of the calico box crab, *Hepatus epheliticus*, from Yucatan, Mexico. The arrow indicates the size when juveniles transform into adult crab in each sex.

Figura 3. Relación entre la longitud del propodio de la quela (PL) y el ancho del caparazón (CW) en machos (n = 255) y hembras (n = 138) del cangrejo caja moteado *Hepatus epheliticus* procedente de Yucatán, México. La flecha indica el tamaño en el cual los juveniles de ambos sexos pasan a la etapa adulta.

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REFERENCES


