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# Caridea postlarvae (Crustacea, Decapoda) in the estuary of the Jamapa River, Veracruz, SW Gulf of Mexico

# Postlarvas de Caridea (Crustacea, Decapoda) en el estuario del río Jamapa, Veracruz, SW golfo de México

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## ABSTRACT

**Background**. In Veracruz, Mexico, 68 species of estuarine decapod crustaceans have been recorded. Of these, 11 belong to the infraorder Caridea, and 8 species have been recorded in freshwater systems. **Goals**. The present study analyzed the specific richness and abundance of carideans postlarvae and their relationship with the dynamics of environmental factors in the estuary of the Jamapa River, Veracruz, southwest of the Gulf of Mexico. **Methods**. The following environmental factors were measured: dissolved oxygen, temperature, total dissolved solids, pH, and salinity. The captures were made with light traps and shrimp bait. The generalized least squares model was used to determine the relationships between the environmental factors with the five months and five sampling sites. The generalized linear model was used to determine the relationships between the abundance of the postlarvae and the months, sites, and environmental factors. **Results**. A total of 8,649 carideans postlarvae were collected, of which 257 belonged to *Macrobrachium acanthurus*, 1,016 belonged to *M. olfersii*, and 7,376 belonged to *Potimirim mexicana*. The highest abundance of the three species was found at the site located on the dock of the Boca del Río Technological Institute, with 6,627 carideans. **Conclusion**. The abundances of postlarvae of *P. mexicana* and *M. olfersii* were within the values reported in other studies. However, the abundance of *M. acanthurus* was low, which may be related to the high values of total dissolved solids or overfishing. The highest density of postlarvae of carideans occurred in the rainy season in sites with *Thypha domingensis* vegetation.

**Keywords**: Atyidae, Caridean shrimps, diversity, estuarine system, Palaemonidae

## RESUMEN

**Antecedentes**. En Veracruz, México, se han registrado 68 especies de crustáceos decápodos de estuario. De ellas, 11 pertenecen al infraorden Caridea y 8 especies han sido registradas en sistemas de agua dulce. **Objetivos**. El presente estudio analizó la riqueza y abundancia específica de postlarvas de carideos y su relación con la dinámica de factores ambientales en el estuario del Río Jamapa, Veracruz, suroeste del Golfo de México. **Métodos**. Se midieron los siguientes factores ambientales: oxígeno disuelto, temperatura, sólidos disueltos totales, pH y salinidad. Las capturas se realizaron con trampas ligeras y cebo para camarones. Se utilizó el modelo de mínimos cuadrados generalizado para determinar las relaciones entre los factores ambientales con los cinco meses y los cinco sitios de muestreo. Se utilizó el modelo lineal generalizado para determinar las relaciones entre la abundancia de las postlarvas y los meses, sitios y factores ambientales. **Resultados**. Se recolectaron un total de 8,649 postlarvas de carideos, de las cuales 257 pertenecían a *Macrobrachium acanthurus*, 1,016 a *M. olfersii* y 7,376 a *Potimirim mexicana*. La mayor abundancia de las tres especies se encontró en el sitio ubicado en el muelle del Instituto Tecnológico de Boca del Río, con 6,627 carideos. **Conclusión**. Las abundancias de postlarvas de *P. mexicana* y *M. olfersii* estuvieron dentro de los valores reportados en otros estudios. Sin embargo, la abundancia de *M. acanthurus* fue baja, lo que puede estar relacionado con los altos valores de sólidos disueltos totales o la sobrepesca. La mayor densidad de postlarvas de carideos se presentó en la época de lluvias en sitios con vegetación de *Thypha domingensis*.

Palabras clave: Atyidae, Camarones carideos, diversidad, Palemónidae, sistema estuarino

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## INTRODUCTION

The infraorder Caridea is made up of 3,754 described species grouped into 45 families; among the most diverse are the families Atyideae, with 526 species, and Palaemonidae, with 1,090 species (WoRMS, 2024). In Veracruz, Mexico, 68 species of estuarine decapod crustaceans have been recorded. A total of 11 of these species belong to the infraorder Caridea. In freshwater systems, 38 species have been recorded, and 8 of those species are part of the infraorder (Álvarez *et al*., 2011).

The *Potimirim* genus from the Atyidae family and the *Machrobrachium* genus from the Palaemonidae family have been reported along the coastline and in the rivers of Veracruz (Alonso-Reyes *et al*., 2010; Cházaro-Olvera *et al*., 2021) and in estuaries and freshwater systems (Álvarez *et al*., 2011). During their development, the individuals from these families undergo four stages: zoea, postlarva, juvenile, and adult (Hernández-Vergara & Jiménez-Rojo, 2008). The postlarvae of these carideans present morpho-physiological adaptations to be able to carry out migrations between the river, estuary, and maritime waters near the coast (De Grave, 2008). This migration is classified as an active movement when the organisms can perform vertical migrations in the water column, or it can be a passive movement when the organisms are transfer by currents (Guerao, 1995). The transport of caridean larvae and postlarvae to estuaries is related with the river currents to the estuaries (Anger, 2013). Therefore, the passive dispersal of larvae and postlarvae may be a factor that determines the recruitment of carideans to estuarine systems, where they return to the river to freshwater conditions after completing development to the juvenile stage.

Postlarvae recruitment has only been documented by Cházaro-Olvera (1996), Cházaro-Olvera *et al*. (2007a), Cházaro-Olvera *et al*. (2007b), and Cházaro-Olvera *et al*. (2009). Thus, the present work will increase the knowledge about the dynamics of the transport of caridean postlarvae in the Jamapa River estuary, Veracruz, located southwest of the Gulf of Mexico. To do this, the present work aims to analyze the abundance and diversity of the organisms of this infraorder and determine their relationships with physicochemical factors.

## MATERIALS AND METHODS

### Study area

The Jamapa River basin is located between 18°45'–19°14'N and 95°56'–97°17'W (Fuentes-Mariles *et al*., 2014). The estuary discharges its waters in the Veracruzano Reef System National Park (PNSAV) (Liaño-Carrera *et al*., 2019). The estuary has a micro-tidal modulation of approximately 2.0 m, with biweekly synodic semidiurnal, diurnal, and lunisolar components (Salas-Monreal *et al*., 2019). The estuary also has a navigation channel in the southern part that generates important changes in its dynamics (Salas-Monreal *et al*., 2019). The shipping channel of the estuary produces strong currents of more than 0.5 ms-1 and a continuous exchange of brackish water with the ocean (Salas-Monreal *et al*., 2020) (Figure 1).

### Fieldwork

Specimens were collected at five sites. The first site was located to the south of the estuary, at the jetty of the Instituto Tecnológico de Boca del Río, Veracruz (ITBOCA). The second site was located to the north of the estuary at the jetty of the Instituto de Ciencias Marinas y Pesquerías of the Universidad Veracruzana (ICIMAP). The third site was located near the estuarine inlet find of the Río Jamapa called Barco. The fourth and fifth sites (Venecia and Estero) were located to the southeast, in communication with the Mandinga Lagoon. The sampling campaign was carried out in September (i.e., the rainy season), November, January, March (i.e., the cold front season), and May (i.e., the dry season) of 2019. The biological material was collected over 12 h using a light trap (Cházaro-Olvera *et al*., 2018). The light trap was placed at the sampling sites at a depth of 0.5 m during the full moon phase because this lunar phase is when the effect of positive phototropism of zooplankton is maximized. The trap was placed at 20:00 h on the first sampling day and removed at 8:00 h the following day. Each sample was filtered through a 300 µm sieve and preserved in 0.5 L plastic bottles. Subsequently, the samples were fixed with 70% ethyl alcohol and labeled with information on the location, date, time, and type of sampling. The abiotic parameters of water temperature (°C), salinity, total dissolved solids (ppm), dissolved oxygen (mg L-1), and pH were measured in situ with a Hanna® HI 9828 multiparameter every month and at each site at the beginning and end of the sampling; later, the average and standard deviation were obtained.

### Laboratory work

The biological material was transported to the Crustacean Laboratory of the FES Iztacala. The material was reviewed, separated, and identified to the species level with the help of a stereoscopic microscope and an optical microscope following the criteria of Holthuis (1954) and Williams (1984).

### Statistical analysis

A generalized least squares (GLS) model was used to determine the relationships between the environmental factors, the five months, and the five sampling sites (Zuur *et al*., 2007). After finding statistically significant differences between the means of the environmental factors of the months and sampling sites, Tukey's post hoc test was applied (Sokal & Rohlf, 1995). A generalized linear model (GLM) was used to determine the relationships between the abundance of caridean species in the postlarva stage with respect to sites, months, and environmental factors. A Poisson logarithmic linear (per counts) model was used, considering each species' abundance as dependent variable, the months and sampling sites as fixed factors and the environmental factors were considered as independent variables. A type III analysis was performed, and the chi-square statistic was obtained using the Wald model. Previously, the values of the environmental factors were transformed to arcsine and the abundance values of the species to log(n+1) (Zuur *et al*., 2007). The GLS and GLM analyses were performed using SPSS Statistics 25 software of IBM corporation.

## RESULTS

### Environmental parameters

The concentration of dissolved oxygen had a range of 3.65 ± 0.65 mg L-1 in November to 6.65 ± 0.04 mg L-1 in May (Table 1). The GLS test showed a statistically significant relationship between the dissolved oxygen and the sampling months ($r = 0.74$; $P < 0.001$; Table 2). Statistically significant differences were not found between the dissolved oxygen concentrations of the sampling sites ($P < 0.05$). However, statistically significant differences were found between the sampling months ($P < 0.05$). After applying Tukey's post hoc test, only significant differences between May and September were found ($P < 0.05$).

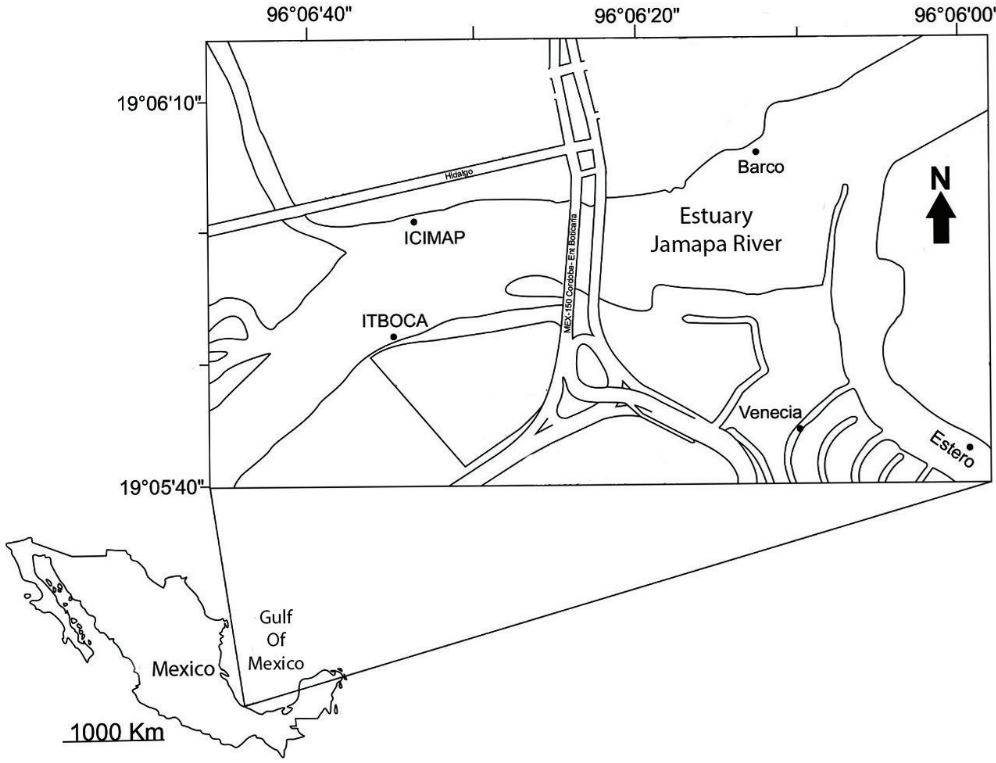


Figure 1. Locations of sampling sites in the estuary of the Río Jamapa, Boca del Río, Veracruz, México. ITBOCA: Instituto Tecnológico de Boca del Río; ICIMAP: Instituto de Ciencias Marinas y Pesquerías, Universidad Veracruzana.

The temperature ranged from 21.66 ± 0.04°C in January to 31.64 ± 0.11°C in May (Table 1). The test GLS showed that there was a positive significant relationship between the temperature with the sites and months of sampling (r = 0.73; $P < 0.05$) (Table 2). Significant differences were observed among the sampling months ($P < 0.001$) (Table 2). When applying Tukey's test, statistically significant differences between May and January, March and Nov, and January and September were found ($P < 0.05$).

Salinity ranged from 0.97 ± 0.06 in September to 35.65 ± 0.01 in May (Table 1). Salinity showed a high correlation with the sites and sampling months (r = 0.91; $P < 0.001$) (Table 2). Significant differences were found between sites and between months ($P < 0.001$). After applying Tukey's post hoc test, significant statistical differences were found between the ITBOCA, ICIMAP, and Barco sites and the Estero and Venecia sampling sites ($P < 0.05$). With respect to months, May differed from the other five sampling months. January was significantly different from September ($P < 0.05$).

The pH ranged from 7.03 ± 0.46 in November to 7.85 ± 0.06 in January (Table 1). The GLS test showed a significant positive relationship between pH and the sites and months of sampling (r = 0.79; $P < 0.001$). Significant differences were found only between the months sampled ($P < 0.001$) (Table 2). Tukey's test showed that there were only significant differences between January and September ($P < 0.05$).

The range of total dissolved solids was 10.95 ± 1.05 ppm in May and 5,842 ± 856 ppm in March (Table 1). The relationship between total dissolved solids and the sites and months of sampling was positive (r= 0.62) and significant ($P < 0.05$). Only the sites presented significant differences ($P < 0.05$) (Table 2). Tukey's test only showed significant differences between the ICIMAP and Venecia sites ($P < 0.05$).

**Abundance and specific richness**

In total, 8,649 caridean postlarvae were collected, of which 257 belonged to *Machrobrachium acanthurus* (Weigmann, 1836), 1,016 belonged to *Macrobrachium olfersii* (Weigmann, 1836), and 7,376 belonged to *Potimirim mexicana* (De Saussure, 1857). The greatest abundance of *M. acanthurus*, *M. olfersii*, and *P. mexicana* was found at the ITBOCA site with 6,627 postlarvae, and the lowest abundance was found at Venecia with 361 postlarvae. According to the collection months, the highest abundance of the three species was found in September with 5,030 postlarvae, and the lowest abundance was found in March with only 40 postlarvae (Table 3).

When the GLM analysis was applied to the abundance of postlarvae of *P. mexicana*, it was observed that the variation was related to the five environmental factors ($P < 0.05$). The abundance of *M. acanthurus* postlarvae was related to the dissolved oxygen and total dissolved solids ($P < 0.05$). The abundance of *M. olfersii* postlarvae was related to dissolved oxygen, temperature, total dissolved solids, and salinity ($P < 0.05$; Table 4).

## DISCUSSION

In the study area, dissolved oxygen values have been reported to range from 5.63 mg L-1 in the dry season to 5.55 mg L-1 in the cold front season and 5.35 mgL-1 in the rainy season (Castañeda-Chávez *et al.*, 2017). These values are consistent with the dissolved oxygen values found in this study. In September, November, and January (i.e., the end of the rainy season and the cold front season), the concentration of dissolved oxygen decreased. This may be because this area has been classified as an urban estuary, so there are discharges of wastewater to the river (Castañeda-Chávez *et al.*, 2017; Salas-Monreal *et al.*, 2020). Furthermore, the high quantity of organic matter transported in the rainy season by the river's own water may decrease the concentration of dissolved oxygen. The dissolved oxygen concentration enables the species of *Macrobrachium* to be present in the estuary. In this regard, Urbano *et al.* (2010) mentioned that values around 5.30 ± 2.15 mgL-1 are within the normal range for the cultivation of postlarvae of most river prawn species. Likewise, Mires (1983) pointed out that the dissolved oxygen concentration suitable for the survival of shrimp postlarvae of the species *M. rosenbergii* (De Man, 1879) is 2.5–8.4 mgL-1.

Table 1. Environmental factors of the Jamapa River estuary, Boca del Río, Veracruz. ITBOCA: Instituto Tecnológico de Boca del Río; ICIMAP: Instituto de Ciencias Marinas y Pesquerías, Universidad Veracruzana; SD, standard deviation. DO: Dissolved oxygen, Sal: salinity, Temp: temperature, Tds: total dissolved solids.

| Month | Sampling site | DO ($mgL^{-1}$) | pH | Temp (°C) | Sal (PSU) | Tds (ppm) |
|---|---|---|---|---|---|---|
| September | ITBOCA | 5.28 ± 0.06 | 7.18 ± 0.01 | 28.47 ± 0.65 | 0.97 ± 0.06 | 890 ± 50 |
| | ICIMAP | 3.88 ± 0.96 | 7.29 ± 0.09 | 30.05 ± 1.02 | 1.07 ± 0.23 | 904 ± 31 |
| | Barco | 4.02 ± 0.02 | 7.18 ± 0.04 | 29.51 ± 0.58 | 2.7 ± 0.75 | 1874 ± 106 |
| | Venecia | 4.85 ± 0.22 | 7.13 ± 0.01 | 29.48 ± 0.66 | 8.31 ± 0.93 | 258 ± 44 |
| | Estero | 4.20 ± 0.14 | 7.19 ± 0.06 | 20.11 ± 0.17 | 14.29 ± 1.46 | 1054 ± 78 |
| | Average ± SD | 4.44 ± 0.06 | 7.19 ± 0.06 | 27.52 ± 4.18 | 5.47 ± 5.77 | 996 ± 578 |
| November | ITBOCA | 5.38 ± 0.26 | 7.75 ± 0.26 | 22.64 ± 0.66 | 6.16 ± 0.52 | 4688 ± 1648 |
| | ICIMAP | 3.99 ± 0.46 | 7.03 ± 0.46 | 24.32 ± 0.54 | 6.09 ± 1.13 | 4493 ± 363 |
| | Barco | 3.65 ± 0.65 | 7.16 ± 0.65 | 27.64 ± 0.11 | 5.22 ± 0.59 | 4226 ± 147 |
| | Venecia | 4.92 ± 0.1 | 7.50 ± 0.1 | 26.09 ± 0.37 | 22.04 ± 0.46 | 18.13 ± 1.18 |
| | Estero | 4.96 ± 0.0 | 7.2 ± 0.07 | 26.45 ± 0.87 | 22.39 ± 1.12 | 18.16 ± 1.34 |
| | Average ± SD | 4.58 ± 0.72 | 7.33 ± 0.29 | 25.48 ± 1.97 | 12.38 ± 8.99 | 2689 ± 2244 |
| January | ITBOCA | 6.01 ± 0.01 | 7.44 ± 0.01 | 23.08 ± 0.78 | 7.04 ± 1.20 | 5006 ± 626 |
| | ICIMAP | 5.11 ± 0.15 | 7.65 ± 0.03 | 21.66 ± 0.04 | 7.46 ± 1.65 | 5091 ± 617 |
| | Barco | 4.11 ± 0.14 | 7.34 ± 0.02 | 22.6 ± 0.07 | 12.89 ± 0.95 | 10.95 ± 1.05 |
| | Venecia | 4.31 ± 0.08 | 7.85 ± 0.06 | 22.13 ± 0.71 | 34.03 ± 0.99 | 25.97 ± 0.47 |
| | Estero | 4.75 ± 0.21 | 7.34 ± 0.02 | 22.38 ± 0.87 | 33.65 ± 0.36 | 25.53 ± 0.24 |
| | Average ± SD | 4.85 ± 0.75 | 7.52 ± 0.22 | 22.37 ± 0.53 | 19.01 ± 13.73 | 2032 ± 2754 |
| March | ITBOCA | 6.11 ± 0.14 | 7.16 ± 0.01 | 24.61 ± 0.57 | 6.14 ± 0.26 | 4913 ± 490 |
| | ICIMAP | 5.44 ± 0.32 | 7.24 ± 0.04 | 24.42 ± 0.21 | 8.02 ± 0.86 | 5842 ± 856 |
| | Barco | 5.15 ± 0.05 | 7.18 ± 0.01 | 24.81 ± 0.28 | 17.99 ± 2.33 | 14.36 ± 1.42 |
| | Venecia | 5.07 ± 0.06 | 7.19 ± 0.02 | 22.97 ± 0.51 | 33.93 ± 0.81 | 27.96 ± 2.37 |
| | Estero | 6.19 ± 0.03 | 7.21 ± 0.04 | 22.66 ± 0.14 | 34.99 ± 0.43 | 27.86 ± 1.6 |
| | Average ± SD | 5.59 ± 0.53 | 7.2 ± 0.03 | 23.89 ± 0.99 | 20.21 ± 13.77 | 2165 ± 2950 |
| May | ITBOCA | 4.87 ± 0.21 | 7.62 ± 0.10 | 31.64 ± 0.11 | 33.37 ± 0.27 | 26.04 ± 0.83 |
| | ICIMAP | 6.65 ± 0.04 | 7.34 ± 0.01 | 30.45 ± 0.17 | 33.84 ± 0.22 | 26.89 ± 0.18 |
| | Barco | 6.06 ± 0.04 | 7.53 ± 0.04 | 28.91 ± 0.16 | 35.65 ± 0.01 | 27.57 ± 0.76 |
| | Venecia | 5.7 ± 0.37 | 7.56 ± 0.37 | 28.81 ± 0.32 | 35.39 ± 0.54 | 26.89 ± 0.18 |
| | Estero | 5.43 ± 0.27 | 7.44 ± 0.27 | 28.92 ± 0.23 | 35.57 ± 0.04 | 27.13 ± 0.28 |
| | Average ± SD | 5.74 ± 0.67 | 7.49 ± 0.11 | 29.74 ± 1.26 | 34.76 ± 1.08 | 26.9 ± 0.56 |

Table 2. Generalized least squares model (GLS) for environmental factors registered in the inlet of the River Jamapa, Boca del Río, Veracruz during 2018 and 2019. df: degrees of freedom, Do: Dissolved oxygen, F: statistic in ANOVA (analysis of variance), Temp: temperature, Tds: total dissolved solids, P: probability level.

| | | Do | | pH | | Temp °C | | Tds | | Sal | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Origin | df | F | P | F | P | F | P | F | P | F | P |
| Corrected model | 8 | 5.79 | 0.001 | 7.44 | <0.001 | 5.39 | 0.002 | 3.19 | 0.023 | 18.74 | <0.001 |
| Intersection | 1 | 360.44 | <0.001 | 11810.17 | <0.001 | 3172.72 | <0.001 | 23.01 | <0.001 | 286.41 | <0.001 |
| Site | 4 | 1.98 | 0.15 | 3.27 | 0.04 | 1.66 | 0.21 | 4.31 | 0.015 | 14.17 | <.0001 |
| Month | 4 | 9.62 | <0.001 | 11.6 | <0.001 | 9.13 | <0.001 | 2.09 | 0.13 | 23.29 | <0.001 |
| Error | 16 | | | | | | | | | | |
| Total | 25 | | | | | | | | | | |
| Correlation coefficient (r) | | 0.74 | | 0.79 | | 0.73 | | 0.62 | | 0.91 | |

In this region of the Gulf of Mexico, in the cold front season, Jasso-Montoya (2012), Avendaño-Álvarez (2013), Contreras-Espinoza (2016), and Castañeda-Chávez *et al*. (2017) reported that the temperature decreases to between 23°C and 24°C. In the study zone, Cházaro-Olvera *et al*. (2022) registered a temperature of 25.11°C ± 0.12 °C in ITBOCA in the cold front season, while Contreras-Espinoza (2016) mentioned that the Jamapa River temperature was 25°C in the cold front season and 29.4°C in the rainy season. Therefore, the temperature values in the Jamapa River estuary are consistent with the behavior of the region's climatic seasons (Zavala-Hidalgo *et al*., 2006). We consider it important to use the Mexican regulations (NOM-001-SEMARNAT-2021) to compare the values obtained in this study. The temperature registered in this work does not exceed the maximum permissible limit of 35°C defined by the official Mexican standard. Existing research shows that the growth of the different stages of development of *M. americanum* (Spence Bate 1868) is optimal at a temperature of 26–29°C (López-Uriostegui *et al*., 2020). Cházaro-Olvera *et al*. (2022) recollected postlarvae of *M. acanthurus* and *M. olfersii* in these temperature values.

In the Jamapa River estuary, a range of salinity values have been recorded from 2 psu in the rainy season to 21 psu in the dry season (Aké-Castillo *et al*., 2016; González-Vázquez *et al*., 2019). In the present work, a wide variation of salinity was also observed. Some river prawn species, such as *M. americanum*, develop adequately between 3 and 15 psu (Chung, 2001; López-Uriostegui *et al*., 2020). This implies that the *Macrobrachium* river prawns require brackish water in their postlarvae development, while juveniles and adults prefer low-salinity water or freshwater (Graziani *et al*., 1995).

Lorán-Nuñez (2013) reported an abundance of 69–120 *M. acanthurus* postlarvae and juveniles in the lower basin of the Papaloapan River. This range is similar to the abundance identified in the present study in the estuary of the Jamapa River, where the abundance was 18–164 in the months of capture. The highest abundance was found in September (i.e., the rainy season) at the ITBOCA sampling site, which was characterized by the presence of *Thypha domingensis* Persoon 1807 vegetation. This finding is consistent with what was reported by Lorán-Nuñez (2013), who found the highest values of abundance in the rainy season. It is important to mention that in a study carried out at another latitude on the banks of the Iguape River in São Paulo, Brazil, the abundance of *M. olfersii* was 23,818 postlarvae, juveniles and adults (Ribeiro *et al*., 2020).

Table 3. Carideans of the Jamapa River estuary. Abundances of five places and five months.

| | Site | | | | | |
|---|---|---|---|---|---|---|
| Species/Community Factor | ITBOCA | ICIMAP | Barco | Venecia | Estero | Total |
| *Macrobrachium acanthurus* (Weigmann, 1836) | 223 | 23 | 0 | 0 | 11 | 257 |
| *Macrobrachium olfersii* (Weigmann, 1836) | 658 | 181 | 62 | 50 | 65 | 1016 |
| *Potimirim mexicana* (De Saussure, 1857) | 5746 | 188 | 805 | 311 | 326 | 7376 |
| Total | 6627 | 392 | 867 | 361 | 402 | 8649 |
| | Month | | | | | |
| Species/Community Factor | September | November | January | March | May | Total |
| *Macrobrachium acanthurus* (Weigmann, 1836) | 164 | 34 | 20 | 18 | 21 | 257 |
| *Macrobrachium olfersii* (Weigmann, 1836) | 609 | 122 | 98 | 10 | 177 | 1016 |
| *Potimirim mexicana* (De Saussure, 1857) | 4257 | 533 | 2436 | 12 | 138 | 7376 |
| Total | 5030 | 689 | 2554 | 40 | 336 | 8649 |

In the Jamapa River basin, pH values ranging from 6 to 9 have been recorded (Houbron, 2010; SEMARNAT, 2002). The pH values recorded in this study were neutral to slightly alkaline and were among the values established by the official Mexican standard (NOM-127-SSA1-1994). In the Jamapa River estuary, the pH values provide a buffer effect to the water, avoiding acidification (Bates, 1973). Pretto (1988) found that for good development of postlarvae and juveniles of *M. rosenbergii* shrimp, pH must range between 7 and 9.

The total dissolved solids were highest in the cold front and rainy seasons. Cházaro-Olvera *et al*. (2022) also found high values of total dissolved solids (732–1,443 ppm) in the cold front season. In the Jamapa River estuary, total dissolved solids in some months and sites exceeded the maximum permissible limit of 1,000 ppm, which was established by the official Mexican standard (NOM-001-SEMARNAT-2021 and NOM-127-SSA1-1994 for drinking water). These concentrations of dissolved solids are due to the transport from the lower basin of the Jamapa River to the estuary (Aragón-López *et al*., 2017), which can affect the respiration process of carideans.

When analyzing the abundance of caridean postlarvae in this study, *P. mexicana* was the most abundant species. This finding is consistent with what was reported in the lower basin of the Papaloapan River by Miranda-Vidal *et al*. (2016), who collected 4,587 crustaceans, with *P. mexicana* being the dominant species at 34% in the dry season; M*acrobrachium* sp. and *P. mexicana* represented 59% and 30% of the abundance, respectively, and were the dominant taxa in the rainy season.

Specific richness is closely related to the dynamics of salinity in estuaries. For example, Barba *et al*. (2005) reported nine species of carideans in Laguna Madre, Tamaulipas, where two of them were associated with submerged vegetation or littoral vegetation. On the other hand, the authors reported 11 species of carideans in Laguna de Terminos, Campeche, where five species were associated with submerged vegetation. In each of the lagoons the authors found at least one dominant species in the taxocene, which is consistent with the present study where the postlarvae of *P. mexicana* were dominant. In the Papaloapan River, Miranda-Vidal *et al*. (2016) also found that *P. mexicana* in the dry season and *Macrobrachium* sp. in the rainy season, respectively, were the dominant species.

In conclusion, the values of the environmental factors were related with the sites and months of sampling. The abundance values for *P. mexicana*, *M. acanthurus*, and *M. olfersii* were within the interval of the values obtained by other authors. The abundances of *P. mexicana* and *M. olfersii* were within the values reported in other studies. However, the abundance of *M. acanthurus* was relatively low, which may be related to the high values of total dissolved solids or overfishing. Finally, the highest density of caridean postlarvae occurred in the rainy season in sites with *T. domingensis* vegetation.

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**Conflict of interests**

The authors declare that there is no conflict of interest.

Table 4. Relationship with GLM of abundance with respect to months, places and environmental factors. B, regression coefficient; Wald's $X^2$ to determine if the explanatory variable of the model is significant; * significant relationship.

| | M. acanthurus | | | *M. olfersii* | | | P. mexicana | | |
|---|---|---|---|---|---|---|---|---|---|
| Source | B | $X^2$ Wald | p | B | $X^2$ Wald | p | B | $X^2$ Wald | p |
| Intersection | 7.97 | 395.96 | < 0.001* | 3,35 | 8.64 | 0.003* | 6.17 | 53.05 | < 0.001* |
| Barco | 2.99 | 221.21 | < 0.001* | -2,50 | 18.24 | < 0.001* | 1.69 | 21.42 | < 0.001* |
| Estero | -1.28 | 14.67 | < 0.001* | -1,89 | 7.97 | 0.005* | 0.66 | 2.37 | 0.24 |
| ICIMAP | 9.34 | 583.01 | < 0.001* | -0,09 | 0.01 | 0.909 | 9.91 | 312.92 | < 0.001* |
| ITBOCA | 1.75 | 141.34 | < 0.001* | -0,81 | 5.51 | 0.019* | 1.95 | 51.88 | < 0.001* |
| Venecia | 0[a] | | | 0[a] | | | 0[a] | | |
| Enero | 2.29 | 460.60 | < 0.001* | -0,47 | 1.07 | 0.300 | 1.23 | 45.95 | < 0.001* |
| March | 8.94 | 783.37 | < 0.001* | 2,71 | 32.18 | < 0.001* | 5.88 | 194.10 | < 0.001* |
| May | 2.54 | 314.07 | < 0.001* | 1,61 | 18.01 | < 0.001* | 2.19 | 71.54 | < 0.001* |
| November | 4.96 | 1068.88 | < 0.001* | 2,01 | 26.05 | < 0.001* | 3.27 | 154.83 | < 0.001* |
| September | 0[a] | | | 0[a] | | | 0[a] | | |
| Dissolved Oxygen $mgL^{-1}$ | 0.002 | 54.27 | < 0.001* | 0,002 | 7.78 | 0.005* | 0.002 | 15.01 | < 0.001* |
| Ph | 0.001 | 9.15 | 0.002* | 0.001 | 0.21 | 0.654 | 0.001 | 0.69 | 0.405 |
| Temperature °C | -0.002 | 211.96 | < 0.001* | 0.001 | 0.75 | 0.386 | -0.001 | 94.20 | < 0.001* |
| Total dissolved solids ppm | -0.001 | 1543.34 | < 0.001* | 0.001 | 48.75 | < 0.001* | -0.001 | 297.61 | < 0.001* |
| Salinity psu | -0.004 | 751.45 | < 0.001* | 0.001 | 3.52 | 0.061 | -0.003 | 351.28 | < 0.001* |

a. zero because this parameter is redundant.

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