v. 5, n. 3, 2025

International Journal of Biological and Natural Sciences

Acceptance date: 19/05/2025

SPATIOTEMPORAL VARIATIONS OF MYSIS LARVAE OF PENAEID SHRIMP IN THE MANDINGA LAGOON SYSTEM, VERACRUZ: ABUNDANCE, BIOMASS AND THEIR RELATIONSHIP WITH ENVIRONMENTAL AND SEDIMENTOLOGICAL VARIABLES (2008-2015)

Asela del Carmen Rodríguez-Varela
Universidad Nacional Autónoma de México, Facultad de Estudios Superiores Iztacala, Biology Department, Coastal Oceanography Laboratory. Estado de México, México
0000-0002-4594-1969

Omar Alfredo Barreto-Segura
Universidad Nacional Autónoma de México, Facultad de Estudios Superiores Iztacala, Biology Department, Coastal Oceanography Laboratory. Estado de México, México

Jacqueline Becerril Aguilar
Universidad Nacional Autónoma de México, Facultad de Estudios Superiores Iztacala, Biology Department, Coastal Oceanography Laboratory. Estado de México, México

Abstract: This study analyzes the spatio-temporal variations in the abundance and biomass of mysis larvae of penaeid shrimp in the Mandinga Lagoon System (SLM), Veracruz, between 2008 and 2015, with the objective of understanding their ecological dynamics and their relationship with environmental and sedimentological factors. Larvae were collected at 13 stations distributed throughout the system, evaluating variables such as temperature, salinity, dissolved oxygen, transparency, sediment type and organic carbon content. The results showed notable fluctuations in density (0.51 to 1231.66 ind/100 m^2) and biomass (0.01 to 12.15 g/100 m^2), with maximums recorded mainly in areas with high submerged aquatic vegetation (SAV) cover and substrates rich in mud and organic matter, especially north of La Redonda and Mandinga. No individuals were observed in La Larga lagoon. The distribution presented an aggregate pattern and was not significantly correlated with physicochemical variables, suggesting that factors such as habitat structure and hydrological dynamics have a greater influence on larval retention. The study provides evidence for the ecological importance of SLM as a penisid breeding ground and underscores the need for systematic monitoring to assess the effects of anthropogenic disturbance and climate change on these coastal ecosystems.
Keywords: mysis larvae, penaeid shrimp, Mandinga Lagoon System, estuarine recruitment.

INTRODUCTION

The study of the larval stages of aquatic organisms, particularly crustaceans, represents an essential component for understanding the ecological dynamics of estuarine and lagoon ecosystems. During the mysis stage, these organisms occupy a key link in the aquatic food web, acting as secondary consumers and as essential prey for a wide range of fish, including species of commercial and ecological relevance (Mauchline, 1980; Price et al., 1988). Despite their importance, knowledge about the biology, ecology and distribution of crustaceans in many tropical and subtropical regions, such as the Mandinga Lagoon System (SLM) in Veracruz, Mexico, remains limited and fragmentary.

The SLM is an estuarine complex of high primary productivity and high biological diversity, located on the central coast of the Gulf of Mexico. This system provides essential habitat for diverse species of fish, crustaceans, and mollusks, many of which depend on the estuaries during some phase of their life cycle. However, the SLM has undergone significant transformations due to anthropogenic pressure, such as urban growth and, especially, the recurrent dredging of La Larga lagoon in 2010, 2015 and 2018, with the objective of restoring marine connectivity and favoring water exchange (Rodríguez-Varela et al., 2019, 2022).

In this context, the analysis of the mysis stage acquires particular relevance, since it allows inferring key aspects of recruitment, reproduction and the structure of local populations of penaeid shrimp (Rodríguez et al., 2001). In addition, the identification and quantification of these larval stages can act as sensitive indicators of habitat quality, given their response to physicochemical changes such as salinity, temperature and nutrient levels (Dall et al., 1990; Lemos-Michel et al., 2013).

From an ecological perspective, mysis show remarkable physiological and ecological plasticity in the face of variable environmental gradients, characteristic of estuaries. This makes them model organisms for investigating population responses to natural and anthropogenic disturbances. Previous studies have shown that their abundance and spatial distribution are closely related to factors such

as estuarine hydrodynamics, food availability and predation pressure (Wittmann and Wirtz, 1999; Barletta et al., 2005). Therefore, knowledge of their ecology in poorly studied lagoon systems, such as Mandinga, allows us to establish baselines for ecological monitoring and conservation of these ecosystems.

Likewise, the study of these organisms acquires relevance in the face of the challenges of climate change and the growing anthropization of coastal areas. The estuaries of the Gulf of Mexico, and particularly those of Veracruz, face pressures such as urbanization, pollution, and hydrological alterations, which can negatively affect the processes of dispersal, settlement, and recruitment of species with planktonic larval stages, such as penaeid shrimp (Kennish, 2002). Documenting the presence, abundance and morphometry of these stages under current conditions will facilitate, in the future, the evaluation of changes in planktonic biodiversity and in the functionality of estuarine systems.

In addition, studies on mysis contribute to the taxonomic and systematic knowledge of crustaceans, a group that in tropical regions, such as Mexico, presents important information gaps. The scarcity of larval identification keys and morphological descriptions hinders the progress of ecological and biodiversity research in these areas (Suárez-Morales, 2003). In this sense, integrative initiatives that document the morphology, ecology and distribution of these organisms are crucial to strengthen the basis of scientific knowledge in megadiverse regions

Like other estuarine systems in the Gulf of Mexico, the SLM represents a key area for recruitment of penaeid shrimp in their early developmental stages, such as larvae and postlarvae (Lara-Domínguez et al., 2011), as well as for other benthic organisms of ecological and fisheries importance. Since the 1970s, several investigations have been documented in the SLM and other Veracruz systems that address these phases, although they have mostly been sporadic, with limited scope or without a specific focus on larval populations of penaeid shrimp (Peniche, 1979; Sánchez, 1979; Díaz and Latournerie, 1980; Arreguín-Sánchez, 1982; Reguero and García-Cubas, 1993; Barrera-Escorcia, 2006; Barreto-Segura, 2019; Rodríguez-Varela et al., 2019, 2020). This gap contrasts with the more systematic efforts developed in regions such as northeastern Tamaulipas or the Campeche Sound, historically recognized as priority areas for the shrimp fishery in Mexico (Castro-Meléndez et al., 1990; Castro and Arreguín-Sánchez, 1991; Barba-Macías, 1999; Ramírez-Rodríguez et al., 2000; Domínguez et al., 2003; Rosas et al., 2004; Wakida-Kusunoki et al., 2005, 2008; Ocaña-Luna et al., 2008; Cervantes-Hernández and Gracia-Gasca, 2011). However, more recent research in other Veracruz systems has begun to document in greater detail the dynamics of penisid larvae and postlarvae, which evidences the potential of this region to generate relevant ecological information (Sánchez and Soto, 1993; Trejo, 2015; Cházaro-Olvera et al., 2020).

Despite the ecological and fisheries importance of the SLM, there is a notable lack of systematic studies documenting the spatiotemporal variations of penaeid shrimp postlarvae. This limitation hinders the understanding of its role as a nursery area, which is essential for the management and conservation of these resources. In this framework, the following research question was posed: What are the spatiotemporal variations in the abundance and biomass of shrimp postlarvae in the Mandinga lagoon system, and how are they related to environmental conditions and sedimentological characteristics of the system? The objective of the study was to contribute to the knowledge of the spatio-temporal variations in the abundance and biomass of penaeid

shrimp postlarvae in the Mandinga lagoon system, Veracruz, Mexico, through the analysis of data obtained during samplings carried out between 2008 and 2015.

MATERIALS AND METHODS

The present investigation was carried out in the Mandinga Lagoon System (SLM) which has been extensively described by Rodríguez-Varela et al. (2019, 2020; 2022) (Figure 1).

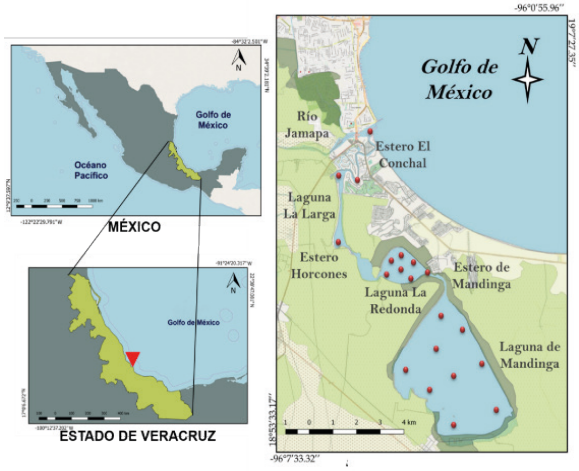


Figure 1. Location of the SLM and sampling stations (Taken from Rodríguez-Varela, 2019).

Annual collections were carried out at 13 sampling stations distributed throughout the system. Conventional hydrometeorological variables were recorded at each station: depth (cm), using a Depthmate Speedtech model SM-5 portable echo sounder; transparency (cm), using a Secchi LaMotte disk; water temperature (°C), salinity (ups) and conductivity (mS/cm), using a multisensor YSI 30; dissolved oxygen (mg/L), using a Waterproof Oakton DO 300 Series oximeter; and pH, using a Waterproof pH Testr. potentiometer.

Additionally, sediment samples were collected using a 6.8 cm × 7.1 cm × 120 cm WaterMark* universal core sampler (Poppe et al., 2000; Zaixso, 2002; TEM, 2016). Samples were washed, dried and dry sieved. Total organic carbon content (%) was determined by the chromic oxidation technique of Walkley and Black, using sediments previously passed through a 0.5 mm aperture sieve. For texture analysis, Wentworth granulometry was used, using a Ro Tap mechanical shaker with sieves of 2.0 mm (gravel), 0.0625 mm (sand) and <0.0625 mm (mud), expressing the results in percentage of dry sediment and classifying the type of texture (Wentworth, 1936; Poppe et al., 2000; Muñóz-Iniestra et al., 2011).

Shrimp postlarvae were collected using a 70 cm × 140 cm Renfro type net, with 700 µm mesh, and a 30 m long by 1.5 m high chinchorro, with mesh opening of 0.635 cm (Zaixso, 2002; TEM, 2016). The captured organisms were fixed in 10% formalin in properly labeled plastic jars and transferred to the Coastal Oceanography Laboratory of the Facultad de Estudios Superiores Iztacala, UNAM. Taxonomic identification was performed based on specialized keys (Pérez-Farfante, 1969; Williams, 1984; Fischer et al., 1995; Rocha-Ramírez et al., 1996; Pérez-Farfante and Kensley, 1997; Arenas-Fuentes and Hernández-Aguilera, 2000; Brusca and Brusca, 2005; Medellín-Mora et al., 2009), and the nomenclature was updated according to the World Register of Marine Species (WoRMS Editorial Board, 2025).

All organisms were counted, weighed and preserved in 70% alcohol. Abundance records were expressed in density (ind/100 m^2) and biomass (g/100 m^2). The spatial distribution of abundance was represented by isolines generated by geostatistical interpolation using the Kriging method, in Surfer v.8 software (Golden Software, 2002), and visualized graphically using QGIS (2016).

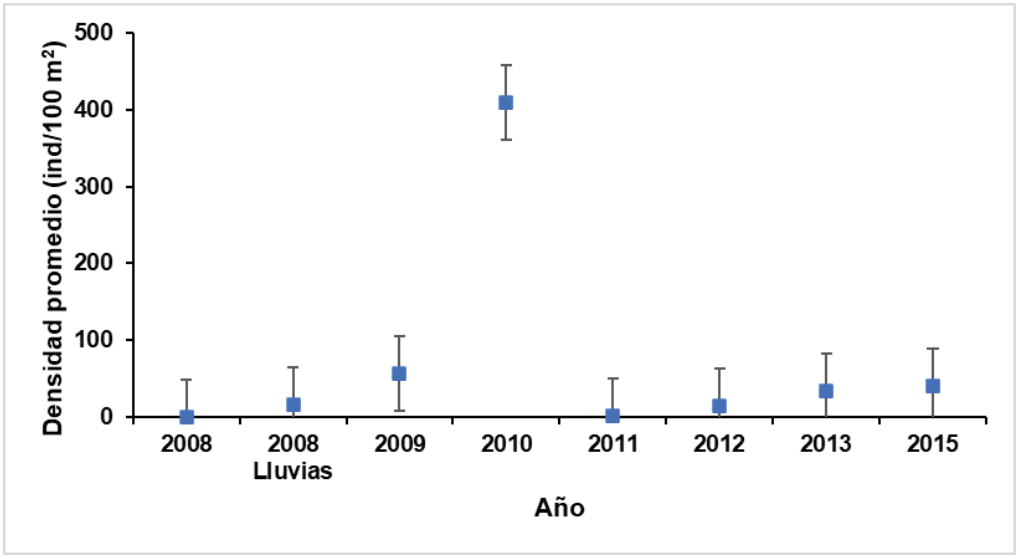


Figure 2. Temporal variation of the average density of mysis larvae in the SLM.

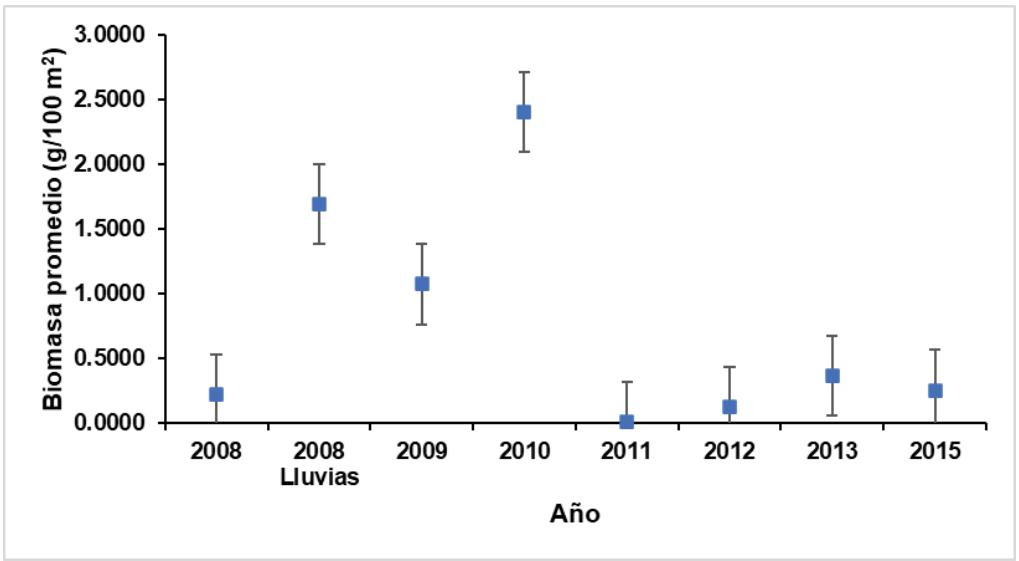
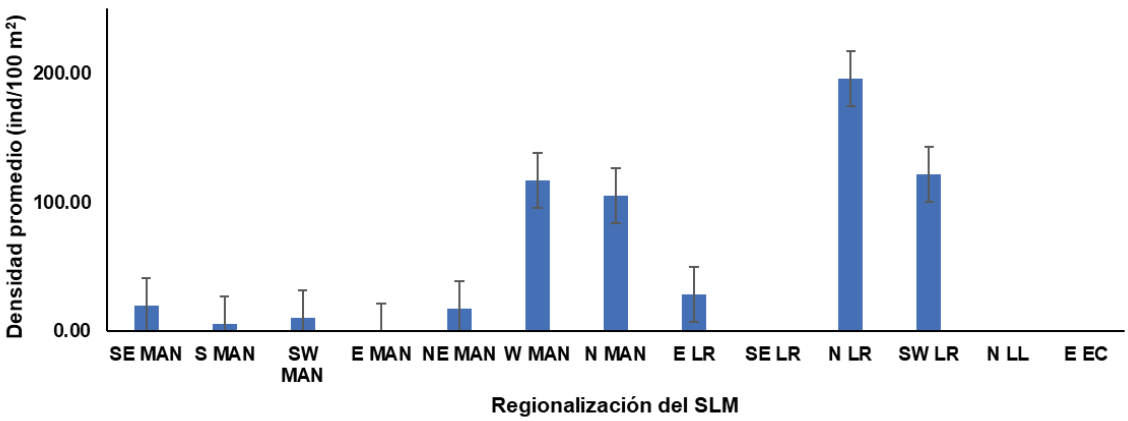


Figure 3. Temporal variation of the average biomass of mysis larvae in the SLM.



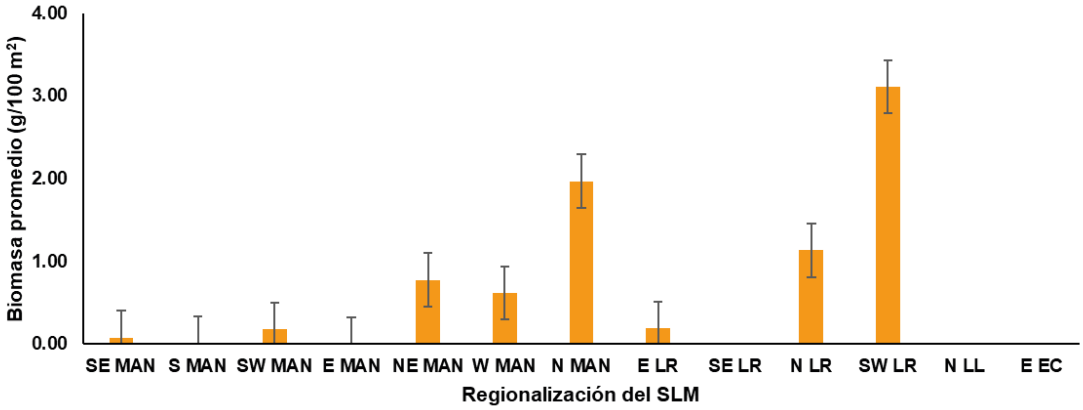


Figure 4. Spatial variation of density and average biomass of mysis in the SLM. Note. SE MAN: southeast Mandinga; S MAN: south Mandinga; SW MAN: southwest Mandinga; E MAN: east Mandinga; NE MAN: northeast Mandinga; W MAN: west Mandinga; N MAN: north Mandinga; E LR: east La Redonda; SE LR: southeast La Redonda; N LR: north La Redonda; SW LR: southwest La Redonda; N LL: north La Larga; E EC: El Conchal estuary.

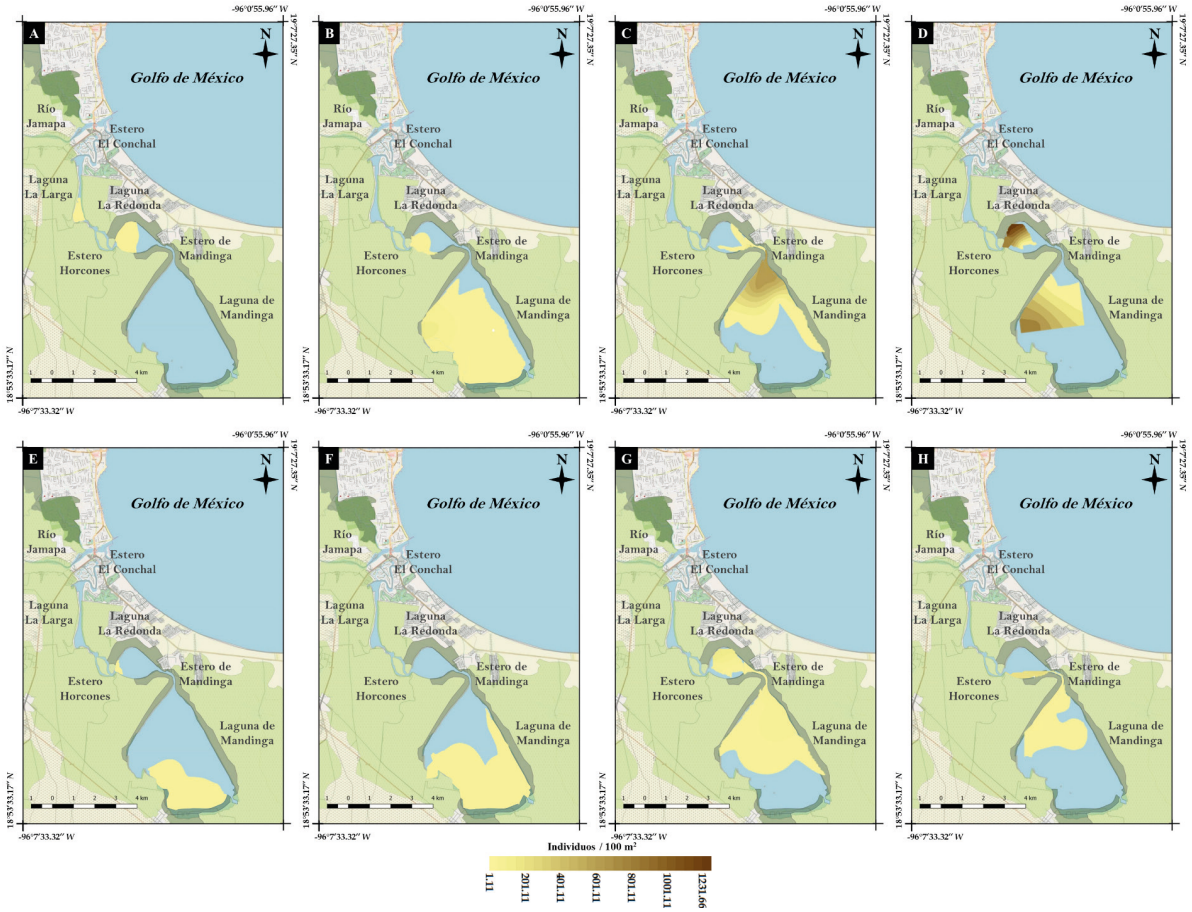


Figure 5. Spatio-temporal variation of mysis density in the SLM during the study period. A 2008, B rains 2008, C 2009, D 2010, E 2011, F 2012, G 2013, H 2015.

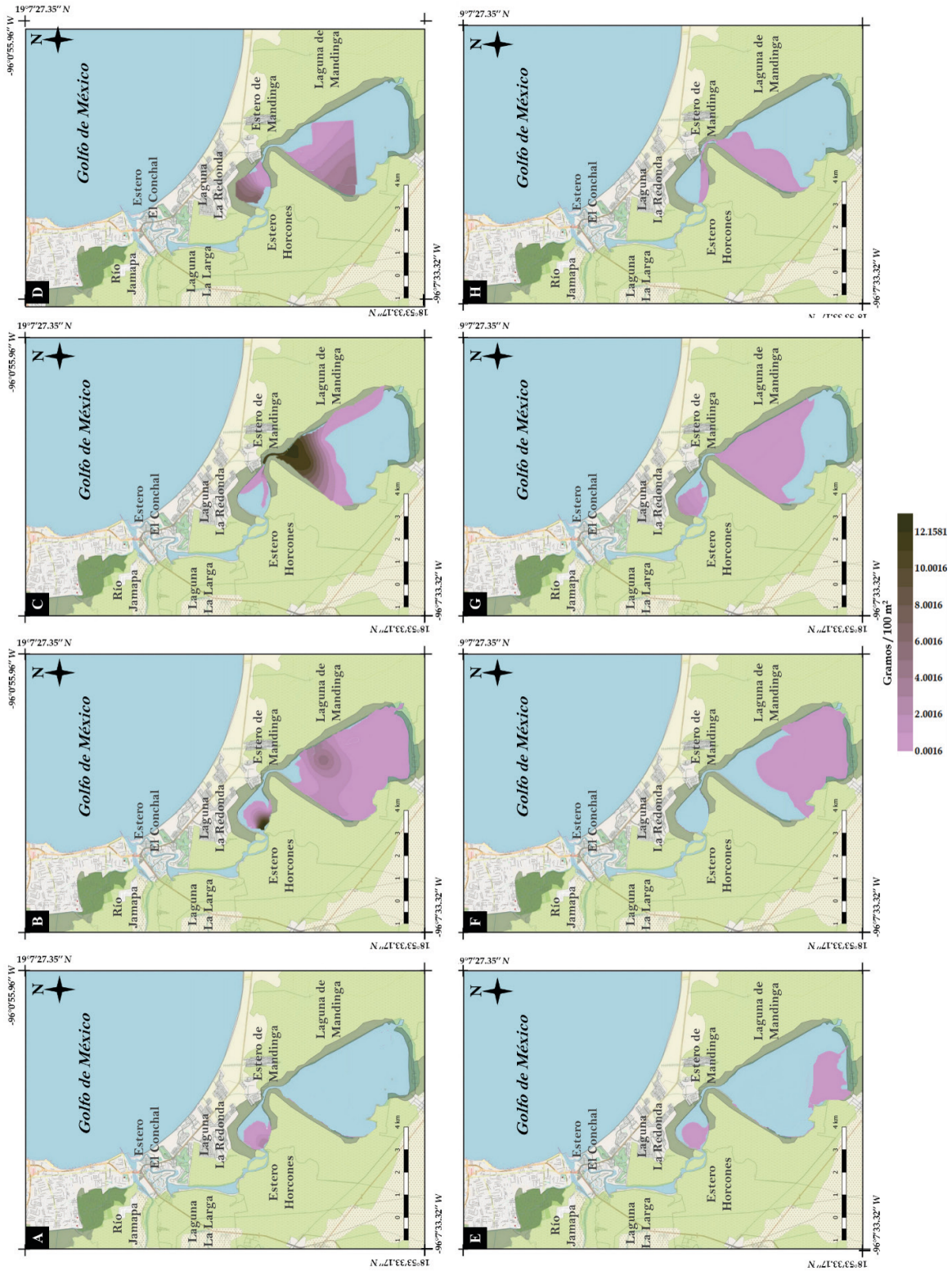


Figure 6. Spatio-temporal variation of mysis biomass in the SLM during the study period. A 2008, B rains 2008, C 2009, D 2010, E 2011, F 2012, G 2013, H 2015.

RESULTS

An average density of 71.90 ind/100 m² was recorded, with a minimum value in 2008 of 0.51 ind/100 m² and a maximum in 2010 of 408.81 ind/100 m² (Figure 2).

The average biomass was 0.77 g/100 m², with a minimum value in 2011 of 0.01 g/100 m² and a maximum in 2010 of 2.40 g/100 m² (Figure 3).

The areas with the highest density (Figure 4a) and biomass records were located west to north of Mandinga, as well as north and southwest of La Redonda. No individuals were recorded in La Larga lagoon (Figure 4b).

The spatio-temporal changes are described below:

2008: The lowest density (1.11 ind/100 m²) was recorded north of La Redonda and the highest (5.00 ind/100 m²) southwest of La Redonda (Figure 5a). The minimum biomass was 0.13 g/100 m² north of La Redonda and the maximum was 2.52 g/100 m² to the southwest (Figure 6a).

2008 rainfall: The minimum density was 16.19 ind/100 m² southwest of La Redonda and the maximum was 120.63 ind/100 m² west of Mandinga (Figure 5b). The minimum biomass was recorded southeast of Mandinga (0.13 g/100 m²) and the maximum southwest of La Redonda (12.15 g/100 m²) (Figure 6b).

2009: A density of 631.74 ind/100 m² and a biomass of 11.80 g/100 m² were obtained north of Mandinga (Figures 5c and 6c).

2010: The lowest density (41.66 ind/100 m²) was recorded northeast of Mandinga and the highest (1231.66 ind/100 m²) north of La Redonda (Figure 5d). The minimum biomass was 0.21 g/100 m² northeast of Mandinga and the maximum was 6.28 g/100 m² north of La Redonda (Figure 6d).

2011: The lowest density was 1.11 ind/100 m² southwest of La Redonda and the highest was 10.00 ind/100 m² south and southwest of Mandinga (Figure 5e). Biomass ranged from 0.002 g/100 m² southeast of Mandinga to 0.05 g/100 m² southwest (Figure 6e).

2012: A minimum density of 20.00 ind/100 m² was recorded south of Mandinga and a maximum of 91.66 ind/100 m² to the southeast (Figure 5f). Biomass ranged from 0.33 g/100 m² southwest to 1.01 g/100 m² also southwest of Mandinga (Figure 6f).

2013: Density ranged from 3.33 ind/100 m² east of Mandinga to 140.00 ind/100 m² north of La Redonda (Figure 5g). Minimum biomass was 0.03 g/100 m² east of Mandinga and maximum biomass was 1.55 g/100 m² north of La Redonda (Figure 6g).

2015: The lowest density was recorded west of Mandinga (5.00 ind/100 m²) and the highest east of La Redonda (228.00 ind/100 m²) (Figure 5h). The minimum biomass was 0.003 g/100 m² northeast and west of Mandinga, and the maximum was 1.53 g/100 m² east of La Redonda (Figure 6h).

The mysis were collected under ambient conditions with an average water temperature of 28.01 °C, ranging from 21.69 to 30.42 °C; average salinity of 25.50 ups, ranging from 14.85 to 31.48 ups; average dissolved oxygen of 8.71 mg/L, ranging from 6.67 to 10.95 mg/L; and average transparency of 76.18 cm, with a minimum of 57.93 cm and a maximum of 88.50 cm.

Sediment characteristics were: average gravel content of 9.67 %, ranging from 5.09 to 19.01 %; sand with an average of 60.74 %, ranging from 46.89 to 66.99 %; sludge with an average of 28.49 %, ranging from 20.73 to 42.02 %; and average total organic carbon of 1.14 %, ranging from 0.72 to 1.86 %.

An inversely proportional correlation was observed with sand proportion (r = -0.92) and depth (r = -0.71), and a directly proportional correlation with sludge content (r = 0.76).

Under these conditions, the spatial distribution pattern of the larvae was evaluated by means of the variance/mean ratio, determining a gregarious or aggregate behavior.

DISCUSSION

The population dynamics of mysis larvae of penaeid shrimp in estuarine lagoon systems represent a key component for understanding recruitment, productivity and connectivity processes between coastal and marine habitats. In the present study, specific patterns of mysis larvae abundance were observed in the Mandinga Lagoon System (SLM), which did not present a statistically significant correlation with physicochemical variables of the environment such as salinity or temperature ($p > 0.05$). This finding is especially relevant when compared with previous works that have pointed to these factors as determinants of larval distribution (Camarena-Rosales, 1982; Doerr et al., 2015).

A possible explanation for this pattern lies in the osmoregulatory tolerance of mysis larvae, which has been documented in several studies (Brito et al., 2000; Alpuche et al., 2005). This physiological capacity allows them to develop in a wide range of salinities, such as those observed in this study (14.85 to 31.48 ups), suggesting that other factors could be playing a more important role in their establishment and permanence in the system. For example, variables such as the availability of submerged aquatic vegetation (SAV), substrate structure and hydrological dynamics appear to be more relevant to the aggregation of these larvae (Minello and Zimmerman, 1991; Clark et al., 2004).

The highest abundance of mysis larvae was recorded in western areas of La Redonda and north and east of Mandinga, characterized by high SAV cover and substrates rich in organic matter. This observation coincides with that reported by Domínguez et al. (2003) in Mecoacán and by Pérez-Castañeda and Defeo (2003) in Ría Celestún, where submerged vegetation not only offers protection from predators, but also improves feeding conditions through the accumulation of detritus and associated microfauna. This reinforces the hypothesis that the structural quality of the habitat is a key factor for the retention of mysis larvae, as proposed by authors such as Pérez-Castañeda et al. (2010) and Rozas and Minello (2011).

In contrast, areas such as La Larga and El Conchal estuary, despite being exposed to seawater ingress, presented low densities of mysis larvae, which could be attributed to the low presence of SAV, higher current velocity and anthropogenic activities such as dredging and boat traffic (Rodríguez-Varela et al., 2019). Intervention in these water bodies, although aimed at increasing connectivity with the sea, can cause significant alterations in salinity gradients, habitat availability and substrate composition, which can negatively influence larval settlement processes (Domínguez et al., 2003; Hart et al., 2012).

The significant increase in the abundance of mysis larvae in 2010 could be associated with dredging activities in the channels connecting to the sea carried out that same year in La Larga. Although this type of intervention can facilitate the entry of larvae into the system, it also entails ecological risks such as loss of benthic habitat, changes in hydrodynamics and increased fine sedimentation, which in the long term can negatively modify the conditions for settlement and growth of the early stages of shrimp (Rodríguez-Varela et al., 2020).

The consistent presence of mysis larvae throughout the sampling period is consistent with evidence that penaeid shrimp exhibit continuous reproduction with two main pulses: spring and autumn-winter (Bauer, 1989, 2018; Ogburn et al., 2013). This supports the importance of considering recruitment as a permanent process, subject to multiple biological and environmental factors that vary spatially and temporally. However, its maintenance is critically dependent on the ecological integrity of breeding habitats.

From a management perspective, the results of this study underscore the need to implement conservation strategies focused on the protection and restoration of estuarine habitats with high SAV cover and optimal sedimentological characteristics for larval development. The degradation of these habitats, often related to urban growth, uncontrolled tourism, and intensive fishing activities, has been pointed out as one of the main causes of the decline in shrimp catches in the Gulf of Mexico (Arreguín-Sánchez et al., 1997, 2009; Barreto-Segura, 2019).

Taken together, the findings presented here contribute significantly to the ecological understanding of the larval stages of penaeid shrimp in an understudied region of the Gulf of Mexico. Furthermore, they highlight the importance of considering an ecosystem approach in the design of fisheries and conservation policies, particularly in highly dynamic systems such as the SLM, where small alterations in habitat can have large-scale repercussions on the sustainability of the shrimp resource.

ACKNOWLEDGMENTS

To the Head of the Biology Department, FES Iztacala, UNAM, for their support in carrying out the samplings. To the Programa de Apoyo a Proyectos para la Innovación y Mejoramiento de la Enseñanza (PAPIME) project EN203804 and the Programa de Apoyo a los Profesores de Carrera para Promover Grupos de Investigación (PAPCA) of the UNAM, for granting economic resources for the purchase of equipment and material used in this research and to the students of the Coastal Oceanography Laboratory, especially Laura Nayani Hernández Barajas and those of the Scientific Research Laboratory VI (group 2602) of the FES Iztacala, UNAM, who participated in the collection and processing of the samples.

REFERENCES

Alpuche, J., Pereyra, A. y Agundis, C. (2005). Respuestas bioquímicas de camarones marinos a factores ambientales. *Revista Electrónica de Veterinaria REDVET, VI*(5), 1-10. http://www.redalyc.org/articulo.oa?id=63617216008

Arenas-Fuentes, V. y Hernández-Aguilera, J. L. (2000). *Fauna carcinológica de México. Crustáceos estomatópodos y decápodos del Golfo de México, Río Bravo, Tamaulipas a Cabo Catoche, Q. Roo. Informe final SNIB-CONABIO. Proyecto No. H022.*

Arreguín-Sánchez, F. (1982). Contribución al conocimiento de la hidrobiología de las lagunas de Mandinga, Veracruz, México. *An. Esc. Nac. Cienc. Biol., Méx.,* 26, 111-134.

Arreguín-Sánchez, F. (2009). Cambio climático y el colapso de la pesquería de camarón rosado (*Farfantepenaeus duorarum*) de la sonda de Campeche. En E. Rivera-Arriaga, I. Azuz-Adeath, G. J. Villalobos-Zapata y L. Alpuche-Gual (Eds.), *Cambio climático en México un enfoque costero-marino* (pp. 399-410). Universidad Autónoma de Campeche.

Arreguín-Sánchez, F., Schultz-Ruiz, L. E., Gracia, A., Sánchez, J. A. y Alarcón, T. (1997). Estado actual y perspectivas de las pesquerías de camarón del golfo de México. En D. Flores-Hernández, P. Sánchez-Gil, J. C. Seijo y F. Arreguín-Sánchez (Eds.), *Análisis y diagnóstico de los recursos pesqueros críticos del golfo de México* (pp. 145-172). EPOMEX Ser. Cient., 7.

Barba-Macías, E. (1999). Variación de la densidad y la biomasa de peces juveniles y decápodos epibénticos de la región central de Laguna Madre, Tamaulipas. *Hidrobiológica, 9*(2), 103-116.

Barletta, M., Barletta-Bergan, A., Saint-Paul, U. y Hubold, G. (2005). The role of salinity in structuring the fish assemblages in a tropical estuary. *Journal of Fish Biology, 66,* 45-72.

Barrera-Escorcia, G. (2006). *Toxicidad del cromo y cadmio en ostión Crassostrea virginica (Gmelin) de la laguna de Mandinga, Veracruz*. [Tesis de Doctorado, UAM Iztapalapa]. https://bindani.izt.uam.mx/downloads/np1939542?locale=it

Barreto-Segura, O. A. (2019). *Análisis ecológico de la comunidad zoobentónica del Sistema Lagunar de Mandinga, Veracruz, Mex.* [Tesis de Licenciatura, Facultad de Estudio Superiores Iztacala, UNAM]. http://132.248.9.195/ptd2019/marzo/0787253/Index.html

Bauer, R. (1989). Continuous reproduction and episodic recruitment in nine shrimp species inhabiting a tropical seagrass meadow. *Journal of Experimental Marine Biology and Ecology*, 127, 175-187. https://doi.org/10.1016/0022-0981(89)90183-4.

Bauer, R. (2018). *Life cycle and seasonal migrations. Life histories*. https://doi.org/10.1093/oso/9780190620271.003.0008.

Brito, R., Chimal, M. E. y Rosas, C. (2000). Effect of salinity in survival, growth, and osmotic capacity of early juveniles of *Farfantepenaeus brasiliensis* (Decapoda: Penaeidae). *Journal of Experimental Marine Biology and Ecology,* 244, 253-263.

Brusca, C. R. y Brusca, G. J. (2005). *Invertebrados*. McGraw-Hill.

Camarena-Rosales, F. (1982). *Contribución al conocimiento de la fase postlarvarias del camarón (Penaeus spp.), en el sistema de lagunas costeras de Mandinga, Veracruz*. [Tesis de Licenciatura, Escuela Nacional de Estudios Profesionales Iztacala, UNAM]. http://132.248.9.195/ptd2014/anteriores/microformas/0037971/Index.html

Castro, R. G. y Arreguín-Sánchez, F. (1991). Evaluación de la pesquería de camarón café *Penaeus aztecus* del litoral mexicano del noroeste del golfo de México. *Ciencias Marinas, 17*(4), 147-159.

Castro-Meléndez, R. G., Medellín-Ávila, M., Bonilla E. C., Rosas-Torres, E., Orta-Núñez, R. y Conde, G. E. (1990). Incidencia de postlarvas de camarón café *Penaeus aztecus* en la Laguna Almagre, Tamaulipas y relación con las poblaciones de alta mar en el Noroeste del Golfo de México. *Ciencia Pesquera*, 7, 121-141.

Cervantes-Hernández, P. y Gracia-Gasca, A. (2011). Análisis de la mortalidad para el camarón rosado *Farfantepenaeus duorarum* (Decapoda, Demdrobranchiata) del banco de Campeche, México. *Pan-American Journal of Aquatic Sciiences, 6*(2), 100-108.

Cházaro-Olvera, S., Morán-Silva, A., Chávez-López, R., Vázquez-López, H. y Rodríguez-Varela, A. del C. (2020). Density of mysis of *Penaeus aztecus* Ives, 1891. On a reef in the southwest of the gulf of Mexico. *Hidrobiológica, 30*(3), 233-242. http:/ hidrobiologica.izt.uam.mx

Clark, R. D., Christensen, J. D., Monaco, M. E., Caldwell, P. A., Matthews, G. A. y Minello, T. J. (2004). A Habitat-use model to determine essential fish habitat for juvenile brown shrimp (*Farfantepenaeus aztecus*) in Galveston Bay, Texas. *Fishery Bulletin, 102,* 264-277.

Dall, W., Hill, B. J., Rothlisberg, P. C. y Staples, D. J. (1990). *The biology of the Penaeidae.* Elsevier.

Díaz, H. F. y Latournerie, J. R. (1980). *Factores fisiológicos que afectan la supervivencia y el metabolismo energético de dos especies de peneidos (Penaeus aztecus y P. setiferus) de la laguna de Mandinga, Veracruz, México*. [Tesis de Licenciatura, Facultad de Ciencias, UNAM]. http://132.248.9.195/pmig2019/0002439/Index.html

Doerr, J., Liu, H. y Minello, T. J. (2015). Salinity selection by juvenile brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) in a gradient tank. *Estuaries and Coasts*, DOI 10.1007/s12237-015-0019-3

Domínguez, J. C., Sánchez, A. J., Florido, R. y Barba, E. (2003). Distribución de macrocrustáceos en laguna Mecoacán, al sur del golfo de México. *Hidrobiológica, 13*(2), 127-136.

Fischer, W.; Krupp, F; Schneider, W.; Sommer, C.; Carpenter, K.E.; Niem, V.H. (2005). *Guía FAO para la identificación de especies para los fines de la pesca. Pacífico centro-oriental. Volumen I. Plantas e invertebrados*. FAO.

Golden Software., 2002. Surfer V. 8. http://www.goldensoftware.com/products/surfer.

Hart, R. A., Nance, J. M. y Primrose, J. A. (2012). The U.S. Gulf of Mexico Pink shrimp, *Farfantepenaeus duorarum*, fishery: 50 years of commercial catch statistics. *Marine Fisheries Review, 74*(1), 1-6.

Kennish, M. J. (2002). Environmental threats and environmental future of estuaries. *Environmental Conservation, 29*(1), 78–107.

Lara-Domínguez, A. L., Contreras-Espinosa, F., Castañeda-López, O. Barba-Macías, E. y Pérez-Hernández, M. A. (2011). Lagunas costeras y estuarios. En Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) (Ed.), *La biodiversidad en Veracruz: Estudio de estado. Vol. I. Contexto actual del estado y perspectivas de conservación de su biodiversidad* (pp. 301-317). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado de Veracruz, Universidad Veracruzana, Instituto de Ecología, A.C.

Lemos-Michel, M. R., Chávez-Sánchez, M. C. y Martínez-Córdova, L. R. (2013). Effect of environmental factors on larval development of crustaceans. *Reviews in Fish Biology and Fisheries, 23*(2), 179-198.

\href{https://doi.org/10.1007/s11160-012-9289-z}{https://doi.org/10.1007/s11160-012-9289-z}

Mauchline, J. (1980). The biology of mysids and euphausiids. *Advances in Marine Biology*, 18, 1-681.

Medellín-Mora, J., Campos, H. N., Franco-Herrera, A. y Jaimes, J. C. (2009). Taxonomía de larvas zoea de crustáceos decápodos del área nororiental del mar caribe colombiano. *Bol. Invest. Mar. Cost.*, *38*(2), 55-73.

Minello, T. J. y Zimmerman, R. J. (1991). The role of estuarine habitats in regulating growth and survival of juvenile penaeid shrimp. En P. F. Deloach, W. J. Dougherty y M. A. Davidson (Eds.), *Frontiers of shrimp Research* (pp 1-16). Elsevier Science Publishers.

Muñoz-Iniestra, D. J., Mendoza-Cantú, A., López-Galindo, F., Soler-Aburto, A. y Hernández-Moreno, M. M. (2011). *Edafología. Manual de métodos de análisis de suelos*. Facultad de Estudios Superiores Iztacala, UNAM.

Ocaña-Luna, A., Hernández-Batún, G. y Sánchez-Ramírez, M. 2008. Abundancia y distribución de juveniles de *Farfantepenaeus aztecus* (Ives 1891), *F. duorarum* (Burkenroad 1939) y *Litopenaeus setiferus* (Linnaeus 1767) en la Laguna Madre, Tamaulipas, México. *Hidrobiológica, 18*(3), 199-208.

Ogburn, M., Criales, M., Thompson, R. y Browder, J. (2013). Endogenous swimming activity rhythms of postlarvae and juveniles of the penaeid shrimp *Farfantepenaeus aztecus, Farfantepenaeus duorarum,* and *Litopenaeus setiferus*. *Journal of Experimental Marine Biology and Ecology,* 440, 149-155. https://doi.org/10.1016/J.JEMBE.2012.12.007.

Peniche, V. R. F. (1979). *Estudio estacional de los crustáceos en la laguna Grande de Mandinga, Veracruz*. [Tesis de Licenciatura, Facultad de Ciencias, UNAM]. http://132.248.9.195/pmig2019/0001970/Index.html

Pérez Castañeda, R., y Defeo, O. (2003). Influence of estuarine zonation on exploited shrimp populations in a mexican biosphere reserve: A feature for management and conservation. *Journal of Marine Biological Assessment, 83,* 781-784.

Pérez-Castañeda, R., Blanco-Martínez, Z., Sánchez-Martínez, J. G., Rábago-Castro, J. L., Aguirre-Guzmán, G. y Vázquez-Sauceda, M. L. (2010). Distribution of *Farfantepenaeus aztecus* and F. *duorarum* on submerged aquatic vegetation habitats along a subtropical coastal lagoon (Laguna Madre, Mexico). *Journal of the Marine Biological Association of the United Kingdom, 90*(3), 445-452. doi:10.1017/S0025315409990865

Pérez-Farfante, I. (1969). Western Atlantic shrimps of the genus *Penaeus*. *Fish.* Bull., *67*(3), 461-591.

Perez Farfante, I. y B. Kensley, B. (1997). *Penaeoid and sergestoid shrimps and prawns of the world. Keys and diagnoses for the families and genera*. Editions du Muséum National d'Histoire Naturelle.

Poppe, L. J., Eliason, A. H., Fredericks, J. J., Rendigs, R. R., Blackwood, D., Polloni, C. F. (2000). *Grain-size analysis of marine sediments: methodology and data processing* (en línea). U.S. Geological survey open-file report 00-358. https://pubs.usgs.gov/of/2000/of00-358/text/chapter1.htm.

Price, K. S., Heard, R. W., y Simons, R. U. (1988). Mysid shrimp as prey in estuarine food webs. *Estuaries, 11*(4), 230-235.

QGIS Development Team. (2016). QGIS Geographic Information System. Open Source Geospatial Foundation Project. https://qgis.org.

Ramírez-Rodríguez, M., Arreguín-Sánchez, F. (2000). Growth of pink *Farfantepenaeus duorarum* Burkenroad, 1939 in Campeche sound, México. *Crustaceana, 73*(10), 1263-1272. http://www.researchgate.net/publication/240681228

Reguero, M. y García-Cubas, A. (1993). Moluscos del complejo lagunar Larga-Redonda-Mandinga, Veracruz, México: Sistemática y Ecología. *Hidrobiológica, 3*(1 y 2), 41-70.

Rocha-Ramírez, A., Cházaro-Olvera, S., Contreras, R. R. y Molina-Bezies, H. (1996). Clave de identificación para estadios zoea, mysis, postlarvas (Caridea y Penaeidea) y megalopas (Anomura y Brachyura) de la laguna de Alvarado, Veracruz, México. *Revista de Zología*, Número Especial (1), 1-22.

Rodríguez, J. P., Ojeda, F. P. y Valdivia, G. (2001). The role of estuaries in the life cycle of marine species. *Aquatic Ecology, 35*(2), 129-143.

Rodríguez-Varela, A. del C., Barreto-Segura, O. A. y Vázquez-López, H. (2019). Diversidad de invertebrados bentónicos del Sistema Lagunar de Mandinga, Veracruz, México. *Novitates Caribaea*, 14,128-146. DOI: https://doi.org/10.33800/nc.v0i14.205

Rodríguez-Varela A del C., Barreto-Segura, O. A. Vázquez-López, H. (2020). Variación espacio-temporal de tres especies de tanaidáceos (Crustacea: Peracarida) en el Sistema Lagunar de Mandinga, Veracruz, México en el periodo 2008-2015. *BIOCYT Biología, Ciencia y Tecnología*, 13, 975-1008. http://dx.doi.org/10.22201/fesi.20072082e.2020.13.77320

Rodríguez-Varela, A del C., Vázquez-López, H., Chávez-López, R., Cházaro-Olvera, S., Á. Morán-Silva, Barreto-Segura, O. A. y Cruz-Gómez, A. (2022). Caracterización sedimentológica del sistema lagunar de Mandinga, Veracruz, México. *BIOCYT Biología, Ciencia y Tecnología,* 15, 1077-1104. http://dx.doi.org/10.22201/fesi.20072082e.2022.15.83061

Rosas, C., Cooper, E. L., Pascual, C., Brito, R., Gelabert, R., Moreno, T., Miranda, G. y Sánchez, A. (2004). La condición reproductiva del camarón blanco *Litopenaeus setiferus* (Crustacea; Penaeidae): evidencias de deterioro ambiental en el sur del Golfo de México. En M. Caso, I. Pisanty y E. Ezcurra (Eds.), *Diagnóstico ambiental del Golfo de México* (pp. 73-87). Secretaría de Medio Ambiente y Recursos Naturales. Instituto Nacional de Ecología.

Rozas, L. P. y Minello, T. J. (2011). Variation in penaeid shrimp growth rates along an estuarine salinity gradient: Implications for managing river diversions. *Journal of Experimental Marine Biology and Ecology 397,* 196-207.

Sánchez, A. J. y Soto, L. A. (1993). Distribución de camarones inmaduros (*Decapoda: Penaeidae*) en el sistema lagunar de Alvarado, Veracruz, México. *Rev. Biol. Trop., 41*(1), 81-88.

Sánchez, Z. A. (1979). *Efecto de la salinidad y temperatura sobre el balance hidrosalino de los peneidos de la laguna de Mandinga, Veracruz*. [Tesis de Licenciatura. Facultad de Ciencias. UNAM]. http://132.248.9.195/pmig2019/0001987/Index.html

Suárez-Morales, E. (2003). Biodiversidad y taxonomía de crustáceos planctónicos en México. *Revista de Biología Tropical, 51*(3-4), 669-756

The Environment Management. (TEM). (2016). *Equipos estandarizados para muestreos hidrobiológicos*. http://redsurbernet.com/brochure.pdf.

Trejo, L. B. (2015). *Variación temporal del camarón café Farfantepenaeus aztecus en la costa de Veracruz durante 1999-2000*. [Tesis de Maestría en Ecología y pesquerías, Universidad Veracruzana]. https://www.uv.mx/veracruz/mep/files/2012/10/Tesis_Beatriz-Trejo-Lopez.pdf

Wakida-Kusunoki, A. T., García-Solorio, L. y Vázquez-Benavides, N. G. (2008). Abundancia de juveniles de camarones peneidos comerciales en la zona norte de Laguna Madre, México. *Hidrobiológica, 18*(1), 85-88.

Wakida-Kusunoki, A. T., Solana-Sansores, R. y González-Cruz, A. (2005). Estimación de la abundancia de camarón café (*Farfantepenaeus aztecus*) en las costas de Tamaulipas, 2002. *CICIMAR Oceánides, 20*(1,2), 17-27.

Wentworth, C. (1936). The method of moments. *J. Sediment. Petrol., 6*(3), 158-195.

Williams, A. B. (1984). *Shrimps, lobsters, and crabs of the Atlantic coast of the Eastern United States, Maine to Florida*. Smithsonian Institution Press.

Wittmann, K. J. y Wirtz, K. W. (1999). Feeding ecology of mysid crustaceans in coastal waters. *Marine Biology, 134*(4), 671-691.

WoRMS EDITORIAL BOARD. (2025). *World register of marine species*. http://www.marinespecies.org/.

Zaixso, H. E. (2002). *Manual de campo para el muestreo del bentos. Versión 1.0*. Universidad Nacional de la Patagonia San Juan Bosco. Facultad de Humanidades y Ciencias Sociales, Comodoro Rivadavia.