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Immigration of Post Larvae of Penaeid Shrimp to Terminos Lagoon, Campeche, México: 2013 Annual Cycle

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Abstract

Immigration density magnitude and entry sizes of shrimp postlarvae to Terminos Lagoon were analyzed through sixteen fortnightly sampling from March to November in 2013, in three levels in the deepest channel of the Puerto Real inlet. Trapezium nets were used with 1.5 m length, 50 cm mouth diameter and 505 µm mesh, during each sampling 12 casts of 15 minutes/each were made. It was determined the presence of two species *Litopenaeus setiferus* and *Farfantepenaeus duorarum*, with total densities of 41.284 and 37.558 Pls 100 m^{-3} respectively. The annual cycle of immigration of postlarvae was very similar for both species, with a clear pattern of immigration throughout the year, linked to climatic variation, with the highest densities (88%) during rainy season. There were two periods of maximum density, related to the periods of greatest reproduction of these species. The density variation among cast reflects the presence of at least two and probably more postlarvae banks, located some closer than others to the mouth of the lagoon and with different densities in them. The average sizes of the two species were 7.9 mm total length of *L. setiferus* and 9.0 mm of *F. duorarum*. The differences in income sizes of both species seem to indicate the habitat preference of adult populations, *L. setiferus* occurring in more coastal areas than *F. duorarum*. Considering the variation in density and sizes throughout each sampling period, it is evident that the larvae on the banks belong to different cohorts and that have coincided in their location in front of the mouth.

Keywords

Shrimp, Immigration, Magnitude, Sizes

1. Introduction

Shrimp fishing in the Campeche Bay represented an important economic resource, although it has been in crisis since the beginning of the Century [1]. However, the reduction of its catch remains a resource with relative importance on the coast of the Gulf of Mexico and the Caribbean Sea [2].

In the area of the Gulf of Mexico, there are three species with the greatest fishing importance: white shrimp, *Litopenaeus setiferus* (Linnaeus, 1767), pink shrimp, *Farfantepenaeus duorarum* (Burkenroad, 1939) and brown shrimp, *Farfantepenaeus aztecus* (Ives, 1891). Within the Campeche Bay, Terminos Lagoon is an important breeding area for several organisms including the penaeid shrimp [3].

The penaeid postlarvae immigration to the nursery areas has been studied in many parts of the world attending the effects of currents and climatic seasons on the transport processes; [4]-[9].

For the Gulf of Mexico it could be mentioned the paper of Rogers *et al.* [7] Criales *et al.* [10], Criales *et al.* [11], Flores-Coto *et al.* [12]. Particularly for Puerto Real inlet, study area, in Terminos Lagoon, Campeche, can be referred to the works of Gracia and Soto [3] and the professional theses of Arenas-Mendieta and Yáñez-Martínez [13], Alarcón-Daowz [14] which give the first idea of immigration of postlarvae to the lagoon, observing that occurs throughout the year, with maxima in July and September and that *F. duorarum and L. setiferus* are the species that enter to the lagoon.

The most recent paper is from Gómez-Ponce *et al.* [15] who assessed the entry of postlarvae of white shrimp *L. setiferus*, during an annual cycle in 2010, and mentioned that the highest density period occurs from June to September; the paper of Gómez-Ponce *et al.* [15] is the immediate antecedent of this paper, as they are part of a larger project whose objective is to monitor and evaluate the immigration of shrimp postlarvae to the Terminos lagoon for a decade.

The success of future generations of adults is certainly closely linked to the size of the populations of postlarvae entering the breeding area, so monitoring will result in important information that can contribute to a better and more efficient management of this important fishery, allowing to estimate possible future densities of adults.

In this sense Rámirez-Rodríguez [1] in his work on the historical development and perspectives of the shrimp fishery in Campeche, mentions that the shrimp fishery in the sea is in crisis since 2000 and that it is necessary to implement proposals to Fisheries Administration, which in our concept require information derived from a monitoring that evaluates the immigration of postlarvae to the breeding areas, in particular to Terminos lagoon.

Therefore the objective of this work is to determine the density magnitude of immigration of postlarvae of Penaeid shrimp and their sizes of entry to Terminos Lagoon through the Puerto Real inlet, during of higher flow velocity period, from March to November of 2013.

2. Study Area

Terminos lagoon is located at the southeast of the Gulf of Mexico in Campeche State, is separated from the Campeche Bay by the Carmen island and connected by two inlets to the marine environment, the Carmen inlet at its western end with a width of 3.8 km and the Puerto Real inlet, sampling site of this work, at the eastern end of the lagoon with a width of 3.2 km (**Figure 1**). To the lagoon flows three rivers: Candelaria, Chumpán, and Palizada with an important contribution of organic matter and fresh water.

The tides generate a general circulation that leads to a net flow East-west penetrating the greater volume of seawater by Puerto Real inlet, leaving mainly by the Carmen inlet [16] [17] [18] [19].

3. Material and Methods

Sixteen fortnightly sampling were made from March to November 2013, which were programmed through the tide calendar of the Instituto de Geofisica (UNAM). In July and September, only one sampling was carried out (**Table 1**).

The sampling point was established in the deepest channel of the Puerto Real inlet. The management of the equipment was carried out from the base of one of the piles of the bridge. The collections were carried out during the period of high

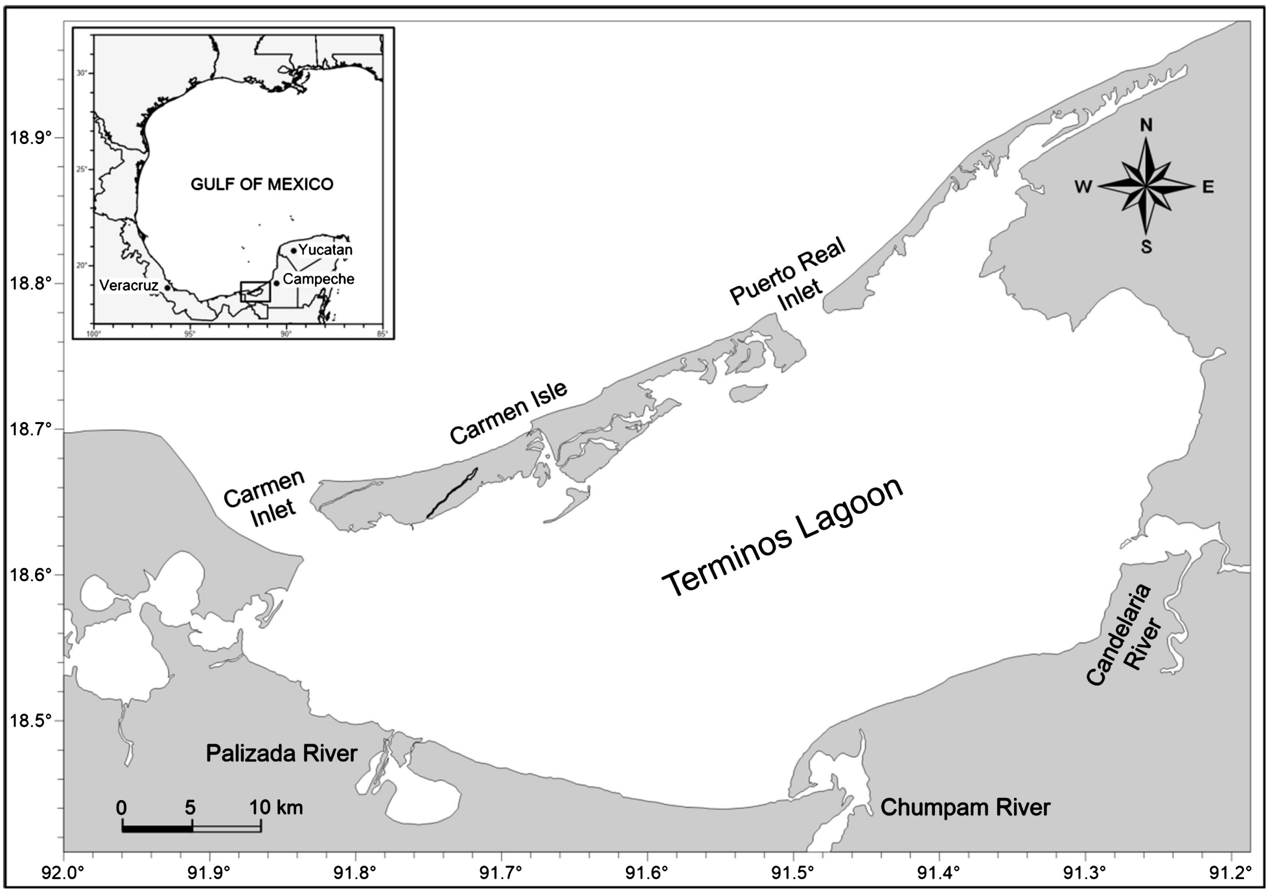


Figure 1. Puerto Real inlet, study area, in Terminos Lagoon, Campeche, Mexico.

Table 1. Sampling dates, March to November 2013.

Collection number	Date	Collection number	Date
1	March 7	9	July 29
2	March 18	10	August 15
3	April 18	11	August 29
4	April 30	12	September 30
5	May 14	13	October 11
6	May 28	14	October 24
7	June 10	15	November 15
8	June 24	16	November 30

current speed, that is, when the speed was equal or greater than 0.5 m/s.

During each fortnightly sampling, 12 casts of 15 minutes each were made, simultaneously in three depths: surface (0.5 m) mid water (5 m) and bottom (12 m). Trapezium nets were used of 1.5 m in length, 50 cm in mouth diameter and 505 μm mesh [20]. Samples were preserved in 4% formalin neutralized with sodium borate.

To estimate the filtered volume, a flowmeter (General Oceanic) was placed in the mouth of each net and the salinity and temperature data were obtained with a YSI 30 thermo-salinometer.

In the laboratory, samples were transferred to alcohol to 70% for their preservation. All postlarvae were extracted from each sample, measured (total length) and identified at the species level, except those less than 6 mm.

The number of postlarvae (PLs) was standardized to 100 cubic meters (PLs 100 m^{-3}).

Analysis of variance (one-way ANOVA) was made to establish whether there were statistically significant differences in postlarvae densities between the three sampled levels, between the average densities and sizes of the identified species to meet the assumptions of normalcy, the density data were transformed to Ln (X + 1) and the homoscedasticity of variances was tested by means of a Barttlet test. A Spearman regression analysis was applied between Pls average densities and temperature and salinity averages, of each fortnightly sampling.

4. Results

Density magnitude and immigration cycle of postlarvae

There were captured 69.660 postlarvae and take out the dot March to November in 576 samples obtained during 16 fortnightly samplings.

It was determined the presence of two species *Litopenaeus setiferus* and *Farfantepenaeus duorarum*, with total densities throughout the collection cycle of 41.284 and 37.558 Pls 100 m^{-3} respectively; 2019 specimens with sizes less than 6 mm could not be identified.

The analysis of variance (one-way ANOVA) indicated that there were no significant differences between surface, mid and bottom water densities of pink shrimp postlarvae ($F = 3.014$, $F\ 0.05\ (2.573) = 0.587$, $p > 0.05$), and white shrimp postlarvae ($F = 3.014$, $F\ 0.05\ (2.573) = 2.376$, $p > 0.05$), so hereafter we will refer to the density as its average value.

During the sampling cycle, two periods of maximum density of both species were presented, the first occurred on June 10 and the second on September 30, with clearly lower densities between these two periods although the lowest occurred at the beginning and end of sampling period (**Figure 2**).

The annual cycle of immigration of postlarvae was very similar for both species, there were, however small differences in their densities during the months of greater abundance, the density of *F. duorarum* was slightly higher in June and that of *L. setiferus* in August and September (**Figure 2**).

Density variation between cast and collection seasons

The densities of the 576 samples show the lowest values occurring during the first three, the last two and the seventh casts; the latter between two high-density periods, the first with the largest values during casts 4 to 6 and the second from 8 to 10 (**Figure 3**).

When analyzing the postlarvae entrance of each species per cast during, rainy, dry and cold fronts seasons (Cold fronts hereafter, north season) it is observed that the higher density occurs in rainy season, (June to September), on the other hand during dry (march to May) and north (October to November) seasons, the densities were extremely low for both species, therefore the two periods of higher density during casts 4 - 6 and 8 - 10 reflect what happened in the time of greatest abundance in the rainy season, but did not occur on the same sampling date (**Figure 4**).

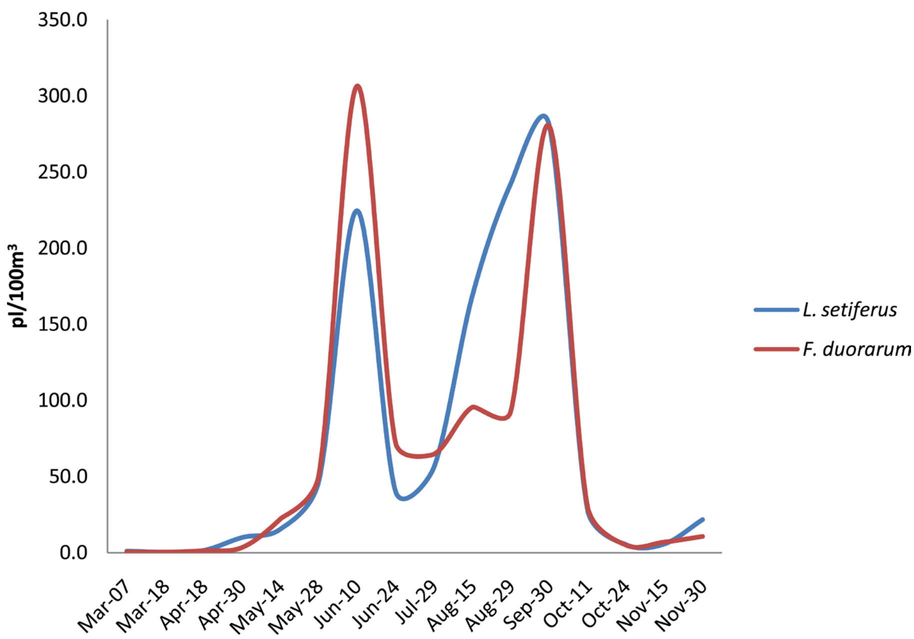


Figure 2. Postlarvae average densities of *F. duorarum* and *L. setiferus* immigrating to Terminos Lagoon though Puerto Real inlet, from March to November 2013.

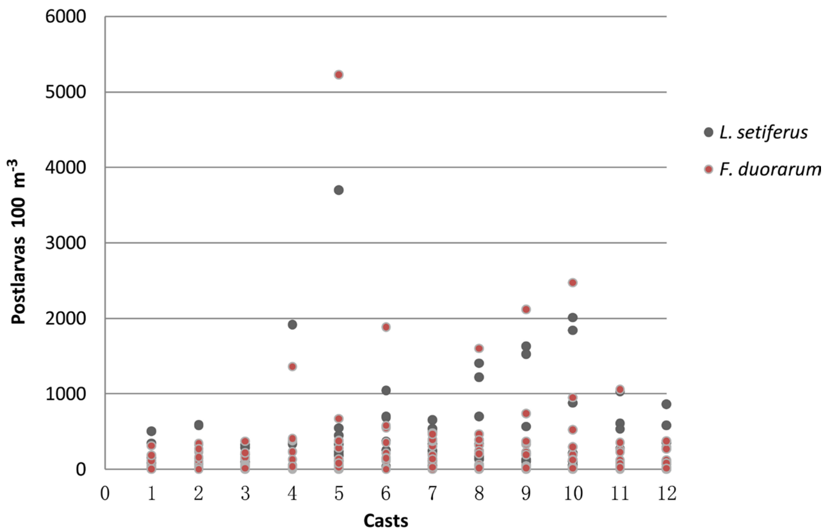
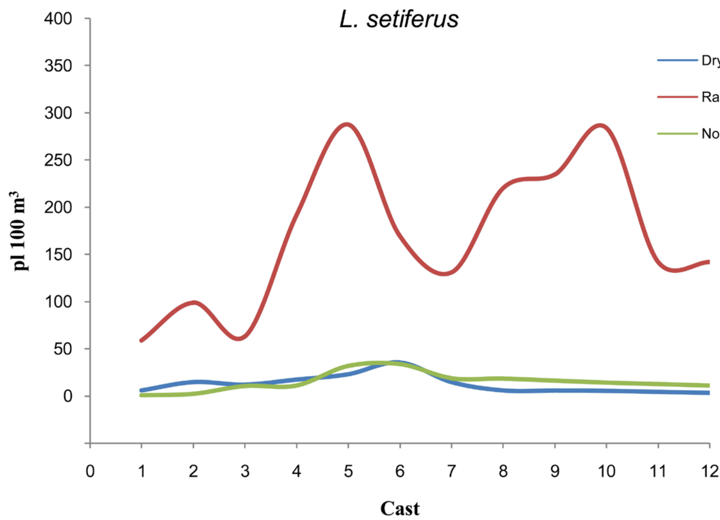


Figure 3. Postlarvae density in each cast during the 16 sampling periods.



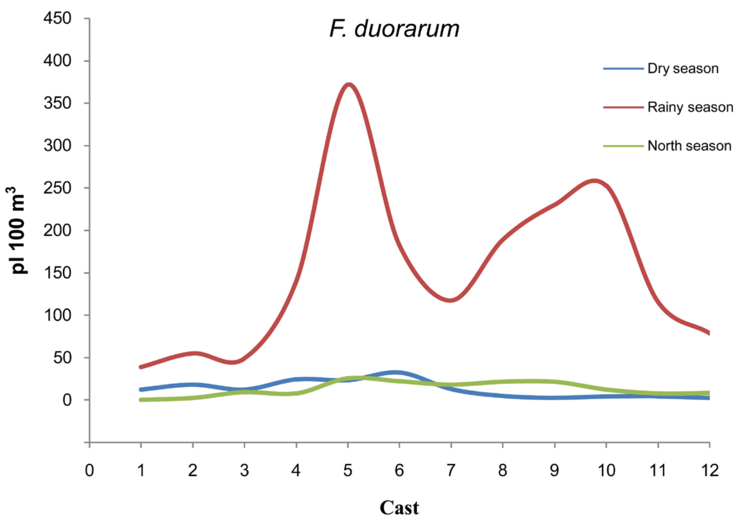


Figure 4. Cast average density of *L. setiferus* and *F. duorarum postlarvae*, during different seasons. The rainy season, June to September; dry season, March to May and north season, October to November.

Sizes

The average sizes of the two species were different 7.9 mm of *L. setiferus* and 9.0 mm of *F. duorarum*.

The size variation throughout the sampling period was also different for each species; *F. duorarum* except for relatively large sizes in March and beginning of April, presented a clearing increased from the second sampling from April to November when the maximum average size of 10.3 mm was recorded, although the maximum individual size was 14.6 mm (Figure 5).

For *L. setiferus* can be considered three periods of entrance according to their sizes, one since March with sizes relatively large until early April, from late April with the sizes smaller (7.3 mm) is increased until June and decrease until September when the second lowest average size of 7.4 mm was registered, then the size increase until November (Figure 6).

Temperature

The annual average temperature was 28.3˚C, with maximum and minimum values of 31.9˚C and 23.5˚C, respectively.

The sampling cycle starts with low values, gradually increasing until the first sampling of August and then gradually descended until the end of the period (Figure 7). Variations in each sampling date were small.

A positive linear relationship was found between the temperature and postlarvae density for the two recorded species, with values of $r = 0.60$ for *F. duorarum* and $r = 0.57$ for *L. setiferus*.

Salinity

Salinity values reached an annual average of 32.9 and minimum and maximum values of 14.1 and 39.1 respectively.

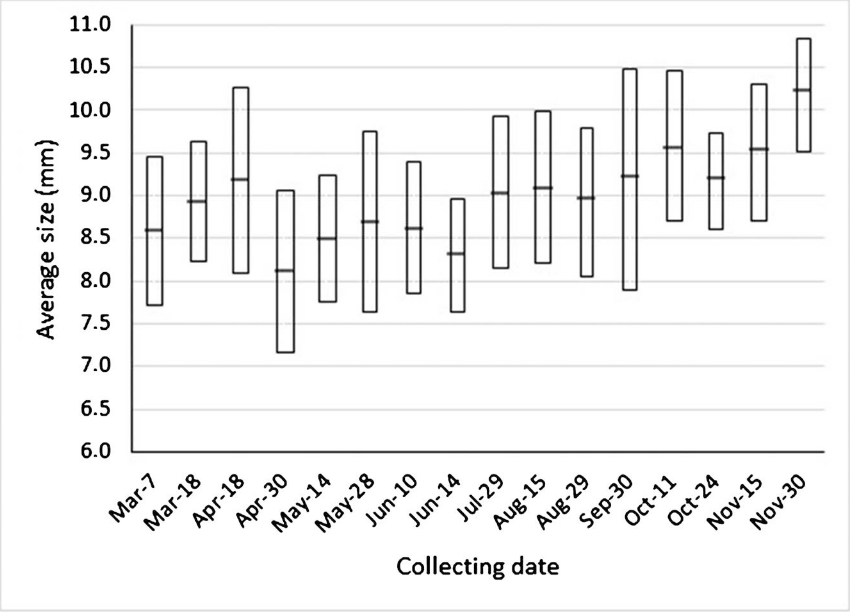


Figure 5. Average size variation and standard deviation of *F. duorarum* postlarvae, through the sampling period.

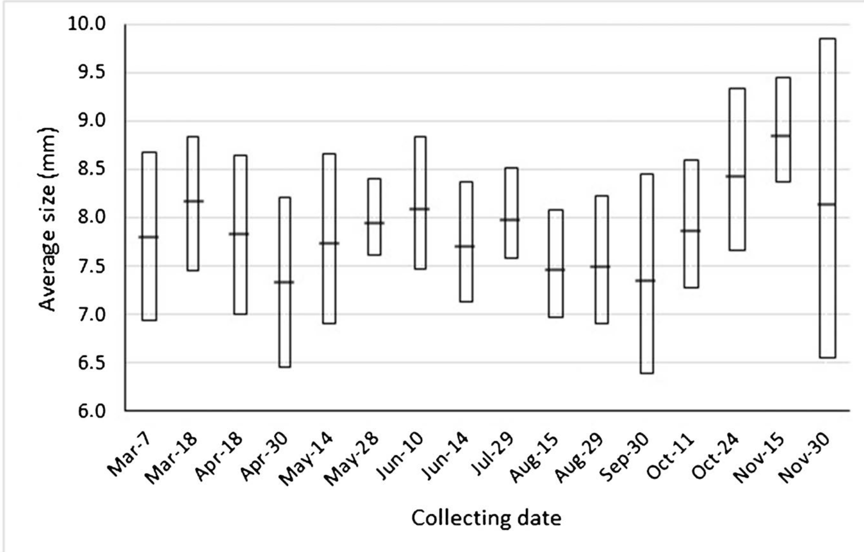


Figure 6. Average size variation and standard deviation of *L. setiferus* postlarvae, through the sampling period.

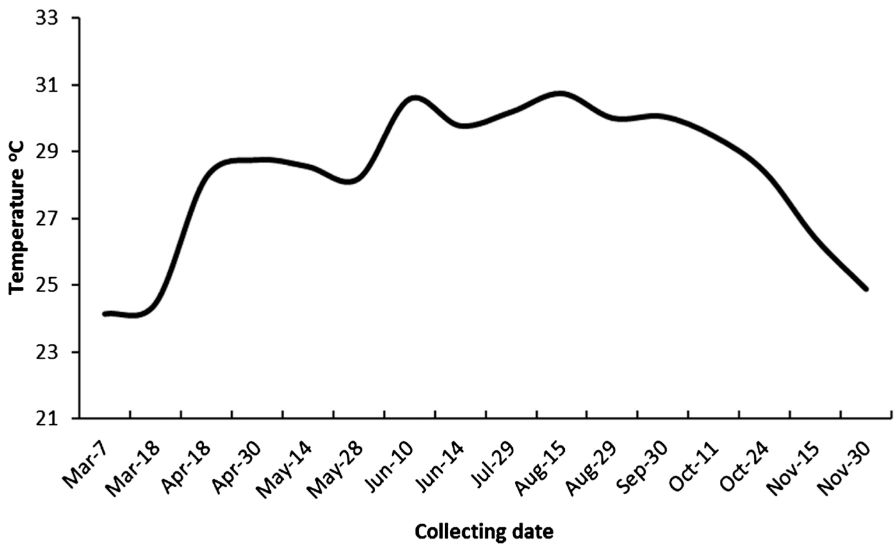


Figure 7. The annual variation of average temperature through sampling period.

Its annual cycle starts with high values until the first fortnight of July, from where it presented a gradual descent until reaching the lowest in the last sampling of November. Whit some exception the variations in each sampling date were small (**Figure 8**). No relationship was found between salinity and the postlarvae density for either of the two species.

5. Discussion

Density magnitude and pattern of postlarvae immigration

Postlarvae of two species *L. setiferus* and *F. duorarum* were recorded; and according to previous works [3] together with *F. aztecus* are the dominant species among the penaeid of the area.

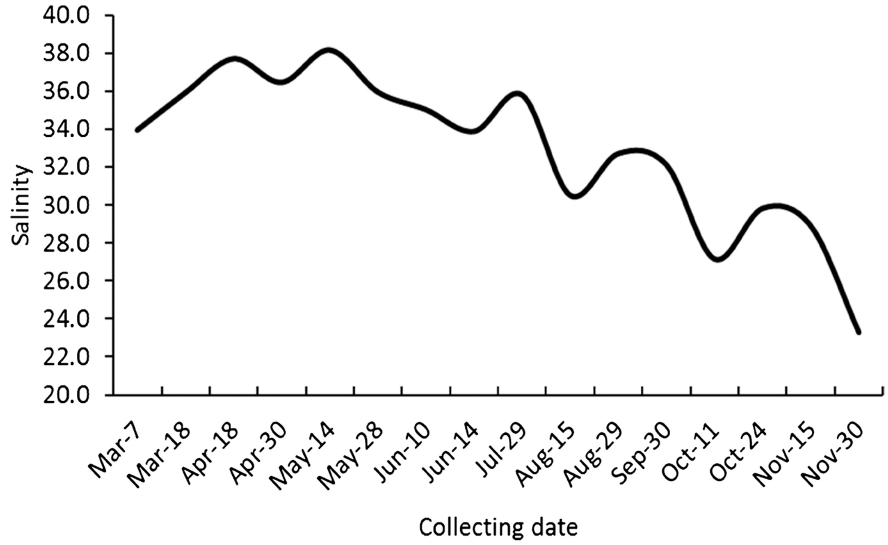


Figure 8. Annual variation of average salinity through sampling period.

The magnitude of immigration from March to November, in absolute numbers was 69,660 Pls which corresponded 41,284 Pls 100 m^{-3} to *L. setiferus* and 37,558 Pls 100 m^{-3} to *F. duorarum*.

The results show that there is a clear pattern of immigration of postlarvae to the Terminos lagoon throughout the year, linked to climatic variation, with the highest densities (88%) during rainy season and high temperatures, while the rest of the year density values were very low. The results fit with the fact that the shrimp spawning cycle according with Gracia and Soto, [21], Gracia and Soto [3], Re-Regis, [22], Gracia *et al.* [23] is uninterrupted throughout the year but with clear increases in the rainy season.

Two periods of maximum density were recorded in one in June and other in September that are consistent with previous results; [3] [13] [14] [15]. The periods of maximum density are necessarily related to the periods of greatest reproduction of these species, as mentioned by Gracia and Soto [21]; Re-Regis, [22].

During the sampling cycle, the density of *F. duorarum* was slightly higher than that of *L. setiferus* from May to June but lower in August and September. These differences can be attributed to a greater or lesser concentration of reproducers at different times. According to Fuentes *et al.* [24] the abundance of *F. duorarum* at least for that decade was greater than *L. setiferus*.

Soto and Gracia [25] found seasonal variations with different centers of adult concentration. Although populations overlap, it can be generalized that the major areas of concentration of *F. duorarum* occur from the north-eastern portion of Terminos lagoon to the northwest, in the carbonated province of the Campeche Bay, in areas not very coastal, the highest concentrations of *L. setiferus* occur from El Carmen inlet to the west, in a silt-clay province, in very shallow areas [22] [24] [25].

This adult populations distribution could help to explain why Flores-Coto *et* *al.* [12] recorded a much more higher postlarvae density of *L. setiferus* (13.332 PL/100 m^3) than *F. duorarum*, (2.198 PL/100 m^3) in the Santana inlet of the Carmen and Machona lagoons, located west of the Terminos lagoon where it can found high concentration of *L. Setiferus* adults.

It could be also considered the variability among years. The obtained postlarvae average by sample 120.9 Pls in this work compared with average 147.9 Pls obtained by Gómez-Ponce *et al.* [15] must be result of such variability. Matthews [26] found great variability between years when estimating postlarvae density migrating to Galveston Bay, Texas.

On the other hand with different methodologies and a complete annual cycle, Arenas-Mendieta and Yáñez-Martínez [13] recorded only 4.740 Pls, and Alarcón-Daowz [14] 1.977 Pls. These differences make it clear that sampling methodology has an important role to play in evaluating the magnitude of immigration.

Postlarvae density, temperature and salinity

The obtained data show that there is no relationship between temperature and salinity with the entrance of Postlarvae to the lagoon during each sampling date, however, analyzing immigration throughout the year, it becomes evident a strong correlation between the postlarvae density and the highest temperatures recorded throughout the annual cycle ($r = 0.778$, *F. duorarum*; $r = 0.778$, *L. setiferus*).

The two periods with the highest density of postlarvae (10 June and 30 September) occurred in temperatures from 29.7˚C to 30.8˚C, similarly Gómez-Ponce *et al.* [15] during main immigration period from May to September recorded temperatures higher than 29˚C.

Salinity did not show a statistically significant correlation with the immigration of postlarvae, nor during each sampling or during the year, however, it seems to have an indirect effect, since it is clear the increase in density of postlarvae in the period that decreases the salinity. Boehlert and Mundy [6] point out that a decrease in salinity serves as a clue to begin the immigration of some organisms. The low salinity is the result of continental waters the discharges, which promotes high primary and secondary production and therefore constitutes the source of food for adults and larvae.

Variation of the postlarvae density between casts and sampling season

The concentration of postlarvae of Penaeid in front of the mouth of rivers and estuarine bodies before penetrating to its breeding area, has been previously reported for several parts of the world [4] [6] [7] [8] [9].

The density of postlarvae over 12 casts in the each of 16 samples periods shows that the lower values were recorded in the first and last casts with two periods of high density between the casts 4 and 10, although they did not occur in the same sampling date (**Figure 3**, **Figure 4**). These maxima should reflect the presence of at least two and probably more postlarvae banks, located some closer than others to the mouth of the lagoon and with different densities in them, fact of which generate the differences in the individual collections.

These results indicate that the higher densities enter about two hours after the tidal flow has begun, which coincides with the described by Young and Carpenter [4] and Rothlisberg *et al.* [8]. Similar results obtained Flores-Coto *et al.* [12] and Gómez-Ponce *et al.* [15] which determined that the higher densities enter in the few hours after of the onset of tidal flow.

Postlarvae size variation

The results show that the average length (**Figure 5**) of *L. setiferus* (7.9 mm) throughout the year were always lower than those of *F. duorarum* (9.0 mm) which can be attributed to the more coastal distribution of the adult populations of the former [22] [24] [25]. This fact supposes that the migration of larvae of *L. setiferus* to the mouth of the lagoon is earlier and in stages less developed than the larvae of *F. duorarum.*

Similarly Baxter and Renfro [27] reported inr Galveston Texas Bay, that the income sizes of *L. setiferus* are lower than those of *P. aztecus*, which seems to indicate the preference of adult populations of *L. setiferus* by more coastal areas and *F. duorarum* and *P. aztecus* for less coastal and deeper areas, as Soto and Gracia [25] point out.

The largest sizes of both species were observed at the end of the sampling cycle, in the north season, this can be attributed independently of the location of the reproducers populations, to the movement of coastal waters to ocean area, a consequence of the collision of the Yucatán shelf current and Veracruz coastal current [28] this fact it means more time for the planktonic larvae to locate near the mouth and consequently the arrival of postlarvae with greater sizes to the lagoon.

It can be generalized that the variation of sizes during its immigration to the lagoon is the result of the distance to the adult populations to the inlet and the direction of the currents. Considering the sizes variation throughout each sampling period, it is evident that the larvae on the banks belong to different cohorts and that have coincided in their location in front of the mouth.

The sizes of the postlarvae immigrating to the breeding areas after passing through their planktonic stages, appear to be similar in most of the different penaeid shrimp species in the world; varying between 5 and 14 mm approximately: Macias-Regalado and Calderón-Pérez [29] in the Mexican Pacific, Forbes and Benfiel [30] in Natal, South Africa; Baxter and Renfro [27] Allen *et al.*, [31] in Galveston, USA, Criales *et al.* [32] in Florida; USA, Young and Carpenter, [4] Rothlisberg *et al.*, [8] in Eastern Australia; Blanton *et al.*, [33] in the North Atlantic, Flores-Coto *et al.* [12] in the Southern Gulf of Mexico.

We assume that regardless of the distance to the Lagoon mouths of the reproducers and the currents involved in the transport, there seems to be a time limit for shrimp postlarvae to reach the epibenthic stage, to enter to the breeding area.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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