Day and night abundance and density of juveniles pink shrimps *Farfantepenaeus notialis* (Pérez-farfante) and *Farfantepenaeus brasiliensis* (Latreille) in La Restinga lagoon, Margarita Island, Venezuela (Decapoda, Penaeidae).

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Abstract

A comparison of the species composition, abundance, density of juvenile penaeid pink shrimps in relation to moon phase during day and night sampling was accomplished in La Restinga Lagoon, Margarita Island, Venezuela. A total of 3403 late postlarvae and juveniles of *Farfantepenaeus notialis* and *F. brasiliensis* was taken with a bottom net (0.5 mm mesh size) on a depth less than 0.5 m over a bottom covered by the sea grass *Diplanthera wrightii*. Water temperature ranged from 27 to 31°C, salinity from 40 to 43 ‰ and oxygen content from 2.86 to 4.04 $ml.l^{-1}$. *Farfantepenaeus notialis* was the dominant species with 3302 juveniles (97.03%). Shrimp density was statistically different ($p < 0.05$) between day and night: 0.9 to 2.9 $shrimps.m^{-2}$ was obtained during day sampling and 0.5 to 5.1 $shrimps.m^{-2}$ during night. Lowest density was obtained during full moon, being lower during the night (0.5 $shrimps.m^{-2}$) than during the day (0.9 $shrimps.m^{-2}$). Highest density during night sampling occurred during crescent moon (5.1 $shrimps.m^{-2}$). Sampling during five consecutive days starting before new moon shows highest density and proportion of captures the exact day of the moon phase equivalent to 36.9 % of the total captures. Lowest densities and percentage of capture were obtained before and after the change of lunar phase. The relation of night/day densities ranged from 0.6 to 3.3 $shrimps.m^{-2}$. Our results show that *F. notialis* was the dominant species of penaeid shrimp inside La Restinga during January-March 1999. Higher abundance and density during night samples confirm the nocturnal behavior of juveniles of both species. Shrimps were captured in higher proportions during waxing and waning moon phases than during full or new moon. The difference on density in relation to lunar phase could be an indication of light intensity or tide associated effect on the behavior of postlarvae and juvenile of *F. notialis* and *F. brasiliensis* shrimps.

Key words: Penaeid shrimps, night and day abundance, density, Margarita Island,Venezuela.

Introduction

Mangroves have a specific importance as a nursery ground for a variety of invertebrates, especially penaeid shrimps (Broad, 1962; Kutkuhn, 1966; Robertson and Duke, 1987; Primavera and Lebata, 1995) owing to its nutrients, organic matter and a variety of micro-habitats that contribute with food and refuges. In Venezuela there are four species of penaeid shrimps exploited by commercial fisheries especially in eastern Venezuela (Kandkher and Lares, 1973). Reproduction (mating and spawning) is carried on in oceanic waters and their larval stages migrate towards coastal areas (Ewald, 1965; Lares, 1985). At the end of the metamorphosis, postlarvae and early juveniles penetrate littoral lagoons where a fast growth phase of the life cycle is developed

(Scelzo, 1982, 1999; Mas and Scelzo, 1984), settle on aquatic submerged vegetation, were they obtain mainly protection and food in similar way to other penaeids species (Rothlisberg *et al.*, 1985, 1995; D´Incao, 1991; Haywood *et al.*, 1993, 1995).

Penaeid shrimps are phototropic organisms in response to light stimulus. Certain behavior characteristics of the Penaeidae can be interpreted in terms of this tropism, but the strength and direction for the response vary with age, sex and physiological condition (Ghidalia and Bourgois, 1961). Light is the major synchronizer of the circadian rhythm in penaeid (Primavera and Lebata, 1995). According to Hughes (1968), the most obvious advantage of the circadian rhythm controlling emergence and subsequent activity is to confine the times of activity of shrimp to the hours of darkness when predation by fish is minimal. In *Farfantepenaeus (Penaeus) duorarum* (Burkenroad, 1939) a close relationship exists between the day-night cycle and the times of activity. The shrimps bury beneath the substrate during the day but emerge at the time of sunset and are active at night (Hughes, 1968). The number of post-larvae observed is almost always higher at night than in day time, with catches generally higher during new moon and at flood tide (García and Le Reste, 1981; Mas and Scelzo, 1984). After entering the estuaries the post-larvae concentrate in shallow areas of less than one meter deep mainly in substrate with high organic matter and submerged aquatic vegetation (Rothlisberg *et al.,* 1995). Aside from protection against predators, burrowing in penaeids may provide escape from extremes in temperature, salinity, and lead to energy conservation through decreased oxygen consumption (Primavera and Lebata, 1995). Brisson (1976) indicated the feeding activity in the shrimps (*Penaeus (Farfantepenaeus) brasiliensis* (Latreille, 1817) and *P. (F.) paulensis* (Pérez Farfante, 1967) is affected by lunar phases, being higher during the dark moon phases and minimum during the clear phase. Also, there was significant influence of the lunar phase upon the abundance of postlarvae of those species being maximum between the waning and new moon, diminishes between the new and waxing and minimum between the waxing moon and the full moon (Brisson, 1977). Those movements are part of the biological timing which involves horizontal movements, e.g. migration, homing, navigation and orientation (DeCoursey, 1983).

Young shrimps find shallower portions of estuaries where adopt a benthonic existence on muddy or vegetated substrates (Broad, 1962; Scelzo 1982, 1999). After several months of growing reaching preadult size, they migrate towards the open sea, being recruited in the population exploited by the commercial fishery (Kutkuhn, 1966). Estuaries are characterized by the dominance of non-vegetated sediments and patches of submerged aquatic vegetation (SAV) (Rozas and Odum, 1987; Ruiz *et al.*, 1993), composed by a diversity of filamentous algae, macroalgae, and submerged phanerogames beds where juveniles fishes and invertebrates, especially crustaceans, found refuges. Species of macroalgae such *Caulerpa, Laurencia, Sarconema, Enteromorpha, Ulva* and *Cladophora,* have been identified in estuarine coastal logoons being utilized as refuges for penaeid shrimps (Staples *et al.*, 1985; Haywood *et al.*, 1995). Aquatic phanerogames such us *Enhalus, Halodule, Halophyla, Zoostera, Ruppia, Spartina, Naja, Syringodium, Ceratophyllum* and *Diplanthera* have been identified in Australia, USA and Venezuela, among others (Saloman, 1968; Giles and Zamora, 1973; Bauer, 1985; Coles and Lee Long, 1985; Staples *et al.*, 1985; Rozas and Odum, 1987; Wassenberg, 1990; D´Incao, 1991; O´Brien, 1994; Kneib and Wagner, 1994; Minello *et al.,* 1994; Haywood *et al.*, 1995; Halliday, 1995; Minello and Webb, 1997; Scelzo, 1982, 1999). Marsh plants decomposed *in situ* were themselves shown to be potential nutritional sources for estuarine organisms (Venkataramiah *et al.,* 1978). In the estuaries organic debris is subjected to agitation by the tidal ebb and flow and there is continual input of nutrient and bacteria to facilitate decomposition. The bacteria-rich detritus is a better food source for animals than the grass material which serves as the base for the particulate matter (Venkataramiah *et al.*, 1978; Primavera and Gacután, 1989). Environmental factors such as water temperature, salinity, oxygen contents, turbidity, sediment composition among other, as being previously investigated, with no single parameter being a consistent nursery area requirement for *"Penaeus"* spp. or *Metapenaeus* spp. (Halliday, 1995). For some species, distribution of postlarvae in the estuaries was correlated with type of substratum, salinity and temperature (Ramasamy and Pandian, 1985). The information obtained is also useful for prediction of recruitment and adult shrimp abundance and commercial landings (Berry and Baxter, 1969; Yoke *et al.,* 1969; Turner, 1977; García and Le Reste, 1981; Staples *et al.,* 1985; Valentini *et al.*, 1991; DeLancey *et al.,* 1994; García, 1996). According to von Prahl (1980), the presence of a series of nutrients and physical-chemical factors acts specifically on the migration of post-larvae of the penaeid shrimps towards the estuary zones. Postlarvae have the ability to ingest the wax from the leaves of mangrove-trees, transforming it into phospholipids, by the action of a wax-degradation enzyme. The leaves, free from wax, are colonized rapidly by bacteria and yeasts, which form a superficial mucous film which is ingested by the more developed postlarvae. The juvenile shrimps take the leaves crushing them to obtain nourishment from the epiphytic flora. The organics products from the crushed leaves are dragged along towards the estuarine channels where, by the metabolic action of biodegradative organisms, metallic nuclei are liberated which favors the proliferation of planktonic algae, which at the same time are ingested by shrimps. Besides mangrove leaves, several species of submerged aquatic vegetation (SAV) in different geographic areas bring food and also protection (Stoner and Zimmerman, 1988).

Scelzo (1999) described the "continental or lagoon phase" of the pink shrimp complex "*Farfantepenaeus brasiliensis- F. notialis*" in relation to the seasonal fluctuations of environmental conditions (salinity, temperature, oxygen and nutrients) during five consecutive annual cycles. In such study species identification, growth rate and relative abundance of juveniles of different species of marine penaeid shrimp's obtained in submerged vegetated areas were done. *F. notialis* is a penaeid shrimp having an anfi-atlantic distribution being present in the western Atlantic, in the Caribbean and northern South America (Pérez-Farfante and Kensley, 1997) and in the eastern Atlantic from Mauritania to Angola and penetrate coastal lagoons in Africa (García, 1977). *F. brasiliensis* is present in the western Atlantic Ocean from North Carolina to Florida, southern Gulf of Mexico to Yucatan and West Indies, Bermuda, Caribbean coast of Central and South America to Rio Grande do Sul, Brazil (Pérez-Farfante and Kensley, 1997). Scelzo (1999) showed that density of juveniles pink shrimps *F. brasiliensis* and *F. notialis* captured in Pasadero and Botadero, La Restinga, Margarita Island on the sea-grass community of *Diplanthera wrightii* (Ascherson, 1869) was comparatively higher and statistically different than those captured on muddy bottom and crushed mollusks shell, without vegetation. Summarizing the information obtained during five year cycles (1979-1983) about the biology (diversity, growth rate, abundance and density) of juvenile penaeid shrimps in La Restinga (Scelzo, 1999) it was demonstrated that species abundance is variable through the year: *F. brasiliensis* is the most abundant species during March and November, the warmest (water temperature above 28 °C) and rainy season, although rain precipitation is reduced, between 300-500 mm. *F. notialis*, the second most abundant species, is dominant during December-February, lapse of the year with lower temperatures than 27 °C, especially in the entrance channel to the Lagoon and the adjacent sea. This alternate dominance of the juveniles of both species in La Restinga could be explained as results of different reproductive strategies allowing the co-existence of both species in the same habitat, but in different time of the year. Juvenile recruitment in the internal sectors of the lagoon, on the submerge phanerogame vegetation *Diplanthera wrighti* is continuous during the year, and it is possible to recognize one cohort or modal group every month, totaling between 12-13 cohorts every year for *F. brasiliensis* and seven cohorts for *F. notialis.* Mean capture density for postlarvae and juveniles oscillated between 2.7 – 5.4 ind.m^{-2}. The present investigation will complement such studies. Null hypothesis is that will not be statistical differences between day and night surveys.

The aim of this study is to compare the species composition, abundance density and growth rate of postlarvae and juvenile penaeid shrimps captures in relation to lunar phases during day and night samplings.

Material and Methods

Study area description

La Restinga is a hypersaline lagoon located in Margarita Island, Venezuela. It is an ecosystem with high productivity (Gómez, 1991 a, b). Geographically is a "cul du sac" similar to other island in the Caribbean Sea (Rojas Beltran, 1977) in which sea water come in and goes out from a unique mouth, located in the south part of the island. The water dynamic, evaporation and reduce rains are factors that contribute to the hipersalinity of this environment (Monente, 1978). La Restinga is characterized by the presence of a forest of four species of mangles: being the red mangrove *Rhizophora mangle* L. 1753 and the black mangrove *Avicennia germinans* (L., 1764) the most abundant (Cervigón and Gómez, 1986).

During February-March 1999, a sampling program took place in La Restinga Lagoon, Margarita Island (11°N - 64°W), Venezuela, especially at "Punta Gaviotas" or "Las Gaviotas" (Fig. 1). Day sampling was carried between 10-12 am and night sampling between 4-5 am. Postlarvae and juveniles of penaeid shrimps were captured on a depth no deeper than 0.5 m over the submerged aquatic vegetation substrate (SAV), covered by the seagrass *Diplanthera wrightii* (Cymodocea). Day and night captures and sampling were carried out during the four lunar phases (first quarter or waxing, full moon, last quarter or waning and new moon). Although light intensity was not measured, lunar brightness was considered to increase from new moon to reach the maximum of light intensity in full moon (Ghidalia and Bourgois, 1961): Local variations of cloud coverage and sediments were not taking in consideration. Water temperature (mercury thermometer ± 0.1 °C), salinity (refractomether ±1 ppt) and dissolved oxygen (Winckler method, $ml.l^{-1}$) content were measured every sampled day.

The capture of shrimps was carried out by means of a hand net (mouth aperture 1 to 1.5 m) with a mesh aperture of 20 mm. In the laboratory, shrimps were identified according to Pérez-Farfante (1970), counted, measured in total length (TL = rostrum-telson) on a graduated millimeter scale and weighed using a electric scale (0.01 g). Sampling area was calculated in relation to the mouth of the net and the cross distance (10-15 meters) and the significance of differences in abundance, measured in day and night times, were tested (Sokal and Rohlf, 1981). Densities of shrimps were expressed as mean ± standard deviation of shrimps by squared meters. A sampling program was developed during five consecutive days, starting two days before the exact day of a new moon and ending two days after the same lunar phase. The objective of this program was to determine if the absence light have importance on shrimp density.

Results

Mean air temperature during each sampling day was 27.3±1.2°C (ranging between 26.0 - 29.0, n= 7). Mean water temperature 28.6±1.6 °C (ranging 27.0-31.0, n= 7). Mean salinity was 41.4±0.9 ppt (ranging 40.0-43.0, n= 7) and mean oxygen content was 3.4±0.4 $ml.l^{-1}$ (ranging 2.9-4.0, n= 7). Sampling in new moon was during low tide. The remaining moon phases were done at high tide.

During February-March 1999 a total 3403 late postlarvae and juveniles penaeid shrimps were captured on SAV, composed mainly by the Cymodecea *D. wrightii*. Results showed that 3302 individuals (97.03%) belong to the pink shrimp *F. notialis* and the remaining 101 (2.97%) to the spotted red shrimp *F. brasiliensis*. *F. notialis* size ranged between 10 and 112 mm TL and weight between 0.05 and 14 g. Te largest *F. brasiliensis* was a female 110 mm TL and 10.85 g. Population structure of juvenile, males and females *F. notialis* measured in TL is shown in Fig. 2. The highest percentage of individual captured belongs to juveniles. No differences between male and female size and proportion were found.

No differences in size of *F. notialis* captured during day and night were found (Fig.3). Day and night shrimp abundance (both species together) fluctuates with light intensity, being higher during night (66.4 %) than day hours (Fig. 4). The difference was statistically different (X^2 = 216.5). Density of capture during day hours oscillated between 0.9 and 2.9 individuals by squared meters (average 1.7 ± 0.8 ind.m^{-2}). During night hours the abundance oscillated between 0.5 and 5.1 ind.m^{-2} (3.4 ± 1.7 ind.m^{-2}) (Table I, Fig. 5). Abundance was different between night and day according to lunar phases (Fig. 6). Night abundance was highest in those samples taken in crescent lunar phase. Only in one occasion, during full moon, the density during day hours was higher than night hours (87 vs 54 ind.), being the lowest of the four lunar phases. The lowest densities were obtained during the light phase (full moon phase).

According to the sampling program developed during five consecutive days, the highest density (36.92 %) was obtained the exact day of the moon (Table II, Fig. 7), diminishing before and after the new moon.

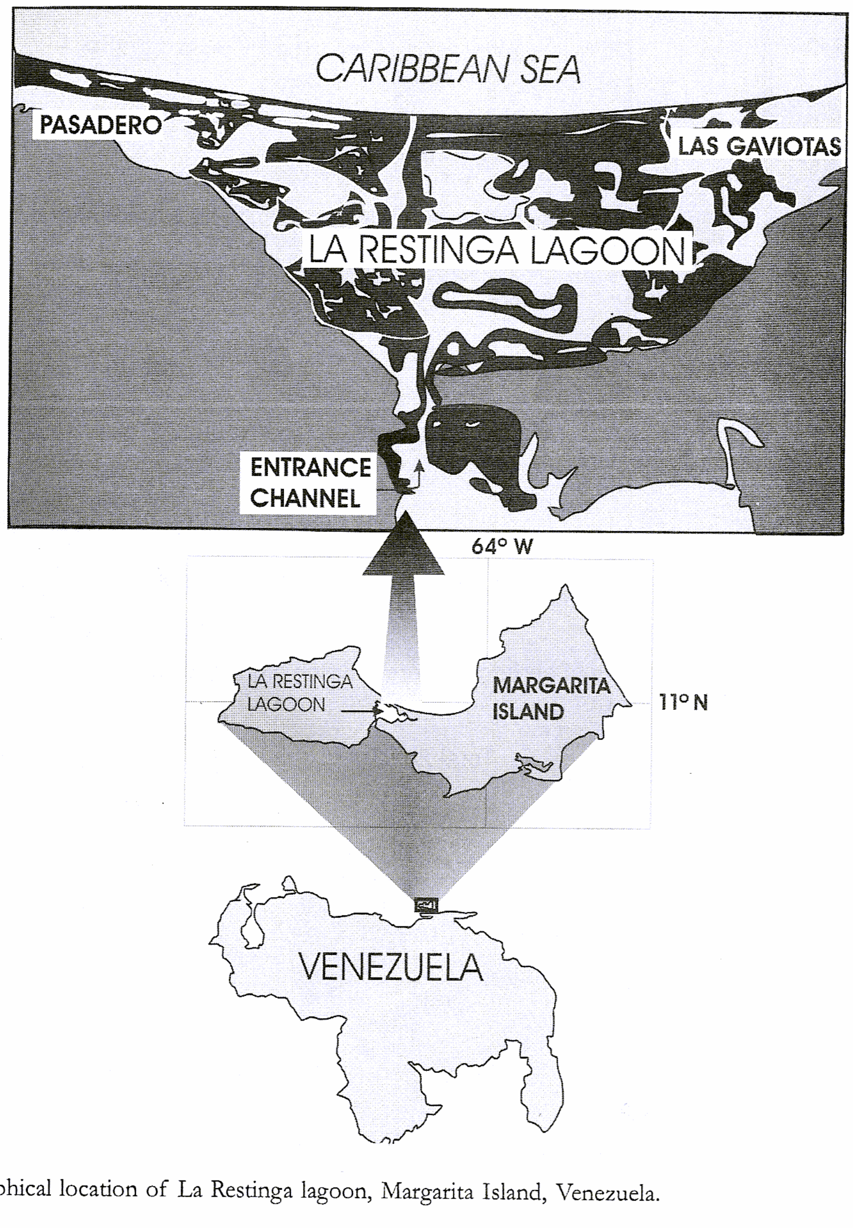

Figure 1: Geographical location of La Restinga lagoon, Margarita Island, Venezuela.

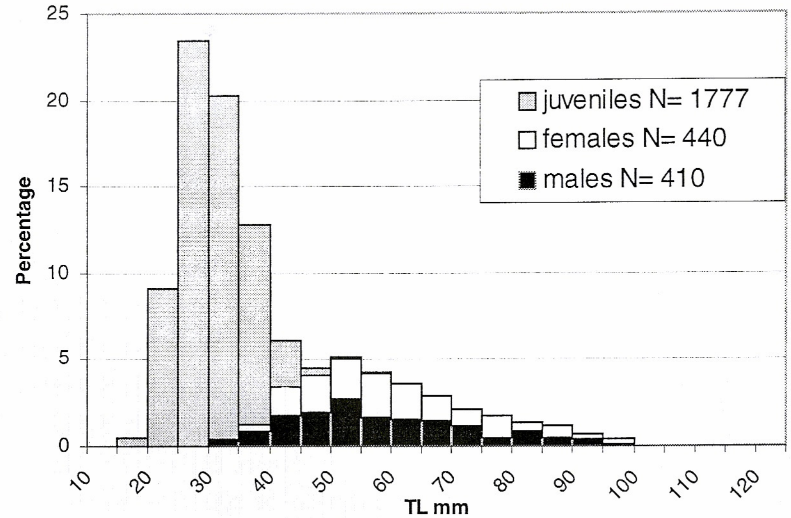

Figure 2: Population structure of juveniles, males and females *F.notialis*. Punta Gaviotas. La Restinga lagoon. Margarita Island. February-March 1999. (TL mm).

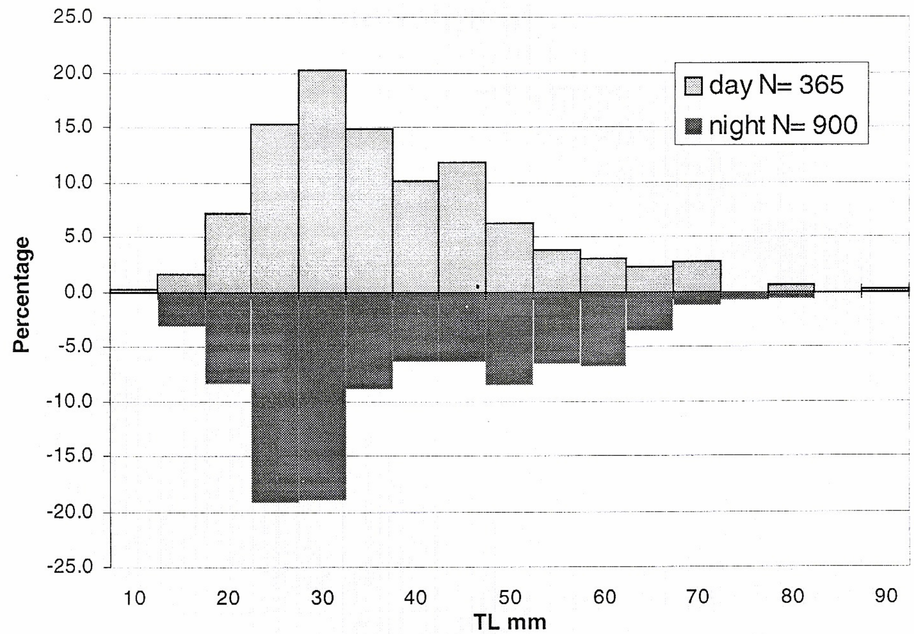

Figure 3: Size of *F. notialis* captured during day and night. Punta Gaviotas. La Restinga lagoon. Margarita Island. February-March 1999. (TL mm).

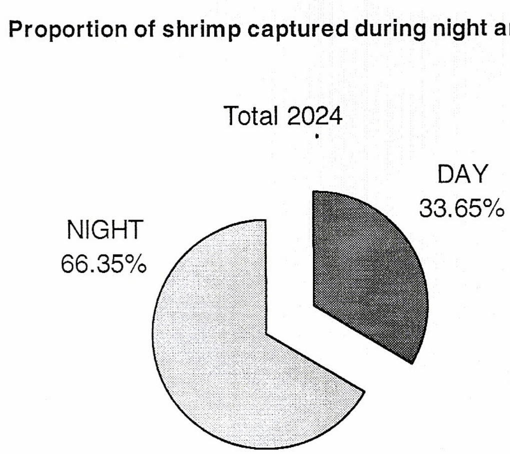

Figure 4: Day/night postlarvae and juvenile shrimps captured in Punta Gaviotas. La Restinga lagoon. Margarita Island, Venezuela. February-March 1999.

Table I: Species composition, comparison between day and night samplings, proportions and density of juvenile pink shrimp captures in "Punta Gaviotas", Margarita Island. Day/night samples during different lunar phases (CM= crescent or waxing, FM= full moon, WM= waning moon, NM= new moon).

Date	Moon Phase	Day Samples			Night samples			X^2	Night/day proportion	Total Density ind.m^{-2}	
		F. notialis	*F. brasiliensis*	Total	*F. notialis*	*F. brasiliensis*	Total				
23/2/99	CM	181		181	512	1	513	158.2	2.8:1	1.8	5.1
2/03/99	FM	84	3	87	54		54	7.7	1.6:1	0.9	0.5
10/03/99	WM	103	21	124	343	66	409	152.3	3.3:1	1.2	4.1
17/03/99	NM	289		289	367		367	9.3	1.3:1	2.9	3.7
TOTAL		**657**	**24**	**681**	**1276**	**67**	**1343**				

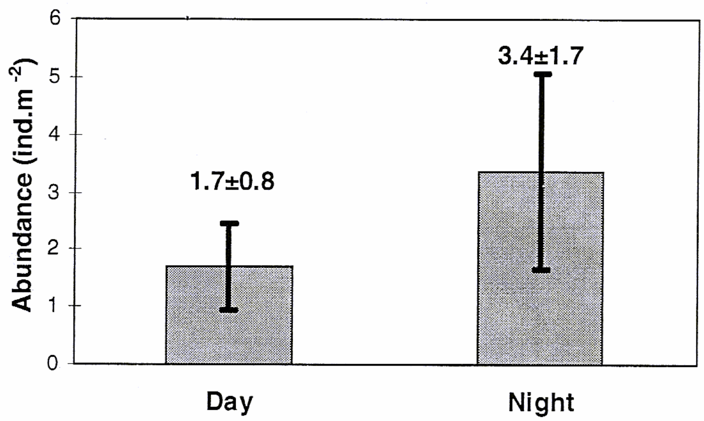

Figure 5: Mean and standard deviation shrimp density (ind.m^{-2}) captured during day and night hours. Punta Gaviotas. La Restinga lagoon. Margarita Island. February-March 1999.

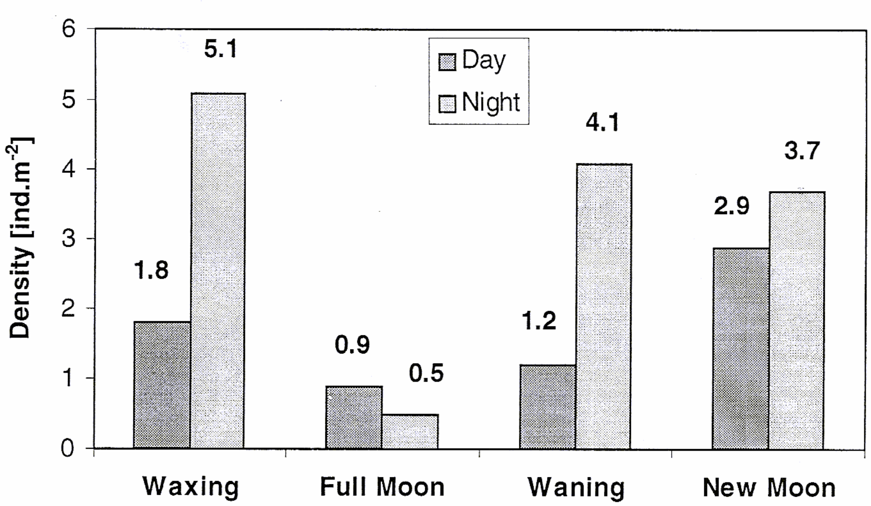

Figure 6: Density of postlarvae and juvenile shrimp captured during day and night hours and lunar phase. Punta Gaviotas. La Restinga lagoon. Margarita Island. February –March 1999.

Table II: Number of individual by species captured and density of postlarvae and juveniles penaeid shrimp captured in "Punta Gaviotas, Margarita", Island, Venezuela, during new moon.

Date	F.notialis	F.brasiliensis	Total	%	Day of the moon	Total Density (ind.m^{-2})
15/2/99	155	3	158	11,71	-2	1.6
16/2/99	226	1	227	16,83	-1	2.3
17/2/99	495	3	498	36,92	0	5.0
18/2/99	238	1	239	17,72	1	2.4
19/2/99	255	2	257	19,05	2	2.6
TOTAL	**1369**	**10**	**1379**	**100**		

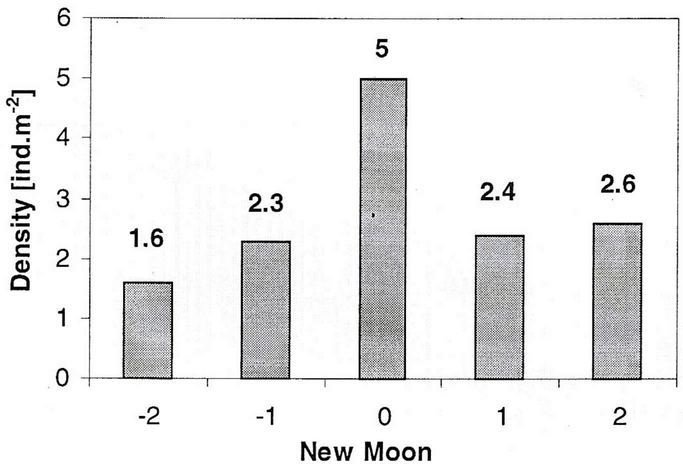

Figure 7: Density of juveniles pink shrimp captured during five consecutive days during new moon at night. Punta Gaviotas. La Restinga lagoon. Margarita Island. Venezuela. February 1999.

Discussion

In Margarita Island it is possible to distinguish two kind of nursery grounds for penaeid shrimps: one is characterized by coastal waters that surround the island where it is possible to find juveniles and preadults and/or adults penaeid shrimps of the species *F. brasiliensis, F.notialis, F. subtilis* (Pérez Farfante, 1967), *Litopenaeus schmitti* (Burkenroad, 1936), *Xiphopenaeus kroyeri* (Heller, 1862), among others of less economic importance (Scelzo, 1999), in a similar way to occurs in other regions, e.g. Ubatuba Bay, Brazil (Valentini *et al.*, 1991 a and b; Costa and Fransozo, 1999). Another important nursery ground in Margarita Island are conformed by coastal lagoons were some of those species, e.g. *F. brasiliensis*, *F. notialis* develop the lagunar phase of grow from postlarva to preadult before the recruitment to adult population in open ocean waters (Angell, 1976; Scelzo, 1982, 1999) in similar way that happened in Lagoa dos Patos, in the south of Brazil in which postlarvae and juveniles of *F. paulensis* develop the lagunar phase (D´Incao, 1991). Previous studies carried on in La Restinga lagoon, showed that *F.brasiliensis* was the dominant species, followed by *F. notialis* and in lesser degree by *F.subtilis* and occasionally *L.schmitti,* studied by Robletto and Scelzo (1982) and Scelzo (1999).The dominance of those species is variable along the year around and correlated with environmental conditions. *F.notialis* juveniles are more abundant during late and early month of the year than *F.brasiliensis* (Scelzo, 1999). According to that, 95 % of juveniles penaeid shrimp captured were attributed to the species *F.notialis.*

Postlarvae and juvenile of the species *F.brasiliensis* and *F.notialis* are difficult to distinguish in small individuals because sexual secondary characteristic –in which are based the criteria for diagnostic of both species- are nor easily visible (Pérez Farfante, 1970). General color pattern and specific chromatophore distribution are other criteria that contribute to species identification, especially in alive or recently dead individuals. Modern identification techniques using ICP-MS trace element analysis were used successfully in other penaeid species (Courtney *et al.*, 1994).

In coincidence with other studies in relation to the effect of natural light intensity on the capture of postlarvae and juvenile penaeid shrimps (Saloman, 1968; Williams and Deubler, 1968; Brisson, 1976; Vasudevan and Subramoniam, 1985), results of the present study carried on in La Restinga lagoon, support the general trend in which sampling success is generally far greater during darkness than during day light hours. *Farfantepenaeus notialis* and *F. brasiliensis* juveniles were more "actives" -and available to net capture- during night hours when 66.4 % of the total captures were obtained. The abundance during night hours was double than during day samplings. Juveniles of those species of penaeid shrimp also showed difference of density among lunar phases, being higher at night during waxing, new moon and waning than during full moon, where the reflected light intensity of the moon is maxima This behavior contrast with other studies in which catches of juveniles penaeid shrimps in coastal lagoons are almost greater at new moon and full moon than at the quarters but is coincident in which the absolute maximum is a new moon (García and Le Reste, 1981). Besides the locomotive activity of postlarvae and juveniles by their appendices (pereiopods and pleopods), their displacement in the water environment are supplemented by currents such as the Coriolis movements, winds, tide movements caused by force of attraction of the moon and the sun and chemical attraction, salinity gradient, endogenous cycles and hydrostatic pressure (Benfield and Aldrich, 1992). Captures during waxing and waning showed strong differences between nights than during the day hours. During new moon the densities were similar during night and day captures, meanwhile during full moon in which was captured the lowest number during the night as well during the day.

Density of captures over SAV showed a maximum of 5 ind.m^{-2}. Penaeid species collected in Guadoloupe Island, Caribbean Sea, showed average densities of 25 ind.1000 m^{-2} (Rojas-Beltrán, 1977) much lower than captures in La Restinga Lagoon. The recruitment of juveniles in SAV showed to be influenced by moon phase and light intensity. Sampling during five consecutive days showed maximum of capture the exact day of the moon (new moon and total darkness) phase, increasing from 1.6 ind.m^{-2} two day before the day of the moon, reaching 5 ind.m^{-2} and decreasing to 2.6 ind.m^{-2} two days after the day of the new moon. Meanwhile some species of penaeid shrimps shows an influence of lunar phases, other species, such as *Fenneropenaeus merguiensis* (De Man, 1888) and *F. indicus* (H.Milne Edwards, 1837) do not show positive correlation with abundance (Bañada, 1985). Hide tide, favorable currents and reduce moonlight during the night are factors that contribute to the entrance of postlarvae into the lagoon, but during March, the minimum variation of water by tide action in La Restinga –circa 30 cm- between flood and low tide is found (Monente, 1978) thus light intensity seems to be more important than tide action as factor promoting the entrance of postlarvae and juveniles of pink shrimps into the lagoon and their settlement on the submerged vegetation.

Data of environmental conditions taking during the study are coincident with previous works on captures of penaeid shrimps in La Restinga lagoon on *D.wrightii* beds (Robletto, 1982; Scelzo, 1999) who reported waters of low transparency, sediments composed mainly with organic matter percentage in the sediments between 4-7 %, high calcium carbonate and ammonium content between 3-.5 µg.at.NH_3-NH_2.

La Restinga is a marine ecosystem of great importance as natural resources in the Caribbean Sea. Its importance has been acknowledged by Venezuelan government, considering the lagoon as a National Park in which no commercial capture can be done, but it is utilized by artisan fisheries, tourism, visited by thousand of people permanently. What's more, no industries can be developed in La Restinga and its surroundings, but tourism activities impact in some part of the lagoon. Care must be taken to preserve the integrity of such environment, especially the areas of submerged aquatic vegetation because of the importance as refuge and food habitat as nursery ground for juvenile marine animals, especially penaeid shrimps whose adult populations in the open sea constitute one of the most important economic activities for the region in Venezuela. Those estuarine habitats are highly complex ecosystems with "noise" rhythmic configurations of multiple tidal, solar and lunar frequencies in which is not possible to find a simple correlation between animal function (endogenous) and environmental variables (exogenous) (DeCoursey, 1983).

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