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Occurrence, population dynamics and habitat characterization of *Mytella guyanensis* (Lamarck, 1819) (Mollusca, Bivalvia) in the Paraíba do Norte river estuary

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• *Abstract:* A survey of *Mytella guyanensis* occurrence and population dynamics were performed in the Paraíba do Norte river estuary. The characterization and the influence of temperature, salinity and substrate, as well as the associated fauna and flora on the population were also examined. *Mytella guyanensis* lives buried in the substrate of the mangrove intertidal zone of the Paraíba do Norte river estuary, from the mouth to 24 km upriver. Average annual density of this bivalve species was 5.2 individuals per m^2, with a predominantly aggregated distribution. The most frequent size was between 4.5 and 5.5 cm in length. Analysis of the substrate demonstrated the presence of two types of substrates in relation to the percentage of silt and clay and the water content. Besides interfering in the population density, the substrate heterogeneity may be a decisive factor in aggregation. Eight species of crustacean decapods and one bivalve species were identified as associated fauna.

• *Resumo:* A ocorrência de *M. guyanensis* no estuário do Rio Paraíba do Norte foi mapeada, determinando-se sua presença ao longo dos afluentes e ilhas aí existentes. O estudo da dinâmica da população foi realizado em área protegida da Ilha da Restinga, coletando-se os animais ao longo de 37 transecções. A cada mês foram feitos 60 lançamentos com um delimitador de 0,1 m^2, sobre uma ou mais transecções. Todo o substrato foi retirado juntamente com os exemplares de *M. guyanensis* e a fauna associada, até a profundidade de 10 cm. A triagem dos exemplares menores foi feita por peneiramento do substrato. O tipo de substrato foi anotado a cada lançamento. Dois tipos de substrato estão presentes na área: um substrato de tipo consistente, constituído por 89.7% de silte e argila e 10.3% de areia fina e outro de tipo não consistente contendo 74.5% de silte e argila e 25.5% de areia fina. O substrato de tipo não consistente apresenta quantidade de água significativamente maior que o de tipo consistente. *Mytella guyanensis* vive enterrada no solo numa profundidade máxima de 1,0 cm, sempre envolvida pelos filamentos do bisso. A densidade média anual observada para a espécie foi de 5,2 indivíduos por m^2; a distribuição espacial predominante foi do tipo agregado, sofrendo interferência do tipo de substrato presente. Houve preferência de fixação da espécie pelo substrato do tipo consistente. Animais entre 4,5 e 5,5 cm de comprimento ocorrem o ano todo, sendo mais numerosos aqueles com comprimento entre 4,5 e 5,0 cm. A presença de formas jovens foi assinalada em baixa frequência em alguns meses do ano. A salinidade da água estuarina variou de acordo com o regime pluviométrico da região, permanecendo dentro dos níveis de tolerância da espécie. A fauna associada está representada por oito espécies de crustáceos e por uma de molusco bivalve.

• *Descriptors: Mytella guyanensis*, Occurrence, Population dynamics, Density, Spacial distribution, Environmental factors, Estuary, Associated fauna.

• *Descritores: Mytella guyanensis*, Ocorrência, Dinâmica da População, Densidade, Distribuição espacial, Fatores do ambiente, Estuário, Fauna associada.

Introduction

In the mangrove intertidal zone of the Paraíba do Norte river estuary, *Mytella guyanensis* is the most abundant bivalve mollusc species. It represents a food resource for the human population along the banks of the estuary, where it is subjected to undiscriminated collecting. Previous works on this species revealed that it lives buried in the substrate of mangrove intertidal zone (Bacon, 1975), has a continuous reproductive cycle depending on the temperature (Grotta & Nishida, 1983), is an osmoconformer (Leonel *et al.*, 1988) and highly tolerant to salinity variations (Leonel & Silva, 1988). Preliminary studies on the population of *M. guyanensis* indicated densities of up to 12.2 individuals per m^2, with aggregated distribution probably induced by the type of substrate (Nishida & Leonel, 1985). Although Dijck (1980) had reported that *M. guyanensis* occurs only in the right bank of the Mandacaru river and the northern face of the Restinga Island, we have known from field observations in the last few years that this species has a broader distribution along the estuary.

Aiming at obtaining basic knowledge to evaluate the potential and to manage rationally the banks of *M. guyanensis* along the Paraíba do Norte river estuary, we surveyed the occurrence of these banks along the estuary and studied the animal population dynamics (density, type of recruitment of juvenile forms and size class distribution), at a place where no human predation had not been registered. In addition, we characterized the environment of this species, through measurements of the temperature, salinity and analysis of the type of substrate at the collection sites.

Materials and methods

The Paraíba do Norte river estuary (6°57' and 7°8'S; 34°50'W) receives various tributaries and includes the Islands Stuart, Tiriri and Restinga (Fig. 1). The survey of *M. guyanensis* banks was carried out visually by several incursions during ebb-tide, and inspection of the outskirts of the river and the islands from the mouth of the estuary up to 24 Km southwards.

To study the population of this bivalve species, a well protected area (of about 540 m^2), apparently sheltered from human predation, was chosen on the Restinga Island (Fig. 1). This area (Fig. 2) is surrounded by a typical mangrove arboreal vegetation, which provides partial shading, but the perimetric region is deprived of mangrove covering. During ebb-tide, this area remains completely uncovered, while during high tide it becomes covered by the water of the Costinha Canal. A small secondary canal running southwards drains the area during ebb-tide and discharges its water in the perimetral region.

Monthly, during a year, in each collection, the temperatures of the substrate collection area, of the substrate of perimetral region and of the estuarine water were recorded with a mercury thermometer (± 0.5°C); water samples from the secondary canal were collected and their salinity was determined by using an A/O refractometer.

Daily measurements of the amount of rain precipitation were obtained from the Estação Metereológica do Ministério da Agricultura in João Pessoa, 500 m from the river estuary.

In order to assess the composition and water content of the substrate, 4 samples of each substrate type (consistent and non-consistent) were collected and placed in plastic bags and kept frozen until analysis. Granulometric analysis of each sample was performed according to Suguio (1973): after dehydration in an oven (at 60°C) to obtain a constant weight, 4 sub-samples of each sample were subjected to the action of hydrogen peroxide and sieved (mesh size 0.053 mm). The water content was determined in 10 sub-samples of each type of substrate. After determining the fresh weight, samples were dehydrated in the oven at 60°C, till constant dry weight (after 96 hours), The Student t test was applied over the arc cosine of percentage of the water content value ($p < 0.005$) (Zar, 1984).

In the chosen area, collections were performed monthly from May, 1985 to April, 1986. Sixty throwings of a wooden quadrant (of 0.1 m^2) were executed monthly in transects.

Thirty seven parallel transects were placed in a continuous way, aiming at the total covering of the collection area (Fig. 2). The collections began in transect 1 and the others were surveyed in increasing numerical sequence, following as initial and final reference points, the existing canal and the vegetation . Every month, a certain number of transects was sampled, without repetition in the following months. Within each quadrant, the substrate was removed to a depth of 10 cm and passed through metallic sieves (mesh aperture of 0.5 cm) and the animals sorted out. The type of substrate of each sample was recorded.

Measurements of the anterior-posterior length of the collected mussels were made using a pachymeter (± 0.5 mm). Considering the size range (from 0.5 to 7.0 cm in length) of the collected animals, thirteen classes of sizes each one with 0.5 cm of amplitude was stablished.

The population density of mussels was determined dividing the total number of individuals by the surface of the sampled area (Santos, 1978; Soares *et al.*, 1982). The surface of the sampled area was calculated multiplying the area of the sample quadrant by the number of throwings. The estimate of the spacial distribution was obtained by the aggregation index (Ia) adopting the sub-regions methods (squares) according to Santos (1978) formula:

$I_a = S^2/D$ where,

I_a = aggregation index

S^2 = variance of Di

Di = number of individuals per sub-region

D = Di average:

i = 2,3,4...n sub-regions

If

$I_a = 1$, the distribution is at random

$I_a > 1$, the distribution is in aggregated form

$I_a < 1$, the distribution is uniform

After calculating the values of Ia, according to Thomas (1951) hyphotesis test, the statistical analysis proceeds, where

$Ho: I_a = 1$

$Ha: I_a > 1$

$I_a < 1$

The chi-square value of the sample was determined and compared with the critical values X^2_b and X^2_c ($\alpha = 0.05$).

The benthic macrofauna associated to *M. guyanensis* population was also identified. The arboreal vegetation was identified through dried samples of branches having reproductive elements.

Results

Distribution and habitat characterization of *M. guyanensis*

In the Paraíba do Norte river estuary, the species occurs in the proximities of the mouth up to 24 Km southwards (Fig. 1), and its occurence has been also recorded from the Guia river (near the confluence of Forte Velho Canal) in

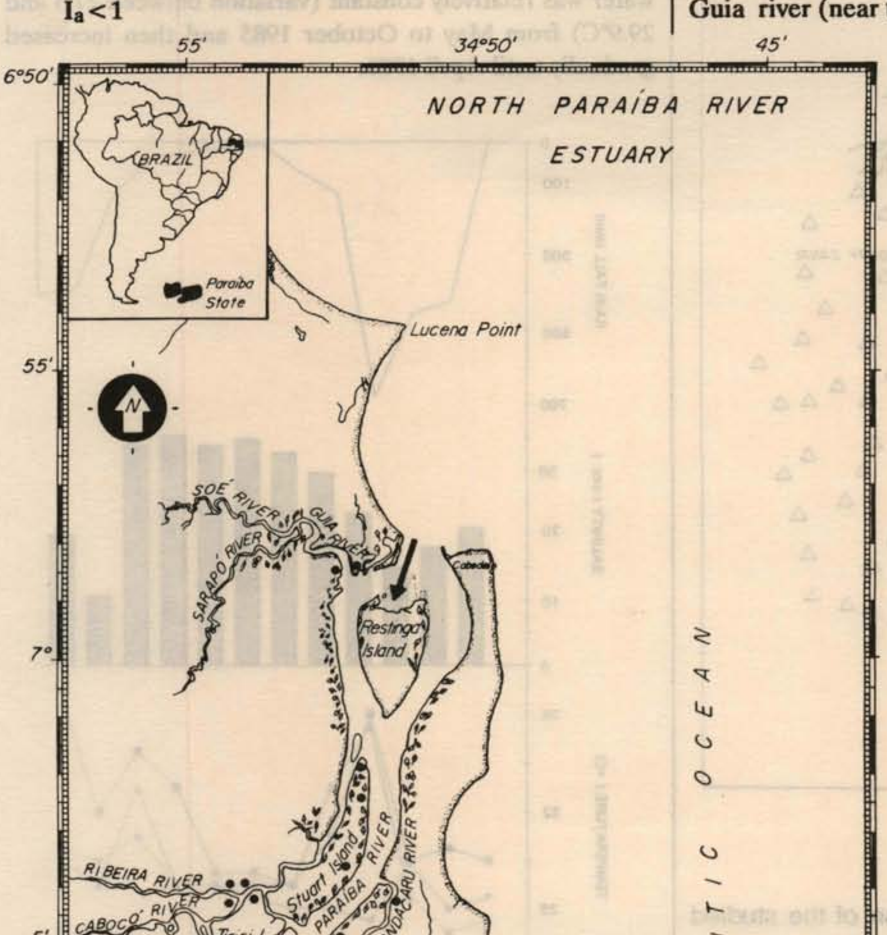

Fig. 1. Collecting area and distribution of *M. guyanensis* in the Paraíba do Norte river estuary. (↓) collecting area; (●) species occurrence.

the northern region of the Restinga Island, in the Stuart and Tiriri Islands, and up the Mandacaru, Tambiá, Paroeira and Ribeira rivers. In the upper region of the estuary and on the Paroeira river banks, many animals were observed with their shells partially exposed, frequently with oysters and barnacles attached to their valves. Less frequentely, *M. guyanensis* was found attached to the pneumatophores of *Avicennia* sp.

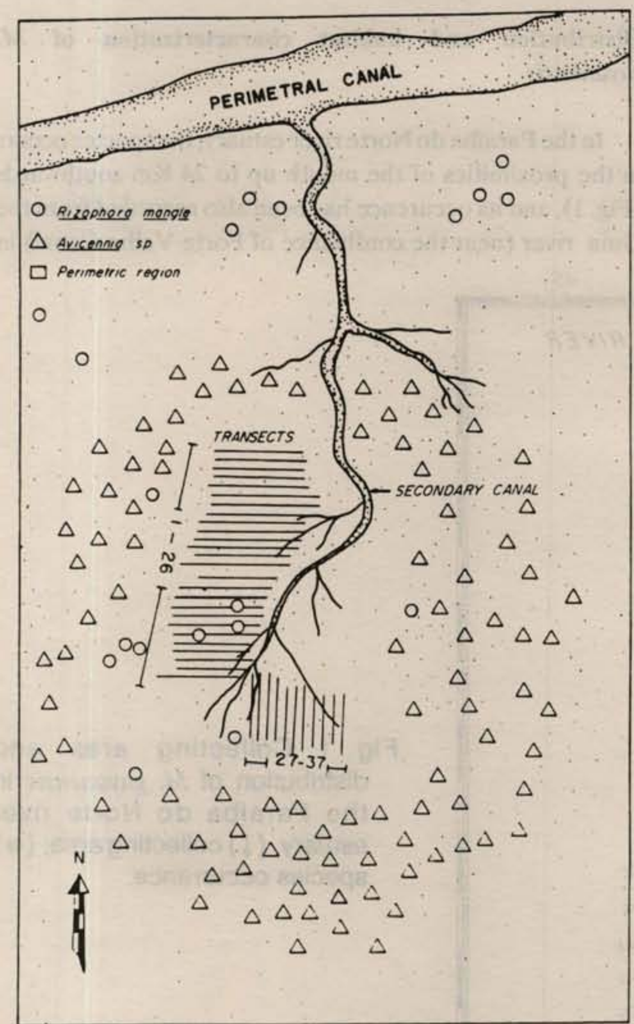

Fig. 2. Schematic representation of the studied area with different transects.

In the studied area, *M. guyanensis* was always found buried in the substrate in a vertical position, with the posterior end of the valves towards the surface. Depending on the consistency of the substrate, the presence of the animal could be identified by an elliptical slit on the surface. The large quantity of byssal threads form an intricate meshwork around the animal, allowing only the siphon region to be free. Large quantities of secondary roots of *Avicennia* sp could be seen intermixing with the byssal threads. Although occurring in small number in the glade banks, *Avicennia* sp emerges its respiratory roots in great number in the whole area. *Rizophora mangle* trees also occurred surrounding the whole mangrove area.

In the studied area the water salinity changed seasonally, according to the rainfall (Fig. 3). The highest salinity values were recorded in the dry season (in summer: 35.4‰) and the lowest in the rainy season (in winter: 10.6‰).

The temperature of the substrate in the sampling sites (variation between 27.0 and 35.5°C) and in the perimetral area (variation between 29.0 and 37.0°C) (Fig. 3) exhibited a similar pattern, but the values from the perimetral region were higher than those from the collecting sites, during most part of the year. The temperature of the estuarine water was relatively constant (variation between 27.5 and 29.9°C) from May to October 1985 and then increased gradually until April 1986.

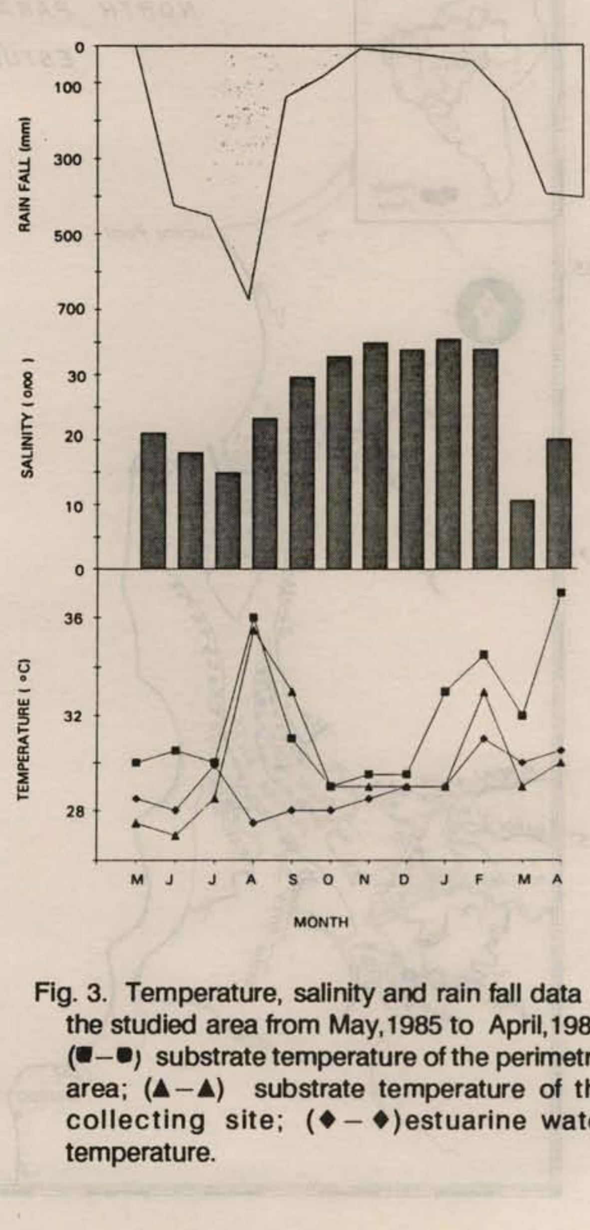

Fig. 3. Temperature, salinity and rain fall data of the studied area from May, 1985 to April, 1986. (■—■) substrate temperature of the perimetral area; (▲—▲) substrate temperature of the collecting site; (◆—◆) estuarine water temperature.

The substrate analysis confirmed the existence of two types of substrates, one non-consistent and another consistent. The consistent substrate was formed by silt and clay (89.7%) and fine sand (10.3%), with water content (57.49% ± 0.9608) lower ($p < 0.005$) than that from the non-consistent substrate (61.55% ± 2.7208). The same solid composition was determined for the non- consistent substrate, but the proportion of the components was different: 74.5% of silt and clay and 25.5 % of fine sand.

Population studies

All the 37 transects were surveyed in one year. The samplings contained a variable number of specimens, a maximum of 46 in October, 1985 and a minimum of 10 animals in December, 1985 (Tab. 1). All through that year, 375 animals were collected. From a total of 720 throwings, 366 fell on the consistent substrate and 354 on the non-consistent substrate, and the total number of animals collected was 313 and 62, respectively. Thus, independently of the number of throwings in the non-consistent substrate, the greatest number of animals was associated with the consistent substrate type and the mean number of animals was different in the two types of substrate, according to Wilcoxon's test, $T = 11$; $p < 0.005$ (Siegel, 1975).

When the samples of all months were pooled, the largest number of individuals corresponded to the size class between 4.5 and 5.0 cm in length, with 120 individuals (Fig. 4). Animals between 4.5 and 5.0 cm, 5.0 and 5.5 cm and 5.5 and 6.0 cm in length occurred along the whole year. The frequency of size classes showed a tendency to a normal distribution in all monthly collections.

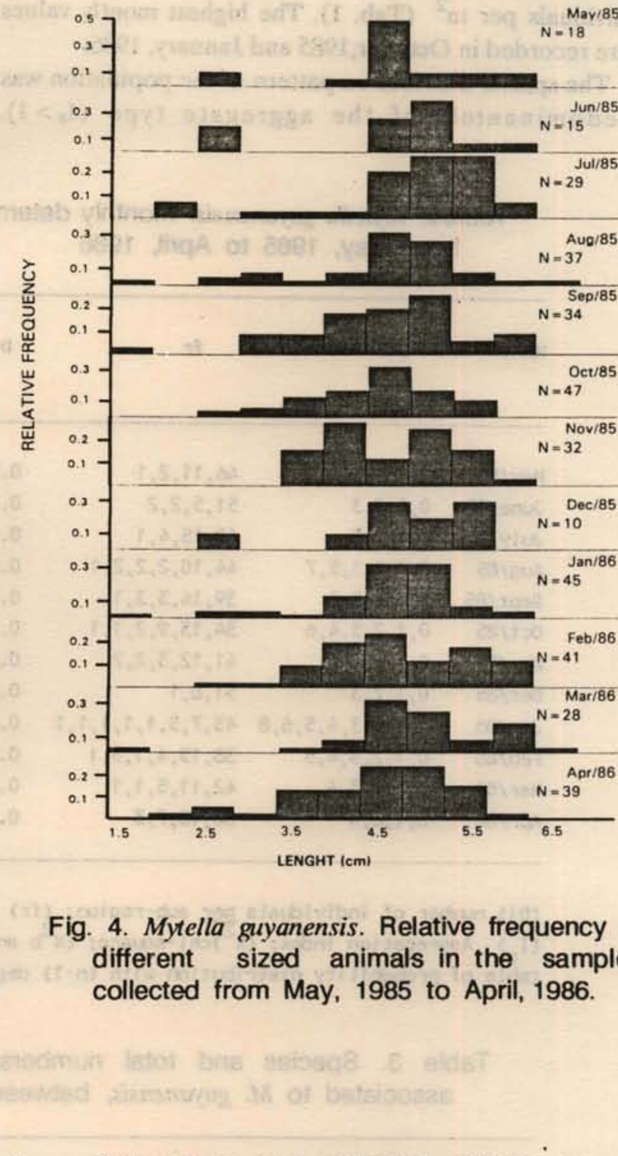

Fig. 4. *Mytella guyanensis*. Relative frequency of different sized animals in the samples collected from May, 1985 to April, 1986.

Table 1. *Mytella guyanensis*: density (m^2) and numbers of throwings and collected animals, as monthly recorded in the consistent and non-consistent substrate

Date	Total of throwings	Consistent substrate Throwings	Consistent substrate Animals	Non-consistent substrate Throwings	Non-consistent substrate Animals	Density (m^2)
May/85	60	6	9	54	9	3.2
June/85	60	4	9	56	6	2.5
July/85	60	30	22	30	7	4.8
Aug/85	60	48	34	12	3	6.2
Sept/85	60	42	27	18	7	5.7
Oct/85	60	45	46	15	1	7.8
Nov/85	60	43	24	17	8	5.3
Dec/85	60	3	3	57	7	1.7
Jan/86	60	46	42	14	3	7.5
Fev/86	60	45	34	15	7	6.8
March/86	60	15	24	45	4	4.7
April/86	60	39	39	21	-	6.5
Total	720	366	313	354	62	5.2

The mean annual density of *M. guyanensis* was 5.2 individuals per m^2 (Tab. 1). The highest montly values were recorded in October,1985 and January, 1986.

The spacial distribution pattern of the population was predominantely of the aggregate type ($I_a > 1$). Distributions of the random type ($Ia = 1$) and uniform type ($I_a < 1$) were observed only in May and December,1985 (Tab. 2).

The macrofauna associated to *M. guyanensis* population varied along the year and included eight species

Table 2. *Mytella guyanensis:* monthly determination of the spacial distribution pattern, from May, 1985 to April, 1986

Month	Di	fr	D	s^2	Ia	x^2, x^2b, x^2c	Spacial distribution
May/85	0,1,2,3	46,11,2,1	0.30	0.38	1.27	$x^2b<x^2<x^2c$	Random
June/85	0,1,2,3	51,5,2,2	0.25	0.46	1.84	$x^2>x^2c$	Aggregate
July/85	0,1,2,5	40,15,4,1	0.48	0.65	1.35	$x^2>x^2c$	Aggregate
Aug/85	0,1,2,3,5,7	44,10,2,2,2,1	0.62	1.91	3.08	$x^2>x^2c$	Aggregate
Sept/85	0,1,2,3,5	39,14,3,3,1	0.57	1.00	1.75	$x^2>x^2c$	Aggregate
Oct/85	0,1,2,3,4,6	34,13,9,2,1,1	0.78	1.39	1.78	$x^2>x^2c$	Aggregate
Nov/85	0,1,2,3,4	41,12,3,2,2	0.53	0.96	1.81	$x^2>x^2c$	Aggregate
Dec/85	0,1,2,3	51,8,1	0.67	0.43	0.70	$x^2<x^2c$	Uniform
Jan/86	0,1,2,3,4,5,6,8	43,7,5,1,1,1,1,1	0.77	2.48	3.22	$x^2>x^2c$	Aggregate
Feb/86	0,1,2,3,4,5	38,13,4,1,3,1	0.70	2.38	4.04	$x^2>x^2c$	Aggregate
Mar/86	0,1,2,3,4	42,11,5,1,1	0.47	0.73	1.55	$x^2>x^2c$	Aggregate
Apr/86	0,1,2,4	38,13,7,3	0.65	1.38	2.13	$x^2>x^2c$	Aggregate

(Di) number of individuals per sub-region; (fr) frequency; (D) Di mean; (S^2) Di variance; (I_a) Aggregation index; (X^2)chi-square; (X^2b and X^2c) critical values obtained from table of probability distribution with (n-1) degrees of freedom and significative level $\alpha=0.05$.

Table 3. Species and total numbers of collected specimens of the fauna associated to *M. guyanensis,* between May, 1985 to April, 1986

Species	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total
						Month							
(Crustacea Decapoda)													
Alpheus estuariensis	4	-	3	-	-	-	1	-	1	-	-	-	9
Clibanarius sclopetarius	1	1	8	5	1	3	-	-	-	-	-	-	19
Eurytium limosum	9	2	5	-	1	3	4	2	3	-	-	2	31
Pachygrapsus gracilis	-	1	-	-	-	-	4	-	-	-	-	-	5
Panopeus occidentalis	3	-	-	-	-	-	-	-	-	-	-	-	3
Sesarma (Sesarma) crassipes	1	-	-	-	-	-	1	-	-	-	-	-	2
Uca (Celuca) cumulanta	-	-	-	-	10	11	9	-	-	3	-	-	33
Uca sp	1	7	6	11	13	30	4	-	3	-	-	-	75
Total													176
(Mollusca-Bivalvia)													
Macoma constricta	6	5	1	2	-	-	-	-	-	-	-	-	14

of decapod crustaceans and one bivalve mollusc species (Tab. 3). The crustaceans represented the most abundant group. The largest species diversity and the greatest number of individuals occurred between May and July and September and November, 1985.

Discussion

The seasonal variation of the salinity in the studied area agreed with previous data found by Sassi & Watanabe (1980) and Petraglia-Sassi (1986) for the Paraíba do Norte river estuary. Maximum and minimal salinity values determined in the present work (10.6‰ and 34.6‰) were within the tolerance range of *M. guyanensis*, whose survival indexes were high according to Leonel & Silva (1988).

The differences obtained for the temperature values of the collecting site (from 27.5 to 35.5°C) compared with those of the perimetral area (from 28.8 to 37.0°C) clearly reflected the differences in the insolation of the latter (Fig. 3). Because it receives direct solar radiation, the temperature of the substrate of the perimetral area was higher than that of the collecting site, wich was protected by the shading of the vegetation. The absence of vegetation and the high perimetral temperature might be the limiting factors of the mussel colonization of the considered area.

Analysis of both types of substrates showed a higher percentage ($p < 0.005$) of free water in the non-consistent one. This statement is corroborated by the fact that the adsorbed water in the clay is either in the oxydril or in the hydroxil form, and that it can only be removed from the clay particles at 100 to 300°C (Santos, 1975). Therefore, during the drying of the material at 60°C, the evaporated water was considered as free water present in the fine sand. This admission is reinforced when one considers that the non-consistent substrate type showed a higher fine sand percentage content (25.5%) than the consistent substrate (10.3%).

All the animals collected in the consistent substrate were buried in the way described by Bacon (1975), with the posterior end of the valves turned up to the surface of the bottom of the environment where they could be identified through the presence of an elliptic slit.

The specimens of *M. guyanensis* in the studied bank were always covered by a thick texture of byssal threads, intermixed with secondary roots of *Avicennia* sp and plant debris. According to Bacon (1975), this kind of nest formed by byssal threads consolidates the burrow of the animal, allowing its living in soft bottoms in areas of rapid sedimentation.

In the studied area *M. guyanensis* was always found at a maximum depth of 1.0 cm; this fact was also reported by Bacon (1975), but is in disagreement with Klappenbach (1965), who stated that this species creeps in the substrate down to a depth of 20 cm during ebb-tide. Such statement is liable to discussion since it is already known that *M. guyanensis* lives buried in the bottom, wrapped in the byssal threads and these threads are closely associated to the substrate and roots. If vertical migration occurs in the substrate, as stated by Klappenbach (1965), the whole nest organization would be disrupted. The data obtained in the present work and the information already available for *M. guyanensis* does not give any support to the migration theory. The occurrence of the animal near the surface of the bottom would also be justified by the presence of reduced siphon sizes. The small siphons of *Mytella charruana* prevents the animal from sinking in the substrate (Narchi & Galvão-Bueno, 1983). In *M. guyanenis* the mantle edge is projected towards the opening of the slit during the high tide (Bacon, 1975).

Among the analyzed environmental factors the substrate type was the most important one in the determination of the population density. The preference for the consistent substrate type was significative ($p < 0.005$); this substrate type offers the best conditions for the consolidation of the walls of the burrow. The results obtained concerning the monthly densities of this species (Tab. 1), clearly reflected the interrelationship between the amount of collected animals and the performed throwings on each type of substrate. Thus, the greatest densities corresponded to the months where the greatest number of throwings fell on the consistent substrate type, and the smallest densities corresponded to the throwings on the non-consistent substrate type. Besides this, one should consider that from the total throwings, pratically half of them fell on the area formed by non-consistent substrate.

The tendency towards aggregation was evident in *M. guyanensis* in most of this study, even though random and uniform distribution have also been recorded. In *M. guyanensis* populations the aggregation was also the distribution pattern found in samples collected at random from radial transects (Nishida & Leonel, 1985). These findings led us to the conclusion that aggregation was the most frequent distribution type of this species. According to Jackson (1968), the heterogeneity of the substrate could be regarded as the determining factor for aggregation. The distribution at random or uniform which we found, could be due to the large number of throwings and low number of collected animals in the non-consistent substrate type in May and December, respectively. The influence of the substrate type on the spacial distribution was also evident in *Anomalocardia brasiliana*, which also occurred in both the aggregate and the random types of distribution, depending on the reducing substrate characteristic (Schaeffer-Novelli, 1976).

The analysis of the frequency of size classes of *M. guyanensis* indicated a tendency to a normal distribution over the major part of the year.

As to the recruitment of juvenile forms in the population, one would expect it to be in accordance with the continuous reproductive cycle of that species (Grotta & Nishida, 1983; Sibaja, 1986) and could therefore occur throughout the year. The occurrence of young forms was recorded only for individuals between 1.5 and 2.5 cm in length during a few months of the year and in low frequency. The absence of individuals smaller than 1.5 cm in length could be attributed to factors such as collection methodology or to the low occurrence of larvae in the pankton, or to both factors. In relation to the interference of the methodology in the sampling of young forms, we admit that during the sorting out of the animals, the mesh size might have allowed undue passages of individuals, depending on the vertical or horizontal position of their anterior-posterior axis.

For *M. guyanensis* Bacon (1975) reported the action of predators on adult mussels only. In the studied bank various species of decapod crustaceans were found among the associated fauna. Among the identified crustaceans, *Eurithium limosum* was the only species described in the literature as a predator of *M. guyanensis* (Bacon,1975). Despite this, predatory action of any of this species was not observed.

Mytella guyanensis is sexually mature only when it attains 4.0 to 4.3 cm in length (Sibaja & Villalobos, 1986). During this study the greatest frequencies and occurrence of individuals were associated to size classes from 4.5 to 5.0 cm and from 5.0 to 5.5 cm in length. According to our results and those obtained by Sibaja and Villalobos (1986), only the animals between 4.5 and 5.0 cm in length should be collected for commercial purposes. The marked decrease in frequency of individuals of classes above 5.5 cm in length suggests the occurrence of mortality among them.

Conclusions

In the Paraíba do Norte river estuary *Mytella guyanensis* has always occurred in banks distributed along its affluents and islands. The species could be found buried at a maximum depth of 1.0 cm involved by byssal threads which anchored it to the secondary roots of *Avicennia* sp.

The average annual density of *M. guyanensis* corresponded to 5.2 individuals per m^2 and the spacial distribution was predominantly of the aggregated type. The most frequent species size ranged between 4.5 and 5.5 cm in length.

In the collecting area two substrate types with different water contents were observed. The heterogeneity of the substrate interfered in the spacial distribution and in the density of *M. guyanensis;* its associated fauna was composed of eigth crustaceans species and one bivalve mollusc species.

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