SPATIAL DISTRIBUTION AND GROWTH OF *MELLITA QUINQUIESPERFORATA* (LESKE, 1778) ON A SANDY BEACH OF SOUTHERN BRAZIL.

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INTRODUCTION

The genus *Mellita* has three species with distributions along the Atlantic coast, from Nantucket to Brazil. These species were considered a single species, *Mellita quinquiesperforata*, since Mortensen's revision (1948), but Harold & Telford (1990) recently showed that three different Atlantic species exist "recognizable by eye and by multivariate analysis, and each with its own distinct geographical range".

Mellita quinquiesperforata (*sensu stricto*) is distributed from the Mississippi Delta, through Central and South America to southern Brazil (Harold & Telford, *op.cit*). Little is known about the biology and ecology of this species, because most previous work was done with *M. isometra* or *M.tenuis*, referred to without distinction as *Mellita quinquiesperforata* (Salsman & Tolbert, 1965; Weihe & Gray, 1968; Bell & Frey, 1969; Ghiold, 1979; Alexander & Ghiold, 1980; Lane & Lawrence, 1982; Telford, 1983; Telford *et al.*, 1985).

The presence of this species on the Brazilian coast was noted by Bernasconi (1955) and Tommasi (1966), who limited its southern distribution to the state of Rio Grande do Sul (RS). Preliminary studies on the sublittoral benthic communities of exposed sandy beaches around the Lagoa dos Patos inlet (RS), done during 1986, revealed great abundances and a clear zonation of this species (Borzone, 1988; Borzone & Gianuca, 1990). A regular sampling program covering the annual cycle allows a preliminary description of some aspects of the population dynamics of *M.quinquiesperforata* in this area to be made.

In the present contribution, the spatial distribution by size and its variation through an annual cycle, and growth estimated by size-frequency analysis are presented.

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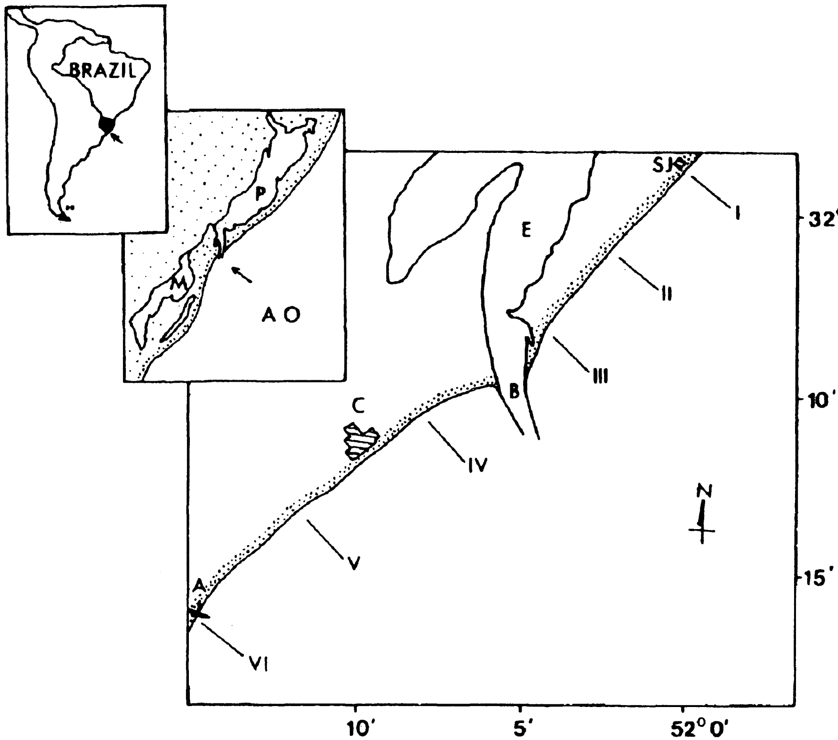

Fig. 1
Study area. I to VI: transects, A: beached ship "Altair", B: Lagoa dos Patos inlet, C: Balneário Cassino, E: Lagoa dos Patos estuary, M: Lagoa Mirim, AO: Atlantic ocean, P: Lagoa dos Patos, SJ: Balneário São José do Norte.

STUDY AREA

The littoral of Rio Grande do Sul state is characterized by an extensive exposed sandy beach (approximately 660 km in length). The inlet of the Patos Lagoon, that connects the hydrologic system Patos-Mirim with the Atlantic ocean, interrupts the beach (Figure 1). The littoral around the inlet receives some influence from this hydrologic system, but the typical exposed sandy beach of the rest of the littoral is maintained. Salinity varies from 17 to 31 ppm, and follows the seasonal fluctuation of the water temperature, with a minimum in the winter (Figure 2).

Sediments are characterized by very fine quartz sands (mean particle size = 3.25 ϕ), which are very well sorted (sd = 0.1 - 0.2 ϕ), and present a variable content of fine material that originates in the continental drainage, seaward and near 6 meters in depths. This deposition is greater at the south of the inlet, where unusual mud banks exist near

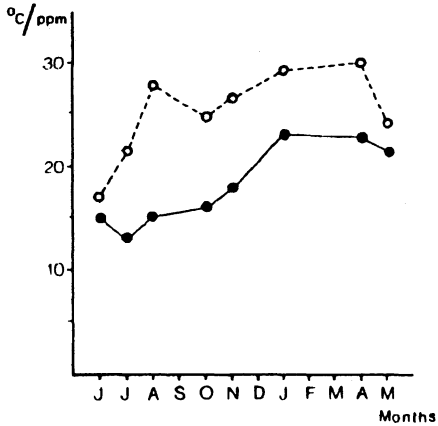

Fig. 2
Mean monthly values of temperature (•) and salinity (°) during the years 1987-1988.

the shore (Borzone & Griep, 1992). Northern the inlet (transect I, see later), the sediments were relatively homogeneous, presenting a minimum standard deviation in stations closest to the shore, indicating the presence or proximity of breakers at those points, and an increase of fine material with depth never exceeding 13 % (Table 1).

This beach presents, most of the time, dissipative morphodynamic states (see terminology in Short & Wright, 1983), characterized by wave heights of 1 to 2.5 meters with periods of about 9 sec. The waves break at 200-500 meters offshore, forming a very wide surf zone, with characteristical 2 or more sand bars present, parallel to the shore (Borzone, 1988). The subtidal was divided in three physical and faunistic zones (Borzone & Gianuca, 1990) using the terminology of Wright *et al.* (1979) and Short (1983) (Figure 3).

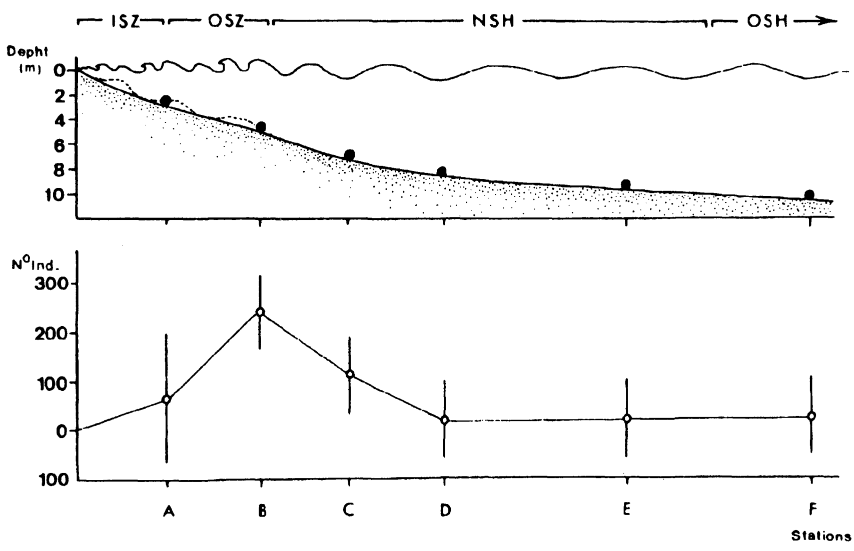

Fig. 3
Distribution of stations along transect I showing the sublitoral zonation (superior); mean abundances of Mellita quinquiesperfortata (± 95% confidence intervals) during the years 1987-1988 (inferior). ISZ: inner surf zone, OSZ: outer surf zone, NSH: nearshore, OSH: offshore. From A to F: station of samples.

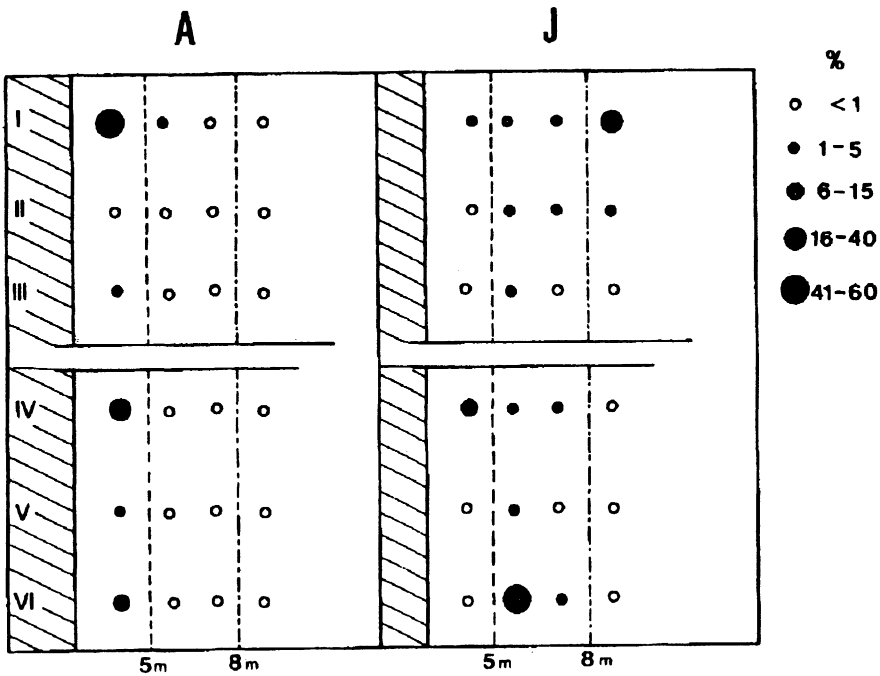

Fig. 4
Schematic distribution of adults (individuals > 30mm) and juveniles (individuals < 10mm) around the Lagoa dos Patos inlet (samples of April and August of 1986 added), expressed as percentages of the total. A: adults (N=134), J: juveniles (N=2,324), I to VI: transects.

METHODS

Macrozoobenthos was sampled in April and August of 1986; June, July, August, October and November of 1987; January, March, April and May of 1988; and June of 1990. In 1986, samples were taken along six transects perpendicular to the shore (Figure 1) from Balneário São José do Norte (32°04' LS-52°00' LW) to the wreck of the vessel "Altair", beached 20 km south of the Lagoa dos Patos inlet (32°16' LS; 52°15' LW) (Rio Grande do Sul, Brazil). At each transect, four samples were taken at depths from 3 to 10 meters. The rest of the collections were made only on transect I, at six stations (whenever and wherever possible) placed at fixed distances from the shore (Figure 3).

Each station was located by Decca navigation. A sediment sample was extracted, and the bottom was dredged twice for 1.5 minutes parallel to the shore, with a modified "Spatangue" anchor dredge which has a 40 x 15 cm frame. Grain size analysis was conducted by sieving the sand fraction at 0.5 *"phi"* (ϕ) intervals and determining the weight percentage of the clay and silt fraction by the standard pipette technique.

Biological samples were fixed in 10 % formalin, and each individual of *M.quinquiesperforata* was measured to the nearest 0,1 mm. The distances measured were: a)

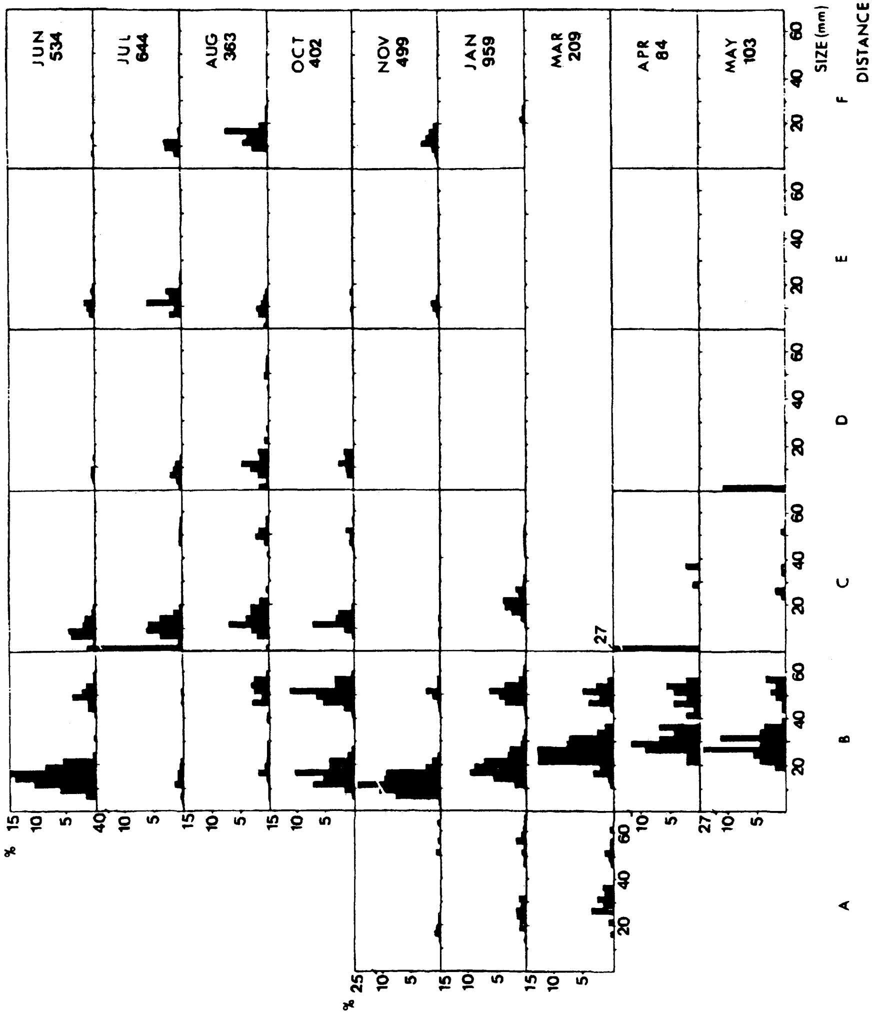

Fig. 5
Size frequency distribution in each sample, expressed as percentages of the total for each transect, during the years 1987-1988. Size intervals of 2.5 mm.

the test length, from ambitus at ambulacrum III (anterior) to ambitus at interambulacrum 5, and b) the test width, the maximal measurement perpendicular to the length. Regression analysis was performed on these two measurements. The former was used routinely as the measure of size, this was preferred to the frequently used "average diameter" (0.5 x [length + width]).

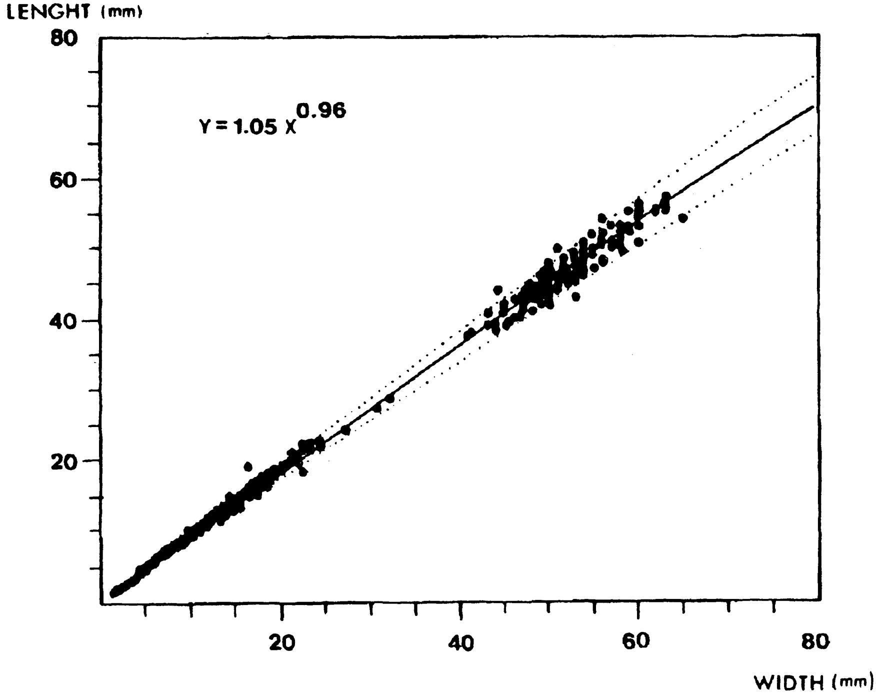

Fig. 6
Scattergram and regression analysis of the relationship between width and length (mm). Dotted lines indicate the 95 % confidence intervals.

Some observations using scuba diving gear were done during March of 1986, and population density was estimated from counts made using a 1/4 m^2 frame.

The growth rate and mortality were estimated using different routines of the software package "Compleat ELEFAN" (version 1.10, October 1989, Guayanilo *et al.*, 1989).

RESULTS

Spatial distribution and density

The survey of 1986 showed the presence of the species in all transects around the inlet, and a very important recruitment was registered in April and August of that year. Individuals greater than 30 mm form a band parallel and closer to shore, near 5 meters in depth, and with the greatest abundances in the northern transect I. Smaller individuals, (width < 10 mm) appear to be more abundant with increasing depth, and in the extreme transects I and VI (Figure 4). Only transect IV showed a high percentage of small individuals closer to shore.

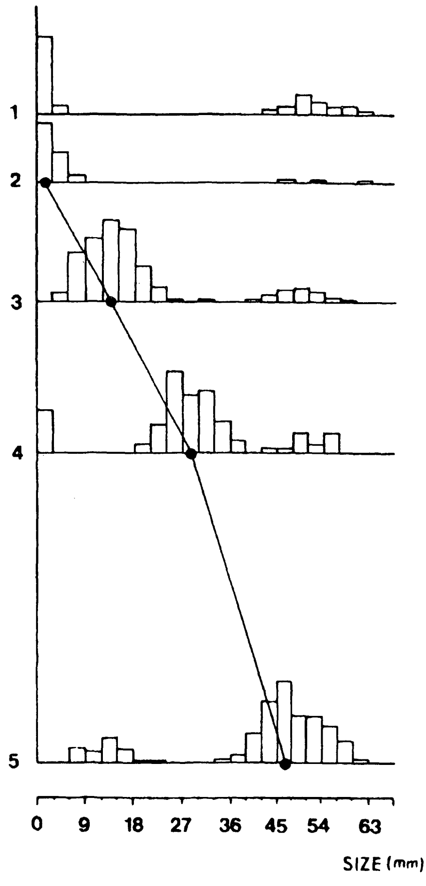

Fig. 7
Size frequency distribution used in a first estimation of growth. Numbers in the y axis identify the samples (see Table 2). Size intervals of 3 mm.

Later samples confirm the preference of the bulk of the population to occupy a band immediately behind the surf zone. During years '87-'88, mean abundances among stations exhibited significant differences (confidence level of 95 %), with a peak in the outer surf zone (station B, Figure 3). The size frequency distribution, determined for each sample during the same period (Figure 5) showed individuals greater than 60 mm only in the shallow station A. Individuals between 40 and 60 mm were most abundant in station B, but also exhibited an important presence in station C during July, August and October. Individuals between 10 and 20 mm, corresponding to the recruitment of 1986, became distributed along the whole transect during winter and spring, accompanied, in July and August, by a decrease in abundance in station B. Another recruitment was registered during June and July of 1987 and April and May of 1988 (width < 2.5 mm), only in stations C and D.

In station B (March of 1988) density was estimated at 12 individuals/m^2 (SD = 3.57, N = 6). In the same station, the sample dredged contained about 151 individuals. If we consider a sampling effort to be equivalent between the different samples, the greatest densities ocurred during summer (January), in station B, with 51 individuals/m^2.

Morphometry

Regression analysis between length (y) and width (x) of 650 individuals, including a large range of lengths, showed the best fit (r = 99.999) in a multiplicative model ($y = ax^b$; a = 1.05, b = 0.960174) (Figure 6). This indicates allometric growth, with an increase of width in respect to length during growth. The shape of the test of adult individuals exhibits a characteristic elliptical outline, where individuals of 50 and 70 mm width have lengths of 45 and 62 mm, respectively. This was first perceived by Clark (1940), who recognized four Atlantic species, and defined this relation as one of

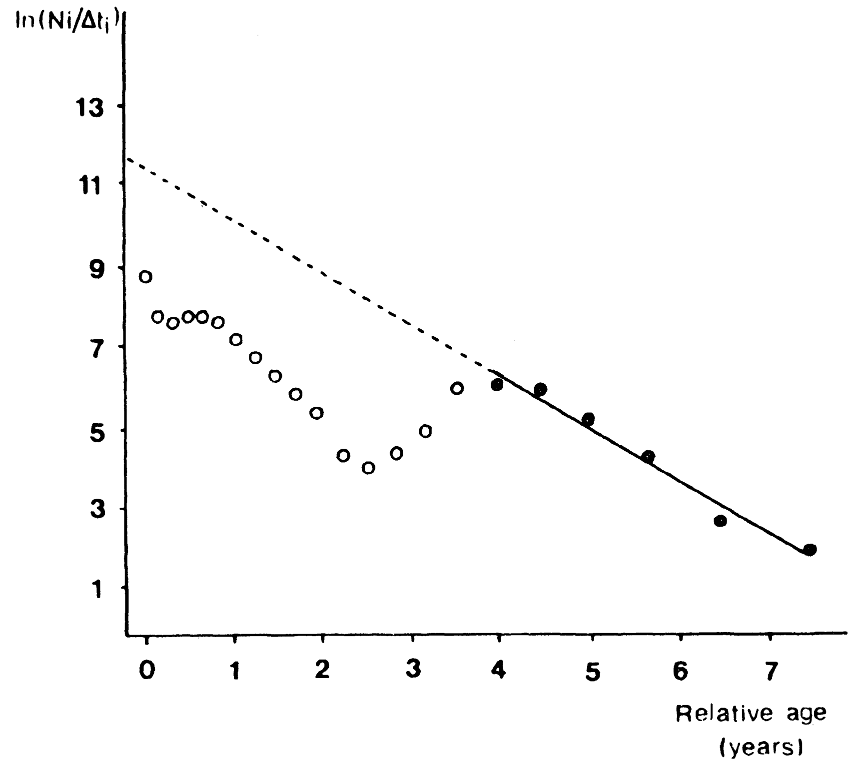

Fig. 8
Length converted catch curve and points included in the computation of Z (solid points).

the specific characteristics. Recently, this was confirmed in three species by Harold & Telford (1990), using multivariate analysis based on many more measurements.

In the present contribution width was selected as the measured of size because it adequately reflects growth increments, and it is less affected by damaged, probably caused by predation. Predation produces several injuries affecting test shape, usually in the posterior part, wich generally projects from the substratum. In June of 1990, injuries were recorded in 24 % of the total individuals sampled (216). In the location of all of the injuries, regeneration occurs, as described by Weihe & Gray (1968) for *M.isometra.*

Growth rate and mortality

In April of 1986 an important recruitment was registered, that extended throughout the winter and showed a peak of abundance in August (1,458 individuals < 8 mm, with a mean of 2.1 mm width). The progression of this cohort in samples spaced at annual intervals, was used in a first estimation of growth (Figure 7). The Bhattacharya method, modified by Pauly & Cady (1985) and present in the routine MPA of the "Compleat ELEFAN" package, was used for determining the mean size of this cohort in each frequency distribution (Table 2). Three growth increments were recognized and plotted as L/t *vs.* L, according to Gulland & Holt (1959) using the routine ELEFAN V of the package. The regression (r = - 0.87) gives an estimation of Loo = 70.3 mm and k = 0.281. Fabens method (1965) applied to the same increment data presented similar results, with a reduction of the value of Loo (63.3 mm) and an increment in the value of k (0.33).

The method developed by Pauly & Davis (1981), that adjusted a restructured size frequency distribution to a "seasonalized" version of the von Bertalanffy growth fit (Pauly & Gaschutz, 1979) and is present in the routine ELEFAN I of the package, was used for a second estimation of growth using the samples of years '87-'88 and June of 1990. The value of Loo and k obtained by the Gulland & Holt method were used not only as seeded values but also as limits of the optimization of the ESP/ASP relation (expressed as Rn = 10^(ESP/ASP)/10). A winter oscillation, expressed by values of C = 1 (cessation of growth) and WP = 0.6 (July), was registered (Table 3).

Mortality was estimated from a length converted catch curve (Figure 8), using the routine ELEFAN II of the package. The same samples of the last estimation were used and the option that transformed all samples into % samples before calculation was selected. Z value was estimated for the different growth parameters, varying from 0.88 to 1.4, for Fabens and Elefan I growth parameters respectively (Table 3).

DISCUSSION

Mellita quinquiesperforata appears to be an important component of the benthic community on South American sandy beaches. In the present study area, this species showed a subtidal distribution near the breakers, characterizing the outer surf zone. It also formed a band parallel to shore, with its greatest abundances at a distance of 0.5 nautical miles, at 5 m depth. Larger individuals tended to be more frequent at shallow stations, near, or in, the inner turbulent zone; while juveniles and recruits tended to be more frequent at intermediate stations, probably in relation to diminished wave action. This may explain the presence of recruits in the shallowest stations of transect IV, southeast of the Lagoa dos Patos inlet, where two long jetties protect the adjacent beaches against strong wave action.

A similar distribution was found by Kenk (1944) in the Gulf of Mexico, who referred to this species as *M.lata*. This work, probably the only ecological reference for *M. quinquiesperforata* (*sensu stricto*), showed an abundance of this species close to shore, just below the zone of moving sand ("surfzone" ?). The test shape, with the greater height near the anterior margin, indicates that *M.quinquiesperforata* is highly specialized, and better adapted to these particular forms of living than other Atlantic species of the genus *Mellita*, with have the apex in a more central position.

M.isometra shows a great bathymetric distribution, ranging from the intertidal zone to 50 meters depth, and is relatively scarce on open beaches with heavy wave action (Weihe & Gray, 1968). In contrast, *M.tenuis* lives exclusively in the sublittoral, forming a band from the shore to 1.5 meters depth (Salsman & Tolbert, 1965), or from the surfzone to a depth of 15 meters, with greatest concentrations at 7 m (Lane & Lawrence, 1980). The lack of more references about the morphodynamic characteristic of the beaches inhabited by this species limits this comparison, but it is probable that these species show a different distribution in relation to the wave exposure of the beach.

Dendraster excentricus, an extensively studied Pacific sand dollar, shows a variety of distributions, positions in the substrate, and trophic habitats in relation to wave exposure. In sheltered bays, with relatively little water movement, it lies flat on the bottom, feeding on detritus; in habitats with moderate water movement, it usually adopts an inclined position, feeding on suspended material; and on shores consistently exposed to strong wave action, it is usually buried (Merrill & Hobson, 1970). The size distribution also varies with exposure. On shores with a wide surf zone, with more than one break, the populations are at greater distance from shore, with individuals becoming progressively smaller with depth. In protected areas, juveniles are most abundant shoreward, and move seaward with age (Merril & Hobson, *op.cit.*).

In situ observations of the individuals indicated that *M.quinquiesperforata* lives buried in the uppermost layer of the sand, with the posterior surface lunule visible. Our observations agree with Kenk (1944), who found that this species moved very quickly under the sand, in a polarized direction, and required a very short time to bury itself. Its migrating capacity is considerable (40 meters/week), and there is active substratum selection (Kenk, *op.cit.*).

The seasonal variation of the position observed in the present population, where most of the members occupy more offshore positions during the winter months, may be explained by active migration or by passive displacement due to the increase of wave action. Similar variations where observed for *Dendraster excentricus* (Morin *et al.*, 1985), where the seaward edge of the bed moved in fall and winter to a great depth.

The variation in abundance results from recruitment, with a peak in winter, and from gregarious behavior that was evident in January. This active behavior, that Weihe & Gray (1968) related to the success of reproduction, contributes to the form of dense bands parallel to the shore and perpendicular to the wave gradient.

The increase of fine material in the sand with depth probably limits the offshore distribution of this species. Southeast of the inlet, where the deposition of mud is very important (Borzone & Griep, 1992), the population is restricted to the shallowest stations (A and B, pers. obs.). It is common for all the members of the genus to prefer a clean, sandy substrate, with low organic content and without mud. Apparently, these species are intolerant at finer particulates, and this supports the hypothesis of podial deposit feeding as a feeding mechanism for *M.isometra* (Telford *et al.*, 1985). It is probable that the same feeding mechanism would be found in *M.quinquiesperforata*, wich has a well developed lantern, a fact that is justified by this new hypothesis (Telford *et al.*, *op. cit.*).

The population dynamics of *M.quinquiesperforata* in the present study area were similar to those reported for other echinoderms, with a variable annual recruitment and a dominant year class. In the present case, growth is easy to estimate by following the progression of this dominant class, and this method was used also by a variety of authors (e.g. Beukema, 1985; Ebert & Dexter, 1975). Recruitment was in all years, but only those of 1986 and 1989 were successful and have a progression in following years. Lane & Lawrence (1980) explained the unsuccessful recruitment in *M.tenuis* as due to mortality during the crucial early stages of benthic life, when physical conditions (turbulence of the surf) may play a fundamental role in the survival of recruits and juveniles. In *M. tenuis* the larvae settle primarily in shallow waters. This was not the case in *M.quinquiesperforta*, that clearly recruits in deep waters, where the increasing of fine material may be the cause of mortality in recent recruits and juveniles.

In echinoderms, as in a great variety of the marine invertebrates, the von Bertalanffy model is not the best to explain growth. Sigmoidal curves were reported for different species of sand dollars (Birkeland & Chia, 1971; Lane & Lawrence, 1982; Steimle, 1990), and the data in the present work probably fits a sigmoidal curve better. The great diffussion of software containing the von Bertalanffy model, and the necessity of comparing results with other works, makes profitable its use.

Growth parameters estimated in the present contribution, with different methods, show only small differences. Faben's method shows the greatest difference in the reduction of the Loo value. A similar trend was observed by Lane & Lawrence (1980) in the estimation of growth for *M.tenuis*. The value of Loo of 63.3 mm given by this method was frequently exceeded by individuals collected during the study, indicating that this probably underestimates the real Loo. It was very difficult to find individuals exceeding 70 mm, only on one occasion was an individual of 80 mm seen, collected by a commercial fish trawl. Mortality rates were relatively high, with an average life expectancy (1/Z) of approximately 1 year. Similar values, however, where found by Ebert & Dexter (1975) for other species of sand dollars.

Growth parameters estimated in this work are different than those presented for the other Atlantic species of *Mellita*. Small values of Loo and k were found for *M.quinquiesperforata*, that grows to a smaller size than other *Mellita* of the northern Atlantic ocean. The relation between Loo and k in echinoderms was revised by Ebert (1975) who found a positive correlation between these two parameters, large species grow faster than small ones. Differences in resource allocation may explain this relation, greater allocations to maintenance and less to growth and reproduction produce a decrease of k value. The habitats preferred by *M.quinquiesperforta*, in the proximity of breakers and behind a heavy wave action, may select for a reallocation of resources in maintenance (e.g., more thick test), diminishing the resources for growth and reproduction. This may explain the smaller size attained by this species. Comparative studies in different morphodynamic beach types should yield interesting results concerning this general adaptative trend.

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ABSTRACT

The spatial distribution by size and its variations through an annual cycle, and the growth estimated by size-frequency analysis of *Mellita quinquiesperforata* are presented. Samples were taken at a subtidal exposed sandy beach located around the inlet of the Patos Lagoon, Rio Grande do Sul, Brazil, from 1986 to 1990. The distribution of the species showed that most of the adult population occupies a band immediately behind the surf-zone, with the greatest abundance at a distance of 0.5 nautical miles from shore, at 5 m depth; smaller individuals appear to be more abundant with increasing depth, probably in relation to diminished wave action. Greater density (of 50 individuals/m^2) was found during the summer resulting from a characteristic gregarious behavior. The population exhibited variable annual recruitment with the presence of a dominant year class. Growth parameters estimated with different methods present small differences, varying from 63.3 to 72 mm for Loo, and from 0.33 to 0.278 for k, respectively. These parameters are smaller than those recorded for other Atlantic species of *Mellita*. This may be related to the preferred habitat of *M. quinquiesperforata*, in the proximity of breakers with heavy wave action, that requires more allocation of resources to maintenance and less to growth and reproduction.

Key words: *Mellita quinquiesperforata*, sand dollars, sandy beach, Southern Brazil.

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Table 1: Mean and standard deviation ( ) of depth and textural sediment characteristics taken in transect I during the years 1987-1988. #: station of samples, Dist.: distance from shore in nautical miles (1 nm = 1,853 meters), Md: arithmetic mean, SD: standard deviation, Skn: skewness, NS: number of samples.

#	Dist.(nm)	Depth(m)	Mud (%)	Md (Ø)	SD(Ø)	Skn(Ø)	NS
A	0.25	2.9(0.58)	0.04(0.01)	3.24(0.01)	0.16(0.01)	-0.03(0.05)	3
B	0.5	4.8(0.76)	0.19(0.33)	3.25(0.01)	0.16(0.01)	-0.01(0.02)	9
C	0.75	7.4(0.82)	3.94(8.18)	3.43(0.47)	0.49(0.68)	0.19(0.32)	8
D	1	8.6(0.70)	3.47(6.77)	3.36(0.27)	0.43(0.59)	0.20(0.30)	8
E	1.5	9.8(0.30)	13.07(19.04)	3.95(1.26)	1.05(1.39)	0.36(0.34)	8
F	2	10.5(0.30)	7.98(16.78)	3.64(0.99)	0.63(1.09)	0.28(0.22)	8

Table 2: Samples used in Gulland & Holt plot (see Figure 7). *: samples used in the estimation of growth. The first two mean in samples 1 and 2 were obtained from frequency histograms with 1 mm intervals.

Sample	Date	N	Mean	SD
1	04.10.86	285	1.6	0.475
			50.2	3.612
2	08.28.86	1,469	2.1*	0.949
			4.7	1.380
			45.0	3.603
			53.8	0.721
3	06.01.87	534	13.8*	4.363
			48.7	3.844
4	05.05.88	103	28.9*	4.306
			49.9	1.886
5	06.04.90	216	13.7	2.539
			45.7*	3.704
			54.8	2.665

Table 3: Growth and mortality parameters calculated for the different Atlantic species of *Mellita*.

Species	Loo	k	Z	Method	Author
M. tenuis	149-143.5	0.462-0.422	-	Waldorf (1946)	Lane & Lawrence, 1980
M. tenuis	117.6	0.456	-	Fabens (1965)	Lane & Lawrence, 1980
M. isometra	123	0.550	0.870	Ebert (1973)	Ebert & Dexter, 1975 (from data of Weihe & Gray, 1968)
M. quinquiespeforata	70.3	0.281	1.347	G & H (1959)	This study
M. quinquiespeforata	63.3	0.330	0.885	Fabens (1965)	This study
M quinquiespeforata	72	0.278	1.408	ELEFAN I*	This study

* This method included parameters of oscillation that result in C = 1 and WP = 0.6 (Rn = 0.08).