Influence of an oil spill on the abundance of *Callichirus major* (Say, 1818) on a sandy beach in southeastern Brazil (Crustacea: Decapoda: Thalassinidea).

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Abstract

The effect of a massive oil spill (May 1994) on the abundance of the *C. major* population was investigated. Data obtained after the spill (August 1994-December 1995) were compared to those collected on a previous period in which no large scale oil spill occurred in the region (October 1987-July 1989; April 1994). Additional data were collected in March 1998, July and October 1999 to verify possible recovery of the population. On each sampling date, burrow openings were counted inside 28 to 60 quadrats (1m^2 each).The t test for paired samples (α = 0.05) was applied for comparisons of corresponding months of different years within and between study periods. Data from the 1987-1989 period showed a seasonal pattern with peaks of variable heights in June and October. Significant differences occurred only in June (1988 vs. 1989), possibly due to variations in recruitment intensity. After the oil spill density decreased markedly and remained low up to December 1995. All mean densities obtained in the 1994-1995 period were significantly different when compared to those of the 1987-1989 period. This made evident that the influence of the spill lasted for at least 19 months. Data collected in 1998 and 1999 were similar to those of the period prior to the spill and point to recovery of the *C. major* population density.

Key words: *Callichirus major*, Thalassinidea, population density, oil spill

Introduction

Thalassinidea species, particularly those belonging to the families Callianassidae and Upogebiidae are commonly found in large numbers inhabiting burrows in intertidal and subtidal sediments (Dworshak and Rodrigues, 1997). These animals are therefore highly susceptible to oil spills in areas near oil plants and refineries. In spite of this, knowledge of the effects of these accidents on Thalassinidea is very limited: Amos *et al.* (1983) studied the physical and chemical properties of the oil that filled *Callichirus islagrande* (Schmitt, 1940) burrows on Mustang Island Beach (Texas, USA) after a spill in the Gulf of Mexico, including brief, qualitative descriptions of abundance decrease and of population recovery; Clifton *et al.* (1984) applied oil experimentally in the sediment of a tidal flat in Willapa Bay (Washington, USA) to analyze the resulting temporal trends of abundance and bioturbation activity of *Neotrypaea californiensis* Dana,1854.

Callichirus major (Say, 1818) is currently known from sandy beaches of the western Atlantic, ranging from North Carolina, USA (Hay and Shore, 1918), up to the of Santa Catarina Island, southern Brazil (Rodrigues and Shimizu, 1997). Morphological differences in adults and larvae (Rodrigues 1985; Strassler and Felder, 1999, respectively) and genetic differences (Staton and Felder, 1995) verified between populations suggest that this apparently wide geographic distribution is due to a complex of sibling species rather than to a single species. In Brazil, *C. major* is among the most common macrofauna species of sheltered sandy beaches. It is the dominant species among the larger, long lived, tube or burrow dwelling components of the fauna (Rodrigues and Shimizu, 1997).

This study investigates the changes in density of a *C. major* population after an oil spill. A post-spill monitoring of this population was conducted and a preliminary analysis of the results was presented by Shimizu and Rodrigues (2000). Here we compare these results to data collected during a previous period with no significant disturbance, to provide a more detailed and objective assessment of the oil spill effects on the population. Recovery of the former levels of density is also assessed based on data collected over three years after the spill.

Material and Methods

Study site

The population of *C. major* analyzed in this study was located on Barequeçaba Beach, São Sebastião, São Paulo (45º16'W/23º49'S). This sheltered sandy beach is 1.2 km long, delimited by two rocky points, and backed by a human settlement. The intertidal zone averages 90 m in width at spring low tides with slope varying seasonally from 1/50 (winter) to 1/60 (summer). The sediment is composed of very well sorted to poorly sorted fine sand, the mean particle diameter ranging from 0.11 to 0.23 mm (3.22 to 2.13 f). Mean temperature and salinity of interstitial water ranged from 20.0 to 28.0ºC and 28.0 to 31.3 parts per thousand, respectively (Shimizu and Rodrigues, 2000).

On Barequeçaba Beach, *C. major* occupies the infralittoral fringe (according to the zonation scheme by Dahl, 1952) and is gradually replaced seawards by another callianassinid, *Sergio mirim* (Rodrigues, 1971).

In May 15, 1994, a massive oil spill occurred in the São Sebastião Channel due to a rupture of the oil duct that connects the local maritime oil terminal to the Cubatão refinery. The greatest impact of the oil spill on the sandy beaches of the region was on Barequeçaba. During the cleaning operation conducted by the local environmental agency, 86 m^3 of oil were removed manually from the higher part intertidal area of this beach (CETESB 1994).

Data collection

Population density was monitored approximately monthly by counting burrow openings inside quadrats delimited by a 1m^2 square frame. The number of quadrats used on each sampling date ranged from 43 to 59 in the 1987-1989 period, and from 28 to 60 in the 1994-1995 period and in the additional samplings in 1998 and 1999 (Table 1). The placement of the quadrats was determined with the aid of a random numbers table. Samplings were avoided near the upper distribution boundary of *C. major*, where densities were very low. The region exposed only on very low tides, was also avoided to prevent biases in counting burrow openings, caused by the occurrence of *S. mirim*. This method tends to be selective against the newly settled, smallest individuals of the population because the openings of the burrows are hardly visible. Thus, it is possible to sample juveniles only when they grow large enough to produce burrow with clearly visible openings, that is, 5 to 7 months after settlement (Shimizu and Rodrigues, 2000).

Table 1: Number of quadrats used on each sampling date for counting burrow openings of *C. major* on Barequeçaba beach.

	1987	1988	1889	1994	1995	1998	1999
Jan					28		
Feb							
Mar		48	46		55	45	
Apr		48		60	60		
May		44	46		60		
Jun		46	46		60		
Jul			46				60
Aug		46		57	60		
Sep		51		60			
Oct	59	46			60		60
Nov	43	47		59			
Dec	44			60			

Data obtained in two monitoring periods are considered for comparison: October 1987 to July 1989, when no large scale oil spill occurred in the region, and April 1994 (one month prior to the accident) to December 1995. Additional data were collected in March 1998, July and October 1999 to assess recovery of the population.

Data analysis

In each sampling period, corresponding months of different years were compared to each other with paired-samples t test ($\alpha = 0.05$) to verify whether the temporal variation of density presented a yearly pattern. Data collected in the period prior to the oil spill (1987-1989) were used as the reference for the assessment of the spill impact (comparisons with data from the 1994-1995 period) and recovery of the population density (comparisons with data from the 1998-1999 samples). As the reference period presented a temporal pattern (see Results) comparisons to other periods were restricted to corresponding months.

When the compared samples had different sizes, data pairs were drawn at random according to the size of the smaller sample. Since the assumption of the test (differences of paired data distributed normally) was not satisfied in some comparisons, the non-parametric Wilcoxon test was also applied. Both tests provided virtually identical results and thus those obtained with the parametric test will be considered here. Tests were performed according to Zar (1996).

Results

The density of *C. major* burrows varied seasonally in the 1987-1989 period with peaks in June (1988 and 1989) and October (1987 and 1988) (Figure 1). When comparing density of one same month in different years (Figure 2A) significant difference occurred only between June 1988 (mean = 7.0 burrow^{-1}) and June 1989 (mean = 4.9 burrow^{-1}) (Figure 2B). This shows that peak values of density can vary from one year to other. Conversely, other comparisons within this period resulted non-significant (Figure 2B) showing that density values of corresponding months in different years were very close, including the peaks of October 1987 and October 1988. Once this pattern was verified, data obtained in 1988 were used as the reference for comparisons with the 1994-1995 period.

After the spill in May 1994 density decreased markedly until November and remained low (about 2 burrows.m^{-2}) in the following 13 months (Figure 3). This decrease was significant as shown by the comparison of paired months (Figure 4A,B).

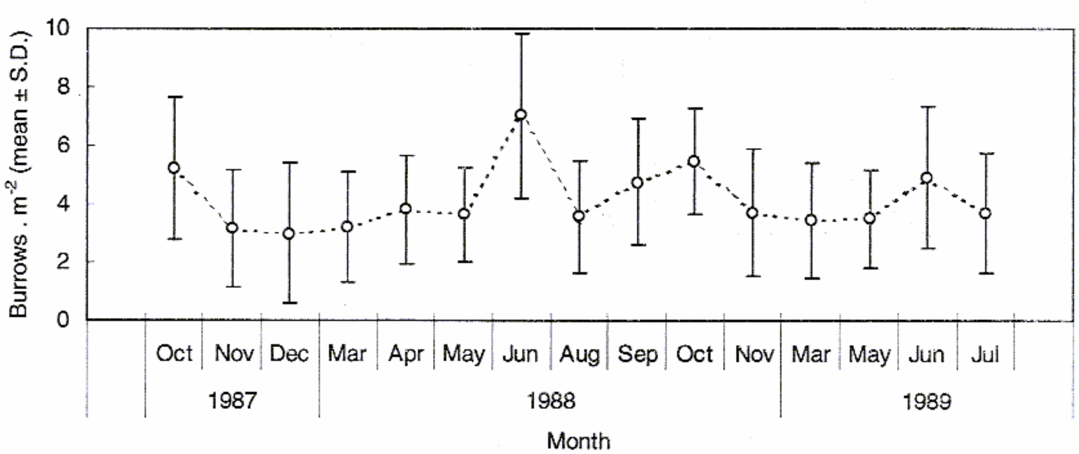

Figure 1: *Callichirus major*, Barequeçaba beach. Temporal variation of mean (± s.d.) density during the 1987-1989 period. Curve included for visual analysis only and does not represent interpolation.

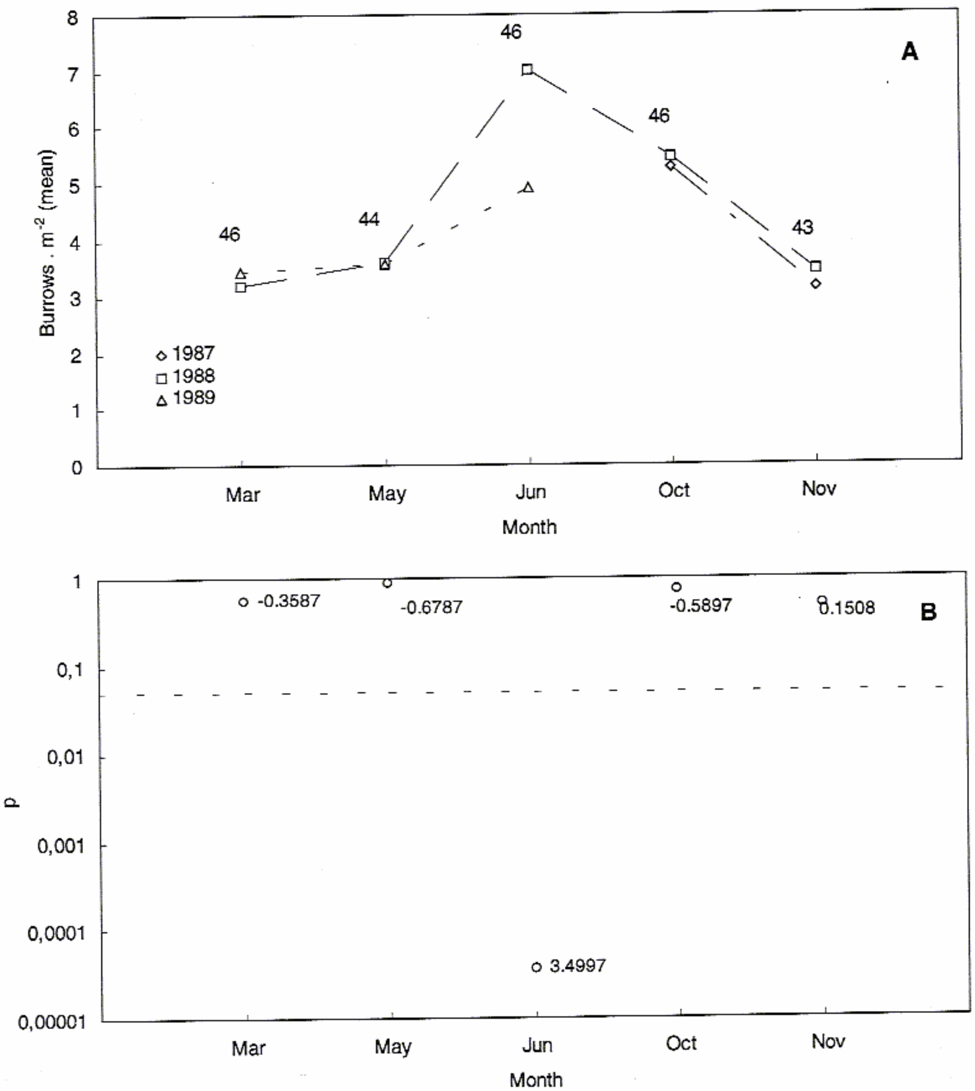

Figure 2: *Callichirus major*, Barequeçaba beach. Comparison of densities between corresponding months of different years in the 1987-1989 period. A - Mean densities (labels indicate the number of data pairs used in the statistical test in each comparison; curves included for visual analysis only and do not represent interpolation). B - Significance levels of paired-sample t test (labels indicate the value of the t statistic in each comparison; dashed line indicates the 0.05 level).

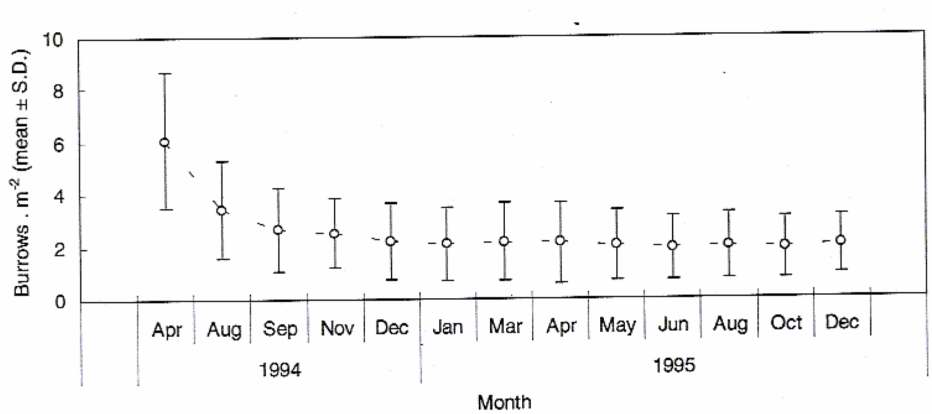

Figure 3: *Callichirus major*, Barequeçaba beach. Temporal variation of mean (± s.d.) density during the 1994-1995 period. Curve included for visual analysis only and does not represent interpolation.

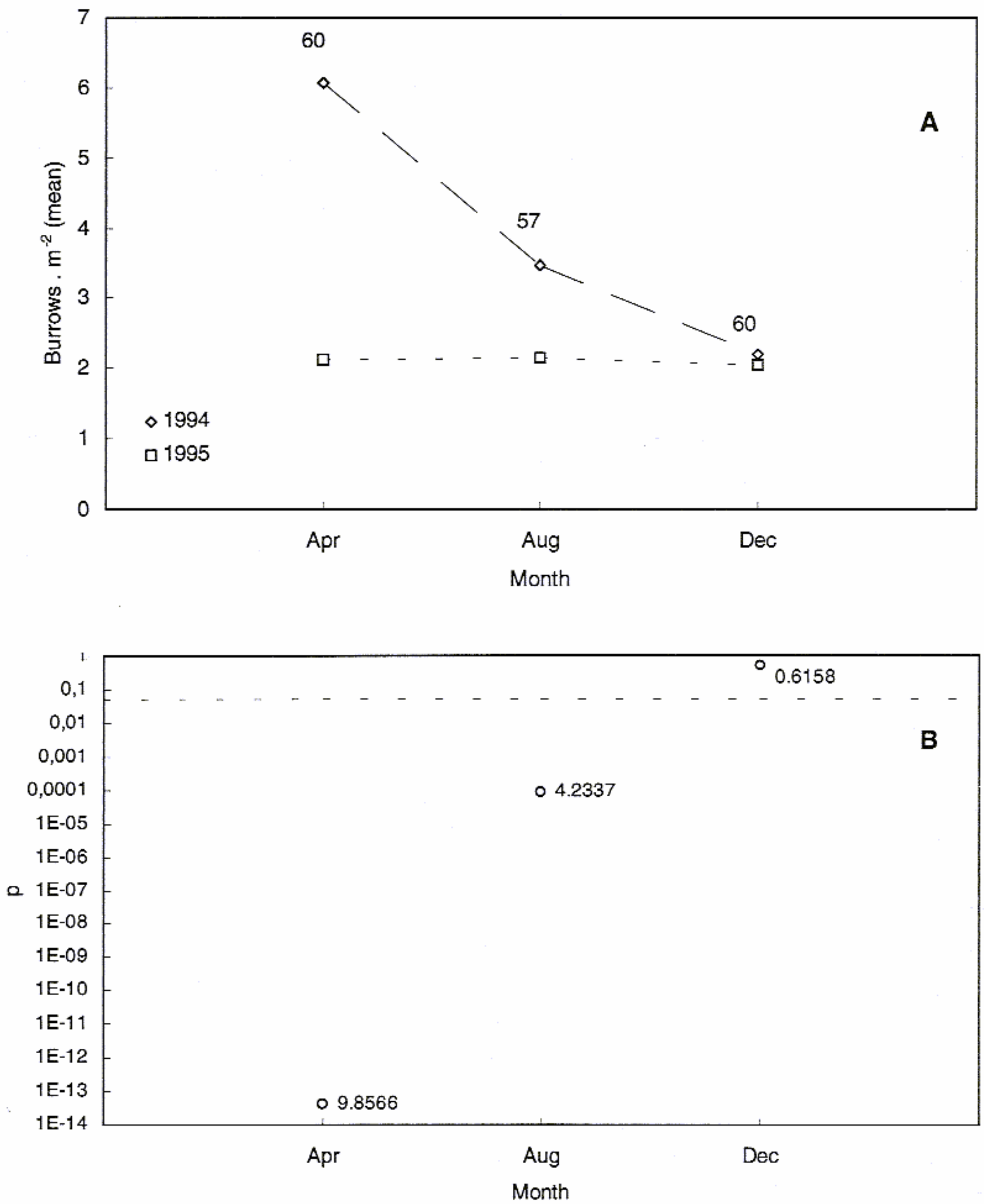

Figure 4: *Callichirus major*, Barequeçaba beach. Comparison of densities between corresponding months of different years in the 1994-1995 period. A - Mean densities (labels indicate the number of data pairs used in the statistical test in each comparison; curves included for visual analysis only and do not represent interpolation). B - Significance levels of paired-sample t test (labels indicate the value of the t statistic in each comparison; dashed line indicates the 0.05 level).

Comparing the data of the 1994-1995 period to those of 1988, the effect of the oil on the population density became even more evident (Figure 5A). All differences between paired samples were significant (Figure 5B). The largest differences and lowest significance levels occurred when comparing paired samples of June and October (1995 vs. 1988). This was due to the lack of seasonal density increase in the 1994-1995 period.

No significant difference was detected when densities of March 1998 and July 1999 samples (Figure 6) were compared to those of the corresponding months of the 1987-1989 period (Figure 7A,B). Conversely, paired samples of October were significantly different since the seasonal increase in density was not detected again in 1999. However these results points to a recovery of population density, since two (March 1998 and October 1999) out of three sample means were very close to those of the corresponding months in the period prior to the oil spill. Additionally, densities of these same two samples differed significantly from those of the corresponding months in 1995 (Figure 8). None of the samples collected in the 19 month period that followed the spill had shown this trend.

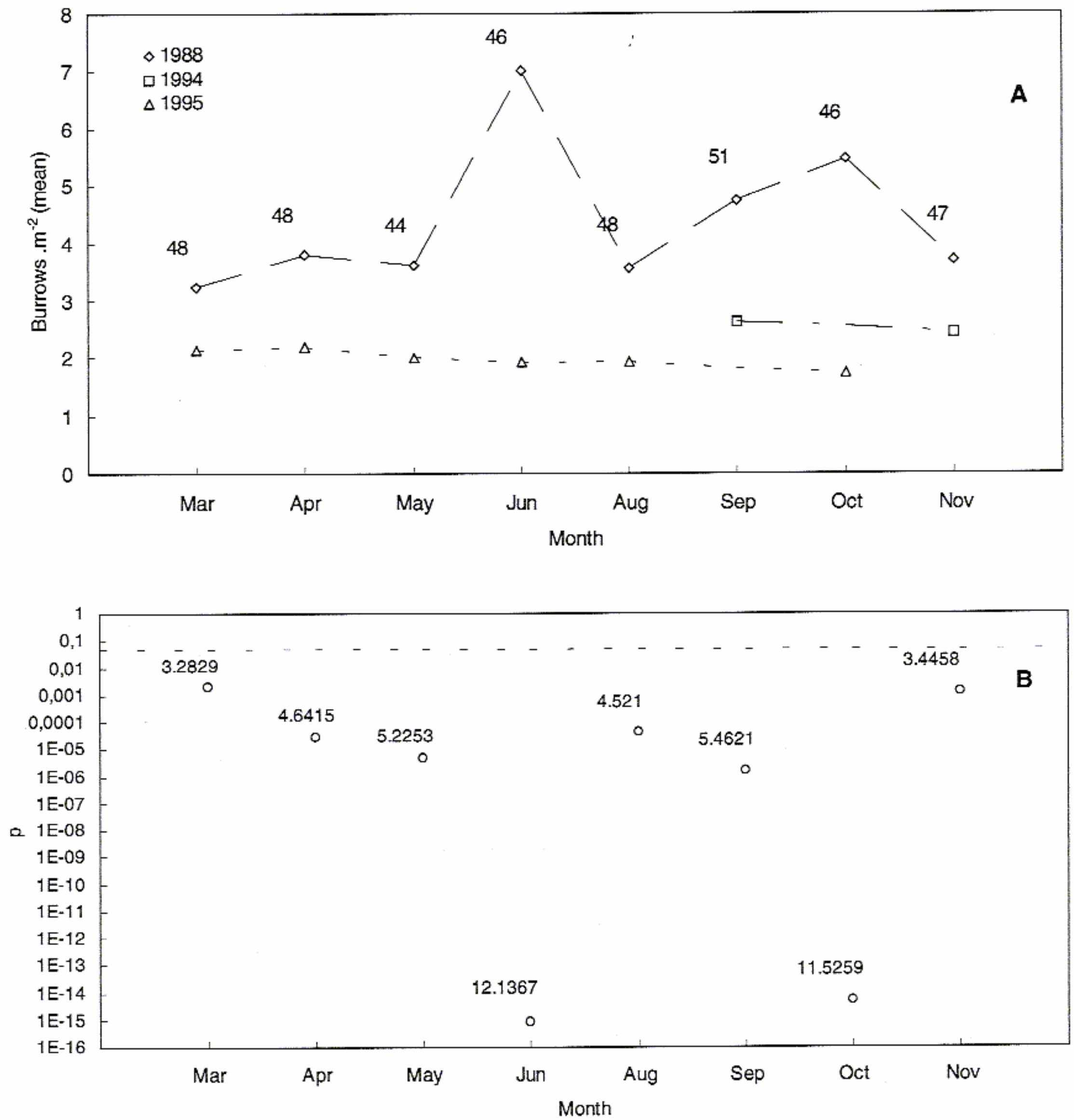

Figure 5: *Callichirus major*, Barequeçaba beach. Comparison of densities between the reference period (1988) and the post-spill period (1994-1995). A - Mean densities (labels indicate the number of data pairs used in the statistical test in each comparison; curves included for visual analysis only and do not represent interpolation). B - Significance levels of paired-sample t test (labels indicate the value of the t statistic in each comparison; dashed line indicates the 0.05 level).

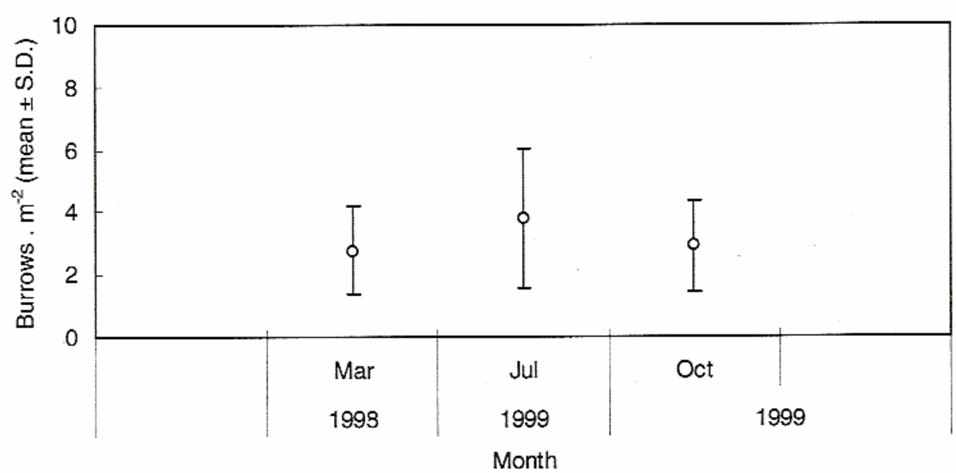

Figure 6: *Callichirus major*, Barequeçaba beach. Mean densities (± s.d.) in the samples collected in 1998 and 1999

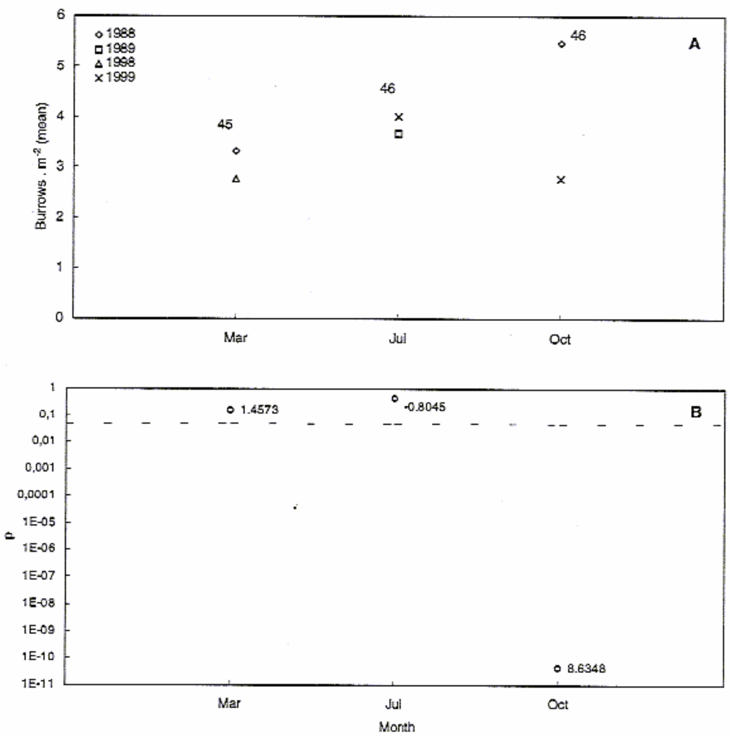

Figure 7: *Callichirus major,* Barequeçaba beach. Comparison of densities in the samples collected in 1998 and 1999 with the corresponding months of the 1987-1989 period. A - Mean densities (labels indicate the number of data pairs used in the statistical test in each comparison). B - Significance levels of paired-sample t test (labels indicate the value of the t statistic in each comparison; dashed line indicates the 0.05 level).

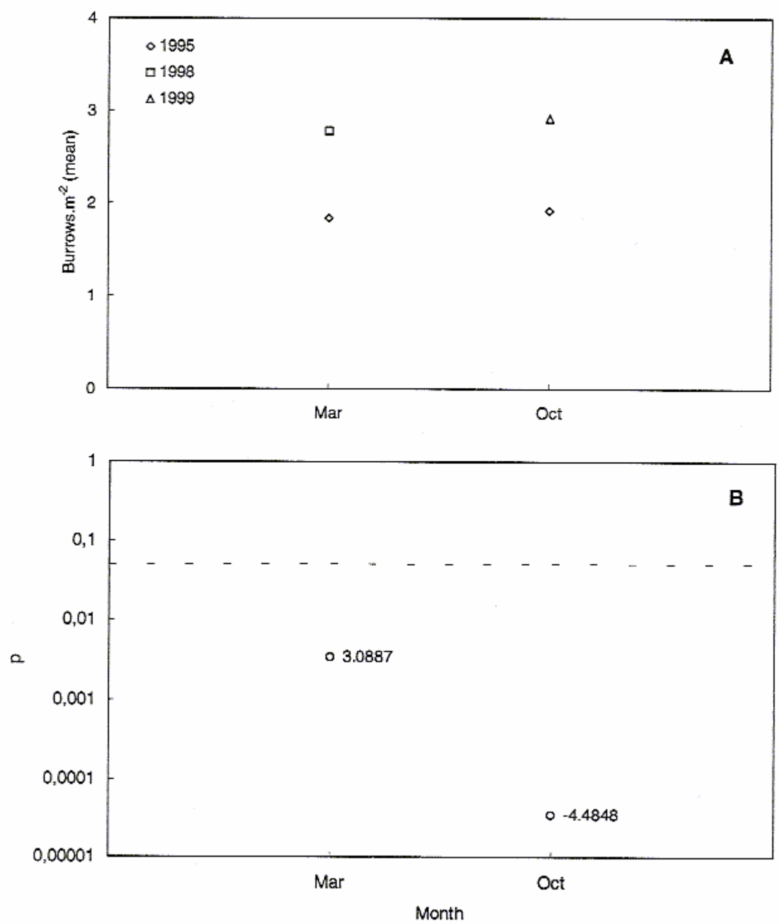

Figure 8: *Callichirus major,* Barequeçaba beach. Comparison of densities in the samples collected in 1998 and 1999 with the corresponding months of the 1994-1995 period. A - Mean densities (labels indicate the number of data pairs used in the statistical test in each

Discussion

Seasonal increase of density in thalassinidean populations is attributed to recruitment events (Tamaki and Ingole, 1993; Dumbauld *et al.*, 1996). This applies to the studied *C. major* population, since the October density peaks recorded in both 1987 and 1988 corresponds to the recruitment period (Shimizu and Rodrigues, 2000). Although data explaining the high density values of June 1988 and 1989 are not available, it is hypothesized here that these values are resultant of an earlier cohort entering the population. This is supported by records of ovigerous females with well-developed ovaries in this population, potentially producing more than one brood per reproductive period (Shimizu, 1997). Should this hypothesis be true, variation in recruitment intensity would account for the difference in density detected between June 1988 and June 1989. Annual variation of recruitment intensity was verified in several thalassinidean populations (Tunberg, 1986; Tamaki and Ingole, 1993; Dumbauld *et al.*, 1996; Pezutto, 1998). Souza *et al.* (1998) also detected a seasonal variation of density in a *C. major* population on Atami Beach, State of Paraná, southern Brazil. These authors suggest that the decrease in density that follows the summer peak is related to mortality and/or reduced burrowing activity.

The decrease and maintenance of low values of density that followed the oil spill are very similar to that recorded by Clifton *et al.* (1984) for *N. californiensis* after experimental exposure to oil. The similarity is remarkable even considering that *C. major* and *N. californiensis* inhabit environments with different climatic, hydrodynamic, and sediment conditions (tropical sandy beach and temperate tidal flat, respectively). A drastic abundance reduction after exposure to spilled oil was also reported (textual description) for *C. islagrande* (Amos *et al.*, 1983). Clifton *et al.* (1984) attributed the lowering of *N. californiensis* density in their experimental plots to emigration and inhibition of recruitment by the layer of oil buried in sediment rather than to mortality. We cannot discard mortality for *C. major* since in Barequeçaba beach oil reached most of the midlittoral zone and the sublittoral fringe rather than delimited plots. By this reason emigration would unlikely be the major cause of density reduction in 1994. Conversely, oil trapped in the sediment might have affected recruitment in 1995 when only a subtle increase in proportion of juveniles occurred (Shimizu and Rodrigues, 2000). A buried oil layer was clearly visible 14-15 cm deep in the sand in May and June 1994 and residual oil was found in the sediment and adhered to the exoskeleton of the specimens during the following six months. Thus it is reasonable to suggest that oil persisted in the sand until settlement period in early 1995 (Shimizu and Rodrigues, 2000). However, further experimental studies are required to distinguish recruitment inhibition from natural variations in reproduction, and larval and post-settlement survival (Hadfield, 1986). This additional information would be especially useful for the studied population since significantly different density values possibly due to natural variation in recruitment occurred (as seen in June 1988 vs. June 1989 comparison).

Data obtained in 1998 and 1999 suggest that density recovered within 20 to 46 months following the spill. Since density values in March 1998 and July 1999 were close to those of the reference period, we believe that the difference between October 1988 and October 1999 was resultant of a natural variation of recruitment rather than of an inhibitory effect due to residual oil. Amos *et al.* (1983) found numerous active burrows (textual description) of *C. islagrande* 29 months after exposure to oil. Clifton *et al.* (1984) reported no evidence of recovery of *N. califiorniensis* in the experimental plots during their study period. Despite the limited sample numbers and the wide time interval estimated for recovery, we believe that the present results are relevant for the knowledge of thalassinidean biology and for assessment of oil spill impacts on sandy beach macrofauna.

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