Distributional patterns, seasonal abundance and moult cycle of *Callinectes danae* Smith, 1869 in the Ubatuba region, Brazil

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Abstract

The occurrence and distribution of *Callinectes danae* as a function of size and moult activity were studied in Ubatuba Bay and the Acaraú River. Three fixed transects were sampled in the estuary and seven within the Ubatuba Bay by means of bottom trawling. Montlhy samplings were carried out from Sep/95 to Aug/96. Salinity, temperature, dissolved oxygen in the water and organic contents of the substratum were monitored. This species shows a widespread distribution over the study area, but only juveniles were found within the estuary while all demographic categories were recorded in the bay with the prevalence of adult crabs. Size comparisons revealed significant differences between samples obtained in the estuary and the bay. Moulting activity was intense in the estuary, observed in at least 50% of the individuals. Highest abundance values occurred in summer. Juveniles outnumbered adults throughout the year. Salinity was the most important factor affecting spatial distribution of this species. A set of favourable conditions, i.e. low salinity, food availability and shelter, characterise the Acaraú River. Such an environment may be regarded as a propitious area for the recruitment and subsequent growth of *C. danae* juveniles.

Key words: distribution, *Callinectes danae*, moult, Ubatuba, Brazil.

Introduction

The distributional patterns of swimming crabs result from a combination of habitat preferences and intra / interspecific interactions (Buchanan and Stoner, 1988). According to Neto and Lana (1994) there is still a lack of studies regarding succession and communuity dynamics of benthic communities along the Atlantic tropical and subtropical coasts of South America.

The swimming crab *Callinectes danae* Smith, 1869 lives in a variety of habitats including muddy bottoms of estuaries, mangroves and certain marine environments such as gravelly areas covered with algae, sandy beaches and deeper oceanic grounds up to 70-m deep, thus tolerating wide salinity variations (Williams, 1984).

Euryhaline species are considered reproductively conservative. Those organisms store energy in low salinity habitats but spawn and incubate their eggs in higher salinity environments (Norse, 1978). The size at which some *C. danae* females attain sexual maturity and the size of females starting their migration are coincident, indicating that both processes are directly related (Pita *et al.*, 1985). Offshore migration of ovigerous females for brooding is required because larval stages are presumably much less tolerant to salinity variations (Paul, 1982; De Vries *et al.*, 1983). Pita *et al.* (1985) hypothesised that osmotic pressure would be important for embryonic development and saline water would facilitate larval buoyancy.

During the juvenile phase, these swimming crabs migrate to estuarine areas (Van Engel, 1958; De Vries *et al.*, 1983). While in this stage, predation pressure is high for what juveniles selectively seek for microhabitats where predatos are less abundant or less effective (Hines *et al.*, 1995). According to Guerin and Stickle (1997), juveniles benefit on the abundance of shelter and food in the estuarine environment, which are often limited in coastal areas.

Since growth and most part of reproductive events of these organisms take place in brackish waters, the estuarine phase of their life cycle is also probably the most critical (Steele and Bert, 1994). Due to the relative abundance of swimming crabs about to mate in near-estuarine areas, reproductive success is thought to be higher in such environments (van Engel, 1958; Shirley *et al.*, 1990).

Temperature, salinity, substrate type and food availability are considered the main factors affecting growth, survivorship and distribution of several crustaceans (van Engel, 1987). The moulting process can also influence their distribution as verified for the blue crab *Callinectes. sapidus* by Shirley *et al.*, 1990. Studies on the influence of environmental factors in the moult cycle had evidenced the importance of temperature, food supply (Chittleborough, 1975), photoperiod (Quackenbush and Herrnkins, 1983) and space availability (Cheng and Chang, 1994). All these factors were shown to affect the intermoult period, molt increment or both.

Shedding the old exoskeleton, *i.e.* moult or ecdysis, is the most obvious manifestation of moulting activity. However, this event usually takes a few minutes within a moult cycle that may last a year or more. Newly moulted crustaceans are extremely vulnerable, with limited capability of locomotion and usage of defensive appendages. Therefore, pre-moult crustaceans usually need to use adequate shelter (Chang, 1995). Endogenous factors as development stage, sexual maturity and state of regenerating appendages do also affect moulting frequency and moult increment (Skinner, 1985). There are both interspecific and intraspecific variations of the intermoult period. In the latter case, development phase and sex account for such variability (Du Preez and McLachlan, 1984; Conan, 1985). The intermoult period usually takes more than 66% of the whole moult cycle, while the pre-moult stage takes only 25%. Therefore, more than one reproductive cycle may occur within a single intermoult period (Santos, 1998).

Reproduction and growth are the physiologic processes of most energetic expenditure (Adiyodi, 1985), for what their intensity should be antagonic for a more efficient consummation of both processes (Adiyodi and Adiyodi, 1970). So far, all brachyuran crabs studied in the subtropical northern coast of São Paulo State show uninterrupted breeding along the year. Yet, the seasonal reproductive patterns of those species are poorly understood, probably due to the difficulty in identifying the stimuli, or their combination, responsible for the observed temporal patterns (Flôres, 1999).

The purpose of the present study is to examine the distribution patterns of *C. danae*, its abundance and moult cycle in Ubatuba Bay and Acaraú River in the Ubatuba region, SP.

Materials and Methods

Ubatuba Bay is located in the northern littoral of São Paulo State, Ubatuba County, within the following latitudinal and longitudinal ranges, 23° 29' 30" S - 23° 32' 30" S and 45° 10' 42" W - 45° 06' 30" W, respectively. The coastline of the northern São Paulo coast is markedly sinuous, enclosing several partially confined embayments. It is suggested that water and sediment exchange between coastal and shelf areas are considerably restricted (Mahiques, 1995).

The continental shelf off Ubatuba is 120-Km wide, divided in two main areas: an inner part, up to 50-m deep, highly influenced by mainland, and an outter area with depths ranging from 50 to 120 m, directly exposed to offshore conditions (Zembruscki, 1979). The inner area is subjected to the discharge of four main rivers: Indaiá, Rio Grande de Ubatuba, Lagoa and Acaraú. Higher deposition of organic matter, decreased salinity and inflow of domestic sewage from the growing Ubatuba County thereby affect this inner region. The Acaraú River is located near the plains of Grande, Tenório and Itaguá beaches, and the input of sewage is particularly heavy at this site. In the outter region, the influence of oceanic currents prevail (Nakagaki, 1998).

Samples were obtained monthly during a 1-yr period (September/1995 to August/1996) at Ubatuba Bay and Acaraú River (figure 1). At the Acaraú River, three fixed transects, each enclosing an area of 320 m^2, were delimited near the river mouth and sampled by trawling with an adapted otter-trawl net manually tractioned. Trawling at transect IV was perfomed with the aid of a shrimp fishery boat supplied with an otter trawl net, enclosing a sample area of 2,500 m^2. The remaining six transects, each enclosing an area of 7 Km^2, were delimited within the bay and sampled using two double-rig nets tractioned by a trawler. The exact location of each transect was chosen as to represent the environmental diversity within the bay, *e.g.* the proximity to sandy beaches, rocky shores or river drainage.

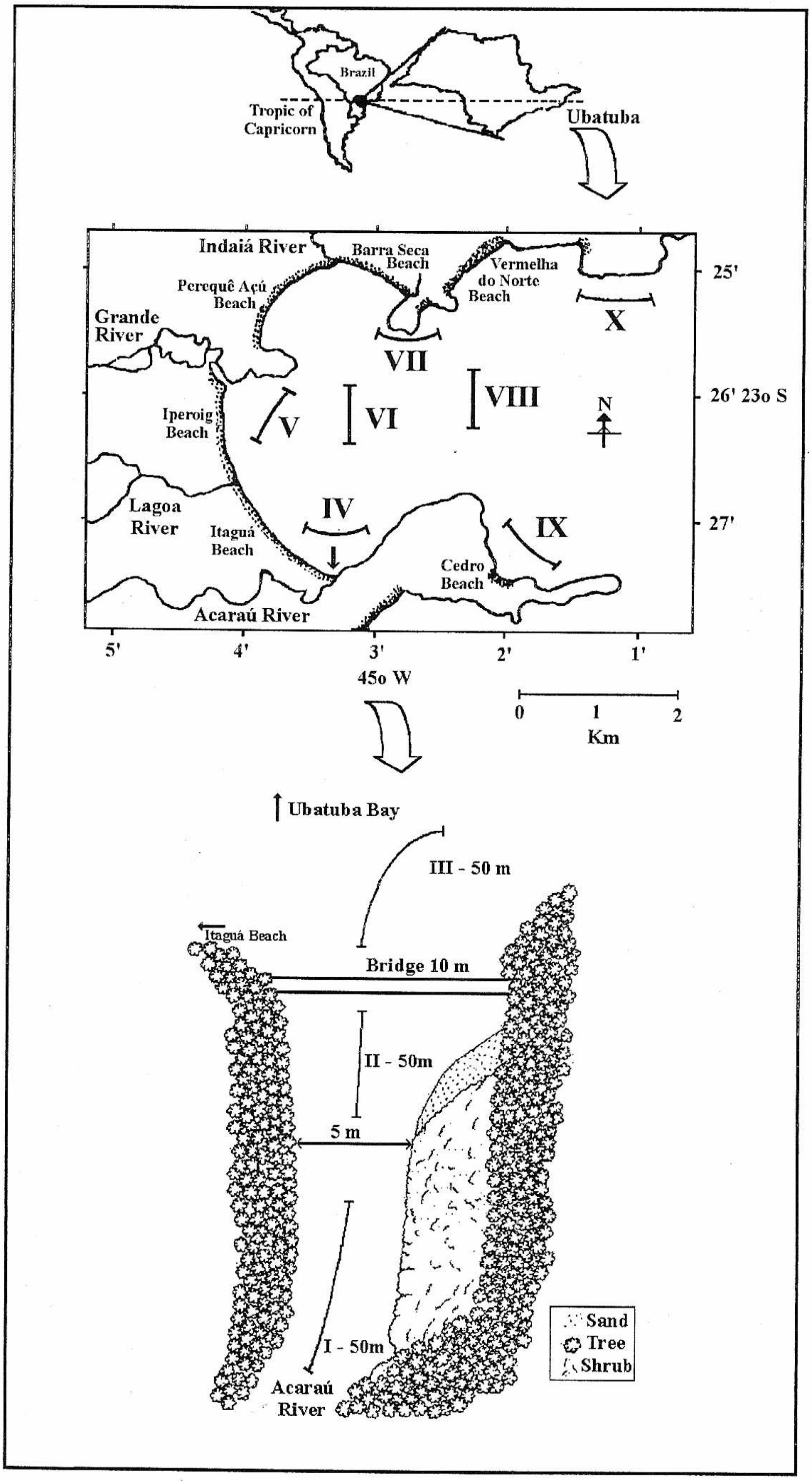

Figure 1: Ubatuba bay and Acaraú river with the localization of the transects sampled from Sep/95 to Aug/96.

Most relevant abiotic factors were recorded at each transect. Bottom-water samples were collected using a Van Dorn bottle. Temperature was measured with a high-precision thermometer, salinity was recorded using an optical rephractometer and dissolved oxygen was determined following Golterman and Clymo (1969) with the addition of sodium azide. Sediment samples were obtained using a Van Veen grabber. Each sample was subjected to sequential sieving according to the Wentworth (1922) scale. Organic matter content of samples in terms of percentage was estimated by subtracting dry weights

The specimens of *C. danae* were separated by transect and month. For biometric analyses, the carapace width excluding lateral teeth (CW) was used as a standard measure of size. Measurements were made using a vernier caliper and recorded with a 0.1-mm precision. Sex was determined by examining the morphology of the abdomen. Crabs were grouped in size classes according to the Sturges formula (Conde *et al.*, 1986):

$I = 1 + \log_2 n$;

Where I is the number of size intervals; n, the number of observations and Log_2 indicates the base 2 logarithm.

Median values of crab size were compared among transects and months using the Kruskal-Wallis non-parametric procedure.

Moult activity was recorded for all species following Skinner (1962 and 1985). For analysis, crabs were grouped in two categories with respect to moult activity. Active crabs included individuals in moult stages A, B, D and E, while inactive specimens were only those found in intermoult (stage C).

Comparisons of environmental factors among the ten transects were made using the Analysis of Variance, complemented by the Tukey test for multiple comparisons in order to verify differences of average values at the 5% significance level.

Results

Number of crabs obtained at each sampled site varied considerably, with a gradual decrease from transect I to transect X (figure 2). Largest catches took place at transects I, II and III at the Acaraú River estuary.

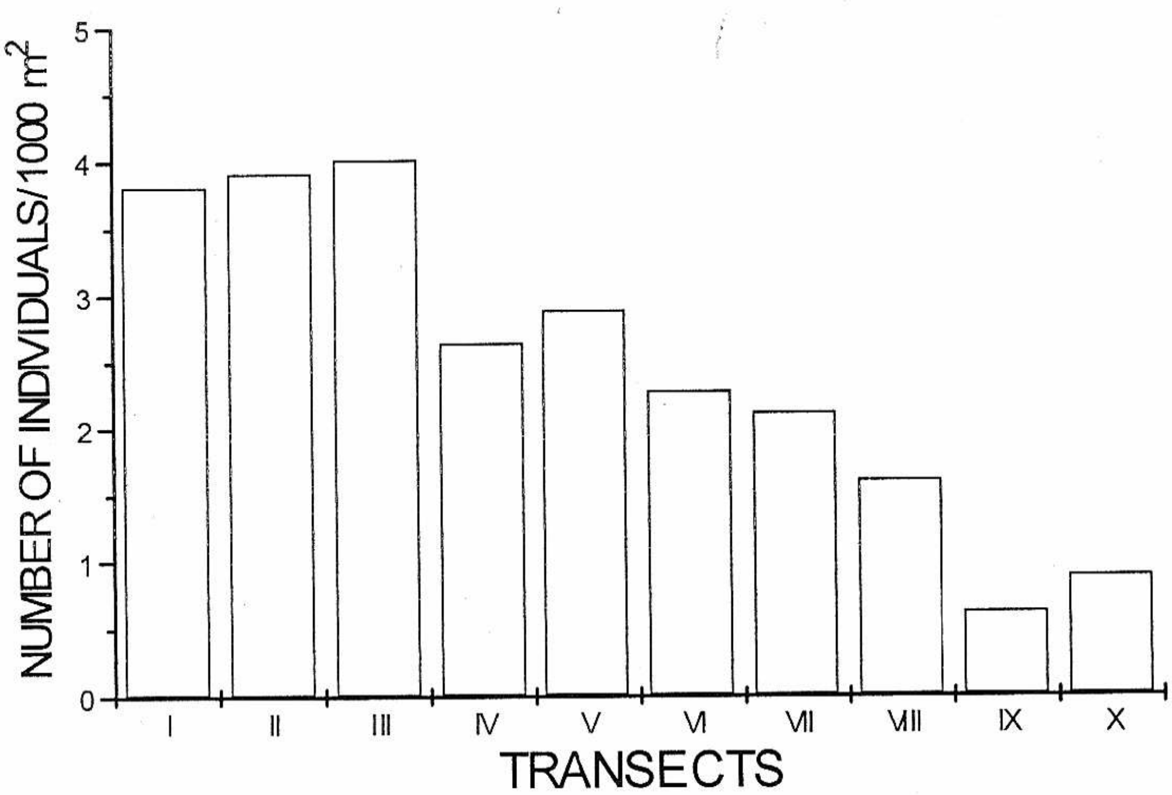

Figure 2: *C. danae*: Bar graph showing overall frequency values at each transect, Ubatuba Bay and Acaraú River included, during the period from Sep/95 to Aug/96.

Monthly abundance of the blue crab *C. danae* at Ubatuba Bay and Acaraú River varied significantly, with highest catches taking place in late summer (February) and early autumn (March) and lowest ones during spring (September to November). Juveniles prevailed throughout the whole sampling period except for March. Seasonal variation of frequency of ovigerous females showed two different peaks, the first in summer (February) and the second in winter (June). All demographic categories were present in all sampled months, evidencing continuous reproduction and recruitment for this species (figure 3).

By examining the monthly frequency of each demographic category at each sampled transect, it can be verified that the occurrence of juveniles is restricted to transects I, II and III delimited within the Acaraú River estuary. In the remaining transects, all demographic categories were recorded with a prevalence of adults (figure 4). This differential distribution pattern is characteristic of *C. danae*.

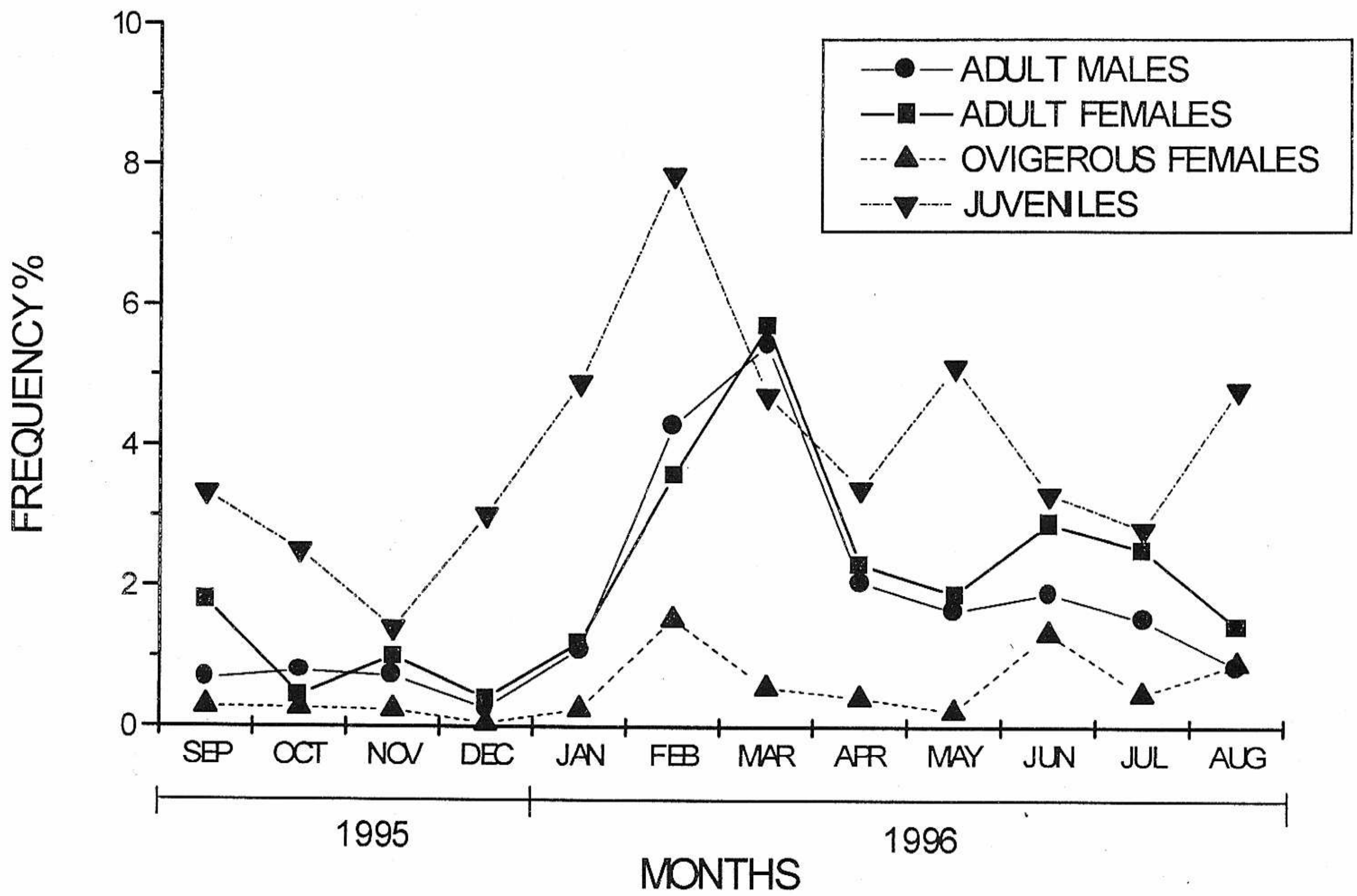

Figure 3: *C. danae*: Line graph showing the frequency of each demographic category from Sep/95 to Aug/96 in Ubatuba Bay and at the Acaraú River.

Size of individuals

Median size of individuals varied significantly among the different sampled transects, with smaller crabs at transects I, II and III compared to the rest. Among those and the remaining transects no statistical differences were detected. Median size of individuals at transect IX did not differ with none of the above referred groups (figure 5).

Moulting activity

The moult cycle was separated in two different components: the active phase (stages A, B, D and E) and the intermoult (C). Figure 6 shows the relative frequency of juveniles and adults together with the moult frequency obtained at each transect.

By pooling the relative frequency of intermoult males and moulting females, i.e. potentially mating individuals, it can be verified that copulation may take place throughout the year (figure 7). Yet, peaks of moulting activity in females (January and May) precede the peaks of oviparous crab (February and June).

Environmental factors

Average annual values of sampled factors and results of statistical tests are presented in table I. Temperature did not differ among transects ($P>0.05$). Other measured variabled did differ among transects. Salinity variation seems to be the main factor explaining this species' distribution.

The granulometric composition of the sediment in the eight transects (figure 8) varying from gravel to silt+clay. During the study period, small variation was observed in the texture of the sediment.

Discussion

Due to the complexity of the marine environment, the distribution of several organisms varies along their development (Olmi *et al.*, 1990). Ontogenetic phase transitions may result in co-occurrent habitat shift as a result of nutritional demands, competition and predation. Blue crabs are an example of how early development stages may be differentially influenced by both physical and biological factors (Pardieck *et al.*, 1999).

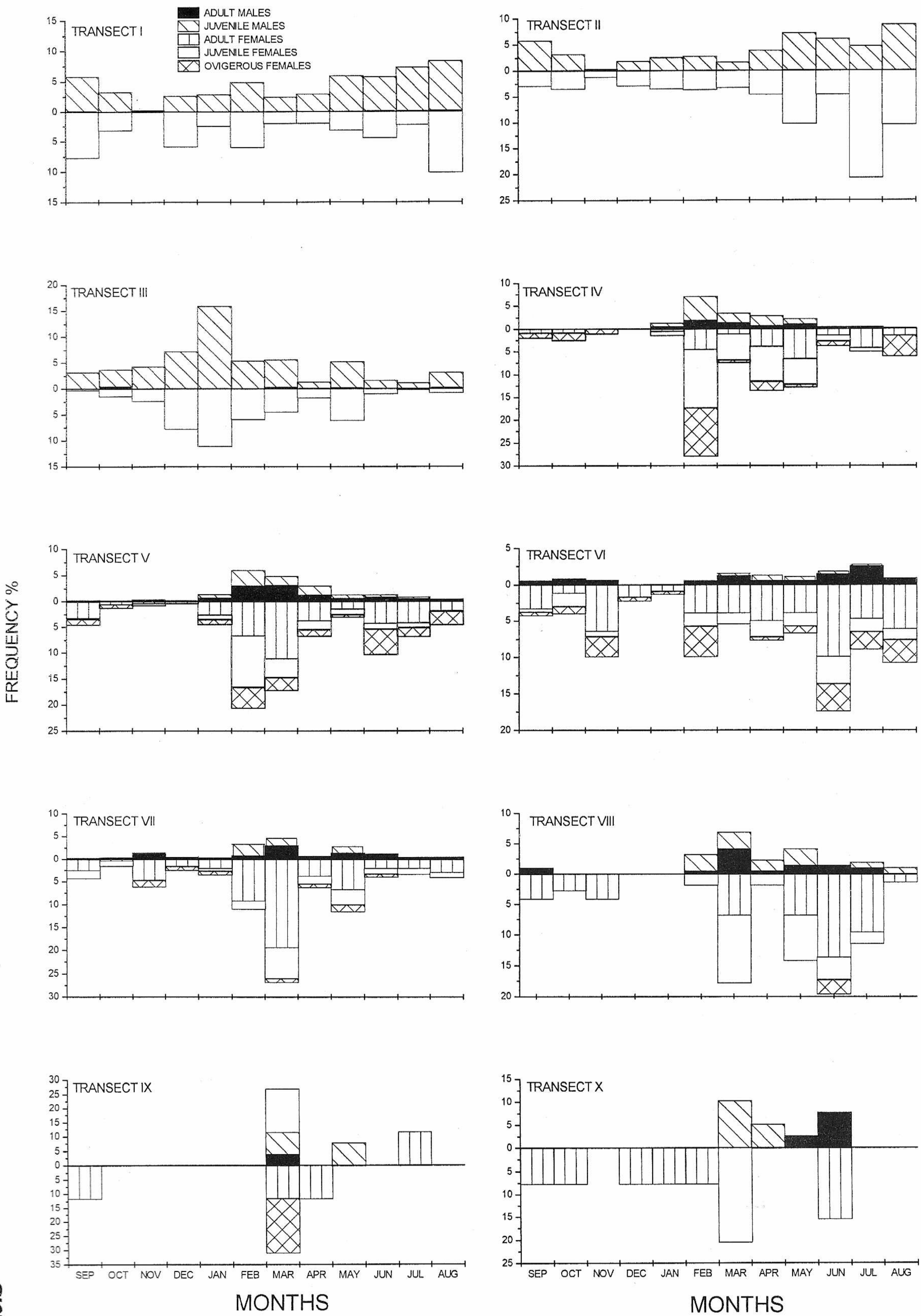

Figure 4: *C. danae*: Bar graph showing the monthly frequency of each demographic category at each sampled transect from Sep/95 to Aug/96.

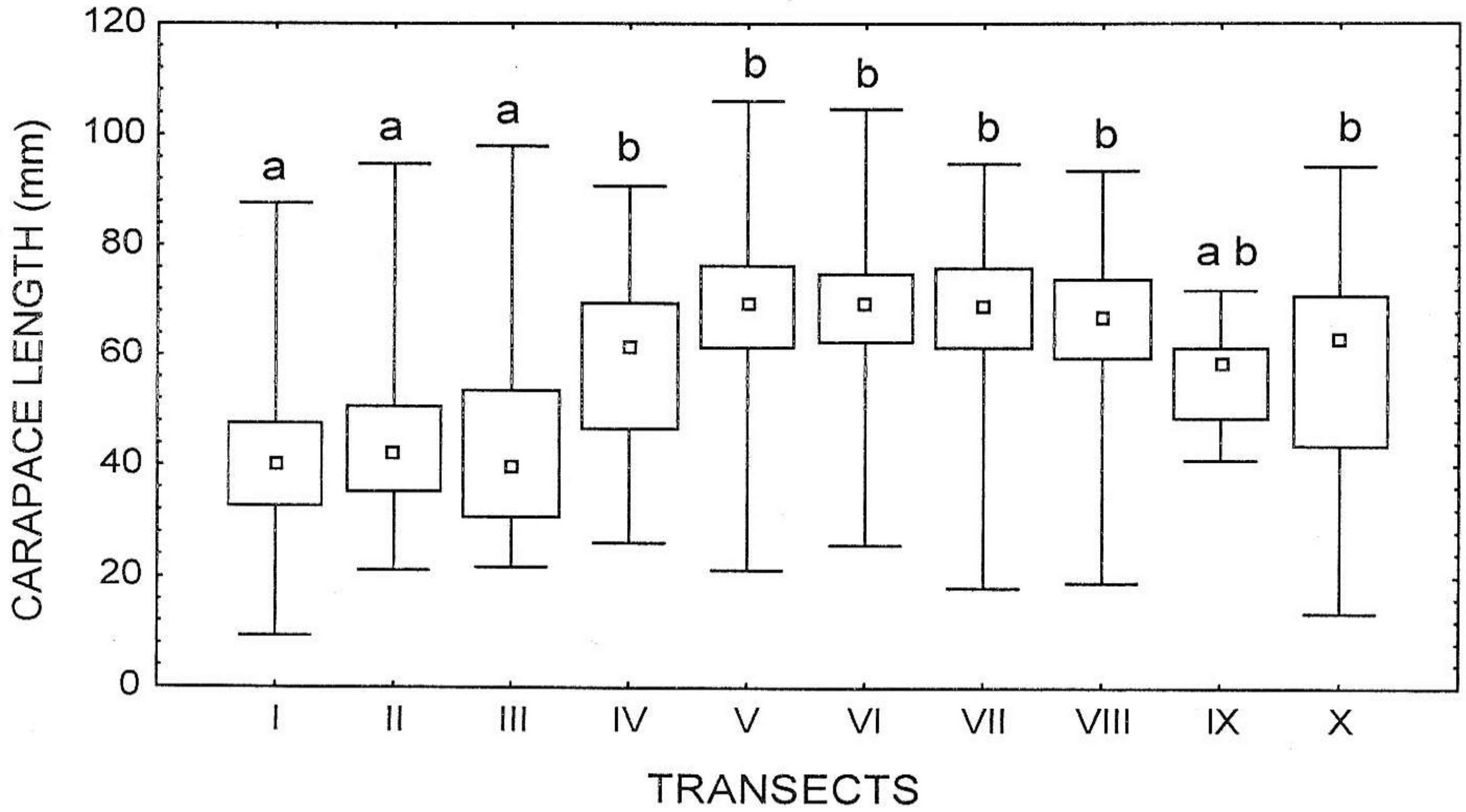

Figure 5: *C. danae*: Box and whiskers plots showing the size of individuals at each sampled transect from Sep/95 to Aug/96. Bars with at least one same letter in common did not differ statistically (α=0.05).

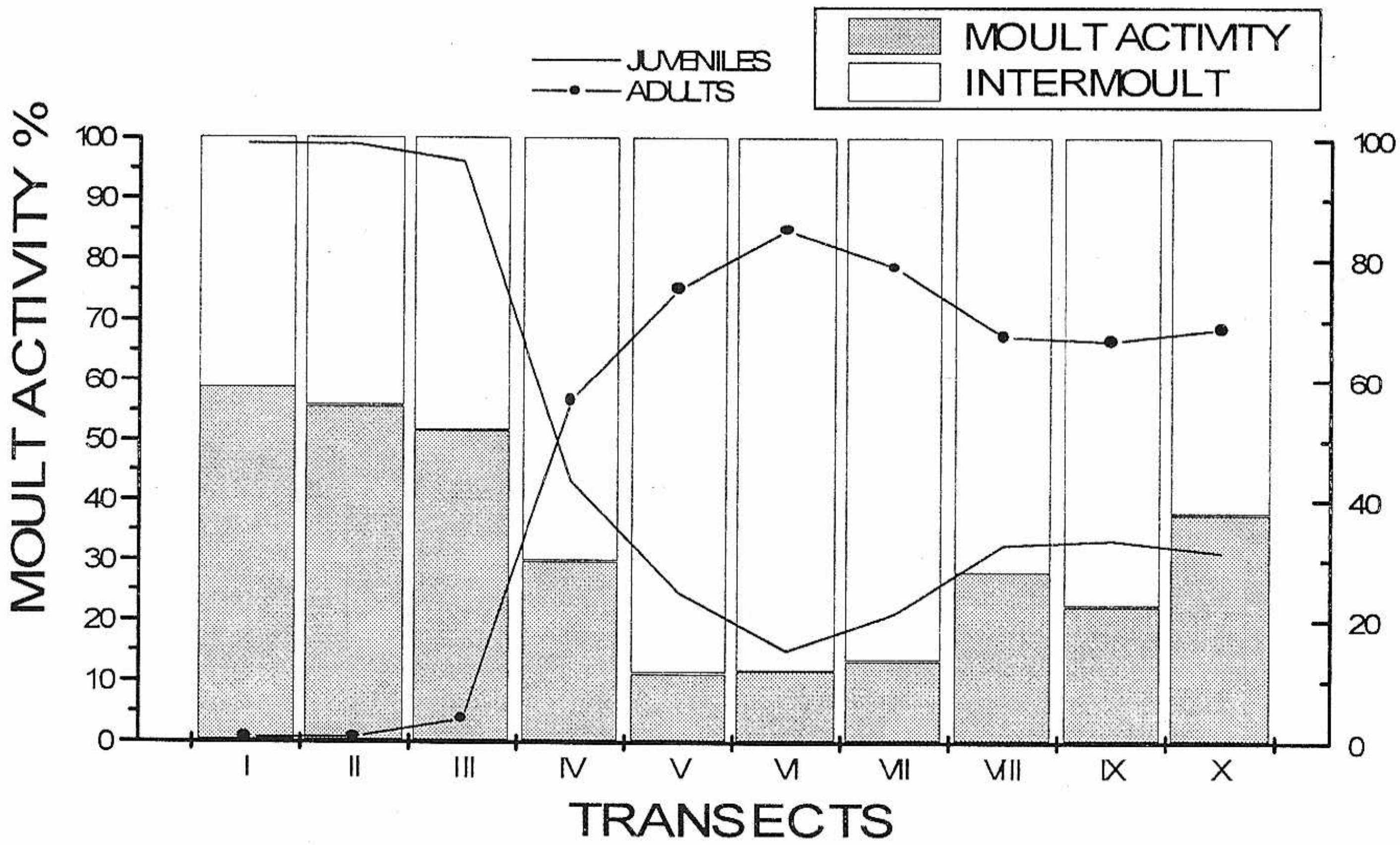

Figure 6: *C. danae*: Bar and line graph showing the relative frequency of young / adult and moulting / non-moulting crabs at each transect from Sep/95 to Aug/96.

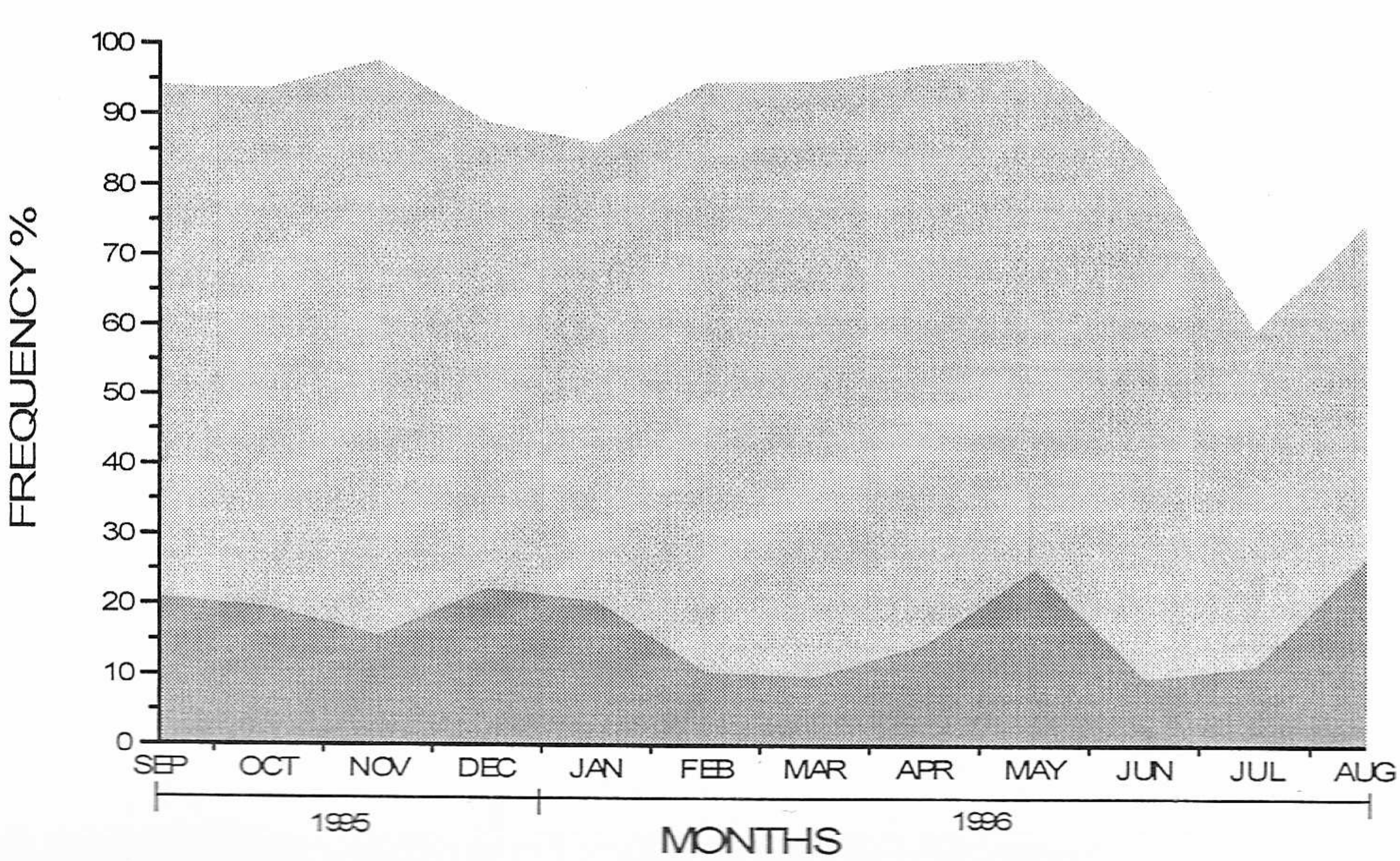

Figure 7: *C. danae*: Area graph for overall monthly relative frequencies of moulting females (dark gray) and intermoult males (light gray) from Sep/95 to Aug/96.

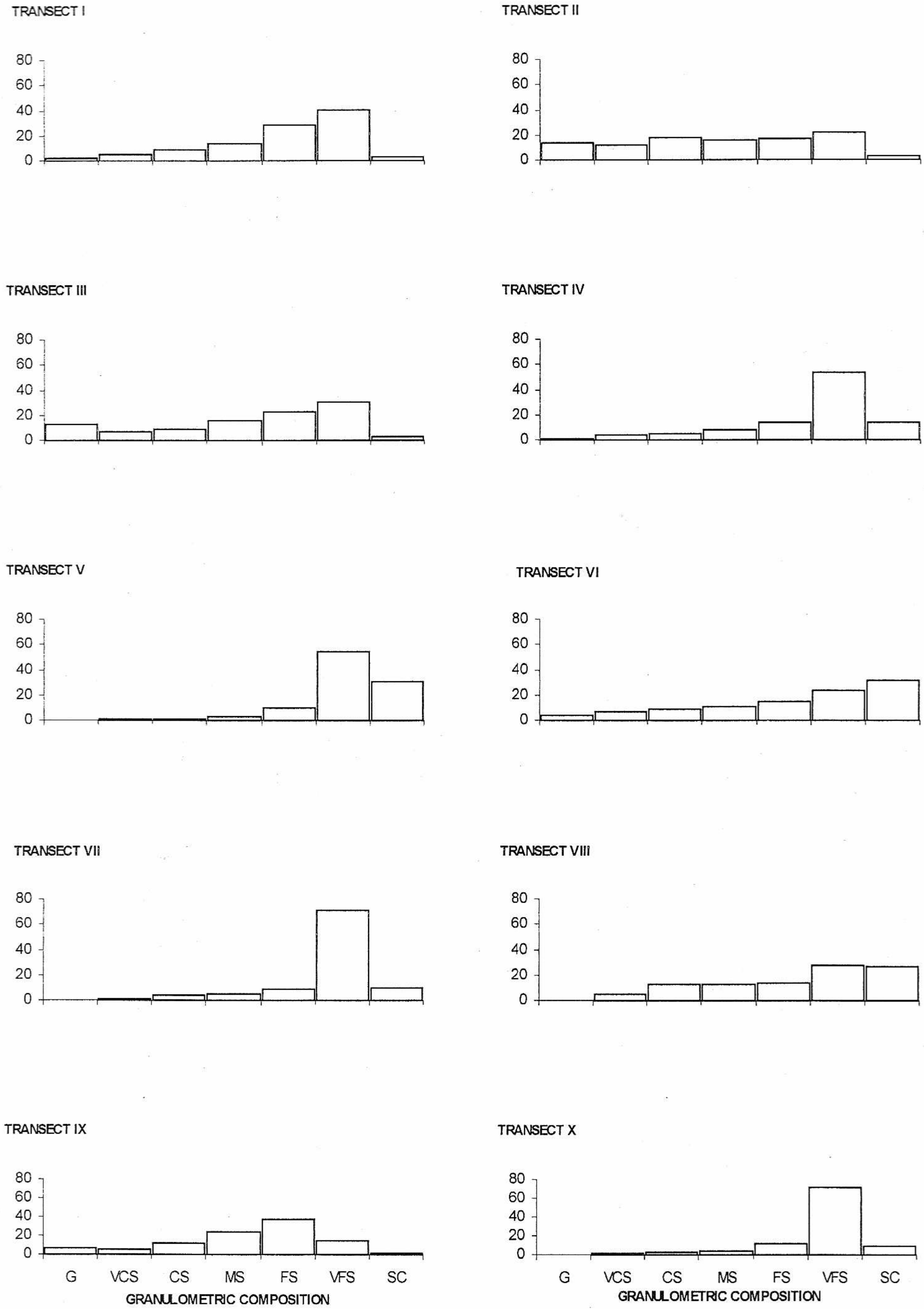

Figure 8: Bar graph showing the granulometric composition of the sediment at all sampled transects, from Sep/95 to Aug/96. (G=granel; VCS=very coarse sand; CS=coarse sand; MS=medium sand; FS=fine sand; VFS=very fine sand; S+C=silt and clay).

The swimming crab *C. danae* was recorded in all sampled transects but higher abundances were recorded in the Acaraú River estuary. There was a size-related distribution over the sampled area as reported by Pardieck *et al.* (1999) who found a higher abundance of early *C. sapidus* stages towards the river headwater. According to the same author, pot-larval stages and juveniles inhabit shallow areas provided with algae cover.

The abundance of the blue crab *C. danae* followed a seasonal variation pattern with highest values in summer. The ability of crustaceans to follow distribution trends according to temperature gradients is well known (Lewis and Roer, 1988). Other studies on *C. danae* had evidenced similar seasonal trends according to temperature variation, with higher catches taking place in summer compared to winter months (Schemy, 1980; Buchanan and Stoner, 1988). Moreira *et al.* (1988) related highest summer abundance of this species with its specific reproductive patterns.

Table I: Average values for pooled data (Sep/95 to Aug/96), respective standard deviations and statistical results for among-transect comparisons. In each measured variable, transects sharing at least one letter do not differ significantly ($p<0.05$).

Transects	Temperature (°C)	Salinity (‰)	Dissolved Oxygen (mg/ml)	Organic Matter Contents (%)
I	26.30 ± 0.71 a	10.53 ± 5.79 a	4.97 ± 1.01 b	5.33 ± 1.28 d
II	24.28 ± 0.53 a	17.06 ± 5.89 b	5.38 ± 1.03 b	4.92 ± 1.71 d
III	25.23 ± 0.74 a	28.10 ± 4.82 c	6.19 ± 1.33 a	8.27 ± 0.34 cd
IV	25.20 ± 0.39 a	32.49 ± 0.53 c	6.60 ± 1.20 a	6.78 ± 2.11 bcd
V	24.90 ± 2.93 a	32.50 ± 2.03 c	5.47 ± 0.63 ab	6.90 ± 1.57 cd
VI	24.00 ± 2.61 a	33.10 ± 1.85 c	5.18 ± 0.67 b	14.5 ± 2.21 ab
VII	24.10 ± 2.79 a	32.90 ± 1.96 c	4.88 ± 0.83 b	6.10 ± 2.42 d
VIII	23.40 ± 2.79 a	33.40 ± 1.78 c	4.61 ± 0.86 b	13.20 ± 1.53 abc
IX	23.70 ± 2.76 a	33.30 ± 1.81 c	5.22 ± 0.42 b	18.50 ± 9.69 a
X	23.40 ± 2.86 a	33.30 ± 1.70 c	5.10 ± 0.82 b	5.30 ± 3.04 d
P	0.638	0.000	0.000	0.000
F (9.110)	0.7766	39.055	5.178	9.875

At the study region, *C. danae* breeds year-round as inferred from the continuous presence of ovigerous females over the sampling period, thus supporting the results obtained by Schemy (1980), Pita *et al.* (1985) and Costa (1998). Yet, two discrete peaks of ovigerous crabs were detected; a smaller one in February and a higher one in June. Winter breeding activity may be attributed to the fact that mild temperatures during that period do not fall beyond the preferential limits for this species, therefore not restraining reproductive activities.

Water temperature is one of the main factors controlling the maturation of oocytes, which may be hasted or delayed at high and low temperatures, respectively (Sastry, 1983). Although playing a major role in triggering reproductive events, other factors other than temperature may be also critical, as the relative timing of known energy-consumming processes brooding and moulting (Steele and Bert, 1994).

The seasonal nature of moulting activity can be ruled by temporal variation of temperature and adequate food availability. Such seasonal change may also result from photoperiod variation (Aiken, 1969).

Among the measured environmental variables, salinity is the most important factor explaining the distribution of this species along this marine – estuarine area. The increasing salinity gradient from the river headwater to the river mouth may provide a means for the orientation of crabs during migration events. If migrating adult females respond according to salinity conditions, variable movement patterns would be then expected in different portions of the estuary. A continuous decreasing salinity gradient is known to ultimately influence the migratory patterns of these crustaceans (Cargo, 1958).

Benthic communities off Ubatuba clearly follow a depth gradient, probably related to changes of the sediment characteristics and physical stability of water masses (Sumida and Pires-Vanin, 1997).

Regarding the granulometric composition of the sediment, finer particles, namely fine and very fine sand, prevailed in all sampled sites. According to Pinheiro (1996), coarser sediments do not favour excavation and burying, which are characteristic habits of these crabs.

Depth variation and the influence of the different water masses in the study region are known to be the most important factors shaping the structure and maintaining the dynamics of the benthic megafauna in Ubatuba (Pires, 1992).

Negreiros-Fransozo and Fransozo (1995) had investigated the distribution of *Callinectes* in Fortaleza Bay and verified that *C. danae* is restricted to shallower areas near estuaries.

Additional studies on the ecological relationships between crabs and their surrounding aquatic habitats would be interesting as to provide a basis for future research.

Acknowledgements

The FAPESP - "Fundação de amparo à Pesquisa no Estado de São Paulo" provided financial support (#95/2833-0; # 96/7133-9; # 96/0333-3) and CNPq - "Conselho Nacional de Desenvolvimento Científico e Tecnológico" (# 133439/95-0).

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Received: 15th Dec 2000
Accepted: 15th Dec 2001