

Research Article

Monitoring of carcinofauna abundance and diversity during eight years of expressway construction in Santa Catarina, Brazil

Felipe Freitas Junior¹, Martin Lindsey Christoffersen² & Joaquim Olinto Branco¹

¹Centro de Ciências Tecnológicas da Terra e do Mar, (CTTMAR). Universidade do Vale do Itajaí
CP 360, CEP 88302-202, Santa Catarina, Brasil

²Departamento de Sistemática e Ecologia, Universidade Federal da Paraíba (UFPB)
CEP 58059-900, João Pessoa, Paraíba, Brasil

ABSTRACT. Crustaceans are important in estuarine ecosystems, transferring energy to higher trophic levels and contributing to artisanal and industrial fisheries. This paper aims to evaluate the carcinofauna diversity and abundance in Saco dos Limões and how this changed when affected by dredging during the construction of an expressway through South Bay, Florianópolis, Santa Catarina, Brazil. Collections were made onboard a commercial fishing boat for three months, day and night, at six sampling sites from 1997 to 2006. The families Penaeidae and Portunidae were the most diverse in terms of taxa, with the largest species abundances. The dominant species were the shrimps *Farfantepenaeus brasiliensis*, *F. paulensis*, and *Litopenaeus schmitti*, and the crab *Callinectes danae*. The largest abundances were found in two areas, in the summer and at night. The diversity and equitability indices showed similar patterns, with the highest values in autumn and winter. According to the Jaccard index, the similarity of the crustacean composition was highest for the years 2005 and 2006 and lowest between 1997 and 2005. The structure of the carcinofauna changed over the years, with high mortalities during dredging operations followed by a recovery in the subsequent years. Our observations indicated that dredging did not have catastrophic effects nor did it produce long-term disturbances in the carcinofauna of the estuary. It is important to monitor natural resources in order to record the extent and limits of human impacts on the environment.

Keywords: human impacts, environmental assessment, crustacean monitoring, dredging activities, qualitative-quantitative variations, Brazil.

Ocho años de monitoreo de la abundancia y diversidad de la fauna carcinológica durante la construcción de una carretera en Santa Catarina, Brasil

RESUMEN. Los crustáceos son importantes en el ecosistema estuarino, transfiriendo energía hacia los niveles tróficos más altos y contribuyendo a la pesca artesanal e industrial. El objetivo del artículo es evaluar la diversidad y abundancia de la fauna carcinológica de la región de Saco dos Limões y sus cambios bajo la influencia de las actividades de dragado durante la construcción de la carretera Bahía sur, Florianópolis, Santa Catarina, Brasil. Las recolecciones fueron realizadas durante tres meses, en seis áreas durante el día y la noche desde 1997 a 2006, con un barco pesquero comercial. Los crustáceos de las familias Penaeidae y Portunidae fueron los taxa más diversos contribuyendo con la mayor abundancia de especies. Los camarones *Farfantepenaeus brasiliensis*, *F. paulensis*, *Litopenaeus schmitti*, juntos con el cangrejo *Callinectes danae*, fueron las especies dominantes. La mayor abundancia ocurrió en dos áreas, durante verano en la noche. Los índices de diversidad y equitabilidad presentaron patrones similares, con el valor mayor en otoño e invierno. El índice de Jaccard indicó una mayor similitud en la composición de la fauna de crustáceos entre los años 2005 y 2006, mientras el menor valor de la ésta ocurrió entre 1997 y 2005. Se observaron cambios en la estructura de la fauna carcinológica a lo largo de los años, ocurriendo una alta mortalidad durante las operaciones de dragado, con un restablecimiento posterior en los años siguientes. El monitoreo de la fauna carcinológica indica que las actividades de dragado no tuvieron efectos desastrosos y no produjeron disturbios sobre la fauna carcinológica estuarina a largo plazo. El monitoreo de los recursos naturales es importante para registrar la extensión y los límites del impacto humano sobre el medio ambiente.

Palabras clave: impacto humano, evaluación ambiental, monitoreo de crustáceos, actividades de dragado, variaciones cualitativas y cuantitativas, Brasil.

Corresponding author: Martin Lindsey Christoffersen (mlchrist@dse.ufpb.br)

INTRODUCTION

Faunal surveys, including a qualitative and quantitative study of the composition of marine invertebrates, are of fundamental importance for the comprehension of the structure, functioning and natural variability of benthic communities. They represent a fundamental requirement for establishing environmental monitoring programs, and serve as a basis for the conservation of biodiversity (Santos *et al.*, 2000; Mantelatto *et al.*, 2004; Braga *et al.*, 2005).

Decapod crustaceans are outstanding in estuaries for their high abundance, biomass, and economic importance. They play an important role in providing a complement of proteins for human populations living at the waterside, and have a fundamental role in processes of soil aeration and sedimentation (Branco & Verani, 1997, 1998; Teixeira & Sá, 1998).

Information on the composition of the carcinofauna in these ecosystems includes ecological approaches (Tankersley *et al.*, 1998; Seed & Hughes, 1997; Seitz *et al.*, 2003; Pérez-Castañeda & Defeo, 2005), spatio-temporal accounts of the distributions of species with economic interest (Pérez-Castañeda & Defeo, 2001; Sharov *et al.*, 2003) and larval dynamics (Johnson, 1985; Dittel & Epifanio, 1990; Forbes & Cyrus, 1991). In Brazil, many papers refer to species inventories off its northeastern (Sousa *et al.*, 2000; Coelho *et al.*, 2004; Almeida *et al.*, 2006, 2007), southeastern (Abreu, 1980; Pita *et al.*, 1985; Moreira *et al.*, 1988; Nakagaki *et al.*, 1995; Oshiro *et al.*, 1998; Costa *et al.*, 2000; Braga *et al.*, 2005) and southern coasts (Melo, 1989; Rodrigues *et al.*, 1994; Branco 1998a, 1998b; Branco *et al.*, 1998a; Pereira *et al.*, 1998; Santos *et al.*, 2000).

In 1995, the government of the State of Santa Catarina began the construction of the Santa Catarina - South expressway, along the margins of Saco dos Limões (South Bay), dredging about $8,5 \times 10^6 \text{ m}^3$ of sand from a bed located in the center of the bay, in order to construct an embankment of 15,9 km (Resgalla Jr., 2001). In this ecosystem, studies have been conducted on population dynamics, reproductive biology, and larval composition of *Cetengraulis edentulus* (Souza-Conceição *et al.*, 2005), associated avifauna (Branco *et al.*, 2004; Branco & Fracasso, 2005), the impact of the construction of this

engineering project on the population of *Anomalo-cardia brasiliiana* (Pezzuto & Echternacht, 1999), the zooplanktonic community (Resgalla Jr., 2001), and on oceanographical and biochemical characters of the region (Schettini *et al.*, 2000).

Because dredging activities may change the structure and dynamics of the bottom communities (Von Dolah *et al.*, 1984; Marques *et al.*, 1993; Bemvenuti *et al.*, 2005), and considering the ecological and economic importance of the crustaceans, this paper aims to analyze the abundance and diversity of the carcinofauna during eight years of collecting, and to assess possible alterations on these organisms resulting from dredgings in Saco dos Limões.

MATERIAL AND METHODS

Saco dos Limões creek is located in South Bay, Santa Catarina State, Brazil (27°36'-27°39'S and 48°33'-48°31'W) (Fig. 1), it has a sandy-mud bottom mixed with biodegradable material, shallow water of high salinity and hydrodynamics controlled by the tidal regime and south-northeastern winds (Resgalla Jr., 2001; Schettini *et al.*, 2000; Souza-Conceição *et al.*, 2005).

From 1997 to 2006 (except 1998 and 1999), samples were taken every three months at day and at night, in six representative areas in the bay (Fig. 1). Area I: 2-4 m deep, with high salinity due to marine circulation; Area II: 2-4 m deep, more exposed to meteorological changes, with high salinity due to invasion of sea water; Area III: 2 m deep, protected from the wind, with a strong influence of continental waters; Area IV: 2 m deep, with the influence of small and superficial freshwater brooks that affect the availability of nutrients; Area V: 2 m deep, with strong influence of a river, having the lowest salinities, high concentration of nutrients and high turbidity; Area VI: 2-8 m deep, mostly marine conditions, an area that received the strongest influence of sediment extraction during the expressway construction, making it deeper than it was originally (Souza-Conceição *et al.*, 2005).

Crustaceans were collected with double-rigged trawl nets, with 3.0 cm net meshes, and 7.5 m total length, pulled by a whaler for 10 min at a speed of 2.0 knots. The captured carcinofauna was sorted from the

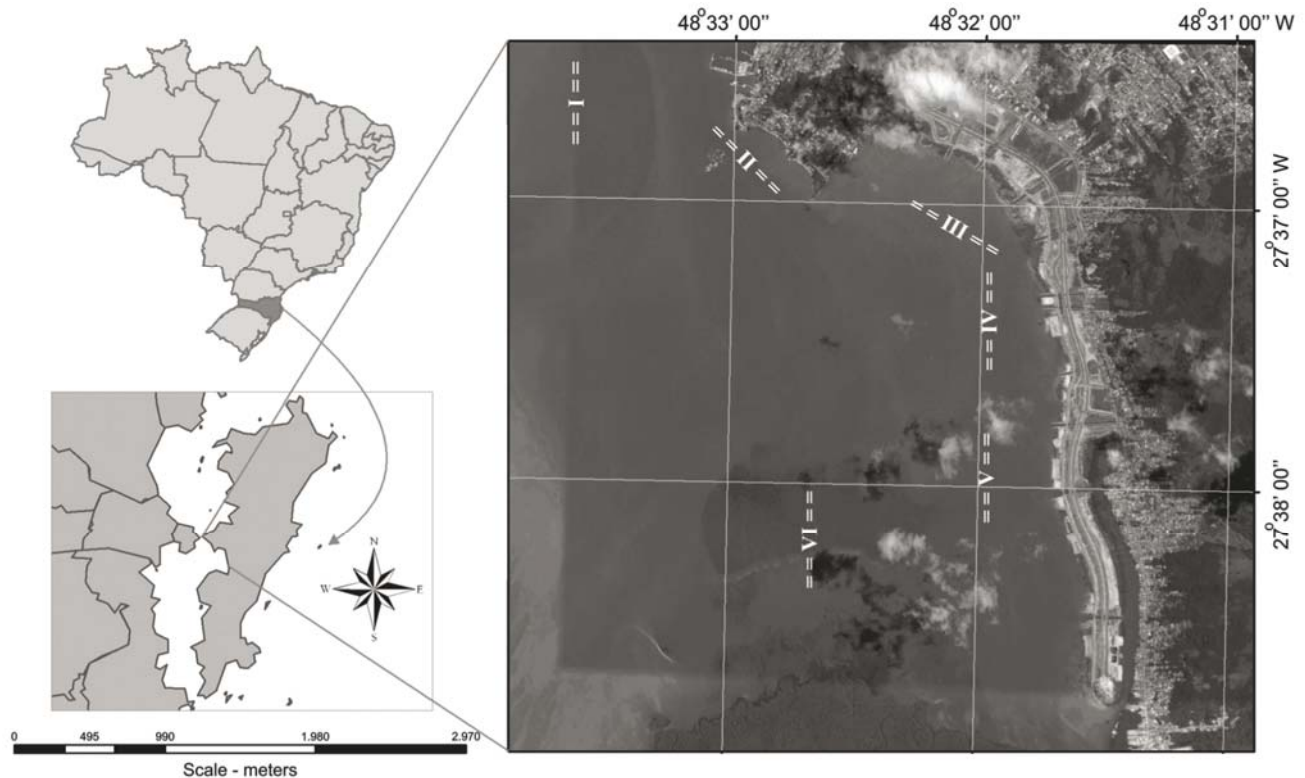


Figure 1. Map indicating collecting areas. In the map of Brazil, the State of Santa Catarina is enhanced. The detail shows the island of Florianópolis with north and south bays. The next detail shows Saco dos Limões in South Bay, with the collecting sites I-VI. (Source: Laboratory of Geo-processing- Universidade do Vale do Itajaí).

Figura 1. Mapa de las citas de colecta. En el mapa de Brazil, se destaca el estado de Santa Catarina. El detalle muestra la isla de Florianópolis, con las bahías norte y sur. El siguiente detalle muestra Saco dos Limões en la bahía sur y las áreas de colecta (Fuente: Laboratorio de Geoprociamiento- Universidade do Vale do Itajaí).

accompanying fauna, conditioned in tagged plastic bags, refrigerated in polyethylene boxes with ice and maintained in a freezer until they were processed. No subsamples were taken. Individuals from the two nets were summed in our analyses, representing the total number of individuals for 10 min in each area. In the laboratory, captured crustaceans were identified according to Pérez-Farfante (1978) and Melo (1996), and their abundance was registered.

During collecting, the surface water temperature and salinity were measured. In 1997 and 2006, a sediment sample was obtained for granulometric characterization, and carbonate and organic matter content was determined.

Species were classified into three categories, according to their occurrence in samples: constant, when present in more than 50% of the samples; accessory, when present in 25 to 50% of the total samples, and occasional, when representing less than 25% (Severino-Rodrigues *et al.*, 2002). Seasons of the year are winter (July-September), spring (October-

December), summer (January-March), and autumn (April-June).

The analysis of parametric variance (ANOVA) (Zar, 1999) was used to verify the existence of significant differences in the environmental parameters, number of specimens, diversity and equitability among areas and sampling year, being tested regarding homogeneity of variance (Barlett test) and normality of distribution (Kolmorov-Smirnov proof). When significant differences were found, the media contrast (Tukey-Kramer test) was applied to indicate which media were significantly distinct.

We used the Jaccard index to evaluate faunal similarities among years. The data standardization was obtained with the logarithmic transformation [$\ln(x+1)$], because of the typical contagious distribution of crustaceans and fish (Colvocoresses & Musick, 1984). Euclidian distances were obtained for the similarities between pairs of species, grouped by the Ward method, with the help of the software Statistica 6.

RESULTS

Environmental parameters

The mean surface water temperature presented a uniform pattern of seasonal fluctuation, not differing significantly among sampling years ($F_{4-18} = 0.227$; $P \geq 0.05$), nor among areas ($F_{5-18} = 0.058$; $P \geq 0.05$). The highest mean values were registered in the summer months (26.9°C), while the lowest occurred during winter (22.8°C) (Fig. 2).

The mean surface water salinity maintained the seasonal tendency shown by temperature, without significant differences among years ($F_{6-18} = 0.657$; $P \geq 0.05$) and sampling areas ($F_{5-18} = 0.241$; $P \geq 0.05$), with the highest mean values occurring in summer (32.4) and the lowest in autumn (27.0) (Fig. 2).

Sediments in Saco dos Limões, just after dredging operations in 1997, varied from terrigenous mud to fine and very fine lithoclastic sand, the latter being found in area VI (Table 1). We named this site the dredging hole, because extractions of material were made here. The highest percentages of organic material were found in areas IV (12.8%) and I (12.2%), and carbonates in area II (18.4%) (Table 1).

After eight years of dredging, a uniform distribution of sediments was observed along the sampled region, being characterized as terrigenous mud in all localities, with larger quantities of organic matter (12.8%) and carbonates (10.7%) in area VI (Table 1).

Composition and abundance

During the eight years of sampling 14 249 decapod crustaceans from 10 families, 16 genera and 21 species were collected. Five of these were common throughout the sampling period (Table 2). Changes in the composition of species were observed along the years, with the lowest contributions in 1997 (five) and the highest in 2005 (15) and 2006 (14). During this last year the presence of the exotic species *Charybdis hellerii* (A. Milne-Edwards, 1867) was registered in the bay (Table 2).

The families Penaeidae and Portunidae together contributed 98.4% of the total captures, while the other eight families represented only 1.6% of the carcinofauna (Table 2). The shrimps *Litopenaeus schmitti* (Burkenroad, 1936) dominated in number of specimens in the 1997 (47.6%) and 2000 (39.8%) samplings. *Farfantepenaeus brasiliensis* Latreille, 1817 dominated in the remaining years (33.2% to 63.1%), while *F. paulensis* (Pérez Farfante, 1967) occupied the second place in abundance in 1997 (28.9%) and 2005 (14.7%), together with *C. danae* in

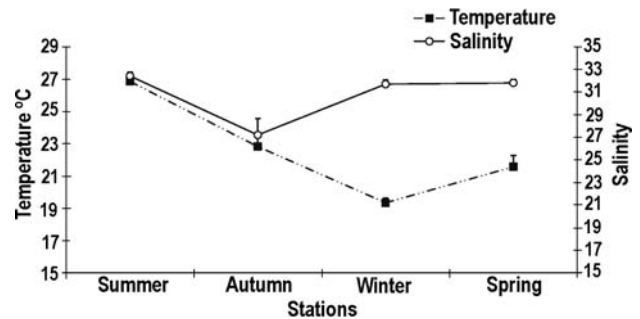


Figure 2. Mean temporal variation in physical and chemical parameters of surface water in Saco dos Limões (south bay) during the study period. Vertical bars: standard error.

Figura 2. Variación temporal media de los parámetros físicos y químicos en Saco dos Limões (bahía sur) durante el periodo de estudio. Barras verticales: error estándar.

2001 (32.3%) and 2004 (20.8%) (Table 2). In the remaining years *F. paulensis* and *C. danae* occupied the third and fourth positions, respectively (except in 2000) (Table 2). *C. ornatus* was the fifth most representative species in the years 1997, 2000, and from 2003 to 2006, being substituted by *Alpheus* spp. In 2001 and by *Xiphopenaeus kroyeri* (Heller, 1862) in 2002 (Table 2). Summarizing, constant species dominated in 1997, 2000, and 2001, while occasional species dominated in the remaining years (Table 2).

The abundance of the carcinofauna fluctuated along the years, with the lowest capture of individuals in 1997 and the highest in 2006 (Fig. 3). Despite changes among sampling years, significant differences were not observed ($F_{7-24} = 0.760$; $P \geq 0.05$). In general, highest abundances were registered during the summer months, except for 1997 and 2002 (autumn), and the lowest in winter.

Although the highest mean abundances of the carcinofauna occurred in areas VI and V, during the night and in the summer and spring months, significant differences in mean values among the sampling sites were not observed during the day ($F_{5-18} = 2.436$; $P \geq 0.05$) and night ($F_{5-18} = 1.896$; $P \geq 0.05$) (Fig. 4).

We have used the analyses of diversity and equitability in an attempt to demonstrate changes in the crustacean community along the years following dredging. Species such as *L. schmitti*, *P. paulensis* and *F. brasiliensis* are important fishery resources along the adjacent coast. Fisheries is prohibited within the studied bay, where resources represent constant species (Table 2).

Table 1. Characterization of the bottom sediments in collecting areas of Saco dos Limões, from January, 1997 to October, 2006.**Tabla 1.** Caracterización de los sedimentos del fondo del área de estudio de Saco dos Limões de enero de 1997 a octubre de 2006.

| Área | Textural classification | 1997 | | Textural classification | 2006 | |
|------|---------------------------------------|-----------|----------------|-------------------------|-----------|----------------|
| | | Carbonate | Organic matter | | Carbonate | Organic matter |
| I | Terrigenous mud | 0 | 12.00 | Coarse clay | 8.44 | 11.92 |
| II | Terrigenous mud | 18.42 | 12.10 | Coarse clay | 9.55 | 11.88 |
| III | Fine to very fine litoclastic sand | 5.07 | 0.19 | Coarse clay | 10.66 | 12.81 |
| IV | Sandy terrigenous mud | 6.10 | 5.19 | Coarse clay | 9.34 | 11.58 |
| V | Terrigenous mud | 0 | 12.82 | Very fine silt | 9.56 | 10.56 |
| VI | Terrigenous mud | 6.19 | 12.20 | Coarse clay | 9.09 | 11.82 |

Diversity

The Shannon diversity index (H') showed moderate differences along the sampling period, with reduced values in 1997, followed by increments and changes up to 2004, attaining the lowest diversity in 2006 (1.16) (Table 2, Fig. 5). However, differences were not observed among the years of collection ($F_{7-24} = 2.158$; $P \geq 0.050$). In general, higher diversities were registered in the months of autumn (2000, 2001 and 2006) and winter (2002, 2003 and 2005) and occasionally in summer (1997 and 2004) (Fig. 5).

When diversity is analyzed as a function of sampling area, higher mean values were observed in Area II (day) and IV (night) (Fig. 6). Notwithstanding these changes, differences were not found among the sampling sites, during the day ($F_{5-18} = 0.449$; $P \geq 0.05$) and night ($F_{5-18} = 2.134$; $P \geq 0.05$).

Equitability

Equitability presented a tendency to fluctuate seasonally, similarly to diversity, with higher values in 1997 (0.77) and lowest in 2006 (0.45), although these values were not significantly different ($F_{7-24} = 2.540$; $P \geq 0.05$) (Table 2 and Fig. 7). Higher values occurred in the winter and autumn months, except in 2004 (summer). Highest equitabilities were registered in Area II (day) and IV (night) (Fig. 8), with results statistically similar for day ($F_{5-18} = 2.436$; $P \geq 0.05$) and night ($F_{5-18} = 1.896$; $P \geq 0.05$).

Similarity

The Jaccard index showed variation among the years of sampling from 31.25 to 76.92%, with the highest values between 2002-2004 (76.9%) e 2005-2006 (75.0%) and the lowest between 2000-2006 (31.3%) and 1997-2005 (33.3%) (Table 3).

Faunistic associations

Considering the annual abundance of the 21 captured taxa and utilizing the Cluster analysis, it was possible to separate the sampling years into three groups with a disjunction distance of "4" (Fig. 9). Group I, formed by the years 1997, 2000, 2003, and 2002, with the lowest abundances occurring in 1997, becoming distanced from 2000, 2003 and 2004. The latter years presented a period of ecological succession, characterized by fluctuations in the capture rates (Table. 2, Fig. 9). Group II, consisting of the years 2001 and 2004, contributed with the highest diversities. Group III is represented by the last years of sampling, when the highest frequencies of specimens and the lowest equitabilities were obtained, indicating that the environment once more showed characteristics of estuarine areas (Table 2, Fig. 9).

DISCUSSION

Estuarine areas such as the one studied herein contain a large number of species, but most are occasional visitors, few representing dominant species. The dominance of families Penaeidae and Portunidae in species richness and abundance corresponds to that registered in other inventories in the south (Moreira *et al.* 1988; Rodrigues *et al.*, 1994; Nakagaki *et al.*, 1995; Branco *et al.*, 1998a; Severino-Rodrigues *et al.*, 2002; Branco & Fracasso, 2004; Braga *et al.*, 2005). The high water temperature in Saco dos Limões creek during the summer month, associated with food availability, as particulate organic matter, may have favored the occurrence of these families (Branco & Verani, 1997; Branco & Moritz Jr., 2001; Pérez-Castañeda & Defeo, 2001; Branco *et al.*, 2002). Freely inflowing larvae may also contribute to the abundance of these groups (Resgalla Jr., 2001).

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------------------|-------------|------|---|-------------|------|---|-------------|------|---|-------------|---|------|---|-------------|------|---|-------------|------|---|-------------|------|---|-------------|------|---|
| <i>Callinectes bocourti</i> | 10 | 1.02 | O | 33 | 1.76 | C | 22 | 1.86 | C | 7 | 1 | 0.05 | O | 39 | 1.98 | C | 1 | 0.07 | O | 88 | 4.59 | C | 27 | 0.93 | C |
| <i>Callinectes ornatus</i> | | | | | | | | | | | | | | | | | | | | | | | | | |
| <i>Portunus spinimanus</i> | | | | | | | | | | 1 | 1 | 0.05 | O | | | | | | | 3 | 0.16 | O | 1 | 0.03 | O |
| <i>Charybdis hellerii</i> | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | 978 | | | 1876 | | | 1182 | | | 1982 | | | | 1965 | | | 1454 | | | 1916 | | | 2896 | | |
| Total species | 5 | | | 8 | | | 11 | | | 11 | | | | 12 | | | 12 | | | 15 | | | 14 | | |
| Índice de richness (D) | 0.58 | | | 0.93 | | | 1.41 | | | 1.31 | | | | 1.45 | | | 1.51 | | | 1.85 | | | 1.50 | | |
| Índice de diversity (H') | 1.23 | | | 1.41 | | | 1.55 | | | 1.39 | | | | 1.46 | | | 1.62 | | | 1.41 | | | 1.16 | | |
| Índice de equitability (J') | 0.77 | | | 0.68 | | | 0.65 | | | 0.58 | | | | 0.60 | | | 0.65 | | | 0.52 | | | 0.45 | | |
| Number of Constant species | 2 | | | 5 | | | 6 | | | 4 | | | | 5 | | | 5 | | | 4 | | | 6 | | |
| Number of Accessory species | 2 | | | 0 | | | 0 | | | 2 | | | | 1 | | | 1 | | | 1 | | | 1 | | |
| Number of Occasional species | 1 | | | 3 | | | 5 | | | 5 | | | | 6 | | | 6 | | | 10 | | | 7 | | |

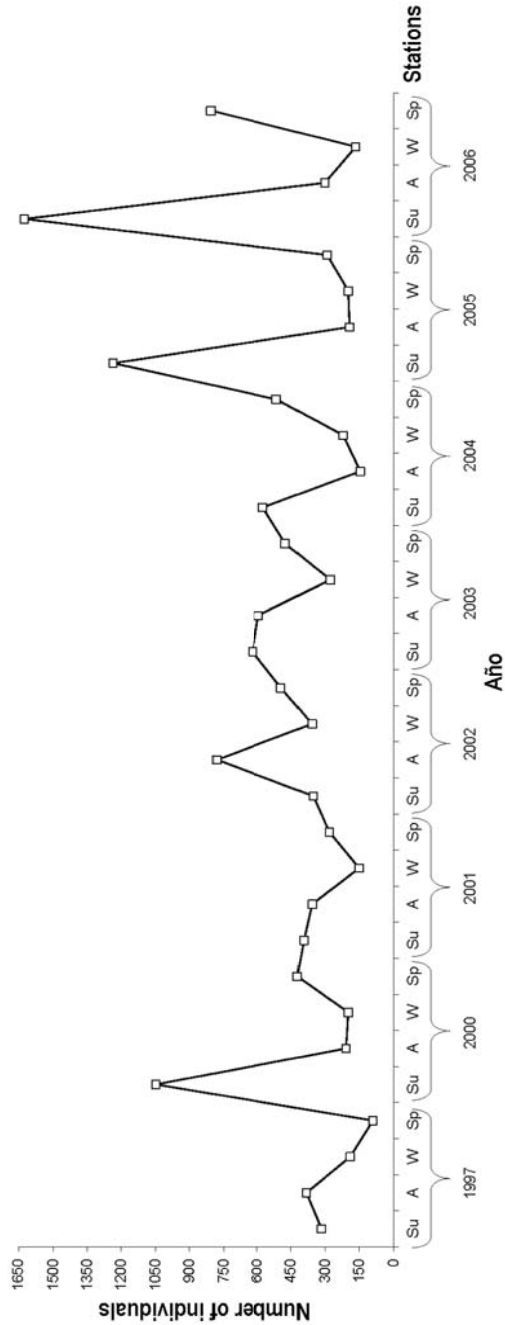


Figure 3. Seasonal variation in the number of crustaceans captured in Saco dos Limões, in the eight years of sampling. Su: summer, A: autumn, W: winter, Sp: spring.

Figura 3. Variación estacional en el número de crustáceos capturados en Saco dos Limões en ocho años de muestreo. Su: verano, A: otoño, W: invierno, Sp: primavera.

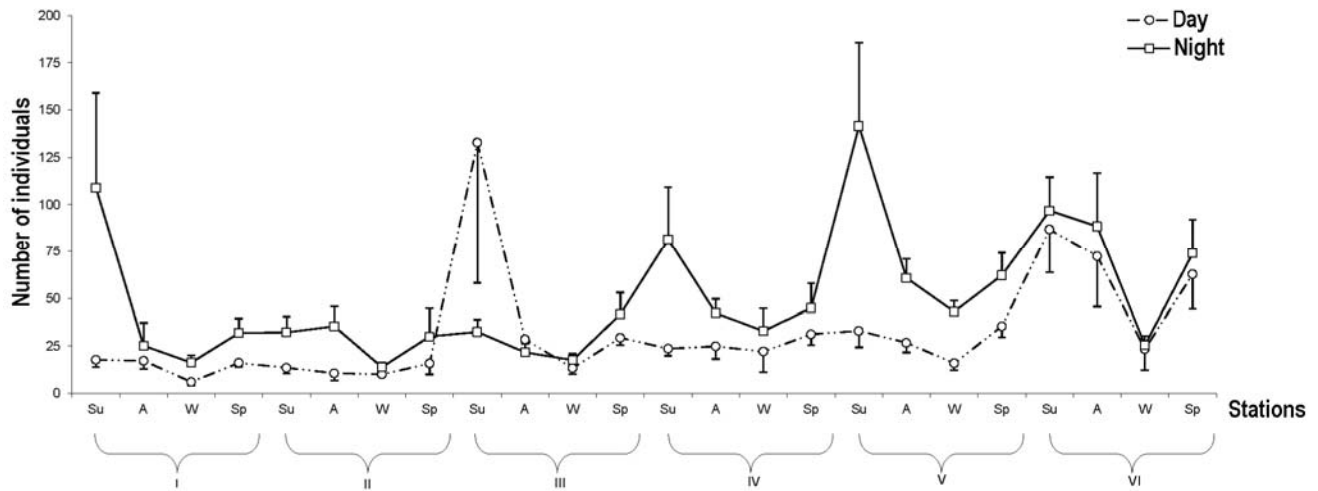


Figure 4. Seasonal variation in the number of individual crustaceans captured in áreas I, II, III, IV, V and VI, in the region of Saco dos Limões, during 2001 to 2006.

Figura 4. Variación estacional en el número de individuos de crustáceos capturados en las áreas I, II, III, IV, V, y VI en la región de Saco dos Limões entre 2001 y 2006.

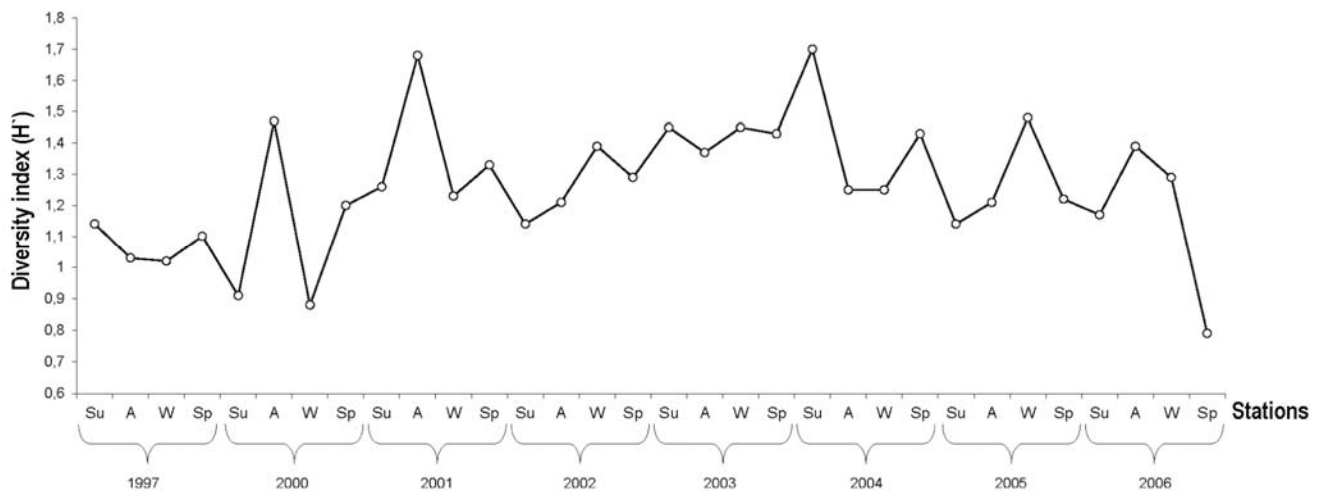


Figure 5. Seasonal variation in the diversity index (H') in Saco dos Limões, during the eight years of sampling.

Figura 5. Variación estacional del índice de diversidad (H') en Saco dos Limões durante los ocho años de muestreo.

According to the findings of several authors at different geographical locations in Brazil and other areas of the world, the seasonal fluctuations in abundance of decapods in Saco dos Limões are correlated to changes in water temperature and salinity (Signoret, 1974; Spivak, 1997; Teixeira & Sá, 1998; Chacur & Negreiros-Fransozo, 2001; Loebmann & Vieira, 2006), sediment texture (Branford, 1981) and life cycle of species (Johnson 1985; Dittel & Epifanio, 1990; Forbes & Cyrus, 1991; Shanks, 1998; Tankersley *et al.*, 1998; Fernandes *et al.*, 2002; Pérez-Castañeda & Defeo, 2005).

In general, the highest captures occur in summer at night, which is probably related to the behavior of

these crustaceans which avoid predators during the day (Neiva, 1966; Santos *et al.*, 2006). The highest diversities and equitabilities, in the months of autumn and winter, were observed during the day, due to seasonal variations in the abundance of dominant species, to changes in the environmental conditions (Mantelatto & Fransozo, 2000), and to the presence of occasional and seasonal species migrating through the study area (Branco *et al.*, 1998b).

During eight years of sampling, changes were registered in the structure of the carcinofauna of Saco dos Limões, evidenced by the low similarity between the initial and final period of sampling, and reinforced

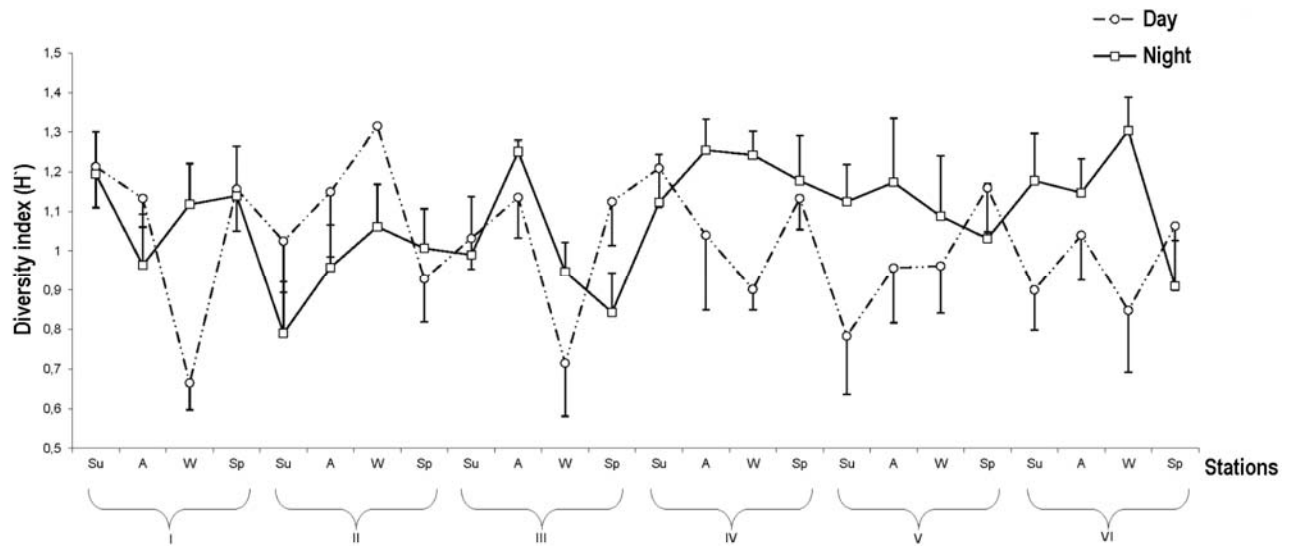


Figure 6. Seasonal variation of the diversity index (H') in areas I, II, III, IV, V and VI, in Saco dos Limões region, during 2001 to 2006.

Figura 6. Variación estacional del índice de diversidad (H') en la áreas I, II, III, IV, V y VI en la región Saco dos Limões, entre 2001 y 2006.

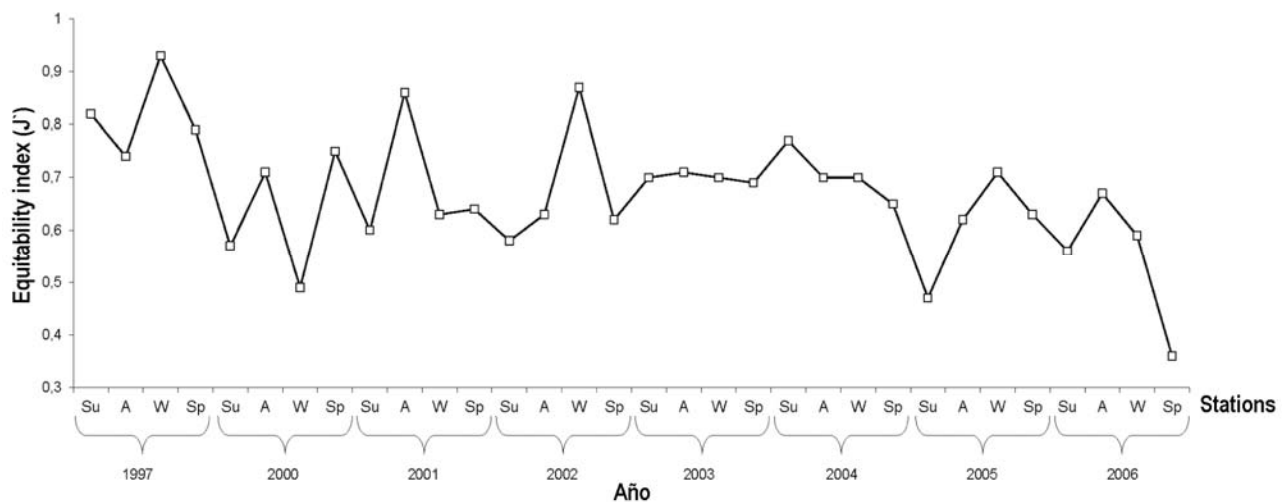


Figure 7. Seasonal variation of the equitability index (J') in Saco dos Limões, during the eight years of sampling.

Figura 7. Variación estacional del índice de equitabilidad (J') en Saco dos Limões, durante los ocho años de muestreo.

by the distinct groupings in the years 1997-2000-2002-2003, 2001-2004 and 2005-2006.

The reduced abundance at the beginning of the monitoring (1997) may be associated to the instability caused by the mechanical action of dredging, cluttering their gills with suspended material and resulting in high mortality rates (Bemvenuti *et al.*, 2005). Although sessile prey with low movement may become vulnerable to the dredging equipment (Von Dolah *et al.*, 1984; Newell *et al.*, 2003, 2004), all species caught in this study are vagile. Vulnerability to

dredges due to slow locomotion may not be applicable in this study.

The recovery of the carcinofauna in the year subsequent to the dredging operation was confirmed by an increase in abundance, number of species and changes in the diversity and equitability indexes. The lowest diversities and the highest equitabilities were registered in 1997 and reflect the reduced species richness during the stressful dredging operations. When dredging ended, changes in the diversity and equitability indexes and in the carcinofauna compo-

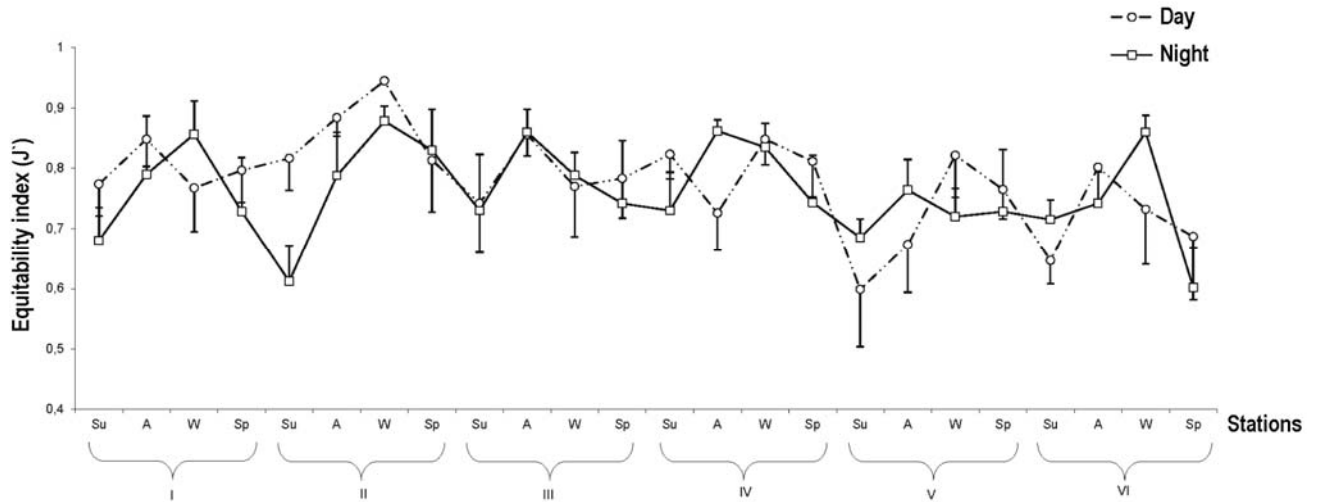


Figure 8. Seasonal variation in the equitability index (J') in areas I, II, III, IV, V and VI, in Saco dos Limões region, during 2001 to 2006.

Figura 8. Variación estacional del índice de equitabilidad (J') en las áreas I, II, III, IV, V y VI, en la región de Saco dos Limões entre 2001 y 2006.

Table 3. Similarity of carcinofauna during eight years of collecting.

Tabla 3. Similitud de la fauna carcinológica durante los ocho años de estudio.

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|-------------|-------|-------|-------|-------|-------|-------|-------|
| 1997 | 62.50 | 45.45 | 45.45 | 41.67 | 41.67 | 33.33 | 38.46 |
| 2000 | | 72.73 | 46.15 | 53.85 | 42.86 | 35.29 | 31.25 |
| 2001 | | | 46.67 | 64.29 | 53.33 | 36.84 | 41.18 |
| 2002 | | | | 64.29 | 76.92 | 36.84 | 50.00 |
| 2003 | | | | | 71.43 | 50.00 | 47.06 |
| 2004 | | | | | | 42.11 | 47.06 |
| 2005 | | | | | | | 75.00 |
| 2006 | | | | | | | |

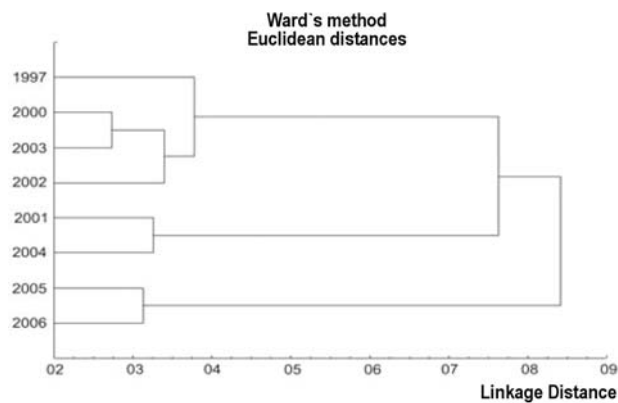


Figure 9. Dendrogram based on data of abundance of species of crustaceans during eight years of sampling.

Figura 9. Dendrograma basado en los datos de abundancia de especies de crustáceos durante los ocho años de muestreo.

sition may indicate the occurrence of ecological succession, until a probable equilibrium characteristic of estuarine environments and bays was reached (Stoner, 1986; Day *et al.*, 1989), with high species richness and dominated by a restricted group.

As a consequence of the high environmental variability in estuaries and bays, the assessment of environmental impacts produced by dredging operations becomes difficult (Bemvenuti *et al.*, 2005). Fluctuations in the indexes of abundance, diversity, and equitability indexes found in this study may be related to the life cycle of these species. The proximity of Areas V and VI with mangroves and freshwater rivers may have contributed to the higher abundances registered in these localities, by providing food availability and favorable conditions for the growth of juveniles. On the other hand, the lower abundance in

Area I is possibly related to the higher faunal exchange in South Bay, as a consequence of the higher current velocity, corroborating the findings of Branco & Verani (1998) and Branco & Masunari (2000) for the populations of swimming crabs and shrimps of the littoral of Santa Catarina.

AKNOWLEDGEMENTS

To Universidade do Vale do Itajaí, through Centro de Ciências Tecnológicas, da Terra e do Mar - CTTMar, for the facilities put at our disposal. To the research group of Laboratório de Biologia, particularly to MSc. Helio Augusto Alves Fracasso and Jan Raphael Reuter Braun. To biologist Cristiano Lombardo Evangelista and to oceanographer Marcos Siqueira Bovendorp for valuable help in field work and in the sorting of animals. To Dr. Carmen Alonso Samiguel, for help with the Spanish abstract and legends.

REFERENCES

- Abreu, J. 1980. Distribuição e ecologia dos Decapoda numa área estuarina de Ubatuba. Bolm. Inst. Oceanogr., 29: 1-3.
- Almeida, A.O., P.A. Coelho, J.T.A. Santos & N.R. Ferraz. 2006. Crustáceos decápodos estuarinos de Ilhéus, Bahia, Brasil. Biot. Neotrop., 6(2): 1-20.
- Almeida, A.O., P.A. Coelho, J.T.A. Santos & N.R. Ferraz. 2007. Crustáceos estomatópodos e decápodos da costa de Ilhéus, Bahia, Brasil. Atlântica, 20: 5-20.
- Bemvenuti, C.E., L.G. Angonesi & M.S. Gandra. 2005. Effects of dredging operations on soft bottom macrofauna in a harbor in the Patos Lagoon estuarine region of the Southern Brazil. Braz. J. Biol., 65: 573-581.
- Braga, A.A., A. Fransozo, G. Bertini & P.B. Fumis. 2005. Composition and abundance of the crabs (Decapoda, Brachyura) off Ubatuba and Caraguatatuba, northern coast of São Paulo, Brasil. Biot. Neotrop., 5(2):1-34.
- Branco, J.O. 1998a. Crustáceos decápodos do manguezal de Itacorubí na Ilha de Santa Catarina, Brasil. In: E.F. Soriano-Sierra & L. Sierra (eds.). Ecologia e gerenciamento do manguezal de Itacorubí. Série Proteção ao Meio Ambiente. IOESC, Florianópolis, Santa Catarina, pp. 139-144.
- Branco, J.O. 1998b. Aspectos ecológicos dos Brachyura (Crustacea: Decapoda) no manguezal de Itacorubí, SC, Brasil. In: E.F. Soriano-Sierra & L. Sierra (eds.). Ecologia e Gerenciamento do Manguezal de Itacorubí. Série Proteção ao Meio Ambiente. IOESC, Florianópolis, Santa Catarina, pp. 145-161.
- Branco, J.O. & H.A.A. Fracasso. 2004. Ocorrência e abundância da carcinofauna acompanhante na pesca do camarão sete-barbas, *Xiphopenaeus kroyeri* Heller (Crustacea, Decapoda), na Armação do Itapocoroy, Penha, Santa Catarina, Brasil. Rev. Bras. Zool., 21: 295-301.
- Branco, J.O. & H.A.A. Fracasso. 2005. Ocorrência e abundância de *Rynchops niger* Linnaeus, no litoral de Santa Catarina, Brasil. Rev. Bras. Zool., 22: 430-432.
- Branco, J.O., I.F. Machado & M.S. Bovendorp. 2004. Avifauna associada a ambientes de influência marítima no litoral de Santa Catarina, Brasil. Rev. Bras. Zool., 21: 459-466.
- Branco, J.O. & S. Masunari. 2000. Reproductive ecology of the blue crab, *Callinectes danae* Smith, 1869 in the Conceição Lagoon system, Santa Catarina isle, Brazil. Rev. Brasil. Biol., 60: 17-27.
- Branco, J.O. & H.C. Moritz Jr. 2001. Alimentação natural do camarão sete-barbas (*Xiphopenaeus kroyeri*), na Armação do Itapocoroy, Penha, SC. Rev. Bras. Zool., 18: 53-61.
- Branco, J.O. & J.R. Verani. 1997. Dinâmica da alimentação natural de *Callinectes danae* Smith (Decapoda, Portunidae) na Lagoa da Conceição, Florianópolis, Santa Catarina, Brasil. Rev. Bras. Zool., 14: 1003-1018.
- Branco, J.O. & J.R. Verani. 1998. Aspectos bioecológicos do camarão-Rosa *Penaeus brasiliensis* Latreille (Natantia, Penaeidae) da Lagoa da Conceição, Florianópolis, Santa Catarina, Brasil. Rev. Bras. Zool., 15: 345-351.
- Branco, J.O., M. Hostim-Silva, A.M.T. Rodrigues, L. Clezar, G.C. Ribeiro & M.S.C. Souza. 1998a. Proteção e controle de ecossistemas costeiros: Manguezal da Baía da Babitonga. Coleção Meio Ambiente IBAMA Série Estudos Pesca, Brasília, pp. 49-58.
- Branco, J.O., M.J. Lunardon-Branco, A.C. Peret, F.X. Souto, R. Schweitzer. & W.G. Vale. 1998b. Associações entre macroinvertebrados e peixes demersais na Armação do Itapocoroy, Penha, SC, Brazil. Braz. Arch. Biol. Tech., 41: 268-277.
- Branco, J.O., M.J. Lunardon-Branco, J.R. Verani, R. Schweitzer, F.X. Souto & W.G. Vale. 2002. Natural diet of *Callinectes ornatus* Ordway, 1863 (Decapoda, Portunidae) in the Itapocoroy inlet, Penha, SC, Brazil. Braz. Arch. Biol. Tech., 45: 35-40.
- Branford, J.R. 1981. Sediment and the distribution of penaeid shrimp in the Sudanese Red Sea. Estuar. Coast. Shelf Sci., 13: 349-354.
- Chacur, M.M. & M.L. Negreiros-Fransozo. 2001. Spatial and seasonal distributions of *Callinectes danae* (Decapoda, Portunidae) in Ubatuba bay, São Paulo, Brazil. J. Crust. Biol., 21: 414-425.

- Coelho, P.A., M.C.F. Santos, A.E.T.S. Freitas, A.C.C.D. Silva & S.M. Santos. 2004. Crustáceos decápodos coletados no estado de Sergipe - Brasil. *Bolm Técn. Cient. CEPENE*, 12: 81-90.
- Colvocoresses, J.A. & J.A. Musick. 1984. Species associations and community composition of Middle Atlantic Bight continental shelf demersal fishes. *Fish. Bull.*, 82: 295-313.
- Costa, R.C., A. Fransozo, F.L.M. Mantelatto & R.H. Castro. 2000. Occurrence of shrimp species (Crustacea: Decapoda: Natantia: Penaeidea and Caridea) in Ubatuba bay, Ubatuba, SP, Brazil. *Proc. Biol. Soc. Wash.*, 113: 776-781.
- Day, J.W., C.A. Hall, W.M. Kemp & A. Yáñez-Arancibia. 1989. Estuarine ecology. John Wiley & Sons, New York, 558 pp.
- Dittel, A.I. & C.E. Epifanio. 1990. Seasonal and tidal abundance of crab larvae in a tropical mangrove system, Gulf of Nicoya, Costa Rica. *Mar. Ecol. Prog. Ser.*, 65: 25-34.
- Fernandes, L.D., S.L.C. Bonecker & J.L. Valentin. 2002. Dynamic of decapod crustacean larvae on the entrance of Ganabara bay. *Braz. Arch. Biol. Tech.*, 45: 491-498.
- Forbes, A.T. & D.P. Cyrus. 1991. Recruitment and origin of penaeid prawn postlarvae in two south-east African estuaries. *Estuar. Coast. Shelf Sci.*, 33: 281-289.
- Johnson, D.F. 1985. The distribution of brachyuran crustacean megalopae in the waters of the York River, Lower Chesapeake bay and adjacent shelf: Implications for recruitment. *Estuar. Coast. Shelf Sci.*, 20: 693-705.
- Loebmann, D. & J.P. Vieira. 2006. O impacto da pesca do camarão-rosa *Farfantepenaeus paulensis* (Pérez-Farfante) (Decapoda, Penaeidae) nas assembléias de peixes e siris do Parque Nacional da Lagoa do Peixe, Rio Grande do Sul, Brasil. *Revta. Bras. Zool.*, 23: 1016-1028.
- Mantelatto, F.L.M. & A. Fransozo. 2000. Brachyuran community in Ubatuba bay, northern coast of São Paulo State, Brazil. *J. Shelf Res.*, 19: 701-709.
- Mantelatto, F.L.M., R. Biagi, F.C.R. Faria, A.L. Meireles & G.A.S. Melo. 2004. Checklist on brachyuran fauna (Decapoda) from infralitoral rocky/sandy bottom of Anchieta Island, São Paulo State, Brazil. *Nauplius*, 12: 135-142.
- Marques, J.C., P. Maranhão & M.A. Pardal. 1993. Human impact on the subtidal macrobenthic community structure in the Mondego estuary (Western Portugal). *Estuar. Coast. Shelf Sci.*, 37: 403-419.
- Melo, G.A.S. 1989. A fauna de Brachyura (Crustacea, Decapoda) do litoral do Estado do Paraná. *Nerítica*, 4: 1-31.
- Melo, G.A.S. 1996. Manual de identificação dos Brachyura (caranguejos e siris) do litoral brasileiro. Plêiade/FAPESP, São Paulo, 604 pp.
- Moreira, P.S., A.M. Paiva Filho, C.M. Okida, J.M.M. Schmiegelow & R. Giannini. 1988. Biologia de crustáceos decápodos, braquiúros, no sistema baía-estuário de Santos e São Vicente, SP. Ocorrência e composição. *Bolm. Inst. Oceanogr.*, 36: 55-62.
- Nakagaki, J.M., M.L. Negreiros-Fransozo & A. Fransozo. 1995. Composição e abundância de camarões marinhos (Crustacea, Decapoda, Penaeidae) na Enseada de Ubatuba (SP), Brasil. *Arq. Biol. Tecnol.*, 38: 583-591.
- Neiva, G.S. 1966. Aspectos sobre a biologia e a pesca do camarão rosa da região centro-sul do Brasil. *Rev. Nac. Pesc.*, 52: 9-12.
- Newell, R.C., L.J. Seiderer & D.R. Hitchcock. 2003. The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanogr. Mar. Biol.*, 36: 127-178.
- Newell, R.C., L.J. Seiderer, N.M. Simpson & J.E. Robinson. 2004. Impacts of marine aggregate dredging on benthic macrofauna off the south coast of the United Kingdom. *J. Coast. Res.*, 20: 115-125.
- Oshiro, L.M.Y., R. Silva & Z.S. Silva. 1998. Composição da fauna de braquiúros (Crustacea, Decapoda) dos manguezais da Baía de Sepetiba-RJ. *Nauplius*, 6: 31-40.
- Pereira, L.E., L.A. Ramos & S.X. Pontes. 1998. Lista comentada de peixes e crustáceos decápodos do estuário do Arroio Chui e região costeira adjacente, RS. *Atlântica*, 20: 165-172.
- Pérez-Castañeda, R. & O. Defeo. 2001. Population variability of four sympatric penaeid shrimps (*Farfantepenaeus* spp.) in a tropical coastal lagoon of Mexico. *Estuar. Coast. Shelf Sci.*, 52: 631-641.
- Pérez-Castañeda, R. & O. Defeo. 2005. Growth and mortality of transient shrimp populations (*Farfantepenaeus* spp.) in a coastal lagoon of Mexico: role of the environment and density-dependence. *J. Mar. Sci.*, 62: 14-24.
- Pérez-Farfante, I. 1978. Shrimps and prawns. In: W. Fisher (ed.). *FAO species identifications sheets for fishery purposes, volume 6. Western Central Atlantic (Fishery Area 31)*, Rome: FAO, Rome, p. 40.
- Pezzuto, P.R. & A.M. Echternacht. 1999. Avaliação de impactos da construção da Via Expressa SC-sul, sobre o berbigão *Anomalocardia brasiliana* (Gmelin,

- 1791) (Molusca: Pelecypoda) na Reserva Extrativista Marinha do Pirajubaé (Florianópolis, SC, Brasil). *Atlântica*, 21: 105-119.
- Pita, J.B., E.S. Rodrigues, R. Graça Lopes & J.A.P. Coelho. 1985. Levantamento da família Portunidae (Crustacea, Decapoda, Brachyura) no complexo baía-estuário de Santos, São Paulo, Brasil. *Bolm. Inst. Pesc.*, 12: 153-162.
- Resgalla Jr., C. 2001. Estudo de impacto ambiental sobre a comunidade do zooplâncton na enseada do Saco dos Limões, Baía-Sul da Ilha de Santa Catarina, Brasil. *Atlântica*, 23: 5-16.
- Rodrigues, A.M.T., M.T. Pereira, P.Z. Wegner, J.O. Branco, L. Clezar, M. Hostim-Silva & E.J. Soriano-Sierra. 1994. Manguezal do rio Camboriú: Preservação e controle da qualidade ambiental. *Série Estudos da Pesca, IBAMA-CEPSUL*, 13: 1-65.
- Santos, M.C.F., J.A. Pereira & C.T.C. Ivo. 2006. A pesca do camarão-branco *Litopenaeus schimitti* (Burkenroad, 1936) (Crustacea, Decapoda, Penaeidae), no nordeste do Brasil. *Bolm. Téc. Cient. CEPENE*, 14: 33-58.
- Santos, S., P.J. Rieger, R.R.R. Vieira & R.A. Barutot. 2000. Composição dos Crustacea (Decapoda) na Lagoa do Peixe, Rio Grande do Sul, Brasil. *Rev. Bras. Zool.*, 17: 213-223.
- Schettini, C.A.F., J. Pereira Filho & L. Spillere. 2000. Caracterização oceanográfica e biogeoquímica dos estuários dos rios Tavares e Defuntos, Reserva Extrativista de Pirajubaé, Florianópolis, SC. *Not. Técn. FACIMAR*, 4: 11-28.
- Seed, R. & R.N. Hughes. 1997. Chelal characteristics and foraging behaviour of the blue crab *Callinectes sapidus* Rathbun. *Estuar. Coast. Shelf Sci.*, 44: 221-229.
- Seitz, R.D., R.N. Lipcius, W.T. Stockhausen, K.A. Delano, M.S. Seebo S. & P.D. Gerdes. 2003. Potential bottom-up control of blue crab (*Callinectes sapidus*), distribution at various spatial scales. *Bull. Mar. Sci.*, 72: 471-490.
- Severino-Rodrigues, E., D.S.F. Guerra & R. Graça-Lopes. 2002. Carcinofauna acompanhante da pesca dirigida ao camarão sete-barbas (*Xiphopenaeus kroyeri*) desembarcado na praia do Perequê, Estado de São Paulo, Brasil. *Bolm. Inst. Pesc.*, 28: 33-48.
- Shanks, A.L. 1998. Abundance of post-larval *Callinectes sapidus*, *Penaeus* spp., *Uca* spp., and *Libinia* spp. collected at an outer coastal site and their cross-shelf transport. *Mar. Ecol. Prog. Ser.*, 168: 57-69.
- Sharov, A.F., J.H. Volstad, G.R. Davis, B.K. Davis, R.N. Lipcius & M.M. Montane. 2003. Abundance and exploitation rate of the blue crab (*Callinectes sapidus*) in Chesapeake Bay. *Bull. Mar. Sci.*, 72: 543-565.
- Signoret, M. 1974. Abundancia, tamaño y distribución de camarones (Crustacea, Penaeidae) de la Laguna de Términos, Campeche y su relación con algunos factores hidrológicos. *An. Inst. Biol. Univ. Nal. Autón. Mex.*, 45: 119-140.
- Sousa, E.C., P.A. Coelho & T.C.S. Calado. 2000. Crustacea Decapoda dos canais da lagoa Manguaba no complexo estuarino-lagunar Mundaú/Manguaba - Alagoas, Brasil. *Bolm. Est. Ciênc. Mar*, 11: 165-192.
- Souza-Conceição, J.M., M. Rodrigues-Ribeiro & M.A. Castro-Silva. 2005. Dinâmica populacional, biologia reprodutiva e ictioplâncton de *Cetengraulis edentulus* Cuvier (Pisces, Clupeiformes, Engraulidae) na enseda do Saco do Saco dos Limões, Florianópolis, Santa Catarina, Brasil. *Rev. Bras. Zool.*, 22: 953-961.
- Spivak, E.D. 1997. Cangrejos estuariales del Atlántico Sudoccidental (25°-41°S) (Crustacea: Decapoda: Brachyura). *Invest. Mar. Valparaíso*, 25: 105-120.
- Stoner, A.W. 1986. Community structure of the demersal fish species of Laguna Joyuda, Puerto Rico. *Estuaries*, 9: 142-152.
- Tankersley, R.A., M.G. Wieber, M.A. Sigala & K.A. Kachurak. 1998. Migratory behavior of ovigerous blue crabs *Callinectes sapidus*: Evidence for selective tidal-stream transport. *Biol. Bull.*, 195: 168-173.
- Teixeira, R.L. & H.S. Sá. 1998. Abundância de macrocrustáceos decápodos nas áreas rasas do complexo lagunar Mundaú/Manguaba, AL. *Rev. Bras. Biol.*, 58: 393-404.
- Von Dolah, R.F., D.R. Calder & D.M. Knott. 1984. Effects of dredging and open-water disposal on benthic macroinvertebrates in a South Carolina estuary. *Estuaries*, 7: 28-37.
- Zar, J.H. 1999. *Bioestatistical analysis*. Prentice-Hall, New Jersey, 663 pp.

Received: 30 April 2009; Accepted: 17 August 2010