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Environmental Impacts of the Nourishment of Balneário Camboriú Beach, SC, Brazil

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ABSTRACT

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From June to August 2002 the municipality of Balneário Camboriú developed a nourishment program in the southern sector of the beach using sediments dredged from Camboriú River mouth. Ecotoxicological, sedimentological and biological samplings were conducted in order to detect environmental impacts related to the project. The interstitial water at the mine site as well as in the pipeline opening showed chronic toxicity suggesting a poor chemical quality of the sediment used in the program. Sediments at the mine site were 30% silt/clay and 7.2% gravel while the native sediments on the nourished beach was 99.8% sand (mainly fine sand) and 0.2% gravel. After the nourishment, beach sediments were composed by 90.2% of medium sands and 9.6% of gravel. Most of the silt and clay was transported to the nearshore-offshore zones within the Balneário Camboriú bay, modifying its surface sedimentolgy. Before the beach nourishment, shallower zones were mainly sandy, with high silt percents found only at the northern and deeper stations. After the beach restoration, up to 27% of silt could be found from the shallower stations to the middle of the bay, while the percent of clay increased from a maximum of 2% before the project to 97% at the northern and deeper stations, suggesting a transport of sediments from the nourished zone towards the north along the depth gradient. More than 2.3 t of biological material was dispersed on the beach around the pipeline on a single day, mostly corresponding to shell hash (58%). Vegetal debris were the second item, with 18,7% of the total weight. The bivalves *Tagelus plebeius*, *Anomalocardia brasiliana* and *Crassostrea rhizophorae*, pertaining to a rich benthic community inhabiting the mine site, summed nearly 21%. Expressive and continuous mortalities of the beach-dwelling suspension-feeding bivalve *Tivela mactroides* occurred along 2003. The strandings occurred from the south to the north, and were observed even during periods of low wave energy. No similar mortalities were registered in neighboring beaches. It is suspected that these events should be a response to the suffocation by the drift of fine sediments and organic matter from the nourished zone towards the north. The municipality is considering the nourishment of all beach extension as an alternative to counteract its erosional tendency as well as to enlarge the beach area available to the increasing population. We expect that specific environmental protection protocols be considered before the start of a new restoration program, in order to minimize its negative impacts on the local ecosystem.

ADDITIONAL INDEX WORDS: *Ecotoxicology, sedimentology, macrobenthos.*

INTRODUCTION

Baneário Camboriú is one of the main tourist resorts in Southern Brazil. Most of the year the local population is around 58,000 inhabitants but increases to more than 1 million during the summer (MORELLI, 1997). Since the 1960' the city has experienced an intensive but not planned growth, resulting in many environmental problems (TEMME *et al.*, 1997). The urbanization of the coastal plain was not conducted on a safe distance from the beach, the sand dunes been replaced by a protection wall, a road and tens of tall buildings along the over than 5.8 km long shoreline. This process changed the dynamic equilibrium of the beach and therefore, Balneário Camboriú has exhibited strong erosional events during storms and a significant reduction of the beach-width with time (TEMME *et al.*, 1997). In order to minimize the losses on the most affected areas, between June and August 2002 the municipality suddenly decided to nourish the southern sector of the beach using sediments which were been dredged from the Camboriú River mouth in order to deepen its navigation channel. Nearly 50,000 cubic meters of sediments were hydraulically dredged and deposited along 800 m of the beach using a movable pipeline (Figure 1). While authorized by the environmental agency of the Santa Catarina State (FATMA), the project was not preceded by any specific study to assess its technical viability and its environmental impacts on the beach and nearshore zones.

According to PETERSON *et al.* (2000b), the degree of habitat degradation caused by beach nourishment projects will depend mainly on a) the season of disturbance; b) characteristics of the sediments deposited as grain size, shell and mud ball contents as well as toxic components; c) geographic extent of the project and; d) dune sedimentology. These effects should be considered in the planning of nourishment initiatives if their environmental impacts are to be minimized. In spite of the sudden execution of the project which precluded the development of optimum impact study designs (GREEN, 1979; NELSON, 1993) in this paper we summarize ecotoxicological, sedimentological and biological data gathered before, during and after the Balneário Camboriú nourishment operations, with the aim of assessing some of their negative consequences on the local environment.

STUDY AREA

Balneário Camboriú is located on the northern coast of the Santa Catarina State, Southern Brazil, and is an dissipative arc headland bay beach delimited by two igneous and metamorphic pre-Cambrian headlands (SCHEIBE, 1986; KLEIN *et al.*, 2002). Adjacent to the southern headland (Ponta das Laranjeiras), the Camboriú River opens to the sea forming an ebb tide delta. Presenting a mean discharge of 3 $m^3.s^{-1}$ (SILVA and SCHETTINI 1997), the river has a drainage area of about 200 km^2 most of them used for rice cultivation. On the other extreme of the beach, the Marambaia brook opens to the sea carrying part of the domestic sewage from Balneário Camboriú city. The beach is 5840 meters long with and average width of 17 meters. It is composed by well-sorted fine to very fine sands with a mean diameter of 0.1 to 0.2 mm. The northern portion of the beach is

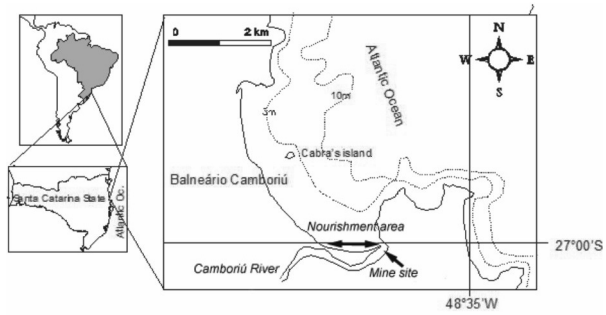

Figure 1. Study area showing the sites of dredging and nourishment on the southern sector of the beach.

exposed to the more energetic southeasterly waves as compared to its southern sector, protected from the waves by the Ponta das Laranjeiras headland (TEMME *et. al*, 1997; KLEIN and MENEZES, 2001; KLEIN *et al.* 2002)

METHODS

Ecotoxicological and Chemical Analysis

Ecotoxicological experiments were conducted both before (LAITANO and RESGALLA JR., 2000) and during the project. Sediment samples were collected at the mine site in October 1999 as well as samples from the water pumped with the sediment by the pipeline in June 2002. The effect of the sediment quality on the embryo-larval development of the sea urchin *Litechinus variegatus* was analyzed through short-term chronic toxicity tests according with the methodology described by CETESB (1992). In the laboratory, sea urchins previously collected in the field were induced to spawn and the embryos exposed for 24 h to the water extracted from the sediment samples. The exposition was stopped when the larvae from the control treatment reached the pluteus stage. Embryos and larvae from all treatments were fixed with formalin 10% and examined on the microscope in order to quantify the number of normal and deformed pluteus larvae and the number of non-developed embryos in each treatment. Additional and independent toxicity tests were conducted for all samples after treatment with EDTA (50 $mg.l^{-1}$), Sodium Thiosulphate (50 $mg.l^{-1}$) and passage through a C18 column (Whatman SPE ODS 500 mg), for identifying the respective toxic components following EPA (1991). The presence of the metals As, Hg, Pb, Cd and Ni in the elutriate samples was evaluated through analysis with an atomic absorption spectrophotometer.

Sedimentological Analysis

Superficial sediments were characterized after different surveys conducted a) on the Camboriú River estuary (ALVES JR and SANTOS, 1998), b) along the beach (TEMME *et al.*, 1997; KLEIN and MENEZES, 2001) and, c) on the nearshore zone. Estuarine sediments were analyzed before the project (1999) in five locations along the river, including in the intertidal/subtidal flat which served as the main source of sediments to the nourishment project (mine site). Beach face sediments and profiles were monitored in Balneário Camboriú from 1994 to 1996 at 18 stations along the beach (KLEIN and MENEZES, 2001). Data of three stations placed at the nourishment zone were used in order to detect sediment changes related to the project. The nearshore sedimentology was analyzed based on two surveys conducted before (1997) and after (2003) the beach nourishment. The first survey comprised 76 stations regularly spaced along the nearshore zone. Fifty-seven stations were re-sampled in May-June 2003 in order to detect possible changes in their sedimentological composition. Sediment samples collected either with a core (beach face stations) or with a Ponar grab (estuarine and nearshore stations) were processed in the laboratory for particle size analysis and determination of Calcium carbonate and organic matter contents. Particle size analysis was conducted through standard sieving (particles > 62 μm) and pippeting (particles < 62 μm) methods. For each sample, the relative percentages of gravel, sand, silt and clay were calculated and the respective statistical parameters estimated following FOLK and WARD (1957). Calcium carbonate and organic matter contents were determined gravimetrically after attack of previously dried (50º C) samples with HCl and Hydrogen peroxide (H_2O_2), respectively.

Biological Analysis

Biological quantitative samples were collected in June 04, 2002 along the zone where the organic material originating from the pipeline was dispersed on the surface of the beach. Samples of the dispersed material were collected in four stations positioned up to 255 m to the north of the pipeline and in two stations up to 95 m to the south. These distances corresponded to the maximum extension of the dispersion zone on the sampling occasion. In each station, three replicates were obtained with a quadrat of 0.25 m^2. In addition, the width of the beach and of the zone of deposition was measured in all stations. In the laboratory the samples were processed separating a) fresh animals and their remains, b) ancient shells and their fragments and c) vegetal debris. All animals were counted, weighed and identified to the lowest taxonomic level. The shell and vegetal debris were only weighed. For each station and species the respective mean density ($individual.m^{-2}$) and biomass (g of fresh $weight.m^{-2}$ and g of fresh $weight.m^{-1}$) were calculated. "Biomass" values were calculated also for shell and vegetal debris. The mean biomass of each item were integrated along the depositional zone (350 m), in order to estimate the total weight dispersed along the shoreline.

RESULTS

Ecotoxicological and Chemical Analysis

According to the sea-urchin tests, the water sampled from the sediment in the opening of the pipeline showed a high chronic toxicity, which could not be reduced by the treatments (Table 1). The toxicity could not be assigned neither to organics nor to oxidants but was probably related to metals as Chromium, which does not form complexes with EDTA and Sodium Thiosulphate. Similar results were found before the nourishment project (1999) by LAITANO and RESGALLA JR. (2000), when analyzing the sediment toxicity directly at the mine site.

Table 1. *Effect percentages in the toxicity tests conducted with the sea urchin Lytechinus variegatus using the water deposited with the sediment at the nourishment site. TS = Sodium Thiosulphate. P < 0.05 = significant difference in relation to the control as indicated by the Tukey a posteriori test.*

Sample	Replicates				Mean	P < 0.05
	1	2	3	4		
Control	3	0	2	0	1.25	
Crude sample	100	100	100	100	100.0	*
Control C_{18}	5	2	5	1	3.25	
Sample C_{18}	100	100	100	100	100.0	*
Control EDTA	0	2	2	0	1.00	
Sample EDTA	100	100	100	100	100.0	*
Control TS	5	5	3	2	3.75	
Sample TS	100	100	100	100	100.0	*

Table 2. *Total weight and relative contribution of the items dispersed around the pipeline in June 04, 2002.*

Item	Weight (kg)	%
Shell hash	1,387.83	58.25
Vegetal debris	445.65	18.70
Tagelus plebeius	314.11	13.18
Anomalocardia brasiliana	105.40	4.42
Crassostrea rhizophorae	93.79	3.94
Tivela mactroides	13.11	0.55
Diopatra cuprea	11.97	0.50
Bulla striata	5.50	0.23
Telina lineata	1.76	0.07
Telina sp	1.63	0.07
Cerithium atratum	1.20	0.05
Neritina.virginea	0.28	0.01
Divaricella quadrisulcata	0.26	0.01
Nassarius vibex	0.25	0.01
TOTAL	2,382.75	100.00

Sedimentological Analysis

The replenishment project modified substantially the sedimentary features not only on the beach face but also on the bay bottom. According to KLEIN and MENEZES (2001) the original sediments of the Balneário Camboriú beach were composed by fine sands (Mz = 0.13 mm) with 99.8% of sand and 0.2% of gravel. On the other hand, the sediment at the mine site was very different from the beach, containing 63.6% of sand, 2.3% of silt, 26.9% of clay and 7.2% of gravel. Analysis conducted on the nourished beach surface in May-June 2003, revealed a significant reduction of its fine fraction with time, as local sediments were characterized by medium sands (Mz = 0.28 mm), with 90.2% of sand, 9.6% of gravel, 0.1% of silt and 0% of clay.

Severe sedimentological changes were also recorded on the nearshore and offshore zones (Figure 2). Before the beach nourishment, shallower zones were mainly sandy, with high silt contents found only at the northern and deeper stations. After the beach restoration, up to 27% of silt could be found from the shallower stations to the middle of the bay, between the Cabras' Island and the nourished zone. In addition, the percent of clay increased from a maximum of 2% before the project to 97% on the northern and deeper stations (Figure 2). This suggests that a substantial volume of fine particles was transported from the nourished zone towards the north, resulting a clear gradation from sand and gravel on the beach to silt and clay along the depth and distance gradients.

Biological Analysis

The sampling along the zone influenced by the discharge indicated that at least 17 species were negatively affected in the region. Most of the species pertained to a typical estuarine fauna inhabitant of the intertidal/subtidal flat or its vicinity. This group comprised the bivalves *Tagelus plebeius*, *Anomalocardia brasiliana*, *Divaricella quadrisulcata* and *Crassostrea rhizophorae*, the gastropods *Bulla striata*, *Nassarius vibex*, *Cerithium atratum* and *Neritina virginea*, the crab *Callinectes danae* , the *polychaete Diopatra cf. cuprea* and the fishes *Netuma barba* and *Genidens genidens* which were killed probably by the action of the hydraulic dredge. On the other hand, the bivalves *Tivela mactroides*, *Tellina lineata* and *Tellina sp.* and the crab *Arenaeus cribarius* are beach dwellers, living on the beach face and nearshore zones. These species

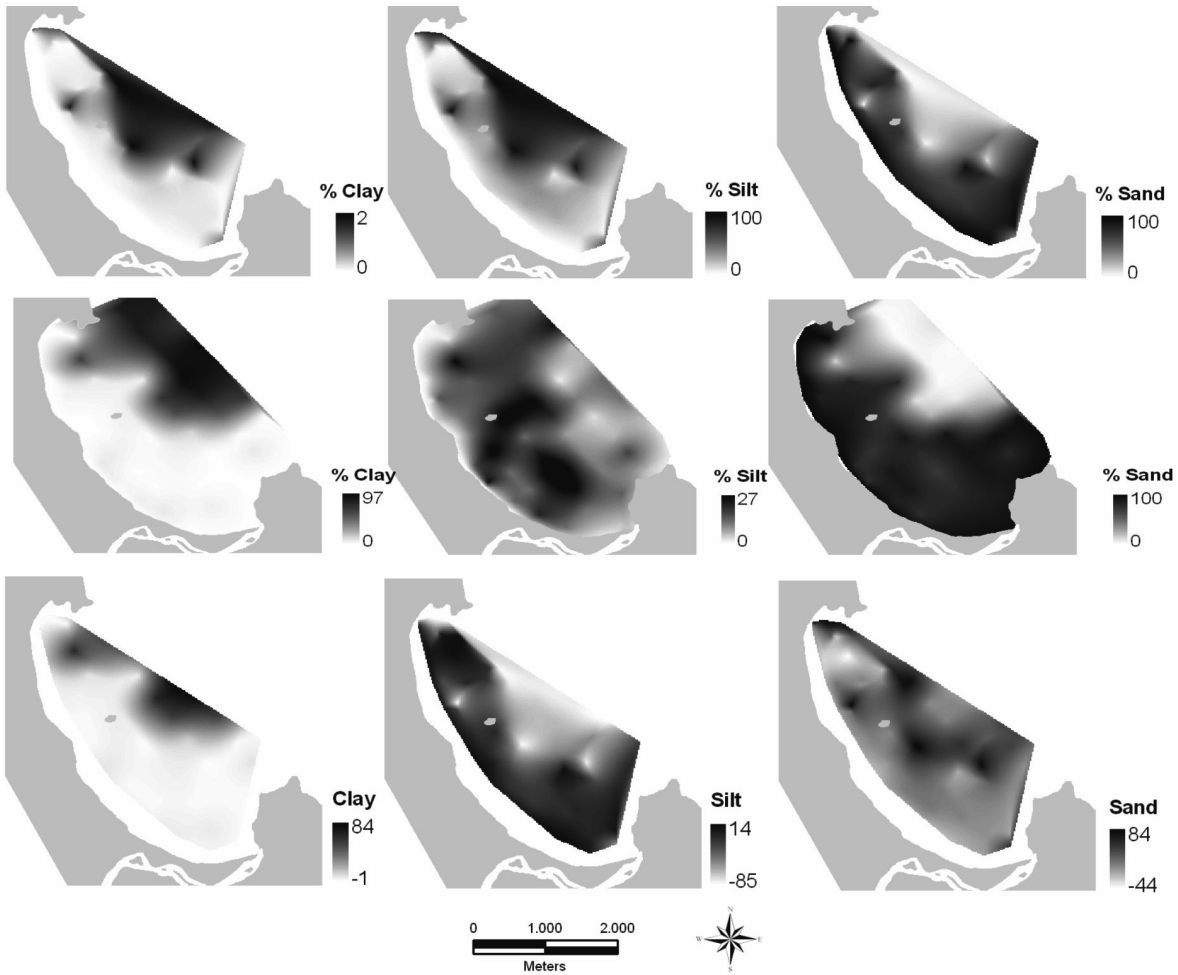

Figure 2. Percentages of clay, silt and sand recorded on two surveys conducted on the Balneário Camboriú Bay before (up) and after (middle) the beach nourishment operatios and respective differences in the percentages measured between the surveys at the same sample sites (bottom).

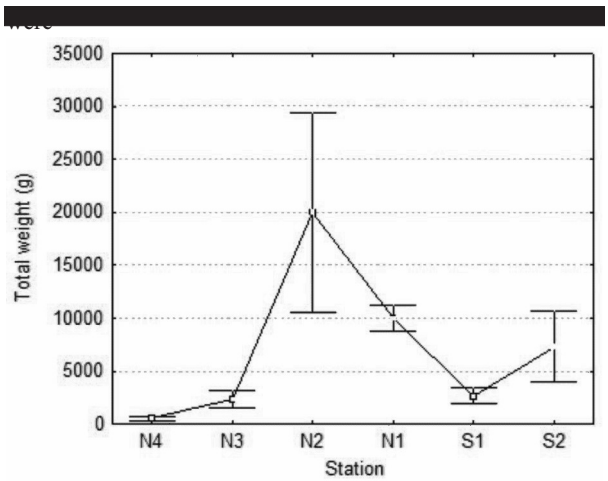

Figure 3. Mean weight (SE) of the material found at the stations sampled along the beach in June 2002. The pipeline opening was situated between stations N1 and S1.

probably killed a) by burying (specially *T. mactroides*), b) by the increased turbidity on the nearshore zone caused by the transport of fine sediments (see below) and/or c) by negative effects related to the chemical characteristics of the dredged sediments. Most of the material was found to the north from the disposal area. Along the sampled stations, the mean weight of the material varied from 0.5 $kg.m^{-1}$ at station N4 to 20 $kg.m^{-1}$ at station N2 (255 and 95 m from the pipeline, respectively) (Figure 3). Along 350 m of the beach where the material was dispersed, its total weight summed 2,382 kg, mostly corresponding to shell hash (Table 2). Vegetal debris were the second item, with 18.7% of the total weight. The bivalves *T. plebeius*, *A. brasiliana* and *C. rhizophorae* together summed nearly 21% (Table 2).

DISCUSSIONS

Analysis conducted in this study showed: a) ecotoxicological effects of the sediment elutriate in the dredging zone as well as in the water deposited with the sediment at the nourished site, suggesting a poor chemical quality of the material used in the nourishment project; b) massive quantitities of shell hash, vegetal debris and death macrofauna deposited by the pipeline on the nourished area, totalizing at least 2.3 t of material exposed along 350 m of restored beach in a single day; c) a very different composition between the original beach sediments and the sediments dredged from the Camboriú River estuary, the latter exhibiting a higher gravel and mud contents than the former; d) significant changes in the characteristics of the beach sediments after the replenishment, which became coarser and more gravelly than the original sediments and e) profound changes in the surface sediments of the Balneário Camboriú Bay, with a very strong increase in their silt and clay contents, suggesting a progressive transport of fine particles from the nourished area towards the northern and deeper zones of the bay.

Whereas the ecotoxicological tests used in this study had suggested contamination by metals in the samples, the techniques for Toxicity Identification Evaluation (TIE), as proposed by EPA (1991) should be considered with caution when applied for marine organisms because they were developed formerly for freshwater analysis, and the complexation of metals with EDTA may vary with the ionic force of the solution.

The chemical analysis of the elutriate were not successful in identifying the presence of metals as As, Hg, Pb, Cd and Ni in the samples and with the exception of Cr, the other metals as Fe and Al are not problematic in terms of toxicity. In addition, positive correlations between sediment toxicity and its contaminants are occasionally not observed due to a) the especiation of the elements; b) their bioavailability and c) different degrees of sensibility of the organisms used in the tests (CHAPMAN *et al.*, 1998; O´CONNOR and PAUL, 2000). On the other hand, sediments of eutrophic aquatic systems as the Camboriú River estuary are known as exhibiting high concentrations of toxic substances like amonium. These substances may render difficult the interpretation of ecotoxicological tests, as their effects may coincide with the effects of other substances (CALMANO and FÖRSTNER, 1996).

While the toxicity found in the samples could not be assigned to a specific substance, it is suggested that the estuarine sediments were not chemically suitable for the Balneário Camboriú beach nourishment. In fact, some authors have pointed out the absence of toxic substances in the sediments as one of the critical conditions to be observed in the choice of mine sites for beach replenishment, as they can impair settling of larvae and/or negatively affect later life stages of the benthic invertebrates in the nourished sites (PETERSON *et al.*, 2000b).

GORZELANY and NELSON (1987) investigated the changes in the benthic fauna of the nearshore zone before and after a beach replenishment project in Florida. The sediment added to the beach was coarser than the original and was trucked in from an on-land spoil pile, possibly containing low levels of toxic components as hydrogen sulfide. The authors did not find signficant negative effects on the fauna after the ending of the nourishment operations, specially as compared to projects where the sediments were extracted from estuarine bottoms with large amounts of mud and hydrogen sulfide. They concluded that matching in grain size between source and nourishment sites and hydrogen sulfide release may be factors of importance in terms of impacting benthic communities in nourished beaches.

The sedimentological analysis conducted in this study revealed substantial changes in the beach and bay sediments after the nourishment operations. Beach sediments become coarser and gravely with time and bay sediments become progressively finer with depth and distance from the shore. Both changes were related to the sediment characteristics at the mine site, which contained almost 30% of silt/clay and more than 7% of gravel. It was specially remarkable the increasing in silt concentrations on the previously sand-dominated southern sector of the bay, and the coverage of most of the bottom in the northern and deeper areas with more than 90% of clay, where the original concentrations were up to 2%. These features indicate a progressive transport of fine particles from the nourished beach towards the north, influencing most of the bay area.

The increasing in silt/clay loading and turbidity has been suggested to impact benthic assemblages in short and long-term scales both on the nourished beaches and nearshore-offshore zones (RAKOCINSKI *et al.*, 1996; PETERSON *et al.,* 2000a; GREENE, 2002a, 2002b). PETERSON *et al.* (2000a) investigated the short-term consequences of beach nourishment and bulldozing on the benthic invertebrates in a sandy beach from North Carolina. After the cessation of the beach restoration, sediments at the nourished sites were characterized by containing extensive amounts of shell hash and several mud balls. In addition, as compared to control sites, the mean grain size on the nourished beach changed from 2.33ϕ (fine sand) to 3.67ϕ (very fine sand almost coarse silt). Dominant components of the intertidal beach macrofauna, the mole crab *Emerita talpoida* and the bean clam *Donax* spp. had their abundance lowered by 86-99% up to 10 weeks after the ending of the nourishment operations, probably affecting energy transfer to the surf zone predators.

On the other hand, studies conducted by RAKOCINSKI *et al.* (1996) during and after extensive beach restoration at Perdido Key, Florida, demonstrated important changes in benthic structure in response to silt/clay loading in the nearshore and offshore areas, more than two years after the end of the project. Responses of the fauna included decreased species richness and total abundance, enhanced fluctuations in these indices and modifications in the assemblage structure even at several

offshore stations. These results supports the hypothesis that stable offshore assemblages may be less resilient to sediment changes from nourishment projects that the nearshore fauna, which inhabits a naturally more instable sedimentary environment (RAKOCINSKI *et al.*, 1996).

During the nourishment operations in Balneário Camboríu, most of their short-term negative impacts were observed at the mine site, with the elimination of a rich assemblage dominated by the bivalves *Anomalocardia brasiliana* and *Tagelus plebeius* and also along the 800 m of nourishing beach, where the local macrofauna is expected to have been killed by the smothering with the pumped sediments.

Given the extensive modifications observed in the sedimentary characteristics of the Balneário Camboriú bay, even in the farthest areas (> 3 km) from the nourished zone, it is expected also that their benthic sublitoral assemblages had experienced significant changes in their structure in a long-term basis. Considering the volume of sediment deposited on the beach and its mud content, we estimate that nearly 15,000 cubic meters of silt/clay were transported to the bay during and after the nourishment operations. In addition large volumes of organic matter (vegetal debris, death fauna and detritus) were also made available to the system with the deposition of sediments dredged from the estuarine zone. The responses of the sublitoral benthic fauna to the beach replenishment are been investigated at 24 stations positioned along five transects regularly spaced on the Balneário Camboriú bay. Samplings has been conducted since December 2001 before the start of the nourishment operations, and will be analysed later.

However, at least one severe impact has been observed in Balneário Camboriú between February and November 2003, when several events of mortality of the infaunal suspension-feeding (NARCHI, 1972) bivalve *Tivela mactroides* were recorded. Previously observed in the region only sporadically after the most severe storms, the continuous coverage of the beach by tons of dead stranded organisms raised concerns in the local population and environmental agencies. Along the year, the mortalities occurred progressively from the south to the north of the beach, and were observed even during periods of low wave energy. No similar mortalities were registered in neighboring beaches where the species is present. It is suspected that these events should be a response to the suffocation by the drift of fine sediments and organic matter from the nourished zone towards the north, as indicated by the sedimentological analysis. Whereas qualitative data on the benthic fauna of Balneário Camboriú beach were provided by WEGNER (1990), no quantitative information exists for the region except for the pea crab *Austinixa patagoniensis* and its host, the ghost shrimp *Callichirus major* (ALVES, 1998; ALVES and RODRIGUES, 2003). However, the expressive biomass of *T. macroides* as revealed by the intensity of the strandings points out this bivalve as a dominant species whose mortalities should have a broader impact in the whole beach and nearshore ecosystem.

The municipality is considering the nourishment of all beach extension as an alternative to counteract its erosional tendency as well as to enlarge the beach area available to the increasing tourist and resident populations. A new study has been started in order to characterize the local beach fauna in spatial and temporal scales in order to provide guidelines for a more reational project planning. We expect that specific environmental protection protocols be considered by the municipality and FATMA before the start of a new beach restoration program, in order to minimize its negative impacts on the local ecosystem.

LITERATURE CITED

ALVES, E.S., 1998. Ecologia populacional de *Pinnixa patagoniensis* Rathbun, 1918 (Brachyura: Pinnotheridae), simbionte de *Callichirus major* (Decapoda: Callianassidae), no mediolitoral da praia de Balneário Camboriú, SC. São Paulo, São Paulo: Universidade de São Paulo, Master's thesis, 139p.

ALVES, E.S and RODRIGUES, S.A., 2003. Distributional patterns of *Austinixa patagoniensis* (Rathbun, 1918) (Decapoda: Pinnotheridae), a symbiotic crab of *Callichirus major* (Decapoda: Callianassidae), in Balneário Camboriú beach, Santa Catarina, Brazil. *Journal of Coastal Research*, SI 35 (Proceedings of the Brazilian Symposium on Sandy Beaches: Morphodynamics, Ecology, Uses, Hazards and Management), 408-417. Itajaí, SC Brazil.

ALVES JR., L. and SANTOS, M.I.F. dos., 1998. Caracterização sedimentológica da enseada de Camboriú, Balneário Camboriú. *IV Seminário Integrado de Iniciação Científica Blumenau*, Santa Catarina, Brasil, p.81.

CALMANO, W. and FÖRSTNER, U., 1996. *Sediments and toxic substances. Environmental effects and ecotoxity.* Berlin: Springer, 335p.

CETESB, 1992. Teste de toxicidade crônica de curta duração com *Lytechinus variegatus*, Lamarck, 1816. *Norma Técnica CETESB*, L5.250.

CHAPMAN, P.M.; WANG, F.; JANSSEN, C.; PERSOONE, G. and ALLEN, H.E., 1998. Ecotoxicology of metals in aquatic sediments: binding and release, bioavailability, risk assessment, and remediation. *Canadian Journal of Fishery and Aquatic Sciences*, 55, 2221-2243.

EPA., 1991. Methods for aquatic toxicity identification evaluations Phase I Toxicity characterization procedures. *EPA/600/6-91/003*, Washington, D.C., USA, 2nd. Ed., 98 p.

GORZELANY, J.F. and NELSON, W.G., 1987. The effects of beach replenishment on the benthos of a sub-tropical Florida beach. *Marine Environmental Research*, 21, 75-94.

GREEN, R.H., 1979. *Sampling design and statistical methods for environmental biologists*. New York: John Wiley & Sons. 272p.

GREENE, K., 2002a. Beach nourishment: possible impacts to fish and fish habitat. *Habitat Hotline Atlantic*, 9(3), 1-5.

GREENE, K., 2002b. Beach nourishment: a review of the biological and physical impacts. Washington, DC: Atlantic States Marine Fisheries Commision, *ASMFC Habitat Management Series #7*, 174p.

KLEIN, A.H.F. and MENEZES, J.T., 2001. Beach morphodynamics and profile sequence for a heakland bay coast. *Journal of Coastal Research,* 17(4), 812-835.

KLEIN, A.H.F.; BENEDET FILHO, L., and SCHUMACHER, D.H., 2002. Short-term beach rotation processes in distinct headland bay beach systems. *Journal of Coastal Research*, 18(3), 442-458.

LAITANO, K. and RESGALLA JR, C., 2000. Uso de testes de toxicidade com larvas de *Arbacia lixula* e juvenis de *Metamysidopsis elongata atlantica* na avaliação da qualidade do sedimento dos rios Camboriú e Itajaí-Açu (Santa Catarina). In: ESPÍNDOLA, G.; BOTTA PASCHOAL, C.M.R.; ROCHA, O.; BOHRER, M.B.C. and, OLIVEIRA NETO, A.L. (Org.). *Ecotoxicologia. Perspectivas para o século XXI*. São Carlos, v. 1, pp. 29-42.

MARTIN, L.; SUGUIO, K.; FLEXOR, J-M., and AZEVEDO, A.E.G., 1988. Mapa geológico do Quaternário costeiro dos Estados do Paraná e Santa Catarina. *Série Geologia Básica*. DNPM, 28, 40 p.

MORELLI, F., 1997. Dinâmica de nutrientes inorgânicos na enseada de Camboriú, Balneário Camboriú, SC. Itajaí, Santa Catarina: Universidade do Vale do Itajaí, Bachelor's thesis, 82p.

NARCHI, W., 1972. Comparative study of the functional morphology of *Anomalocardia brasiliana* (Gmelin, 1791) and *Tivela mactroides* (Born, 1778) (Bivalvia, Veneridae). *Bulletin of Marine Science*, 22(3), 643-670.

NELSON, W.G., 1993. Beach restoration in the Southeaster US: environmental effects and biological monitoring. *Ocean & Coastal Management*, 19, 157-182.

O´CONNOR, T.P. and PAUL, J.F., 2000. Misfit between sediment toxicity and chemistry. *Marine Pollution Bulletin*, 40(1), 59-64.

PETERSON, C.H.; HICKERSON, D.H.M., and JOHNSON, G.G., 2000a. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy

beach. *Journal of Coastal Research*, 16(2), 368-378.

PETERSON, C.H.; SUMMERSON, H.C.; THOMSON, E.; LENIHAN, H.S.; GRABOWSKI, J.; MANNING, L.; MICHELI, F., and JOHNSON, G., 2000b. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. *Bulletin of Marine Science*, 66(3), 759-774.

RAKOCINSKI, D.F.; HEARD, R.W.; LECROY, S.E.; MCLILLAND, J.A., and SIMONS, T., 1996. Responses by macrobenthic assemblages to extensive beach restoration at Perdido key, Florida, U.S.A. *Journal of Coastal Research*, 12(1), 326-353.

SCHEIBE, L.F., 1986. A geologia de Santa Catarina Sinopse Provisória. Geosul, Ano 1, 7-38.

SILVA, F.L and SCHETTINI, C.A.F., 1997. Contribuição à hidrologia do estuário do Rio Camboriú: avaliação da contribuição fluvial. *Resumos Expandidos da X Semana Nacional de Oceanografia* (Itajaí, Santa Catarina, Brazil), pp. 496-498.

TEMME, B.; KLEIN, A.H.F.; CARVALHO, J.L.B., and DIEHL, F.L., 1997. Morphological behaviour of beach of Balneário Camboriú: preliminar results. *Notas Técnicas da FACIMAR*, 1, 49-65.

WEGNER, E., 1990. Contribuição ao conhecimento da macrofauna bentônica da praia de Camboriú, SC. Florianópolis, Santa Catarina: Universidade Federal da Santa Catarina, Hydroecology Course Report, 37p.