

EFFECTS OF DREDGING OPERATIONS ON SOFT BOTTOM MACROFAUNA IN A HARBOR IN THE PATOS LAGOON ESTUARINE REGION OF SOUTHERN BRAZIL

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ABSTRACT

An evaluation was made of the effects of dredging on the soft bottom community in the channel of the Rio Grande harbor in the Patos Lagoon estuarine region of southern Brazil. During four seasonal cruises, samples were collected from nine biological stations, one of which was located outside the dredged area. Three macrobenthic samples were collected on each cruise from each station, using a 0.08 m² van Veen grab. A cluster analysis was applied to group summer and autumn cruise stations before the dredging period, revealing larger numbers of species (35-36 spp.) and higher densities of organisms. The station located outside the dredging area was always included in this group, regardless of the sampling period or conditions of salinity. Another group comprised the winter and spring stations during the dredging period. This group was characterized by stations with the fewest species (20-18 spp.) and the lowest and most variable organism densities. The efficient strategies of resilience of the dominant estuarine species may minimize the effects of dredging on the biota through the rapid recolonization of the soft bottom of the harbor channel.

Keywords: macrobenthos, resilience, diversity.

RESUMO

Efeito das operações de dragagem sobre a macrofauna de fundos moles em uma área portuária, região estuarina da Lagoa dos Patos, sul do Brasil

Objetiva-se avaliar a resposta da associação de macroinvertebrados bentônicos ao efeito de dragagens do canal de acesso ao Porto de Rio Grande, na região estuarina da Lagoa dos Patos, RS, Brasil. Foram tomadas 3 amostras em nove estações de coleta, durante quatro cruzeiros sazonais. Uma das estações foi posicionada a montante da área dragada. As coletas foram efetuadas com um pegador van Veen de 0,08 m². A análise de classificação (Similaridade Bray-Curtis) agrupou as estações de verão e outono, realizadas antes do início das dragagens, as quais mostraram maiores valores do número de espécies (35-36 spp) e das densidades do macrozoobentos. A estação localizada a montante da área de dragagem esteve sempre incluída neste grupo, independente do período de amostragem ou das condições de salinidade na região estuarina. Um segundo grupo incluiu as estações realizadas na primavera e no inverno, que coincidiram com o período de dragagem. Estas estações apresentaram menor número de espécies (20-18 spp.) e densidades, mas com um aumento da variância. A eficiente estratégia de resiliência das espécies estuarinas dominantes pode minimizar o efeito da dragagem sobre a biota, através de uma rápida recolonização das áreas dragadas no canal de acesso ao Porto de Rio Grande.

Palavras-chave: macrobentos, resiliência, diversidade.

INTRODUCTION

The dredging of harbors to deepen them constitutes a very common anthropic disturbance in coastal areas, especially in estuaries featuring port facilities. Dredging may remove large amounts of sediment, change a harbor's features and modify the structure and dynamics of the soft bottom community (Kenny & Rees, 1996; Lewis *et al.*, 2001). Considering the relevant role of the benthic fauna in the secondary production of the estuarine system (Day *et al.*, 1989), any impact upon the macrobenthos may seriously harm the ecology and economy of the ecosystem, limiting its ability to function as a nursery area.

However, the effects of dredging on soft bottom organisms may be difficult to identify, for the dredge may miss some areas entirely, leading to some sediment slumping (Jones, 1986). Estuarine species are usually very resilient in recolonizing the substrate after a defaunation process (Whitlatch & Zajac, 1985), although records show that periods of fauna recovery may be highly variable, with intervals ranging from weeks to years (Jones, 1986). The difficulty in predicting the type of response from the soft bottom benthic community in waters

subjected to dredging requires that studies and analyses of such effects be conducted on a case-by-case basis (Harvey *et al.*, 1998).

In this study, the goal was to assess the effect on a soft bottom community resulting from the removal of approximately 2,330,000 m³ of sediment during the dredging of the channel leading into the port of Rio Grande at the southernmost tip of Brazil.

METHODS

Four cruises were taken in the year 2000 aboard the Fundação Universidade Federal do Rio Grande (FURG) Oceanographic Vessel Larus: Jan 1 (summer cruise), May 15 (autumn cruise), Aug 3 (winter cruise) and Oct 23 (spring cruise). On each cruise, samples were collected at nine sampling stations distributed along a stretch of approximately 8 km, whose northern end lay adjacent to the city of São José do Norte and included the areas of Rio Grande's new port and superport, its southern end delimited by the jetties at the mouth of the estuarine region of Patos Lagoon (Fig. 1). Station 9, located more than 1 km upstream from the area of dredging

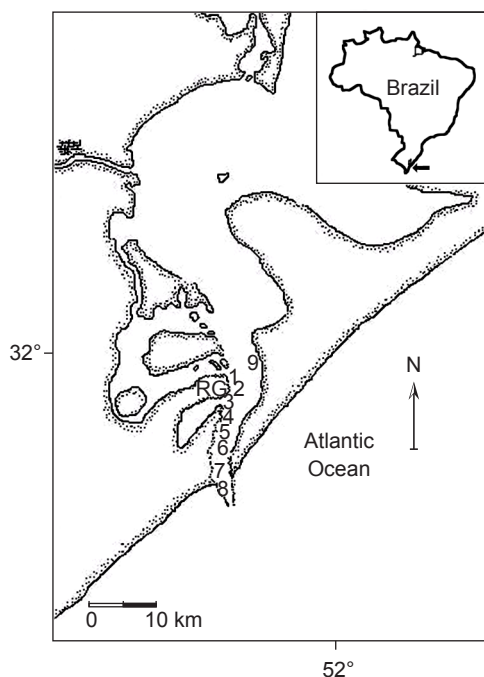


Fig. 1 — Map of the study area showing the sampling stations (numbers 1 to 9) in the channel of the Rio Grande harbor, Patos Lagoon estuarine region. The location of the city of Rio Grande City identified as RG on the map.

carried out during a period of predominant flushing tides, was not affected by the dredging activities.

The dredging operation in the channel leading into the port of Rio Grande began on July 11, 2000 and removed about 2,330,000 m³ of sediment. During the first phase (winter), the dredged area comprised stations 1, 2 and 3. The second dredging phase (spring) included areas nearer the access inlet and the jetties, reaching stations 4 to 8.

At each of the nine sampling stations, three samples were taken using a van Veen grab with a 19 x 41 cm opening (0.08 m²). The samples were sieved on board the vessel through a 0.05 mm-pore nylon sieve to ensure the retention of macrofauna (Holme & McIntyre, 1984). The organisms retained were fixed in 5% formalin. At the laboratory, samples of biological material were screened down to the smallest possible taxon and quantified. Benthic macroinvertebrate density was expressed in ind / 0.08 m².

Table 1 presents sampling station coordinates and granulometric percentages in the sediment collected before (summer cruise) and after dredging (spring cruise).

Table 2 lists the composition of the macrobenthic invertebrates found in the nine stations on each of the seasonal cruises. The mean and standard error of the total organism densities were recorded (Fig. 2). A hierarchical cluster analysis was made (Fig. 3) based on fourth-root transform abundance data to determine the similarities among the sampling stations. The

similarity index of Bray-Curtis was used with the UPGMA amalgamation method, as proposed by Field *et al.* (1982). Statistical analyses were made using the STATISTICA® 98 edition and PRIMER 5.0 software.

RESULTS

Salinity records of the surface water at the nine sampling stations show extreme values of 25 to 34 for the summer cruise and 2 to 4 for the autumn trip, whereas the values for winter and spring were always zero. Superficial water temperatures showed extremes ranging from 18 to 25 °C in summer and from 19 to 21 °C in spring, with constant values of 18 °C in autumn and 12 °C in winter. Station 9 was located at a 9 m depth and station 6 at 16 m. The remaining sampling sites were at a depth of 12 m. Sand rates increased after dredging, with concomitant decreases in silt and particularly clay rates (Table 1).

Analyses of composition and number of macrobenthic species during the four seasonal cruises in the inlet areas of the Rio Grande port indicated two situations. In the first, prior to dredging and with greater diversity, 36 species were identified on the summer cruise and 35 in autumn. In the second situation, corresponding to samples collected during the dredging period, 20 species were found in winter and only 18 in spring. Peracarid crustaceans and polychaetes were the main taxonomic groups differentiating the two situations in terms of diversity (Table 2). A minimum

TABLE 1
Sampling stations position and sediment granulometry performed before (summer cruise) and after (spring cruise) of the dredging operations. (sediment data from Dr. Paulo Baisch, Geochemistry Laboratory, FURG).

Stations	Lat. S	Long. W	Summer Sand (%)	Summer Sylt (%)	Summer Clay (%)	Spring Sand (%)	Spring Sylt (%)	Spring Clay (%)
1	32°02'386	52°04'476	03.3	35.4	61.3	11.9	34.2	53.8
2	32°03'276	52°04'185	08.0	31.2	60.8	21.8	32.0	38.4
3	32°04'052	52°04'524	27.2	23.7	49.4	20.5	25.4	54.1
4	32°04'718	52°05'235	14.0	29.8	56.2	5.4	38.9	55.7
5	32°06'062	52°05'907	12.7	28.7	58.6	32.8	24.8	42.0
6	32°08'190	52°06'052	08.9	33.9	57.1	14.2	37.6	48.1
7	32°09'467	52°05'721	11.8	32.8	55.4	21.5	29.7	48.7
8	32°10'200	52°05'227	27.7	23.9	48.3	60.9	20.7	19.3
9	32°01'086	52°02'807	74.3	12.1	13.6	34.7	17.4	48.1

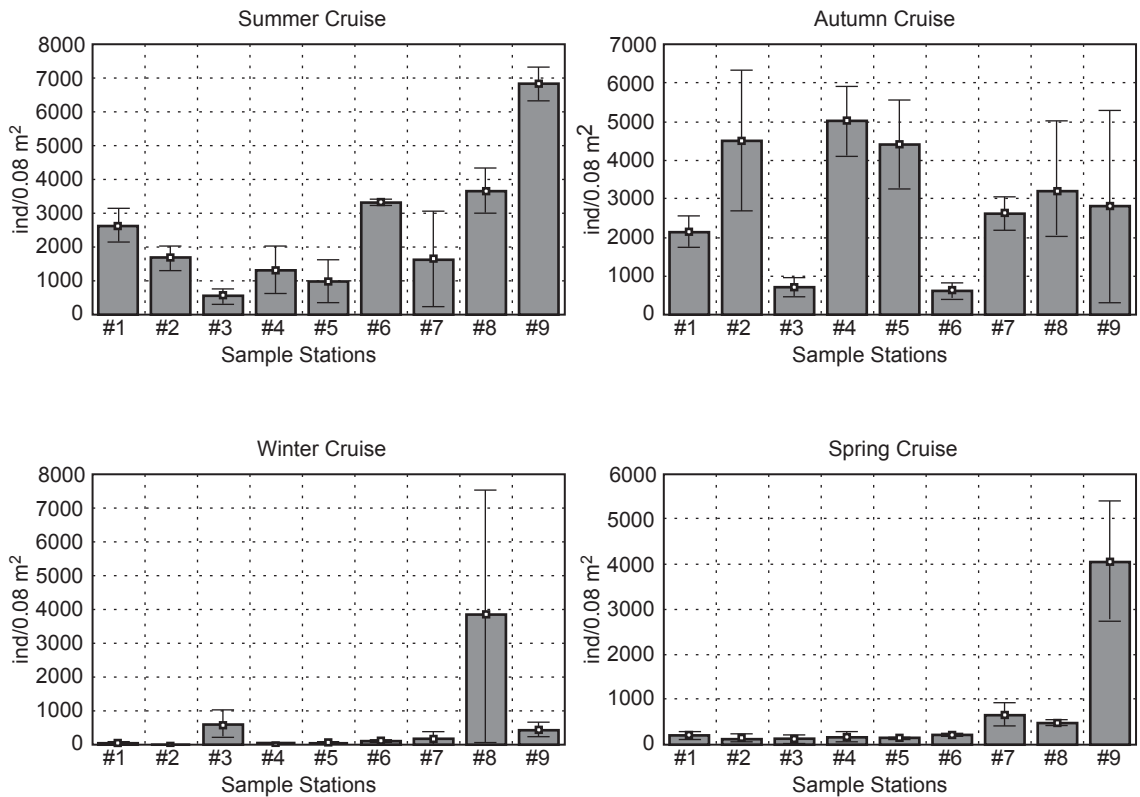


Fig. 2 — Mean and standard error of the total number of organisms in the sampling stations during the four seasonal cruises.

of 12 and a maximum of 19 species were collected at the nine sampling stations during the summer cruise, while the number varied from 11 to 19 in autumn. In winter, after the areas of stations 1, 2 and 3 had already been dredged, the lowest number of macrozoobenthic species were found at station 2 (5 spp.) and the highest at station 9 (12 spp.), situated upstream from the dredged area. In spring, when the dredged areas extended along the entire length of the access channel into the port of Rio Grande, there was a marked decrease in diversity. During that period, only 1 species was found at station 5, while the highest number of species (9 spp.) was again found at station 9 (Table 2).

Macrozoobenthic densities in the channel area, independently of sampling period or station, were largely dominated by the gastropod *Heleobia australis* (95 to 99% of the total organisms). Macrozoobenthic densities showed distinct trends before and after dredging. Stations 1 to 8, sampled in summer and autumn, showed more homogeneous

densities than they did after dredging began (Fig. 2). In winter and spring, except for station 9, mean densities of benthic macroinvertebrates showed a higher variability (Fig. 2).

Cluster analyses revealed the formation of three station clusters at the level of 60% of similarity, plus one isolated station (Fig. 3). The stations sampled in winter and spring were grouped in the upper portion of the dendrogram (Cluster 1), all of them under the effect of dredging activities. These stations were characterized by low numbers of species and low macrozoobenthic densities (Table 2, Fig. 2). The largest number of stations, most of them sampled in summer and autumn, was grouped in Cluster 3. This group always included station 9. This set of stations showed the greatest number of species and of macrozoobenthic densities, and hence, of the dominant species *Heleobia australis*. The stations presenting macrozoobenthos with intermediate densities and diversity were grouped in Cluster 3 (Fig. 3).

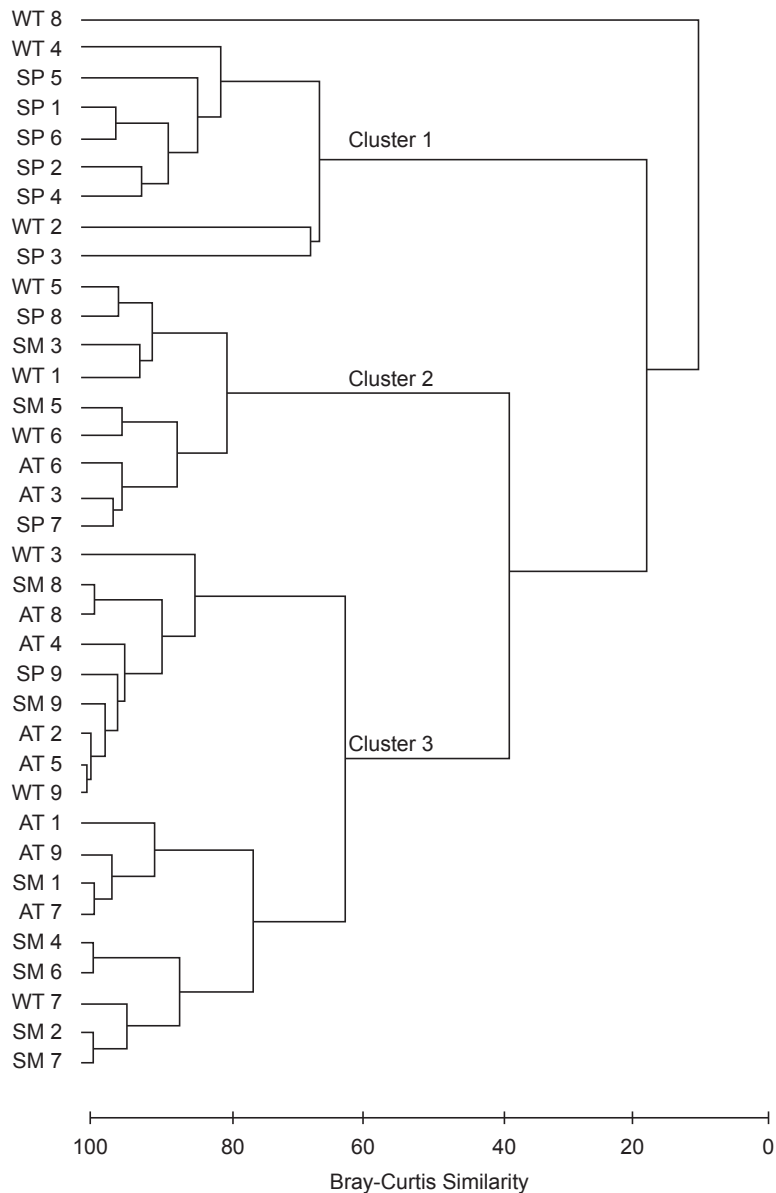


Fig. 3 — Cluster of the sampling stations in the channel of the Rio Grande harbor. The letters denote the sampling season (SM = summer; AT = autumn; WT = winter; and SP = spring). The number before the letters denotes the sampling station.

DISCUSSION

The number and composition of species as well as the macrozoobenthic density in the harbor of the port of Rio Grande were consistently lower at the stations located where the bottom had been dredged. This pattern was reflected by the clusters, which discriminated samples prior to dredging or those taken upstream from the dredged area

from samples that showed the effect of substrate removal. However, an analysis of such results must take into account that species inhabiting coastal lagoons are subject to considerable natural stress (Wilson & Jeffrey, 1994).

Estuaries and coastal lagoons are characterized by the variability and low predictability of their environmental conditions, which determines a limit on the number of species that might colonize

such ecosystems (McLusky, 1989). Choked lagoons stand out among such coastal mixohaline environments for their severe environmental conditions, which are aggravated by the narrow mouthed inlet, which limits water exchanges with the marine medium (Kjerfve, 1994).

Patos Lagoon is a huge choked lagoon (10,300 km²) with a long narrow entrance channel and unstable bottom substrates, low tidal oscillations (0.5 m of tidal range), long flushing events, dominant wind forces and intermittent stratification events due to runoff and rainfall (Garcia, 1997). Its highly variable salinity characterizes the estuarine region (1,000 km²) chemically as a highly unstable area (Niencheski & Baumgarten, 1997). Such conditions limit the number of marine species that are able to colonize the channel and the sublittoral bottom (between 2 and 6 m of depth) near the mouth of the lagoon (Bemvenuti *et al.*, 1992).

Surveys with sublittoral and channel samplings (between 3 and 18 m of depth) in the estuarine region of the lagoon recorded 30 to 40 benthic macroinvertebrate species during periods of higher salinity, this number dropping by half during periods of near-zero salinity (Bemvenuti, 1997a; Bemvenuti & Netto, 1998). The number of macrozoobenthic species recorded in the present study in summer (36 spp) and autumn (35 spp) reflected the influence of salt water on the estuarine region of the lagoon during the study. Small marine species predominated in this period, predominantly polychaete species, whose occurrence in the mouth inlet depends on the permanence of marine waters in the region (Bemvenuti *et al.*, 1992; Bemvenuti & Netto, 1998). The reduction in the number of species in winter and spring coincided with a reduction in salinity, which reached values close to zero, and with the dredging period in the channel. The influence of the decreased salinity on macrobenthic diversity is undeniable in the estuarine region of Patos Lagoon, a situation in which resident estuarine species prevail (Capitoli *et al.*, 1978; Bemvenuti, 1997a), with *Heleobia australis* and the polychaetes *Heteromastus similis* and *Nephtys fluviatilis* predominating. In a sediment defaunation field experiment conducted in the summer, these polychaetes showed high resilience and the ability to recolonize the substrate in just over 2 months (Bemvenuti, 1997a).

The drastic reduction in the number of species such as that found in the dredged area in spring reached an intensity never before recorded in seasonal surveys of the sublittoral of this estuarine region (Bemvenuti *et al.*, 1992; Bemvenuti & Netto, 1998), suggesting that dredging strongly affects macrozoobenthic composition and diversity. In this sense, it should be kept in mind that the stations upstream from the dredged area consistently presented a less variable number of species.

Seasonal macrozoobenthic abundance was notably influenced by the predominance of *Heleobia australis*. This estuarine superficial deposit-feeding gastropod shows a clearly opportunistic behavior (Lana, 1986; Bemvenuti *et al.*, 1992) and may reach high densities in the infralittoral and the channel, where it benefits from a widely available epistrate niche and from the absence of other abundant sedentary epifaunal species (Bemvenuti, 1997a). In contrast to the dramatic reductions in *H. australis* densities in areas subjected to dredging in winter and spring, the maintenance of their densities in areas or periods free of dredging effects points to the species' susceptibility to substrate disturbances. Some stations in the dredged area also presented highly variable in mean densities, which is considered evidence of environmental stress (Warwick & Clarke, 1993).

Because of its abundance and broad distribution, *Heleobia australis* is one of the main items in the diet of the catfish *Genidens genidens*, *Netuma barba* and *N. planifrons*, the blue crab *Callinectes sapidus* and the shrimp *Farfantepenaeus paulensis* in the sublittoral and channels in the study area (Bemvenuti, 1997c). The dramatic reduction in *H. australis* density in dredged areas may reduce food availability for these species, which, besides their ecological importance, constitute key fishing resources for the maintenance of small-scale fishing in the region.

Any analysis of a possible food shortage resulting from lower densities of *H. australis* after dredging must, however, take into account the life pattern of the dominant macrozoobenthic species in the channel. The opportunistic traits of *H. australis* enable this species to recolonize the substrate rapidly after a disturbance, as was found in the estuarine region along a gradient of contamination by urban sewage (Angonesi, 2000) and after a sulfuric acid spill (Bemvenuti *et al.*, 2003). Another aspect to

keep in mind is the sedimentary pattern commonly found after the passage of suction dredges, which leads to the formation of undisturbed “hummocks” of undredged material (Grave & Whitaker, 1999). These sedimentary patches of relatively undisturbed hummocks have a high biological significance in the process of repopulation by the indigenous benthic community within the dredged area (McCauley *et al.*, 1977). This recolonization process results from the migration of adults or by larval establishment, and both these pathways can originate from adjacent undisturbed areas or residual populations on the hummocks (McCauley *et al.*, 1977, Maurer *et al.*, 1981).

Opportunistic species such as *H. australis*, which even has the ability to move along with the water surface tension (Bemvenuti *et al.*, 1992), take advantage of the new conditions after the channel has been dredged. It is worth noting that although the dredging operations resulted in a tendency to increase the coarse fractions action (Table 1), grab samples collected during the spring cruise revealed the deposition of a fine layer of silt and clay covering the sandy sediment. The presence of fine sediments correlates positively with the occurrence of high densities of a superficial deposit feeder such as *H. australis* (Bemvenuti, 1997b, c).

The reduction in the number of species and organism density, which was reflected in changes in the structure of the benthic community, is unequivocal evidence of the effect of dredging on the soft bottom fauna in the channel of the Rio Grande harbor. However, one should keep in mind that the channel is dominated by a few resident estuarine species such as *Heleobia australis*, *Heteromastus similis* and *Nephtys fluviatilis*, which are highly resilient to physical disturbances (Bemvenuti, 1997a; Angonesi, 2000; Bemvenuti *et al.*, 1993). Depending on the environmental conditions, the diversity may increase through the recruitment of marine species occurring in lower densities, which may remain in the channel area for several months following the inflow of more saline waters. The low predictability of the successful outcome of marine fauna and the short residence time of these marine species in the estuary indicate that the benthic community is structured according to severe environmental conditions. On the other hand, the high resilience of estuarine species suggests that such organisms have highly efficient mechanisms

for rapid recolonization after disturbances such as those caused by substrate dredging in the channel leading into the port of Rio Grande.

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