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# An experimental evaluation of the short-term effects of trawling on infaunal assemblages of the coast off southern Brazil

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*Bottom trawling is a large-scale fishing activity along the Brazilian coast, but its effects on benthic infauna are still poorly known. This is the first experimental evaluation of benthic responses to bottom trawling along the Brazilian coast. We tested the effects of trawling on macroinfaunal assemblages on the inner continental shelf off Paraná (southern Brazil) by using a sampling design with adjacent trawl and control areas. We hypothesized that if trawl fishing has a negative effect then we should expect lower numbers of species and lower benthic densities after an experimental trawling. Sampling was conducted at adjacent sites within each area to minimize confounding due to spatial variation. Five sites were sampled at a control, and five at an experimental area for infaunal and sedimentological variables. Sampling was carried out just before and one hour after experimental trawling. Multidimensional scaling followed by a PERMANOVA did not show any clear variation tendencies in the structure of the benthic assemblages in the impacted area before and after trawling. However, variance analysis showed a significant and unexpected increase in infaunal total density, in the density of the numerically dominant species (except for the polychaetes* Capitella *sp. and* Loandalia tricuspis*) and in species richness in the experimental area. Conversely, no significant variations were recorded in the control area. We suggest that the overall increase in benthic density after a disturbance is correlated with the reworking of the sediment matrix and benefits the suspension-feeders after sediment resuspension.*

**Keywords:** bottom trawling, inner continental shelf, infaunal impact, infaunal assemblage, southern Brazil

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## INTRODUCTION

The impacts of fishing in the oceans and in coastal areas are a worldwide concern. As a result of the decline in fish stocks on a global level, the effectiveness and sustainability of many current fishing techniques are open to argument (Lokkeborg, 2005, 2007; Gray *et al.*, 2006, 2007; Longhurst, 2007). Bottom trawling, which uses steel or wooden doors connected to funnel-like nets of variable meshes designed to slide along the marine bottoms and to capture organisms at the water–sediment interface, is practised in at least 75% of the global area of continental shelves (Kaiser *et al.*, 2002). Due to its low selectivity (Kaiser & Spencer, 1996) and impact on the physical structure of the sediment (Schwinghamer *et al.*, 1998), the negative effects of bottom trawling have been compared to agricultural activities and rainforest cutting in terms of biodiversity reduction (Watling & Norse, 1998), and eventual prevalence of opportunistic species (Thrush & Dayton, 2002).

Despite increasing public awareness of the impact of trawling, both descriptive and experimental investigations which have tried to assess the benthic responses have generated mixed results. Impacts seem to be more intense in stable marine bottoms in comparison to areas naturally disturbed by waves and currents (Jennings *et al.*, 2001; Kaiser *et al.*, 2000, 2006; Hiddink *et al.*, 2006). Trawling is a major source of sediment resuspension (Palanques *et al.*, 2001), resulting in changes in the nutrient and contaminant flows, exposition of anoxic sediment layers, and a general increase in the biological demand for oxygen (Kaiser *et al.*, 2001; Olsgard *et al.*, 2008). Marks left by the trawling doors on relatively stable sediments may remain visible for up to 10 weeks or even one year after the disturbance (Schwinghamer *et al.*, 1998). Conversely, Collie *et al.* (2000) suggested that the benthic assemblages of sandy bottoms may be reestablished within 100 days, and can withstand two to three trawlings a year. Kaiser & Spencer (1996) showed that experimental trawling may cause short-term changes in benthic assemblages in places with strong tidal currents, but that these changes could not be detected six months later.

Bottom trawling may remove many epifaunal organisms and litter (Pranovi *et al.*, 2000), cause mortality of invertebrate species such as gastropods, echinoderms, crustaceans, polychaetes and bivalve molluscs (Bergman & Van Santbrink, 2000; Kaiser *et al.*, 2006), and reduce fish abundance (Hixon & Tissot, 2007) and overall biomass (Burridge *et al.*, 2003).

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The decline in species richness and number of organisms may cause, in extreme cases, their functional extinction in the environment (Pranovi *et al.*, 2000). The negative systemic effects of bottom trawling may also induce changes in prey–predator relationships (Jennings & Kaiser, 1998; Kaiser *et al.*, 2001, 2002), leading to modifications in the trophic structure, not necessarily reversed as fishing activity falls (Kaiser *et al.*, 2002). Such negative impacts may cause an overall decline in marine resources, including those commercially explored. In this context, understanding the benthic responses to the impact of fishing is essential for a more adequate handling of fishing activities (Lokkeborg, 2005).

Fishing is still the main economic activity of traditional populations along the coast of the Paraná State in southern Brazil. The prevailing technique is otter trawling, with sea-bob-shrimp (*Xiphopenaeus kroyeri*) and white shrimp (*Litopenaeus schimitti*) as the main targets (Perez *et al.*, 2001). Industrial trawling targeting shrimps occurs off Paraná as well, but since there are no local fishing ports, fish landing mostly occurs in the States of São Paulo and Santa Catarina (Haimovici & Klippel, 1999).

The potential impact of artisanal and industrial trawling on the benthic assemblages of the inner shelf platform off Paraná is still poorly known (Pelaes & Borzone, 2007). The impact assessment of trawling on local shelf bottoms is a prerequisite for improved fishing management. Our study assesses the short-term effects of bottom trawling on the structure of infaunal assemblages of Paraná's inner shelf, as determined from experimental trawling. We tested the hypothesis that short-term reductions in species richness, total density and the density of numerically dominant species should be expected in experimentally trawled areas in comparison to undisturbed areas.

## MATERIALS AND METHODS

### Study area

The coastal line of the State of Paraná (Figure 1), which belongs to the southern sector of the Brazilian coast between Cabo Frio and Cabo de Santa Marta, extends for about 100 km in a north-east–south-west direction (Martins *et al.*, 2004). Coastal and platform waters suffer intrusion of the South Atlantic Central Water in late spring and early summer (Matsuura, 1986). The average water temperature may vary between 21°C in the winter and 29°C in the summer, following a well defined seasonal gradient. Salinity varies from 28 to 37 psu, with the lowest values occurring in the surface layers (Brandini *et al.*, 2007). The tidal regime is semi-diurnal with maximum amplitude of 2.2 m, and the climate is humid subtropical (Lana *et al.*, 1989). Sediment is relatively homogeneous, with low silt and clay content, and a dominance of moderately to well-sorted fine sands (Veiga *et al.*, 2005). This pattern is a result of strong currents near the bottom, which vary in intensity and direction (Borzone

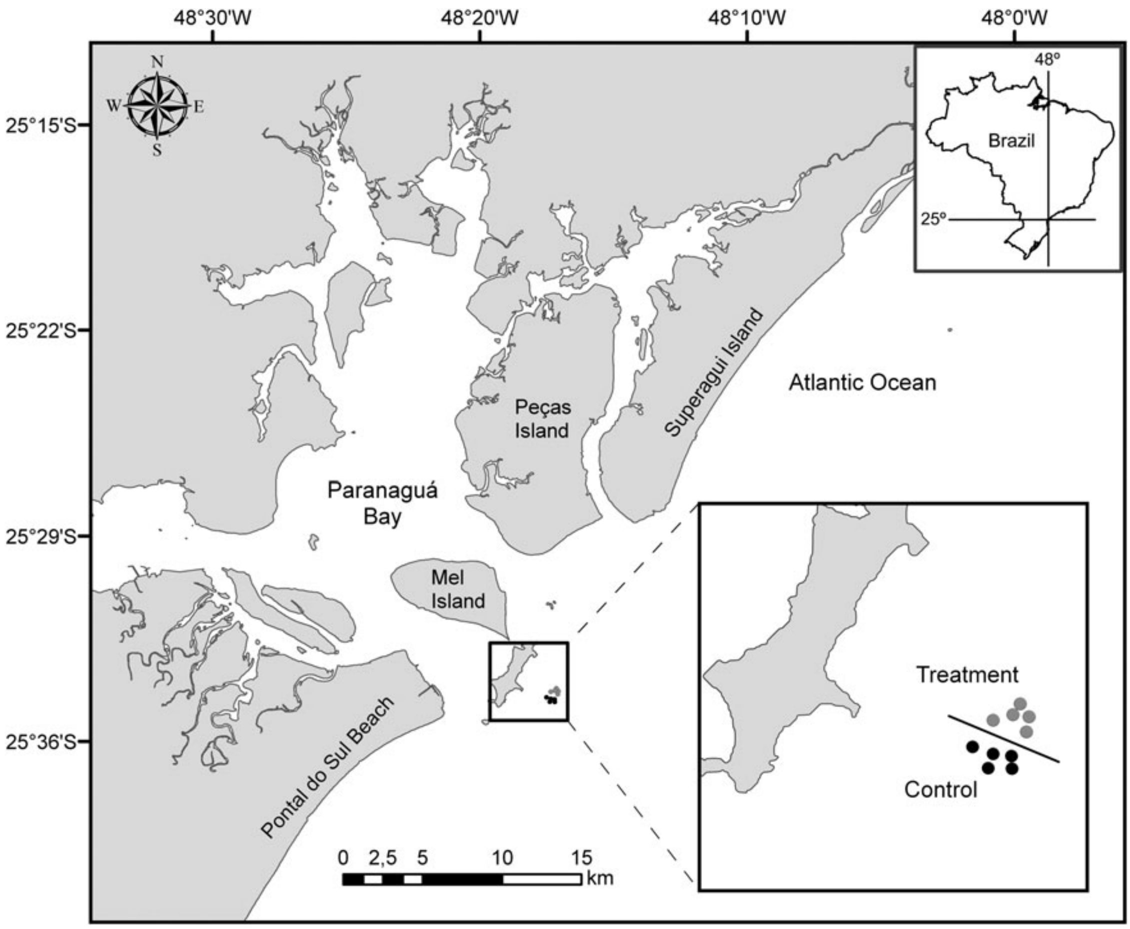


**Fig. 1.** Map of the study area showing the control and impact sites.

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*et al.*, 1999). Hydrodynamic energy levels are directly conditioned by frontal systems coming from the south. The low declivity, absence of natural obstacles and the dominance of sandy bottoms in Paraná's inner platform (Veiga *et al.*, 2005) offer ideal conditions for bottom trawling. Gonçalves & Lana (1991) suggested that the large-scale distribution of benthic invertebrates in the inner platform would be related to the hydrodynamic gradient and corresponding depositional environments. Pelaes & Borzone (2007) carried out a descriptive evaluation of the effects of trawling on macrobenthic assemblages in an adjacent area, and were not able to detect significant differences between trawled and un-trawled sites.

## Experimental design, field sampling and laboratory routines

Since all the sectors of Paraná's inner platform are potential targets for trawling, special care was taken to define an adequate experimental area. We tried to avoid the methodological bias of many recent experimental studies, usually conducted on recently trawled grounds, where community composition has already been modified, and further effects are likely to be minimal. Commercial trawling is legally restricted all along the Paraná coast from October to December. This period of closure corresponds to the reproductive peak of the sea-bob-shrimp *Xiphopenaeus kroyeri*. Soon after the end of the closure period, an experimental area was selected close to the outlet of Paranaguá Bay, between 25°34′05.1″S and 48°16′51.6″W, in December 2006 (Figure 1). The area was signalled with buoys to avoid commercial trawling, thus guaranteeing that the experimental area would remain un-fished for at least 110 days, e.g. from the beginning of the closure till the sampling dates. This criterion followed Collie *et al.* (2000), who suggested that the recolonization of macrobenthic animals takes an average of 100 days in the sandy substrates of shallow shelf areas. The trawling experiment was carried out in two adjacent areas about 800–1000 m apart, 1 km long and 1 km wide at a depth of 10 m, defined as the control and treatment.

Before-impact sampling was carried out on 21 February 2007. Using a GPS, five sites were defined in each area. In each site, six replicates were taken for biological and one for sediment analyses. Sampling for infauna and sediment characterization was made through SCUBA diving, using corers 10 cm in diameter by 10 cm high (total area 78.5 $cm^2$). Pilot tests had shown that the precision of the estimates of faunal numbers obtained with this core size in comparison to larger ones was acceptable (Elliott, 1977). The experimental trawling was performed on the following day. After-impact sampling was done one hour after the disturbance, and followed the same before-impact design. For the experimental trawling, we used an outrigger boat, equipped with a cabin or 'superstructure', winch, outrigger booms, and a 60 HP engine, common for Paraná's artisanal fleet. Two standard cod end nets (11 m long with 11 m between the sleeves and 2.20 m of mouth) were operated simultaneously. The distance between opposite knots in the mesh was 40 mm in the sleeve and 30 mm in the bag with the net stretched. The four doors used (two for each net) were wooden rectangles, with an iron base, measuring 1.20 m by 0.50 m and weighing 40 kg. Nets were trawled twice at the impacted areas, following a pattern which impacted on all sampling sites (Figure 2).

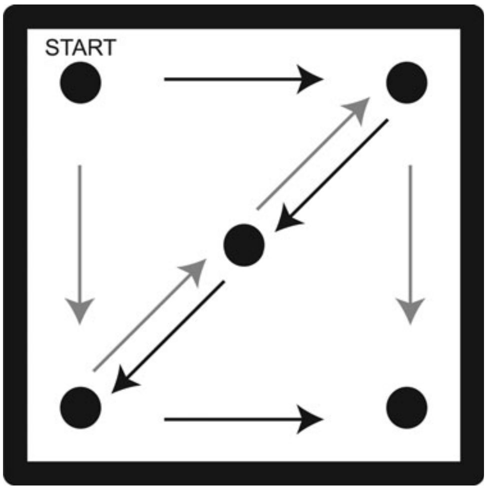


**Fig. 2.** Diagram of experimental trawling of five sites of the impacted area. First trawling is represented by black arrows and second trawling by grey arrows.

Biological samples were sieved through a 0.5 mm mesh and the animals fixed in 10% formalin, separated, and identified to the lowest taxonomic level with a stereoscopic microscope.

Sediment texture was determined by sieving and pipetting methods. Sediment statistical parameters were obtained by the software SysGran, version 3.0 for Windows (Camargo, 2006), using the McCammon b method (McCammon, 1962). Carbonate content was measured by weight difference after acidification of 10 g of sediment in HCl (10%). Organic matter content was estimated by burning 5 g of sediment in a muffle furnace at 550°C for 1 hour.

## Data analysis

Differences in total number of individuals, number of taxa and densities of the six numerically dominant species were individually tested by an analysis of variance which followed the statistical model: treatment (fixed, 2 levels: control and impact), time (fixed, 2 levels: before and after, orthogonal to treatment) and sites (random, 5 levels nested in the combination of treatment and time). Student–Newman–Keuls (SNK) tests were performed on significant terms of the model. Normality and homogeneity of variances were verified by the Kolmogorov–Smirnov and the Cochran tests respectively. In the absence of homogeneity, data were transformed (Underwood, 1997).

The same statistical model was used in a non-parametric permutational multivariate analysis of variance (PERMANOVA) available in PERMANOVA software version 1.6 (Anderson, 2005). A non-metric multidimensional scaling (nMDS) analysis was performed to visualize short-term variation patterns in the infaunal structure previously tested by the PERMANOVA. Multivariate analyses used the Bray–Curtis similarity coefficient with data transformed to $\ln(x+1)$. We used a standard BIOENV routine to estimate the relationship between sediment (mean grain size, sorting, clay percentage, organic matter and calcium carbonate content) and infaunal variables.

Except for PERMANOVA, all analyses were conducted using the software R (R Development Core Team, 2011)

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combined with GAD (Sandrini-Neto & Camargo, 2011), vegan (Oksanen *et al.*, 2011) and sciplot (Morales, 2011) packages.

# RESULTS

## Sediment variables

Large and irregular ripple marks on the sediment were observed by SCUBA divers, both in the control and treatment areas before and after the experimental trawling. However, no bottom marks which could be arguably attributed to trawling were detected just one day after the experimental trawling.

Local sediments, classified as moderately to very well-sorted fine sands, were similar between the control and impacted areas. Percentage content of sand, silt and clay were respectively 97%, 1.65% and 1.35% in the control area, and 97.8%, 1% and 1.2% in the treatment area. Organic matter content in the control area varied from 0.57% to 4.42% and carbonate content from 1.78% to 8.11%. Organic matter values were lower in the trawled area (from 0.57% to 1.16%), while carbonates varied from 1.38% to 5.57%. The highest values of carbonates (8.11%) and organic matter (4.42%) were recorded at site 5 of the control area after trawling, due to the presence of shell fragments and plant debris.

## Infaunal assemblages

A total of 8769 individuals belonging to 89 taxa were collected. Polychaetes were the most abundant and diverse group, forming 89% of the total faunal numbers, followed by crustaceans with 6% and sipunculans with 3%. Ophiuroids, molluscs, octocorals, nemerteans, lancelets and hemichordates were less abundant, together representing 2% of the total number of individuals. Among polychaetes, the most frequent taxa were the spionid *Apoprionospio* sp. with 3248 individuals (37% of the total), the capitellid *Capitella* sp. with 2437 individuals (28%), and the paraonid *Aricidea albatrossae* with 945 individuals (11%), which jointly represented 75% of the total infaunal numbers. These three species were numerically dominant in both areas before and after the experimental trawling.

Total numbers of individuals, total number of taxa and the density of numerically dominant species did not vary significantly between the trawled and un-trawled areas before and after the experimental disturbance (Table 1; Figure 3). SNK tests revealed large site to site variations within each combination of treatment and time (Table 2). The observed variation patterns for the total number of individuals, and for the densities of *Apoprionospio* sp., *Capitella* sp. and *Aricidea albatrossae* indicated a background patchy distribution. The total number of taxa differed significantly before and after trawling, but this was most probably related to spatial rather than to temporal variations due to the short time interval between samplings.

**Table 1.** Summaries of analysis of variance for selected taxa. Data transformed to[1] square root,[2] fourth root and[3] ln(x + 1) before analysis.

| | | **Total number of individuals** | | | **Total number of taxa** | | |
|---|---|---|---|---|---|---|---|
| **Source** | **df** | **MS** | ***F*** | ***P*** | **MS** | ***F*** | ***P*** |
| Treatment = Tr | 1 | 580.80 | 0.097 | 0.760 | 61.63 | 4.227 | 0.056 |
| Time = Ti | 1 | 7776.30 | 1.293 | 0.272 | 86.70 | 5.947 | 0.027 |
| Tr × Ti | 1 | 7084.03 | 1.178 | 0.294 | 32.03 | 2.197 | 0.158 |
| Site (Tr × Ti) | 16 | 6014.90 | 6.724 | <0.001 | 14.58 | 2.181 | 0.010 |
| Residual | 100 | 894.60 | | | 6.68 | | |
| | | ***Apoprionospio* sp.[1]** | | | ***Capitella* sp.[1]** | | |
| **Source** | **df** | **MS** | ***F*** | ***P*** | **MS** | ***F*** | ***P*** |
| Treatment = Tr | 1 | 0.67 | 0.049 | 0.827 | 1.64 | 0.118 | 0.736 |
| Time = Ti | 1 | 13.82 | 1.010 | 0.330 | 1.84 | 0.133 | 0.721 |
| Tr × Ti | 1 | 6.75 | 0.493 | 0.493 | 12.75 | 0.921 | 0.352 |
| Site (Tr × Ti) | 16 | 13.69 | 5.420 | <0.001 | 13.85 | 7.478 | <0.001 |
| Residual | 100 | 2.53 | | | 1.85 | | |
| | | ***Aricidea albatrossae*[1]** | | | ***Kalliapseudes schubarti*[3]** | | |
| **Source** | **df** | **MS** | ***F*** | ***P*** | **MS** | ***F*** | ***P*** |
| Treatment = Tr | 1 | 2.79 | 0.517 | 0.482 | 36.28 | 28.409 | <0.001 |
| Time = Ti | 1 | 7.73 | 1.436 | 0.248 | 3.38 | 2.648 | 0.123 |
| Tr × Ti | 1 | 7.39 | 1.372 | 0.259 | 7.95 | 6.228 | 0.024 |
| Site (Tr × Ti) | 16 | 5.39 | 7.398 | <0.001 | 1.28 | 3.697 | <0.001 |
| Residual | 100 | 0.73 | | | 0.35 | | |
| | | ***Loandalia tricuspis*[1]** | | | ***Chaetozone* sp.[2]** | | |
| **Source** | **df** | **MS** | ***F*** | ***P*** | **MS** | ***F*** | ***P*** |
| Treatment = Tr | 1 | 24.11 | 64.331 | <0.001 | 10.62 | 16.666 | 0.001 |
| Time = Ti | 1 | 0.47 | 1.260 | 0.278 | 0.85 | 1.327 | 0.266 |
| Tr × Ti | 1 | 0.02 | 0.043 | 0.838 | 1.42 | 2.232 | 0.155 |
| Site (Tr × Ti) | 16 | 0.37 | 2.529 | 0.003 | 0.64 | 2.632 | 0.002 |
| Residual | 100 | 0.15 | | | 0.24 | | |

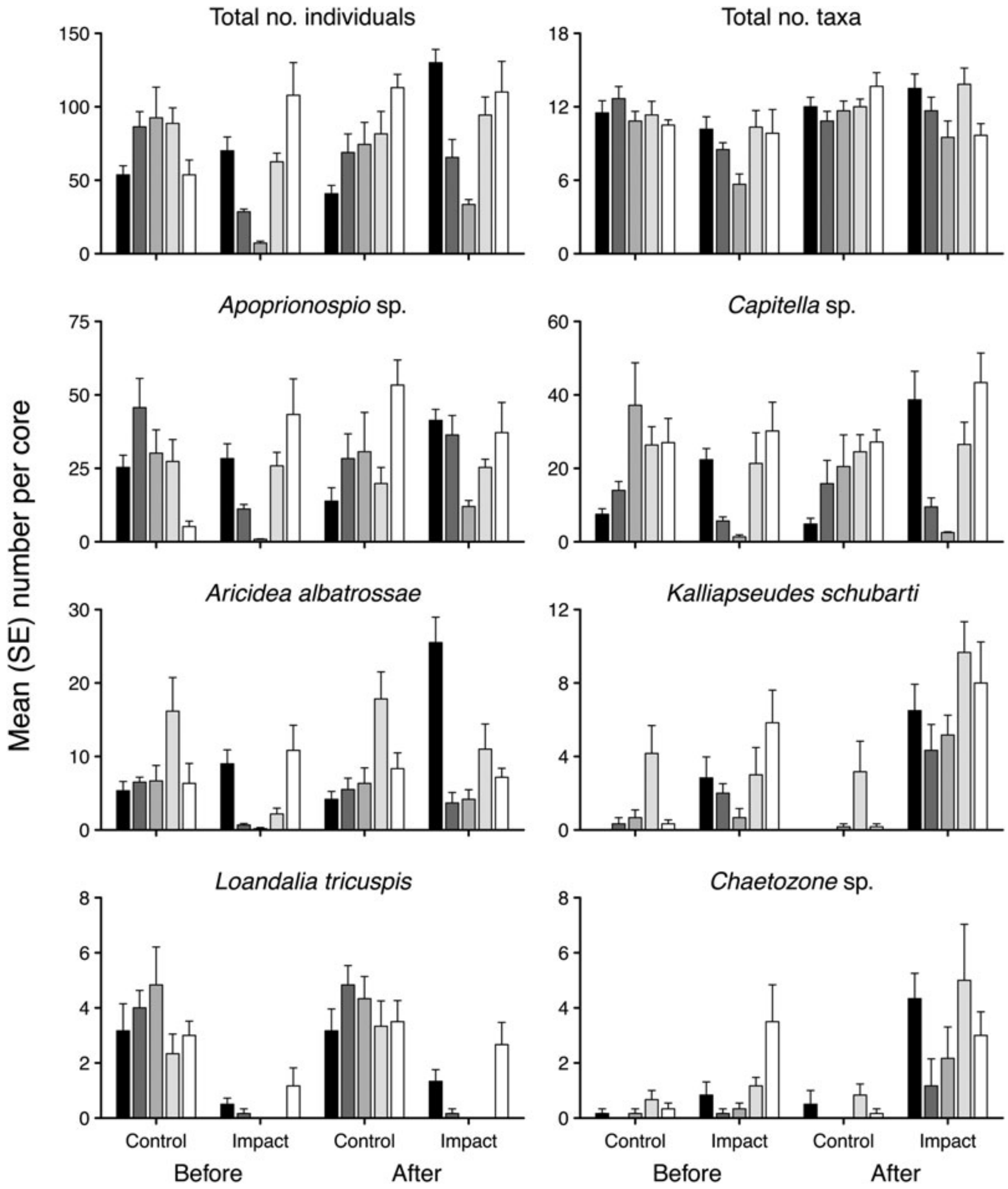


**Fig. 3.** Mean (SE, N = 6) numbers of taxa or animals in control and impact sites, both before and after trawling.

Average densities of *Loandalia tricuspis* were higher in the control area (3.47; 3.83 ind/78.5 $cm^2$) compared to the impacted area (0.37; 0.83 ind/78.5 $cm^2$), both before and after trawling. A contrary pattern was observed for *Chaetozone* sp., with a higher density in the impacted (4.57; 10.30 ind/78.5 $cm^2$) than in the control (0.27; 0.30 ind/78.5 $cm^2$) area, both before and after trawling. The tanaidacean *Kalliapseudes schubarti* was the only species to provide some indication of trawling

**Table 2.** Student–Newman–Keuls tests for the comparisons among sites (1 to 5) in the control and impact areas, both before and after trawling. <, indicates $P<0.05$; =, indicates $P > 0.05$.

| | Before | | After | |
|---|---|---|---|---|
| | Control | Impact | Control | Impact |
| Total number of individuals | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 < 5 | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 = 5 |
| Total number of taxa | 1 = 2 = 3 = 4 = 5 | 3 < 1 = 2 = 4 = 5 | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 = 5 |
| *Apoprionospio* sp. | 5 < 1 = 2 = 3 = 4 | 3 < 1 = 2 = 4 = 5 | 1 = 2 = 3 = 4 < 5 | 1 = 2 = 3 = 4 = 5 |
| *Capitella* sp. | 1 = 2 = 3 = 4 = 5 | 2 = 3 < 1 = 4 = 5 | 1 < 2 = 3 = 4 = 5 | 3 < 2 < 4 = 1 = 5 |
| *Aricidea albatrossae* | 1 = 2 = 3 = 5 < 4 | 2 = 3 = 4 < 1 = 5 | 1 = 2 = 3 = 4 < 5 | 2 = 3 = 4 = 5 < 1 |
| *Kalliapseudes schubarti* | 1 = 2 = 3 = 5 < 4 | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 5 < 4 | 1 = 2 = 3 = 4 = 5 |
| *Loandalia tricuspis* | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 = 5 |
| *Chaetozone* sp. | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 = 5 | 1 = 2 = 3 = 4 = 5 |

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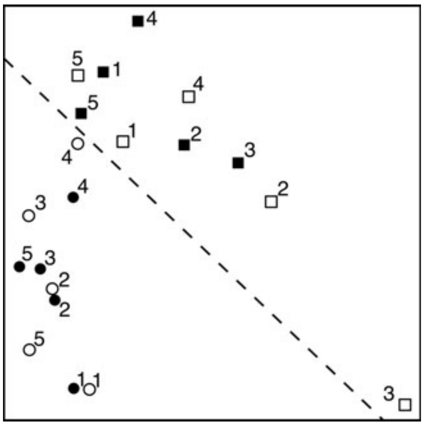

**Fig. 4.** Two-dimensional non-metric multidimensional scaling ordinations on sample means, comparing macrofaunal assemblages in the control (○) and impact (□) sites before trawling, and control (•) and impact (■) sites after trawling. Sites are indicated with numbers from 1 to 5. Scale bar = 0.07 cm.

effects, despite its high within-site variability. Average densities in the control area before trawling were very similar to densities after trawling (1.1 and 0.7 ind/78.5 $cm^2$), respectively. Conversely, its density in the treatment area was lower (2.87 ind/78.5 $cm^2$) before trawling than after trawling (6.73 ind/78.5 $cm^2$).

No consistent and unambiguous benthic effects which could be ascribed to trawling were detected by the PERMANOVA. Sites differed significantly within the treatment and time interaction, indicating that small-scale variations were greater than other sources of variation (site (Tr × Ti) interaction, $P < 0.001$ for 9999 permutations). In addition, the nMDS plots did not show any consistent variation patterns which could be attributed to trawling. If trawling had significant effects, trawled sites would be more separated from un-trawled sites after the experimental disturbance (Figure 4).

The BIOENV routine showed weak relationships between infaunal and sediment variables. The variables selected for the control area (mean grain size and carbonate content) were the same both before and after trawling. Different variables (clay and sorting respectively) were selected for the impacted area before and after trawling (Table 3).

## DISCUSSION

The experimental trawling did not cause detectable short-term changes in the overall structure of the infaunal assemblages in the sandy bottom of a high energy inner platform environment off Southern Brazil. Univariate and multivariate graphical results showed larger within- than between-treatment differences for most infaunal variables. PERMANOVA results suggest that the spatial structure of the local assemblage is largely determined by the ability of the individual species to cope with a high-energy sedimentary environment, most notably by maintaining a patchy distribution. A lack of clear distributional trends can be attributed to such physical processes. This patchiness may also weaken the statistical likelihood of detecting consistent changes in the infaunal structure due to trawling.

The marked short-term density variations of infaunal assemblages in the inner shelf of Paraná State, detected even in this spatially restricted study, is probably related to local hydrodynamics and a marked influence of the estuarine plume from the nearby Paranaguá Bay. Noernberg *et al.* (2007) showed that the bay mainly acts as a supplier of nutrients, pollutants and sediments to the inner continental shelf, influencing both the biological productivity and the redistribution of sediments.

Heterogeneity in the spatial distribution of benthic fauna is known to occur from m to km (Morrisey *et al.*, 1992; Chapman *et al.*, 2010). Disturbances induced by storms, wave action and biological interactions may also play a major role on the structuring of local benthic assemblages, as previously reported in other platform areas off south-eastern Brazil (Soares-Gomes & Pires-Vanin, 2003). Animals living in such high-energy bottoms are already adapted to periodic sediment resuspension and smothering (Collie *et al.*, 2000) and probably more resilient to bottom disturbance, either natural or induced by commercial trawling.

The few significant differences between treatments, as detected by PERMANOVA, were due to significant background variations in the densities of *Loandalia tricuspis* and *Chaetozone* sp., both before and after disturbance. However, such variation patterns rather reflected background spatial variation than putative effects of the disturbance itself. The only species to show some evidence of responding to the disturbance was the tanaidacean *Kalliapseudes shubarti*, as indicated by the significant density variation within the combination treatment and time. The short time between experimental trawling and sampling may be evidence that this activity could spread and bring small species up to the surface layers, some possibly from below 10 cm depth, increasing their likelihood of being sampled by cores. However, it is not possible to infer that the observed pattern was arguably a response to bottom trawling since the variation on a larger scale may be dependent on smaller scales (Chapman *et al.*, 2010).

The absence of evident visual changes in the local sandy bottoms, as noted by SCUBA diving, does not necessarily imply that the sediment matrix was not affected by trawling. The impact of doors and nets on the sea floor is probably more subtle, indirect and difficult to quantify, and would therefore require other methodological approaches (De Biasi, 2004), besides routine sediment analyses, in order to be detected. In fact, Spearman's coefficient of the Bio-Env analysis suggests that the sediment matrix was slightly affected by the sliding of trawl doors and nets. Infaunal structure was mainly related to the clay content at the impact area, before trawling. After trawling, biological variables were more correlated to sorting. These variations may be an indication that the surface fine sediment fraction was resuspended and

**Table 3.** Relationship between the biological and sedimentological variables (mean grain size, sorting, clay percentage, organic matter and calcium carbonate content) assessed by BIO-ENV routine in both treatments (control and impact) and at both times (before and after experimental trawling).

| Treatment/time | Selected variables | Spearman's coefficient |
|---|---|---|
| Control/before | Mean grain size + $CaCO_3$ | 0.388 |
| Control/after | Mean grain size + $CaCO_3$ | 0.308 |
| Impact/before | Clay | 0.386 |
| Impact/after | Sorting | 0.344 |

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transported after the experimental trawling. On the other hand, the control area remained stable with the same correlation trends among biological and sedimentological variables both before and after trawling. However, only considering sediment variables as the expression of changes in the physical environment would be a reductionist approach, since in fact they result from complex interactions, widely discussed recently (Kaiser *et al.*, 2006; Chapman & Tolhurst, 2007). The complexity of this relationship shows that similar sediment environments do not necessarily bear the same benthic assemblages (Zajac *et al.*, 2000).

Our sampling effort was mostly directed towards infaunal species and our results contrast those in the shallow waters of the northern hemisphere, where infauna appears to be more sensitive to trawling than epifauna (Queirós *et al.*, 2006; Hinz *et al.*, 2009). Atkinson *et al.* (2011) showed that epifaunal abundance, number of species and species diversity decrease with increasing trawling intensity. The magnitude of benthic responses varies significantly with gear type, habitat and among taxa (Collie *et al.*, 2000). Considering the high disturbance levels imposed by the commercial fishing regimes, trawling impacts may in fact be more evident than observed herein. As such, our results do not necessarily reflect the actual impact caused by trawling on commercial fishing grounds.

This is the first experimental evaluation of benthic responses to bottom trawling along the Brazilian coast. In summary, trawling procedures did not show consistent effects, even at the small spatial and temporal scales assessed. As a result of large background infaunal variation at small scales, only one infaunal species appeared to be affected by trawling and the biological effects were undetectable or as ephemeral as the physical ones, as suggested by previous studies (Drabsch *et al.*, 2001; Kenchington *et al.*, 2001). Despite the obvious limitations of such experimental analyses, including logistics to carry out a more rigorous spatial replication, the applied sampling design allowed for a better evaluation of infaunal responses to trawling at small spatial and temporal scales in a subtropical shelf platform.

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