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SHORT NOTE

The effects of trawling on the benthic fauna of the Gulf of Nicoya, Costa Rica

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Abstrat: Four van Veen grab replicates where collected to sample macrofauna (organism retained on a 500 µ mesh sieve) at four stations in the Gulf of Nicoya, during October 24, 1997, January 16 and April 30, 1998. This information was used to search for any effects of trawling on the benthic fauna. Two stations where located in a trawled area, and two stations where in a protected area. Diversity (H') varied from 2.01 to 3.52 in the trawled area and from 2.13 to 2.78 in the protected area. Diversity was generally higher in the trawled area, and this was in contradiction to what we would have expected from other studies where the trend has been that trawling reduces diversity. Brittlestars and lancelets seemed to be the groups mostly harmed by the trawling, while amphipods where more abundant in trawled areas. The multivariate analyses did not reveal the patterns of faunal change as well as we hoped. This is surely because of our lack of more replicate samples. The multivariate analyses are easily confounded when few sites are analyzed. We have found differences in the type of fauna found in trawled and protected areas and, considering the differences in environmental variables in our stations and our lack of replication, this indicates that there *are* differences and a larger investigation is in order to reveal its magnitude.

Key words: Grab, trawling, Gulf of Nicoya, benthic disturbance.

Commercial fishing has important effects on marine benthic habitats. The disturbance includes habitat destruction, removal of target and non-target species (bycatch), and physical disturbance of the seafloor (Messieh *et al.* 1991, Gilkinson *et al.* 1998). The Gulf of Nicoya is an estuary on the Pacific coast of Costa Rica and the main fishing area of the country (Vargas 1995). The lower part of the estuary is subjected to heavy fishing activity all year, with around 70 boats searching for several species of penaeid shrimps (like *Penaeus occidentalis, P. stylirostris*) using ottertrawls. The upper gulf has been protected against commercial fishing since 1966. This makes the gulf an ideal site for studying effects of commercial fishing. The objective of this study was to evaluate the impact of shrimp trawling in the benthic infaunal communities of the Gulf of Nicoya estuary.

Grab samples were collected during three cruises in the Gulf of Nicoya, Costa Rica: October 24th 1997, January 16th 1998, and April 30th 1998. During each cruise we sampled four sites, two in a protected area and two in a trawled area. Table 1 gives the exact locations of the stations. At each site we collected four grabs (25 cm x 25 cm van Veen grab) for fauna analysis and two cores for sediment analysis (the top 20 cm layer of sediments sampled with a vacuum-corer). The grab samples were stored

TABLE 1

Station code, area (trawled or protected), sampling date, location (latitude and longitude), depth (m), silt and clay content of sediment (%), number of species, number of individuals, and Shannon-Wiener diversity index. Gulf of Nicoya, Costa Rica

Station code	Trawled/ protected	Sampling date	Location	Depth	Silt and clay %	Number of species	Number of individuals	Diversity (Shannon, log base e)
T1a	Trawled	10.24.97	9°55`713``N 84°47`603``W	18	8.8	30	190	2.39
T1b	Trawled	01.16.98	9°55`713``N 84°47`603``W	17	12.7	43	309	3.1
T1c	Trawled	04.30.98	9°55`713``N 84°47`598``W	17	14.1	32	207	2.67
T2a	Trawled	10.24.97	9°57`547``N 84°44`997``W	6	17.4	29	395	2.01
T2b	Trawled	01.16.98	9°57`518``N 84°44`966``W	6	20.6	67	709	3.52
T2c	Trawled	04.30.98	9°57`538``N 84°44`955``W	5	34.4	71	994	2.97
P1a	Protected	10.24.97	9°58`756``N 84°52`171``W	4	3.1	46	501	2.19
P1b	Protected	01.16.98	9°58`756``N 84°52`171``W	7.5	1.7	35	392	2.13
P1c	Protected	04.30.98	9°58`800``N 84°52`168``W	4	1.7	45	382	2.69
P2a	Protected	10.24.97	9°56`980``N 84°57`800``W	20	13.6	29	128	2.26
P2b	Protected	01.16.98	9°56`980``N 84°57`800``W	17.5	21.0	36	154	2.78
P2c	Protected	04.30.98	9°56`807``N 84°57`615``W	22	21.1	36	259	2.59

in bottles with a 10% seawater-buffered formalin solution, stained with Rose Bengal. The fauna was sieved in a combination of 1 mm and 0.5 mm sieves and the animals stored in vials containing 70% alcohol.

Univariate measures were calculated for each station. The indices used were: Total number of individuals and species, and Shannon-Wiener diversity H' (log base *e*). The PRIMER package of multivariate methods were used on log (x + 1) transformed abundance data (Clarke and Warwick 1994, Underwood 1997), including hierarchical agglomerative clustering (classification) and non-metric multidimensional scaling (MDS).

Table 1 shows sample locations, environmental variables and some univariate indices.

Station labeled ***a*** where sampled in October 1997, ***b*** in January 1998 and ***c*** in April 1998. T indicates that the station is in the trawled area and P indicates that the station is located in the protected area.

The classification analysis done on log (x+1)-transformed species abundance data are included in Fig. 1. Stations T1 and P2 tended to group together before they grouped together with station P1, leaving station T2 in its own cluster and suggesting that station T2 was very different from the others. The MDS plots based on log (x+1)-transformed species abundance data are included in Fig. 2. It is clear that station T2 was separated from the other stations, while stations T1, P1 and P2 were grouped closer together.

The ANOSIM (Analysis of Similarity) test showed that all the stations were significantly different from each other. ANOSIM tests the null hypothesis "There are no differences in community composition at the stations". If R=0 the null hypothesis is true. In our case R is 0.745, closer to 1, which is the extreme value. More important, it is significant (= 0.05).

Dominating species is defined as species accounting for more than 50% of the individuals

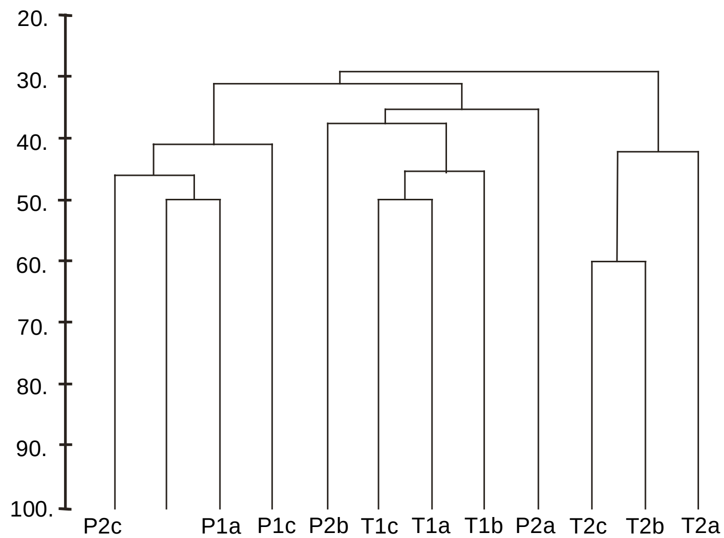

Fig. 1. Classification analysis (Cluster) based on log (x+1)-transformed species abundance data for the six trawled (T) and six protected (P) stations in the Gulf of Nicoya, Costa Rica.

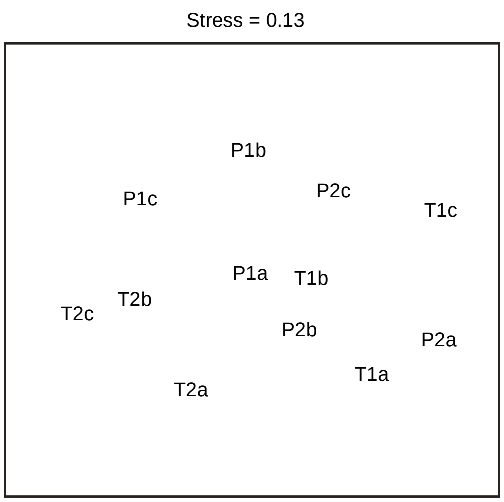

Fig. 2. Multiple Dimensional Scaling (MDS) plots based on log (x+1)-transformed species abundance data for the six trawled (T) and six protected (P) stations in the Gulf of Nicoya, Costa Rica.

in the four replicatesthe polychaetes. *Paraprionospio pinnata* and/or *Spiophanes duplex*, both belonging to the family Spionidae were almost always present among the dominating species. Amphipods were only among the dominating species in the trawled areas, while lancelets, represented by *Branchiostoma californiensis*, and ophiuroids were found in protected sites. Of special interest is the catch of the shrimp *Sicyonia mixta* (Burkenroad 1946), which has never been observed in Costa Rica earlier.

When comparing community composition based on phyla, there seems to be a difference between the trawled and protected stations (Fig. 3). At the trawled stations (T1 and T2), the annelids (polychaetes) and arthropods dominated the community, while at the protected stations (P1 and P2) echinoderms (brittlestars) and chordates (*B. californiensis*) were also important.

The trawled stations were typically composed of more than 50 % polychaetes, 30 % arthropods (mainly amphipods), some mollusks and a few percent chordates (*B. californiensis)*, sipunculids and echinoderms (brittlestars). The protected stations had more or less the same proportion of polychaetes (around 50 %), mollusks and sipunculids, but the arthropods represented less than 20 %, and *B. californiensis* and brittlestars each comprise between 5 and 15 %.

From environmental variables alone we would expect station T1 to resemble station P2. The cluster does not group these stations together, but in the MDS ordination these stations are fairly close together. The multivariate analyses, performed using the species counts, seem to reflect the difference in environmental variables at the sites rather than any effects of trawling activity. Station T2 that is the definite mud-

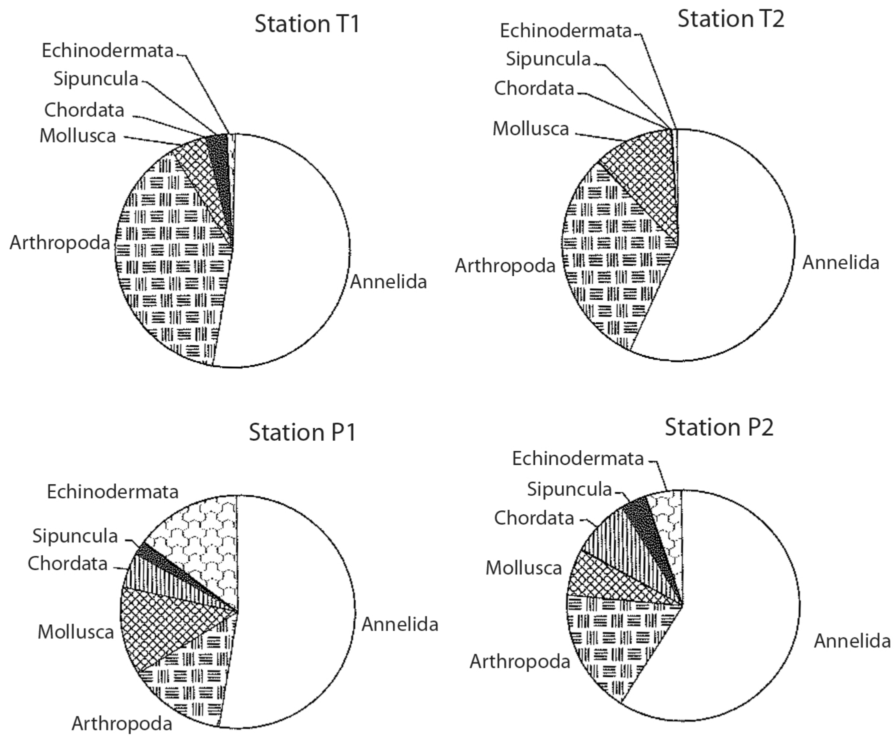

Fig. 3. Sector diagram showing phyla composition at the four sampling sites. Abundance data are pooled replicates from the three sampling dates. The clear difference between the trawled stations (top) and protected stations (bottom) should be viewed with caution. Using only two stations in each area leaves us with only one degree of freedom. Gulf of Nicoya, Costa Rica.

diest station, closest to the mouth of Barranca River and the least saline is also the station that differs most from all other stations. This can be seen both in cluster classification and in MDS ordination. P1 was the station with the coarsest sediment type and this station as well is separated from the others in both cluster and MDS. In the MDS ordination we see a depth gradient. The shallow stations appear on the left side of the ordination.

When viewing the samples at the phyla level it is easier to see differences between areas that can be attributed to trawling activity. Fig. 3 shows that there are some groups that are not seen often in trawled areas, while others are found to be more abundant in trawled areas. Echinoderms are known to be affected by trawling activity. They are physically injured by the trawl and not very able to immigrate and recolonize recently trawled areas. The arthropods however are more abundant in trawled areas. They are more mobile and able to quickly immigrate to trawled areas and take advantage of the food resources made available by the plowing of the trawl boards in the sediment (Currie and Parry 1996). The lancet *B. californiensis* was found only in protected areas with coarse sediment. This benthic animal would be expected to be harmed by trawling activities, but another explanation may be that this lancelet prefers coarse sediment types and is therefore more often found in station P1.

Ferraro and Cole (1995) suggested that analyzing data at phylum level had the effect of dampening natural variability in faunal patterns, revealing effects of anthropogenic impacts. However, when we did multivariate statistics on the phylum data we did not see the differences very clearly. We found that other equalities where more dominating than the differences we could see out of the raw data. E.g. we thought station P1 and P2 would be clustered together because of the echinoderms that could be found at both stations. However, we found that because of lancelets that were found in large quantities at station P2c in April, this station grouped together with P1a and P1b and made a cluster totally separated from the rest of the samples. This problem goes throughout our entire dataset. Small variations in a station at one time confound the entire analysis. This goes to emphasis the need for proper replication (Underwood 1997).

Few stations and large variation in environmental variables have made this study less clear in its conclusions. The multivariate and univariate statistics suffer from this in that we have few degrees of freedom and stations that already are expected to differ from each other. Still we have found some effects that can be attributed to the trawling activity, and from such a small-scale study this is more than could be expected.

Our set of stations was not ideal. Important parameters such as depth and sediment content of silt and clay varied substantially and there is no doubt that this has influenced the results. Also the need for more stations in each area (trawled *vs*. protected) must be stressed. Thus, a larger study would give interesting results.

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