Final Report

"Shrimp and crab trawling impacts on estuarine soft-bottom organisms"

A Project Supported by the NC Fishery Resource Grant Program

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Abstract

This project addressed questions about the possible impacts of trawling for crabs and shrimp in North Carolina estuaries on populations of organisms associated with soft-bottom habitats. The organisms of interest included benthic microalgae, demersal zooplankton, and macrobenthic animals, encompassing the lower trophic levels in the benthic food chain and the essential trophic coupling that supports estuarine fishery production. The approaches used in this project included sampling before and after experimental trawling at several estuarine locations, sampling in areas actively trawled and closed to trawling, and sampling during several seasons over two years to address seasonal and interannual effects. Sampling began in February, 1999, and ended in November, 2000 at six locations in the Pamlico River Estuary. Commercial fisherman Henry Daniels provided the use of his trawler for experimental work.

Experimental trawling had no significant effect on the biomass of benthic microalgae, no consistent effect on the abundance of demersal zooplankton, and only a slight but non-significant effect on the abundances of benthic macrofaunal animals. Benthic microalgae were significantly more abundant in untrawled locations than in trawled locations, with strong seasonal variation as well. Abundances of demersal zooplankton were not significantly or consistently different between untrawled and trawled

locations. There were higher abundances of benthic macrofauna in trawled locations than at untrawled locations, but only at certain times of the year. There also were few differences in the benthic macrofauna dominating at trawled and untrawled locations. Seasonality was very important and interannual variation was observed, but less important than seasonal differences.

We conclude that there is little evidence of direct, negative impacts of trawling activity on these soft-bottom organisms. Seasonality differences were more impressive than all other differences. Although trawling *per se* does not seem to have a consistent effect on estuarine soft-bottom benthos, there are interesting differences between trawled and untrawled habitats that merit further investigation.

Introduction

There are conflicting points of view on possible impacts of trawling activities in estuarine ecosystems. One argument is that the physical disruption of the bottom created by trawling activity harms bottom-dwelling organisms by some combination of mechanical damage, displacement of the organisms themselves, sedimentation, enhanced exposure to predation, and selective impacts on certain members of the bottom-dwelling group. A different point of view holds that trawling mimics natural disturbance and stimulates benthic production as if the bottom were cultivated. Given the magnitude of trawling activities in North Carolina's inshore waters and the controversies surrounding these activities, it is important to resolve these issues so that effective management approaches can be taken.

Trawling activities may have a variety of impacts on estuarine habitats, including direct disturbance of the bottom and associated flora and fauna, effects on target species, direct effects on non-target species (bycatch), effects on habitat structure, sediment resuspension, alteration of processes at the sediment-water interface, and other indirect effects on natural and human uses of these habitats. Trawling effects may be expected to vary considerably among different kinds of habitats, among different gear or fishing types, and with differing intensity. Clearly, the issues with regard to impacts of trawling are complex and not amenable to comprehensive resolution in a single study.

We chose to focus on the effects of trawling on non-target, bottom-dwelling organisms that are important as food sources for commercially important estuarine species. These organisms included benthic microalgae, microscopic algae that live at the sediment-water interface and that frequently reach biomass levels substantially exceeding the biomass of phytoplankton in the overlying water column (Freeman, 1989; Nearhoof, 1994, Cahoon et al., 1999). In addition we considered trawling effects on demersal zooplankton, a diverse group of small (typically one to a few mm in length) animals including various small crustaceans, nematodes, and other animals that associate with soft-bottoms and that are important grazers of benthic microalgae and prey for larger animals.

Approach

We used both experimental and observational approaches in our investigation of trawl effects.

Our experimental approach involved sampling in selected areas before and after trawling activity using Mr. Daniels' vessel, configured as a standard shrimp trawler. The locations sampled included Rose Bay, Pungo Creek, and South Creek (Fig. 1), all of them closed to normal trawling activity. We obtained a permit from the N.C. Division of Marine Fisheries for experimental trawling in these closed areas. We sampled along a line, then Mr. Daniels trawled along that line using GPS to mark the vessel's position and guide it back to the same locations. Observations of the trawl's sediment plume provided visual confirmation of positioning. Samples were collected using a Ponar sediment grab sampler (20x20 cm). Eight replicate sediment cores for benthic microalgae, five replicate cores for demersal zooplankton, and seven replicate samples for benthic macrofauna were collected at each sampling location. We also collected water samples for analysis of chlorophyll *a*, a measure of phytoplankton biomass. Experimental trawling was conducted in February, March, and July of 1999, and in April and August of 2000.

Observational sampling consisted of sampling locations that were either trawled or untrawled. We sampled benthic microalgae, demersal zooplankton, and benthic macrofauna at three pairs of locations in the Pamlico River Estuary (Indian Island, North Creek, and Wades Point, Fig. 1). At each location two areas were chosen based on whether they were open to trawling or inaccessible to trawling and a requirement that these "trawled" and "untrawled" areas were as nearly adjacent as possible. Two of the untrawled sites were in areas with crab pots and one was along the edge of a boat channel. Trawled areas were generally within 50 feet of the untrawled areas, although usually in 1-3 ft deeper water. Sampling was conducted in March, May, July, and November of 1999, and in April, May and August of 2000. Sampling methods were the same as above.

Analytical methods used for sample workup followed standard procedures. Benthic microalgal biomass was measured as chlorophyll *a* following the method of Whitney and Darley (1979). Phytoplankton biomass was measured as chlorophyll *a* using the fluorometric method of Welschmeyer (1994). Demersal zooplankton were initially fixed in formalin-seawater-Rose Bengal, then separated from sediments by flotation in a hypertonic solution of magnesium sulfate. Animals were identified and counted by microscopy. Benthic macrofauna were removed from sediments by wet sieving using a 0.5 mm mesh sieve, fixed in a 10% formalin solution, identified to lowest taxon, and counted. Representative specimens for each taxon were sent to experts in the field for verification of identifications.

Results

Experimental trawling yielded no significant effects on benthic microalgal biomass in Rose Bay, Pungo Creek, or South Creek (Fig. 2a). Benthic chlorophyll *a* levels were noticeably lower in the latter two habitats, but this is likely a sediment grain size effect; both locations had muddy sediments, which have been found to support lower sediment chlorophyll *a* levels than fine sands (Cahoon et al., 1999), such as those typical of Rose Bay.

Benthic microalgal biomass was significantly higher in untrawled areas than in adjacent trawled areas at Wades Point, Indian Island, and North Creek (Fig 2b). However, sediment chlorophyll *a* levels were higher in the trawled areas in each of these locations than in the experimental trawl areas noted above. In addition, the sediment chlorophyll a levels in the untrawled areas were considerably higher than values found in other estuarine locations in eastern North Carolina (Nearhoof, 1994). These results suggest that some factor other than trawling controls benthic microalgal biomass in these areas. Untrawled areas, as noted above, were usually densely packed with crab traps, so an effect from the presence of crab traps (nutrient loading from bait, suppression of benthic grazers by trap-associated consumers) must be considered.

Nematodes were the most abundant demersal zooplankters at all sites and times. Although nematodes are generally considered to be interstitial meiofauna living primarily within sediments, some are capable of limited swimming above the substrate. Gut content analyses of shrimp have found nematodes frequently, indicating their importance as food for epibenthic consumers. Other demersal zooplankter taxa were either absent or very rare, so analyses of the effects of trawling on demersal zooplankton focus on nematode abundances.

Experimental trawling had inconsistent effects on nematode abundance (Figs. 3-5). Among samples taken in March and July of 1999 and April, 2000 at Rose Bay, Pungo Creek, and South Creek, three before and after sets showed decreases in nematode abundance after trawling and six showed no significant effect. The sets showing decreases were all taken in March or April, however, when overall nematode abundances were much lower than in July. Thus seasonality appears to have a much more important effect on nematode abundance than direct trawling impacts.

Comparisons of nematode abundance in trawled and untrawled areas at three locations in March, 1999 showed that nematode abundance was higher in the trawled area at one location but not significantly different in the other two locations (Fig. 6). Nematode abundances were higher in these locations than at the experimental trawl locations at the same time (spring), but similar to those in July at the experimental trawl locations. Thus, seasonal and locational differences appear more important in determining nematode abundances than trawling effects.

The benthic macrofaunal community at all sites was dominated by a relatively few, opportunistic species, with polychaetes being the numerically dominant group at all sites. Common taxa included the burrowing polychaete *Mediomastus* (mostly *M. californiensis*), the tube-building polychaetes *Maranzellaria* (primarily occurring in spring samples) and *Streblospio*, and the clams *Macoma mitchelli* and *M. balthica* (most common in spring samples). Although there was some variation in total faunal density among sites (Fig. 7), the dominant fauna were similar with the exception of greater relative abundance of *Macoma* in the Rose Bay experimental trawl site.

There were some inter-annual differences in density of infauna, with greater overall densities of polychaetes in 2000 compared to 1999 and greater densities of amphipods in 1999 compared to 2000 (although amphipod densities were low in both years) (Fig. 8). However, the strongest temporal pattern related to seasonality. Abundances of all taxa were significantly greater in spring samples with a dramatic decline during summer (Fig. 9). This low abundance of infauna during summer may reduce potential density responses to trawling activities at this time, since low initial abundances would not allow for much additional decline.

There was no statistically significant effect of experimental trawling on macrofaunal abundances for any of the 3 sites examined (Fig. 10). This, the disturbance associated with a double pass of a trawl over previously untrawled bottom did not significantly affect abundances. However, the pre-trawl samples did have consistently higher densities than after trawling, though the difference was small and variable.

Comparisons between normally trawled areas and nearby untrawled areas indicated differences that varied between years. In 1999 there were greater densities of polychaetes, bivalves, and amphipods in the trawled areas than the untrawled areas (Fig. 11). However, the difficulty in finding suitable untrawled areas close to trawled areas, with similar sediment type and water depths, that were also not in close proximity to crab pot activities raises the possibility that effects were not the result of trawling but were related to the presence of nearby crab pot sets. Underscoring the potential variability in effects, there were no significant effects of trawled vs. untrawled areas on polychaete or amphipod abundances in 2000 samples (Fig. 12). With respect to seasonality, polychaetes exhibited similar responses to trawling in spring vs. summer while bivalves only showed an effect in spring, possibly reflecting their low summer densities.

Conclusions and Recommendations

We found no significant or consistent effect of experimental trawling on any of the soft-sediment organisms we studied. Although there were some differences in the abundances of soft-sediment organisms between trawled and untrawled areas, these differences did not always reflect a negative effect of trawling. Furthermore, we suspect that in the untrawled areas the presence of numerous crab traps may have created its own set of effects on soft-bottom organisms. In addition, differences among locations, between years, and, especially, among times of year were more important in determining abundances of soft-bottom organisms than trawling effects. Thus, we conclude that shrimp and crab trawling has limited effects, at most, on soft-bottom organisms in the estuarine ecosystems we examined.

We think that soft-bottom habitats in the estuarine waters of North Carolina experience substantial and frequent natural disturbance from storm events. Wave- and current-induced disturbance is at least qualitatively similar to the disturbance caused by trawling at the sediment-water interface. Consequently, we think that soft-bottom organisms in shallow estuarine areas are adapted to some level of disturbance, so that trawling activity is not particularly harmful. One important qualification, however, is that intense or especially frequent trawling activity may overcome the resilience of soft-bottom organisms to disturbance. Another qualification is that soft-bottom communities in naturally sheltered, relatively undisturbed habitats may be less resilient to trawling disturbance.

We offer two recommendations based on our findings and our analysis of those findings:

1) An assessment of the intensity and frequency of trawling activity should be made in an effort to identify areas where and times when trawling activity may be especially intense. It is possible that some threshold level of trawling effort exists, above which an ecosystem's soft-bottom community does show negative impacts.
2) The possibility is raised from the results of this study that dense aggregations of crab traps may have effects (not necessarily negative) on soft-bottom organisms nearby. Given the numbers of crab traps deployed in N.C. waters these effects should be examined.

Objectives and Work Tasks

Objectives:

1) Determine the effects of experimental trawling activity on the abundances of soft-bottom organisms.
2) Determine the differences, if any, in the abundances of soft-bottom organisms in comparable trawled and untrawled areas.
3) Determine the effects of seasonality and differences among locations on the abundances of soft-bottom organisms in all sample locations.

Work Tasks:

1) Obtain permits for experimental trawling in closed locations (Rose Bay, Pungo Creek, South Creek).
2) Conduct experimental trawling and sampling (before and after) in closed locations in several seasons during two years.
3) Sample soft-bottom organism abundances in adjacent trawled and untrawled areas (Wades Point, Indian Island, North Creek).
4) Process benthic microalgae, demersal zooplankton, and benthic macrofauna samples and analyze data.
5) Present results, conclusions, and recommendations to public.

All objectives have been met. Work tasks #1-4 have been completed. Work task #5 has been partially completed (presentation to NC Commercial Fishing Expo in February, 2001, discussion of results at the May meeting of the Flounder FMP committee meeting, presentation to June meeting of the Crustacean Fisheries Advisory Committee, this report, and formal publication planned).

There were no changes in the Objectives or Work Tasks.

There were no changes in the budget (except for approval of Year 2 funding, as originally planned).

No equipment (cost >$500) was purchased.

Literature Cited

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Acknowledgments

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Figure 1. Map of locations where experimental trawling (Rose Bay, Pungo Creek, and South Creek) and comparison sampling of trawled and untrawled areas took place (Wades Pont, Indian Island, and North Creek).

Figure 2a. Effects of experimental trawling on benthic microalgal biomass; "BT" = before trawling, "AT" = after trawling. None of the BT vs. AT comparisons yielded a significant difference using 1-way ANOVA.

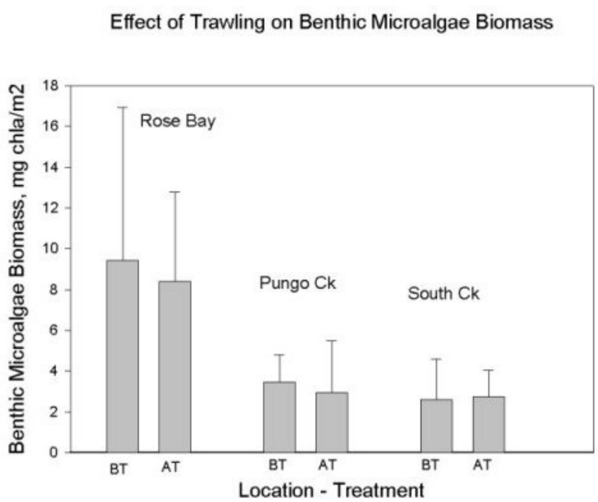

Figure 2b. Comparisons of benthic microalgal biomass in trawled (TR) and untrawled (NT) areas for all sampling times. There were significant differences between the two treatments at Wades Point and Indian Island (1-way ANOVA, F=9.22, df = 1,11, P<0.05 and F=6.18, df=1,11, P<0.05, respectively), but not at North Creek.

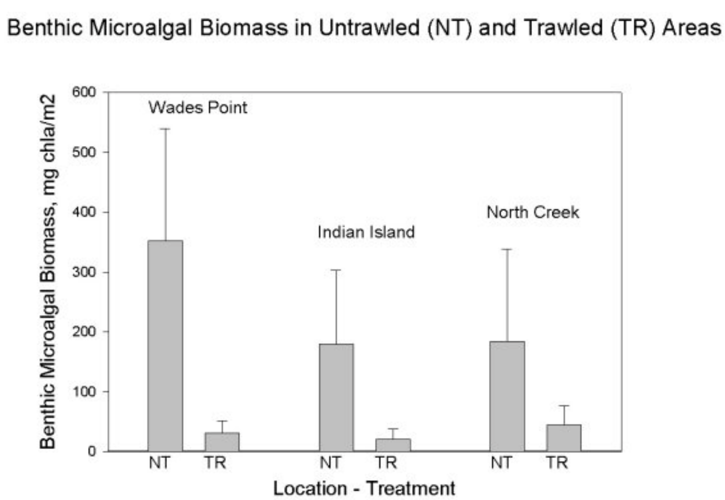

Figure 3. Effects of experimental trawling on nematode abundance, March, ‘99; “BT” = before trawling, “AT” = after trawling. Only the BT vs. AT comparisons for Rose Bay yielded a significant difference using 1-way ANOVA (F=23.2, df=1,4, P<0.01).

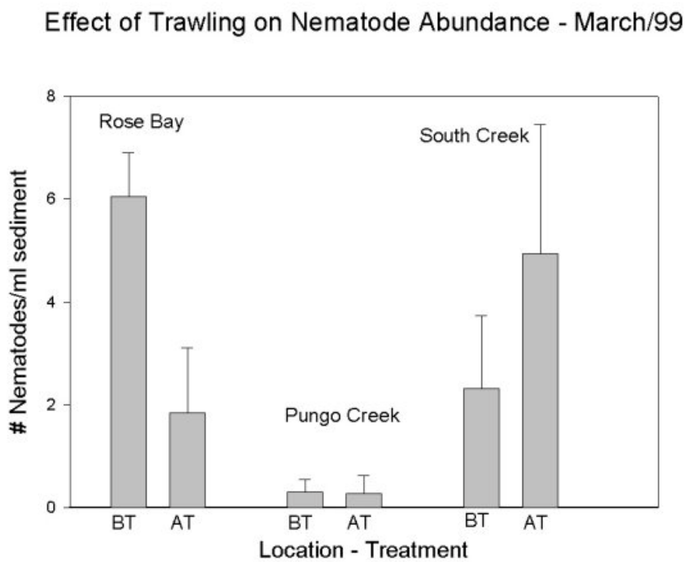

Figure 4. Effects of experimental trawling on nematode abundance; July, ‘99. None of the BT vs. AT comparisons yielded a significant difference using 1-way ANOVA.

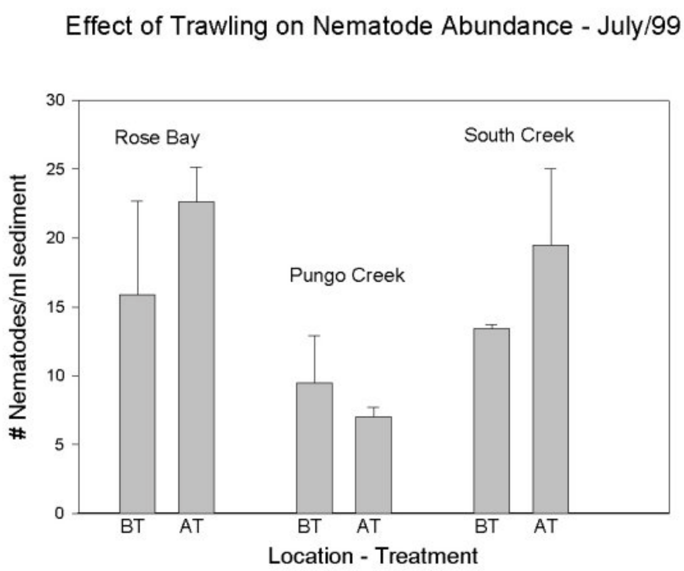

Figure 5. Effects of experimental trawling on nematode abundance; April, '00. Only the BT vs. AT comparisons for South Creek yielded a significant difference using 1-way ANOVA (F=39.0, df=1,4, P<0.005).

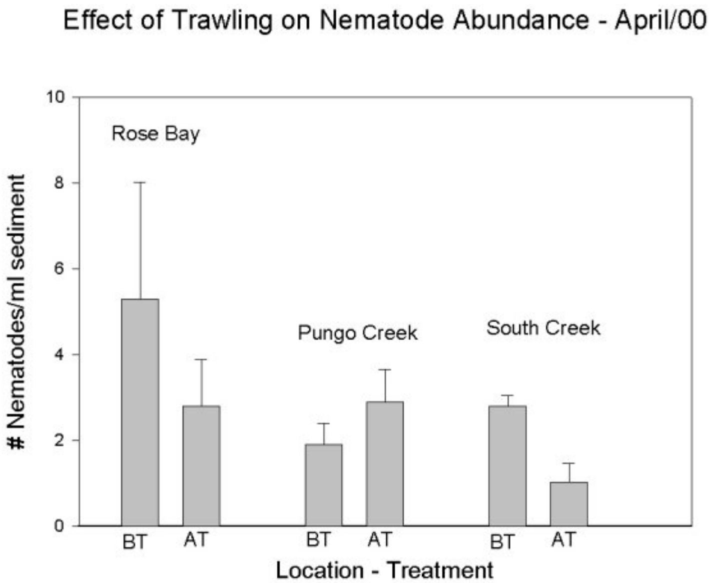

Figure 6. Comparisons of benthic microalgal biomass in trawled (TR) and untrawled (NT) areas for July, 1999. There were significant differences between the two treatments at Wades Point (1-way ANOVA, F=16.85, df = 1,4, P<0.05), but not at other locations.

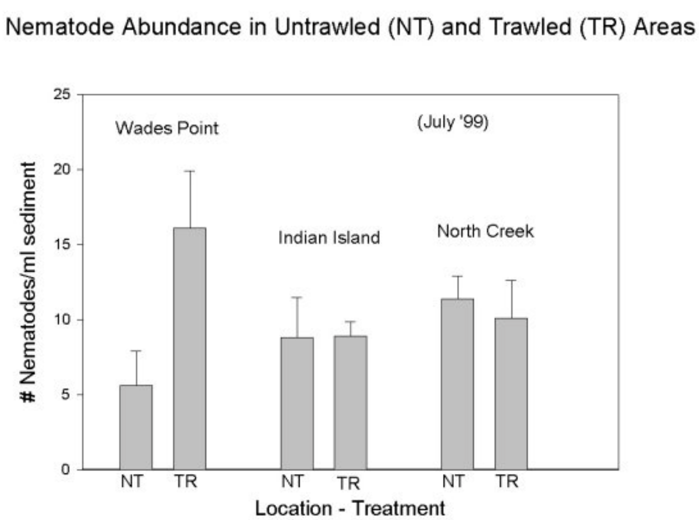

Figure 7. Mean total density at each site

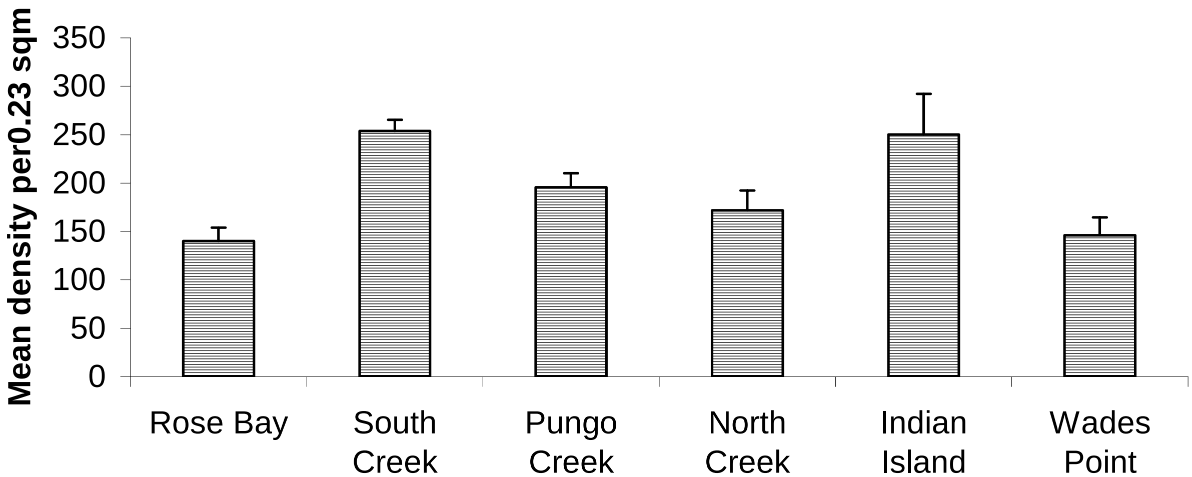

Figure 8. Mean macrofaunal density for major taxonomic groups by year. NS= no significant difference; ** p<.001, *** p<.0001 (ANOVA).

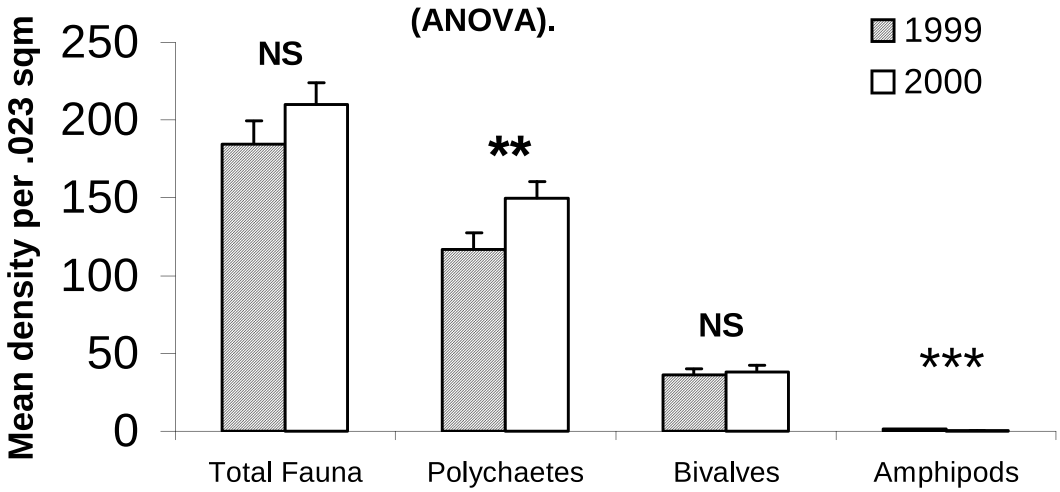

Figure 9. Mean macrofaunal density by season, for major taxonomic groups. (ns= not sigificant, ***p<.001(ANOVA))

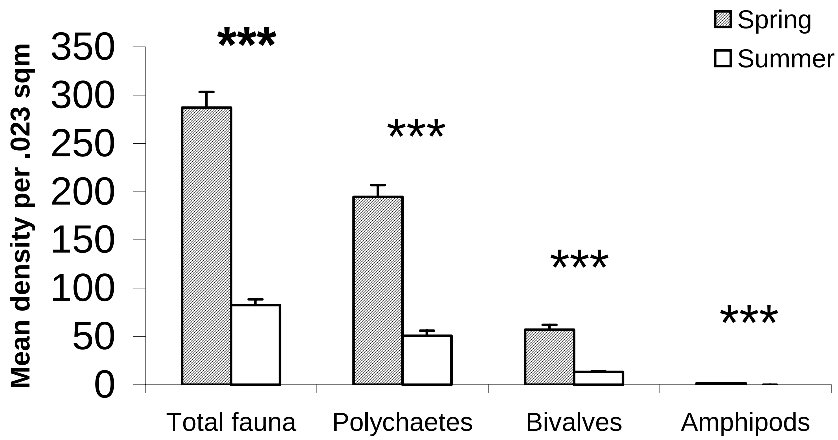

Figure 10. Mean macrofaunal density by major taxonomic groups, for experimentally trawled areas. NS= no significant difference.

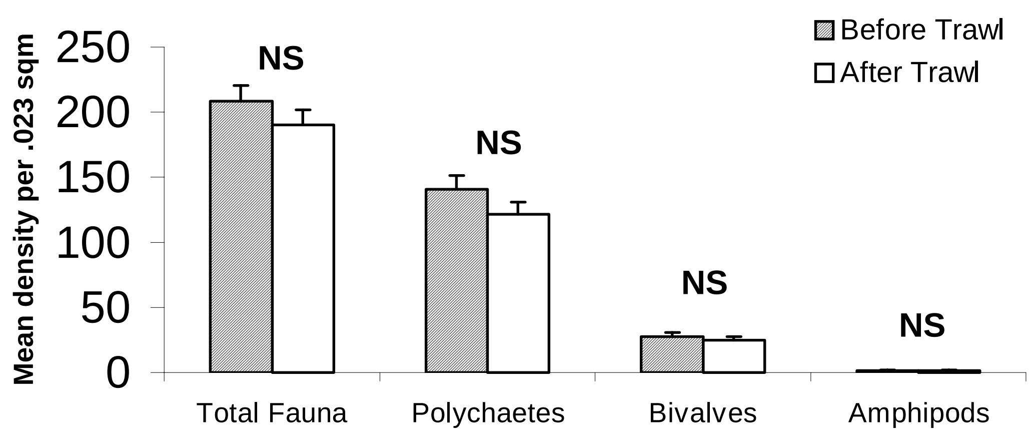

Figure 11. Mean macrofaunal density, by major taxonomic groups, for regularly trawled areas vs untrawled areas in 1999. (* p<0.001 (ANOVA)).**

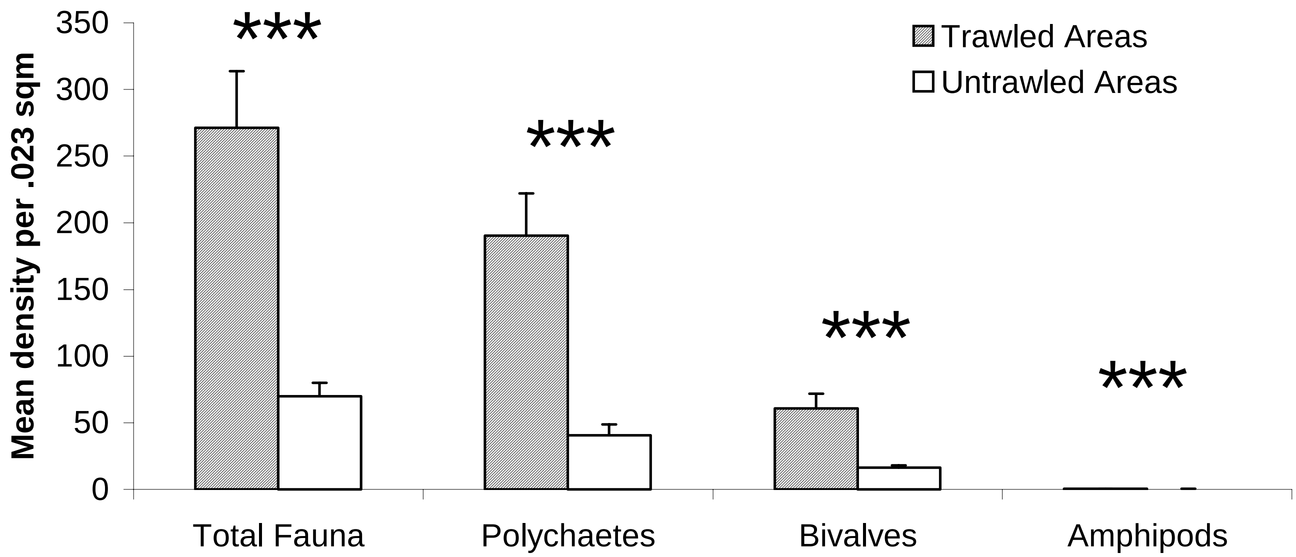

Figure 12. Mean macrofaunal density, by major taxonomic groups, for regularly trawled areas vs untrawled areas in 2000. NS= no significant difference; * p<.05 (ANOVA)