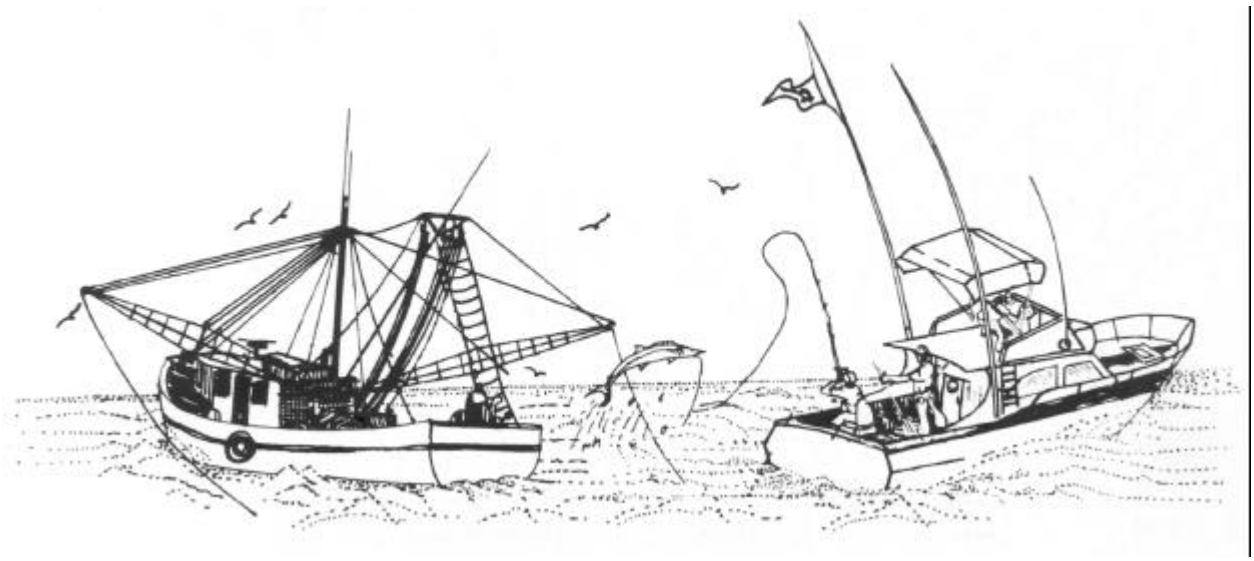
ANNOTATED BIBLIOGRAPHY OF FISHING IMPACTS ON HABITAT - OCTOBER 2000 UPDATE



Gulf States Marine Fisheries Commission

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Annotated Bibliography of Fishing Impacts on Habitat - October 2000 Update

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Introduction

This is first in a series of updates to the Gulf States Marine Fisheries Commission's *Annotated Bibliography of Fishing Impacts on Habitat* originally produced in February 2000. The Commission's Habitat Subcommittee felt that the gathering of pertinent literature should continue. The first update contains 47 new articles since the publication of the original bibliography. The update uses the same criteria that the original bibliography used to compile articles. It attempts to compile a listing of papers and reports that address the many effects and impacts that fishing can have on habitat and the marine environment. The bibliography is not limited to scientific literature only. It includes technical reports, state and federal agency reports, college theses, conference and meeting proceedings, popular articles, and other forms of nonscientific literature. This was done in an attempt to gather as much information on fishing impacts as possible. Researchers will be able to decide for themselves whether they feel the included information is valuable.

Fishing, both recreational and commercial, can have many varying impacts on habitat and the marine environment. Whether a fisher prop scars seagrass, drops an anchor on a coral reef, or drags a trawl across the bottom, each act can alter habitat and affect fish populations. While fishing can have many varying impacts on habitat, this bibliography tries to narrow its focus to the physical impacts of fishing on habitat. It does not try to include the ecosystem effects of fishing. Removal of predators, prey, and competitors can have very serious and extensive effects on the ecosystem, but it is not addressed here. Also, the bibliography tries not to include bycatch issues and the act of discarding bycatch back into the marine environment. While the bibliography includes research on physical fishing impacts on animals, if the animal was caught or retained and then later discarded, the bibliography does not deal with this issue. Some included papers may not directly apply to the above guidelines. However, it is thought that inferences can be made on how this action could affect other habitat, animals, or environments, i.e., lost gear that affects a marine mammal could also affect fish in the same way.

The bibliography is global in scope. The bibliography's global nature was an attempt to include similar fisheries and gear types throughout the world. While it might not be possible to compare gear types and fishing methods from one area to another directly, some conclusions can be drawn and inferences made on the associated habitat impacts. Although global in scope, only reports and articles in English were included.

Most of the articles in this update were published this year, but older articles were included if they were not already in the bibliography. The annotated bibliography is now available on the Commission's web site at http://www.gsmfc.org/fishingimpacts.html. It is also available as a ProCite® searchable database. Users of this document should feel free to contact the editor with comments, suggestions, and updated information.

Ambrose, W.G., M. Dawson, C. Gailey, P. Ledkovsky, S. O'Leary, B. Tassinari, H. Vogel, and C. Wilson. 1998. Effects of baitworm digging on the soft-shelled clam, *Mya arenaria*, in Maine: Shell damage and exposure on the sediment surface. Journal of Shellfish Research. Vol. 17(4):1043-1049.

Abstract: Experiments conducted during the fall of 1997 on an intertidal flat in Maine determined the extent of shell damage and exposure of *Mya arenaria* on the sediment surface resulting from commercial bloodworm (*Glycera dibranchiata*) digging. We conservatively estimate that worm diggers dig up and expose on the sediment surface approximately 6% of the greater than 2 mm fraction of the clam population each time they turn over the sediment. Twenty percent of the clams had at least one valve damaged. Fifteen percent of intact clams exposed were found with their siphon up (normal living position), 41% with their siphon down, and 44% were horizontal on the sediment surface. Large clams (5.7 cm average shell length) placed on the sediment surface in the siphon up position reburied faster and to greater depths than those in horizontal or inverted positions. Small clams (2.7 cm shell length) buried faster than large clams, and those placed horizontally or with their siphons up reburied faster than clams placed with their siphons down. We detected no difference in reburial patterns between large clams exposed on undug and recently dug sediment. Our recovery of large clams after 10 days, however, was much greater (91.8%) from undug sediment than dug sediment (59.4%) and we found twice as many clam shells exhibiting evidence of predation in the dug than the undug area. Only about 50% of the small clams were recovered live. Shell damage of recovered dead clams indicated that predators consumed some missing clams. Our results suggest that baitworm digging negatively affects the survival of *Mya arenaria* by directly damaging shells and by exposing clams to increased risk of predation.

Anonymous. 1971. The heavy tickler chain - right or wrong? World Fishing. Vol. 20(10):8-10.

Appledorn, R.S., M. Nemeth, J. Vasslides, and M. Scharer. 2000. The effect of fish traps on benthic habitats off La Parguera, Puerto Rico. Unpublished report to the Caribbean Fishery Management Council. Hato Rey, Puerto Rico.

Summary: This report examines the use and effects of fish traps on benthic habitats off the southwestern coast of Puerto Rico. The purpose of the study was to determine the distribution of traps among the various benthic habitat types and the potential impact that these traps may have upon the benthic system. The results of the study show low, but definite habitat damage caused by traps on coral/hardbottom areas.

Aschan, M.M. 1991. Effects of Iceland scallop dredging on benthic communities in the Northeast Atlantic. ICES Benthos Ecology Working Group, Special International Workshop on the Effects of Physical Disturbance of the Seafloor on Benthic and Epibenthic Ecosystems. Bedford Institute of Oceanography. 10 p.

Abstract: In this paper the effects of dredging on the macrobenthos of *Chlamys islandica* fields will be presented. The study was conducted from the research vessel R/V *Johan Ruud* during the summers 1987-1990 in an area south of Jan Mayen at 60-120 m depth and at the northern side of Spitsbergen at 25-80 m depth. Data on the faunal composition was collected by dredging, photography and underwater video recording. In addition to *Chlamys islandica* the dominating species are *Strongylocentrotus droebachiensis*, *Ophiopholis aculeata*, *Ophiura robusta* and *Astarte* sp. At Jan Mayen both the sea cucumber *Cucumaria frondosa* and the crustaceans *Sabinea septemcarinatus* and *Spirontocaris spinus* are common. In the Svalbard areas, the crustaceans *Hyas coarctatus*, *Sclerocrangon boreas*, *Lebbeus polaris* and *Balanus* which encrusts the scallops are characteristic. As a result of the scallop dredging the number of species, the number of individuals/sample and the biomass in each sample, diminished from 1987 to 1990 in the Moffen areas (N Svalbard). *Strongylocentrotus droebachiensis* and *Pagurus pubescens* became more dominant during the four years of heavy dredging, because they probably stand the physical disturbance better than other species. In the Jan Mayen area no recovery could be observed two years after the fishery stopped. However, *Ophiura robusta* and polychaetes showed an increase.

Ault, J., J. Serafy, D. DiResta, and J. Dandelski. 1997. Impacts of commercial fishing on key habitats within Biscayne National Park. Cooperative Agreement No.: CA-5250-6-9018. 80 p.

Abstract: Recreational and commercial harvesting of fishes and invertebrates is permitted in Biscayne National Park (BNP). While there are obvious economic and social benefits associated with fishing in BNP, there may also be insidious effects that reduce ecosystem productivity. Specifically, these effects are in the form of habitat modification and degradation resulting from the use of certain fishing gears. The purpose of the present study was to determine the extent of the effects of commercial activities which predominate in terms of both human participation and areal coverage, namely, bait shrimp trawling and trapping of spiny lobster, stone crab, and blue crab. This project was composed of three principal components: 1) analysis of existing data; 2) field surveys and ground-truthing; and 3) field experiments. Techniques in scientific data visualization and advanced statistical analysis were used to facilitate assessment and modeling. The major activities and findings of our research program are summarized below. 1) Existing data, reports and literature were compiled and analyzed to provide syntheses of the historical development, landings and effort, and current gear and practices for each fishery. 2) Spatially-explicit databases pertaining to submerged natural habitats within BNP and adjacent areas of Biscayne Bay were obtained, integrated, and analyzed. The areal extent of each of BNP's five major benthic communities (i.e., seagrass, hardbottom, mixed seagrass/hardbottom, bare bottom, and offshore coral reef) were quantified and mapped. 3) Questionnaires were designed and distributed to commercial trap and trawl fishermen to characterize temporal and spatial fishing effort patterns. About 25% of the bait shrimp trawlers responded. No questionnaires were returned from lobster, stone crab or blue crab fishermen. Bait shrimp trawlers operating within BNP fish areas measuring about 165 km^2 during the wet season (June-November) and

350 km^2 during the dry season (December-May). These areas represent about 24.6% and 52.2% of BNP's entire submerged substrate, respectively. Seagrass habitats are the primary habitats trawled, followed by mixed seagrass/hardbottom, and then hardbottoms. 4) A series of aerial overflights were conducted to estimate the location and numbers of commercial traps from their surface buoys within BNP. Traps were then inspected using SCUBA and snorkeling techniques to characterize the immediate microhabitat upon which the respective traps were set. Trap "footprints" were also captured on video tape. Lobster and stone crab traps were found primarily over *Thalassia* beds, while blue crab traps were found primarily over *Halodule* beds. 5) Controlled trawling experiments were conducted over seagrass and hardbottom communities. Pre-trawl underwater video recordings were compared with post-trawl recordings of five linear transects that had received from one to five rollerframe trawl passes. While we were unable to detect any damage along the seagrass bed transects, damage to sessile invertebrates along the hardbottom transects was conspicuous after one pass. The rate of damage appeared to decrease with subsequent trawling efforts. The sponge *Ircina felix* and the corals of the genus *Pseudoplexaura* appeared to be the taxa most vulnerable to breakage or dislodgement by trawling. 6) Trap experiments revealed that damage to underlying seagrasses depended on soak time, trap type and plant species. For lobster traps, mean *Thalassia* loss was approximately 1% of initial plant cover after one day, 7% after one week, and 26% after one month. For stone crab traps mean loss of *Thalassia* cover was 4% after one day, 27% after one week, and 74% after one month. Blue crab traps reduced *Halodule* coverage by 4% after one day, by 24% after one week and by 70% after one month. 7) The bait shrimp fishery regularly comes in contact with large contiguous areas of BNP's submerged habitat resources. Restriction of commercial bait shrimp fishing in BNP's seagrass habitats cannot be justified solely on the basis of physical habitat damage. However, the issue of juvenile fish and crab bycatch deserves further attention, if not directed research. 8) While rollerframe trawling does not appear to damage seagrasses, damage to sessile invertebrates (i.e., sponges and soft corals) in hardbottom communities is conspicuous and is likely to be long-lasting. Hardbottom habitats would undoubtedly benefit from closure of commercial bait shrimping in areas that support high densities of sponges and corals. The feasibility of accurately marking the boundaries of BNP's hardbottom areas and preventing nocturnal trawling within them should be investigated. 9) It is essential to conduct a limited number of additional trawl effects experiments in conjunction with area closures to obtain precise estimates of habitat recovery rates for sponge and soft-coral habitats damaged by commercial trawling activities. 10) The primary benthic resource that the three major trap fisheries affect is seagrass habitat. The extent of damage to the habitat is a function of gear soak time, trap type, and the particular seagrass species which constitute the habitat. We strongly recommend that additional field experiments be conducted which focus on the rate at which *Thalassia* and *Halodule* recolonize after being impacted by trap-damage. 11) We further recommend that additional measurements of size and spatio-temporal extent of each of the trap fisheries be conducted. These studies are required before definitive estimates of cumulative Park-wide resource damage resulting from commercial trap fishing can be made.

Blaber, S.J.M., D.P. Cyrus, J.J. Albaret, C.V. Ching, J.W. Day, M. Elliott, M.S. Fonseca, D.E. Hoss, J. Orensanz, I.C. Potter, and W. Silvert. 2000. Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. ICES Journal of Marine Science. Vol. 57(3):590-602.

Abstract: Estuaries and associated coastal waters support many essential fisheries, a fact which contributes to their disproportionately high economic value. They are, however, also among the most extensively modified and threatened of aquatic environments. Almost all have been strongly affected by human beings, and fisheries are an integral part of human activities on the coast. We have taken a global perspective in synthesizing the effects of fishing on estuaries and coastal waters. Rather than attempt to cover all regions of the world in detail, we review eight process-orientated categories affected by fishing, with case studies for each of them: target organisms, non-target organisms, nursery functions, trophic effects, habitat change, reduced water quality, human environment, and potential for local extinctions. Fishing in the estuarine and nearshore environment has clear impacts on the structure and functioning of these ecosystems, although other, non-fishing issues also effect these ecosystems. This creates multiple interactions and reinforces the need for an integrated approach to coastal zone management. Nonetheless, some form of fish-based action plan could be created, especially within estuaries, which would provide management objectives for a particular system.

Black, K.P., and G.D. Parry. 1999. Entrainment, dispersal, and settlement of scallop dredge sediment plumes: field measurements and numerical modelling. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 56(12):2271-2281.

Abstract: Entrainment, dispersal, and settlement of sediment plumes generated by scallop dredging were measured with an instrumented towed sled and downstream sensors during a series of experiments conducted in the main scallop grounds in Port Phillip Bay in southeastern Australia. When three 36-ha experimental plots were subjected to closely supervised, intensive dredging by commercial fishers, it was found that dredges suspend a thin layer of sediment (~0.5 cm thick) inducing initial near-bed concentrations of 2-15 kg$\cdot$m^{-3} in a billowing turbid plume. At one field site where 30% of seabed sediment was less than 4 phi, concentrations reduced after 30 min to about 2% of the initial value and grain sizes decreased to a predominantly mud-sized sediment with a mean size of 5-6 phi. A numerical model was developed to depict plume transformations and settlement patterns. The model accurately predicted patterns of sedimentation and temporal changes to suspended sediment concentration and grain size distribution in the plume. By explicitly treating local seabed grain size, current, and water column turbulence, the model can be applied to other locations and conditions to examine suspended sediment concentrations and potential sediment-related impacts of scallop dredging.

Brown, B., and W.H. Wilson, Jr. 1997. The role of commercial digging of mudflats as an agent for change of infaunal intertidal populations. Journal of Experimental Marine Biology and Ecology. Vol. 218(1): 49-61.

Abstract: This study assessed the influence of commercial digging for worms and clams of a mudflat on the associated benthic infaunal community in Lowes Cove, Walpole, Maine, USA. Four replicate experimental sites were established within each of which were two m^2 digging plots and one 1 m^2 undug, control plot. Digging was done with a four-tined hoe by thrusting the tines into the sediment surface and pulling the sediment towards the digger. Such digging was repeated until an entire plot was dug. Two digging intensities were analyzed low frequency digging (plot was dug twice a month) and high frequency digging (plot was dug twice a week). By the end of the 2.5 month experiment, the density of polychaetes *Heteromastus filiformis* (Claparede), *Streblospio benedicti* (Webster and Benedict), and *Tharyx acutus* (Webster and Benedict) as well as the total number of taxa were significantly reduced in the plots that had been dug (regardless of frequency) relative to those of the control. Other densities (total number of individuals, *Scoloplos fragilis* (Verrill), *Exogone hebes* (Webster and Benedict), *Hydrobia totteni* (Morrison), total oligochaetes) were not affected by the digging. The lack of undug mudflats in Maine makes comparison of these results to benthic communities in undisturbed areas virtually impossible.

Buhs, F., and K. Reise. 1997. Epibenthic fauna dredged from tidal channels in the Wadden Sea of Schleswig-Holstein: spatial patterns and a long-term decline. Helgoländer Meeresunters. Vol. 51(3):343-359.

Abstract: The epibenthic fauna dredged in the channels of the Wadden Sea of Schleswig-Holstein is dominated by crustaceans. Mean species richness is lower in a southern region (7.6 ± 2.2 species per haul) which is part of the Elbe estuary and lacks protective barrier islands. A northern region is more marine and is protected by a seaward barrier of high sands and islands. Here mean species richness is 10.9 ± 2.8. Within channels, there is no significant inshore-offshore gradient, and species number does not increase with depth. Stratified sampling near the island of Sylt revealed that abundance and diversity are high along the gentle upper slope (5 m depth) of channels when mussels are present, but low in the absence of mussels. Abundance and diversity are also low along the steeper slope below (at 10 and 15 m depth). In a channel with scattered stones and boulders, highest diversity (16.0 ± 5.1) and dense epibenthic assemblages were encountered along the upper and middle slopes (5 and 10 m). Comparisons with historical surveys suggest that a decline of nearly fifty percent of all epifaunal species within the last hundred years may be attributed to fishery disturbances.

Clark, M. 1999. Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. Oceanologica Acta. Vol. 22(6):593-602.

Abstract: Major commercial fisheries for orange roughy (*Hoplostethus atlanticus*) occur on seamount features, which are widely distributed throughout the New Zealand region. When the fishery developed in the late 1970s to early 1980s, it occurred mainly on flat bottom, but over time has become more focused on seamounts. In the 1995-96 fishing year, it is estimated that about 70 % of the catch of orange roughy within the New Zealand EEZ was taken from seamounts. Seamounts on the Chatham Rise have been fished for over ten years. Examination of commercial catch and effort data show strong declines in catch rates over time, and a pattern of serial depletion of seamount populations, with the fishery moving progressively eastwards to unfished seamounts along the southern margins of the Rise. Catch rates on seamounts in other regions of New Zealand have also generally shown a similar pattern of rapid decline. There is growing concern over the impact of trawling on seamounts, and the effects this can have on the benthic habitat and fauna, and the long-term sustainability of associated commercial fisheries.

Collie, J.S., S.J. Hall, M.J. Kaiser, and I.R. Poiner. 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. Journal of Animal Ecology. Vol. 69(5):785-798.

Abstract: 1) The effects of towed bottom-fishing gear on benthic communities is the subject of heated debate, but the generality of trawl effects with respect to gear and habitat types is poorly understood. To address this deficiency we undertook a meta-analysis of 39 published fishing impact studies. 2) Our analysis shows that inter-tidal dredging and scallop dredging have the greatest initial effects on benthic biota, while trawling has less effect. Fauna in stable gravel, mud and biogenic habitats are more adversely affected than those in less consolidated coarse sediments. 3) Recovery rate appears most rapid in these less physically stable habitats, which are generally inhabited by more opportunistic species. However, defined areas that are fished in excess of three times per year (as occurs in parts of the North Sea and Georges Bank) are likely to be maintained in a permanently altered state. 4) We conclude that intuition about how fishing ought to affect benthic communities is generally supported, but that there are substantial gaps in the available data, which urgently need to be filled. In particular, data on impacts and recovery of epifaunal structure-forming benthic communities are badly needed.

Dustan, P. 1977. Beseiged reefs in Florida's Keys. Natural History. Vol. 86(4):72-76.

Eleuterius, L.N. 1987. Seagrass ecology along the coasts of Alabama, Louisiana, and Mississippi. Pages 11-24 *in* M.J. Durako, R.C. Phillips, and R.R. Lewis, editors. Proceedings of the symposium on subtropical-tropical seagrasses of the southeastern United States 12 August 1985. Florida Marine Research Publications. No. 42.

Summary: This paper discusses the distribution and abundance of seagrasses along the Alabama, Mississippi, and Louisiana coasts. The author briefly discusses prop scarring of seagrass and shrimping impacts on seagrass under his discussion of anthropogenic impacts on seagrass.

Ferns, P.N., D.M. Rostron, and H.Y. Siman. 2000. Effects of mechanical cockle harvesting on intertidal communities. Journal of Applied Ecology. Vol. 37(3):464-474.

Abstract: 1) Shellfish of marketable size can be harvested much more quickly and efficiently using mechanical methods such as tractor-powered harvesters and suction dredgers than by traditional methods. The adverse effects of such machines on non-target organisms need to be considered carefully before licensing such activities. 2) A tractor-towed cockle harvester was used to extract cockles from intertidal plots of muddy sand and clean sand in order to investigate the effects on other benthic invertebrates and their predators. 3) Harvesting resulted in the loss of a significant proportion of the most common invertebrates from both areas, ranging in the muddy sand from 31% of *Scoloplos armiger* (Polychaeta) (initial density 120 m^{-2}) to 83% of *Pygospio elegans* (Polychaeta) (initial density 1850 m^{-2}). Significant effects could not be detected in most populations with a density of less than 100 m^{-2}. 4) Populations of *Pygospio elegans* and *Hydrobia ulvae* (Gastropoda) remained significantly depleted in the area of muddy sand for more than 100 days after harvesting, and *Nephtys hombergi* (Polychaeta), *Scoloplos armiger* and *Bathyporeia pilosa* (Amphipoda) for more than 50 days. 5) Invertebrate populations in clean sand with relatively few cockles *Cerastoderma edule* (Pelecypoda) recovered more quickly than those in muddy sand with a more structured community, which included several tube-dwelling species such as *Pygospio elegans* and *Lanice conchilega* (Polychaeta). 6) Bird feeding activity increased at first on the harvested areas, with gulls and waders taking advantage of invertebrates made available by harvesting. Subsequently, in the area of muddy sand, the level of bird activity declined compared with control areas. It remained significantly reduced in curlews *Numenius arquata* and gulls for more than 80 days after harvesting and in oystercatchers *Haematopus ostralegus* for more than 50 days. 7) It is concluded from this study that tractor dredging for cockles in high density areas causes a sufficiently large mortality of non-target invertebrates that harvesters should be excluded from areas of conservation importance for intertidal communities such as invertebrates, fish and birds.

Giovanardi, O., F. Pranovi, and G. Franseschini. 1998. “Rapido” trawl-fishing in the Northern Adriatic: preliminary observations on effects on macrobenthic communities. Acta Adriatica. Vol. 39:37-52.

Abstract: The "rapido", a kind of beam trawl, is used only in the Adriatic Sea. Preliminary results of a study on the impact of the "rapido" gear on macrobenthic communities in the Adriatic Sea (Chioggia-Venice) are presented. Experimental hauls were carried out at two sites (one prohibited to all trawl-fishing activity and one used for commercial fishing) at a distance of 2-3 nautical miles from the coast. With the aim of simulating the action of commercial fishing, either one or several consecutive passages were carried out. Results indicated that trawling produces a furrow about 7 cm deep in the bottom sediment, which disturbs macrobenthic communities. After experimental hauls, the mean abundance values at all stations showed statistically significant differences with respect to controls; no significant statistical differences were found in the commercial fishing area for biomass.

Although fished and control areas did not exhibit significant differences two weeks after the experiments, analysis of the diversity indexes revealed that complete recovery had not occurred, since the control areas always had higher values than the fished areas. This study shows that gear such as the "rapido" has a very severe impact on benthic biocoenoses and that its use should, therefore, be better regulated.

Hall-Spencer, J.M., and P.G. Moore. 2000. *Limaria hians* (Mollusca: Limacea): a neglected reef-forming keystone species. Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 10(4):267-277.

Abstract: 1) The case is made for recognition of the marine bivalve *Limaria hians* as a reef-forming species, which plays a key architectural role in certain benthic communities around the United Kingdom and Ireland. 2) This species uses byssal threads to construct nests that can coalesce to form reefs that cover hectares of seabed, contain multiple conspecifics and bind sediment. In so doing, *L. hians* modifies physical, chemical and biological processes at the sediment-water interface. 3) Such nests support a high diversity of associated organisms in coarse-grade sediments (19 species of algae and 265 species of invertebrates from six discrete nests in Loch Fyne are reported on), although the biological interactions between species both inside and outside this assemblage (e.g. predatory cod) are unknown. 4) Being insubstantial, labyrinthine structures situated on the sediment surface, *Limaria* nests are sensitive to mechanical impacts, such as those caused by moorings, hydraulic dredging for infaunal bivalves and scallop dredging. 5) At appropriate sites, the status of *L. hians* can contribute a useful indication of disturbance on coarse-grade sediments.

Hamilton, A.N., Jr. 2000. Gear impacts on essential fish habitat in the southeastern region. Unpublished Report. National Marine Fisheries Service, Southeast Fisheries Science Center, Mississippi Laboratories. 40 p.

Summary: This report summarizes the Southeast Fisheries Science Center's December 1999 workshop on gear impacts on essential fish habitat. The workshop outlined the status of gear impact science in the southeastern United States.

Hansson, M., M. Lindegarth, D. Valentinsson, and M. Ulmestrand. 2000. Effects of shrimp-trawling on abundance of benthic macrofauna in Gullmarsfjorden, Sweden. Marine Ecology Progress Series. Vol. 198:191-201.

Abstract: Hypotheses about effects of shrimp-trawling on large benthic macrofauna were tested in a manipulative experiment in Gullmarsfjorden, Sweden. The experiment lasted 1.5 yr and included 3 trawl sites and 3 control sites, each of which was sampled at 4 times before and 4 times after trawling was commenced (a total of 480 samples). Gear and intensities were chosen to approximate those before trawling was prohibited 6 yr before the experiment. The overall trend was that biomass and abundances of animals decreased as a consequence of trawling but few taxa differed significantly among treatments. The mean abundance of

echinoderms, in particular the brittlestars *Amphiura* sp., decreased significantly and substantially after 7 to 12 mo of trawling. In general, however, changes in abundances of animals from one time of sampling to another, and from before to after trawling started, differed among sites. General models based on size and feeding strategy did not accurately predict differences among taxa in sensitivity to disturbances. Differences in overall impacts between this and previous experiments are discussed in terms of fishing intensity, natural variability and experimental design.

ICES. 2000. Effects of different types of fisheries on North Sea and Irish Sea benthic ecosystems. Review of the IMPACT II Report. Unpublished report to the European Commission Directorate-General Fisheries. Extract from the 2000 Report of the Advisory Committee on the Marine Environment. 20 p.

Summary: This report stems from a request from the European Commission Directorate-General Fisheries to review the report "The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems" (Lindeboom and De Groot, editors). ICES was requested to formulate management advice as to how the effects of the gears discussed in the report could be measurably reduced without unduly reducing the targeted catch. The group recommended effort reduction, gear substitution, change in gear usage, gear modifications, spatial closures, real time closures, improvement of habitat, species adjustment, and bycatch quotas.

ICES. 2000. Report of the working group on ecosystem effects of fishing activities. ICES CM 2000/ACME:02 Ref.:ACFM + E. 93 p.

Summary: This report examines the ecosystem effects of fishing activities in the Baltic Sea and bottom trawl impacts on the benthos in the North Sea and Irish Sea. It examines potential effects of bottom trawls, mitigating the effects of bottom trawls, and achieving reductions in effects.

Kaiser, M.J., K. Ramsay, C.A. Richardson, F.E. Spence, and A.R. Brand. 2000. Chronic historical fishing disturbance has changed shelf sea benthic community structure. Journal of Animal Ecology. Vol. 69(3):494-503.

Abstract: 1) Bottom fishing using towed nets and dredges is one of the most widespread sources of physical disturbance to the continental shelf seas throughout the world. Previous studies suggest that degradation and ecosystem changes have occurred in intensively fished areas. Nevertheless, to date it has been difficult to attribute habitat and benthic community changes to fishing effort at a spatial scale that is truly representative of commercial fishing activities. 2) In this study we present convincing evidence that chronic bottom-fishing disturbance has caused significant and widespread changes in the structure of two distinct soft-sediment benthic assemblages and habitats. 3) Our study compared the benthic fauna found in areas that have been exposed to either high or low levels of bottom-fishing

disturbance over the past 10 years. We were able to validate the fishing effort data in some areas using scars in the shells of a long-lived bivalve mollusc (*Glycymeris glycymeris*) which result from fishing disturbance. Shell scars occurred most frequently in bivalves collected from the area of highest fishing effort. 4) Multivariate analyses and the response of abundance/biomass curves indicated that chronic fishing has caused a shift from communities dominated by relatively sessile, emergent, high biomass species to communities dominated by infaunal, smaller-bodied fauna. Removal of emergent fauna has thus degraded the topographic complexity of seabed habitats in areas of high fishing effort. The communities within these areas currently may be in an alternative stable state.

Koslow, J.A., G.W. Boehlert, J.D.M. Gordon, R.L. Haedrich, P. Larancell, and N. Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES Journal of Marine Science. Vol. 57(3):548-557.

Abstract: Exploited deepwater (>500 m) species generally exhibit clear "K-selected" life-history characteristics markedly different from most shelf species: extreme longevity, late age of maturity, slow growth, and low fecundity. Many also aggregate on restricted topographic features such as seamounts, and as a consequence are notably unproductive, highly vulnerable to overfishing, and have potentially little resilience to overexploitation. Since 1964, deepwater fisheries have contributed 800,000-1,000,000 t annually to global marine fish landings. Underlying this apparent overall stability is the "boom and bust" cycle that has characterized many individual fisheries. The accumulated biomass of previously unfished stocks is typically fished down, often within 5-10 years, to the point of commercial extinction or very low levels. Most deepwater stocks are today overfished or even depleted. Depletion of species from deep-sea environments that dominate mid to upper trophic levels may have long-term ecological implications, but the risks of reduced stock size and age structure to population viability, the potential for species replacement, and the impacts on prey and predator populations are not generally known. However, trawl fisheries have been shown to have potentially severe impacts on the benthic fauna of seamounts, where these fish aggregate. This fauna, dominated by suspension feeders, such as corals, is typically restricted to the seamount environment and is characterized by high levels of endemism, which suggests limited reproductive dispersal. The ability of the benthic community to recover, following its removal by trawling, is not known.

Lart, W.J., T.M. Dalby, P.H. MacMullen, and P.F. Willerton. 1993. Benthic and ecosystem impacts of dredging for pectinids. Commission of European Communities. Seafish Consultancy Report on EC special study project on the protection of marine species. Ref 92/3506. Seafish CR No. 71.

Lenihan, H.S., and F. Micheli. 2000. Biological effects of shellfish harvesting on oyster reefs: resolving a fishery conflict by ecological experimentation. Fishery Bulletin. Vol. 98(1):86-95.

Abstract: We conducted a large-scale field experiment to test whether clam and oyster harvesting applied alone and in combination on intertidal oyster reefs have impacts on resident shellfish populations. This experiment was conducted to resolve a long-standing conflict between oyster (*Crassostrea virginica* (Gmelin, 1791)) and clam (*Mercenaria mercenaria* (Linnaeus, 1758)) fishermen who contend that the other fishery causes high rates of mortality to their respective species. Intertidal oyster reefs located in two estuarine creeks near Wilmington, North Carolina, were harvested for clams only, oysters only, both clams and oysters, or were left undisturbed as controls. Experimental harvesting was conducted over a one-year period by a professional shellfisherman who used realistic fishing techniques (clam rakes and oyster tongs), intensity, and frequency. Harvesting impact on hard clam and oyster populations was assessed by sampling naturally occurring oysters before and after harvesting, and sampling both naturally occurring clams (all size classes) and transplanted, hatchery-raised clams (20-37 mm in length) after harvesting. Clam and oyster harvesting had obvious negative effects on populations of oysters. There was a substantial decrease in the number of live oysters on clam-harvested and oyster-harvested reefs compared with unharvested, control reefs. Clam and oyster harvesting, applied together, reduced oyster densities and killed unharvested oysters at a level similar to that caused by each type of harvesting applied separately. The effects of shellfish harvesting on populations of hard clams varied between the two sites (i.e., creeks). In both creeks, clam harvesting, alone and combined with oyster harvesting, significantly decreased the number of live, naturally occurring clams. Oyster harvesting alone decreased the number of live, naturally occurring clams only at one site. Clam harvesting also decreased the number of live, transplanted clams on reefs, but there was no effect of oyster harvesting, because the transplanted clams were juveniles too small to be harvested with oyster tongs. Overall, the combined effect of both types of harvesting applied together did not have a negative synergistic effect on clam and oyster populations. Consequently, both clamming and oyster harvesting should be permitted on some reefs, but maintaining large populations of oysters and clams on intertidal oyster reefs will require protection of some reefs from both types of harvesting.

Lindegarth, M., D. Valentinsson, M. Hansson, and M. Ulmestrand. 2000. Interpreting large-scale experiments on effects of trawling on benthic fauna: an empirical test of the potential effects of spatial confounding in experiments without replicated control and trawled areas. Journal of Experimental Marine Biology and Ecology. Vol. 245:155-169.

Abstract: Disturbances due to trawling and dredging is a serious threat to assemblages of benthic marine animals. We tested hypotheses about effects of trawling on benthic assemblages in a manipulative field experiment, using gear and intensities relevant to future management of trawling in a Swedish fjord. Three trawled and three control sites were sampled at several times before and after trawling was initiated. This paper describes how conclusions about effects of trawling might differ between experiments involving replicate sites and experiments using only one trawled and one control site, as in several recent studies. Analyses of selected taxa showed that abundances of many species changed differently among control sites. Differences in temporal change between pairs of single

trawled and control sites were also frequent. Neither the quantitative nor the qualitative nature of differences between treatments could, however, be coherently interpreted among the different combinations of trawled and control sites. This is consistent with results obtained from analyses using all sites, which showed no consistent effects of trawling on any of these taxa. These results provide empirical evidence that spatial confounding may cause serious problems to formal interpretation of experiments, which use only one control and one trawled area. Such potential problems can best be solved by ensuring that the study incorporates more than one control site.

Maekawa, K.S. 1996. The effect of dredging on megafauna on the northern edge of Georges Bank. Unpublished Report. University of Rhode Island.

Mensink, B., C.V. Fischer, G.C. Cadee, M. Fonds, C.C. Ten Hallers-Tjabbes, and J.P. Boon. 2000. Shell damage and mortality in the common whelk, *Buccinum undatum*, caused by the beam trawl fishery. Journal of Sea Research. Vol. 43(1):53-64.

Abstract: Common whelks *Buccinum undatum* collected from the southern North Sea were investigated to study the amount of shell damage and mortality caused by the beam trawl fishery. The ability of whelks to repair their damaged shells was studied in the laboratory. Whelks *(n=876)* were caught with a fine-meshed 3-m beam trawl or with commercial 4- and 12-m beam trawls, while in some areas whelks were also caught with baited traps (used as a reference). Shell damage varied considerably for the different groups. In whelks collected by beam trawling, minor shell damage was observed in 17--75%, and severe damage (when protection against predators and scavengers is lost) in 10--83%. Whelks caught with baited traps sustained only minor shell damage (0--27% of the individuals). Their damage was statistically significantly less than in beam-trawled specimens. Most whelks in all groups exhibited signs of former shell damage, which had since been repaired. Whelk survival was studied in the laboratory over a six-week period. Only 40% of the whelks caught with the 12-m beam trawl survived, irrespective of the damage suffered. Whelks that survived and recovered had repaired their shell after six weeks. More than 95% of the whelks caught with baited traps survived the six-week experimental period; this is statistically significantly higher than the survival of animals caught with the 12-m beam trawl. At five locations females were screened for the presence and stage of imposex. Mild imposex development (mostly stages 1 and 2) was observed at all locations with incidences of 32--80%. It is concluded that the beam trawl fishery may be a much greater source of mortality in common whelks than previously thought.

Moore, S.L., and M.J. Allen. 2000. Distribution of anthropogenic and natural debris on the mainland shelf of the Southern California Bight. Marine Pollution Bulletin. Vol. 40(1):83-88.

Abstract: Various studies have been conducted to quantify debris found along beaches; however, little information has been compiled about debris found on the seafloor. This study

describes the distribution, types, and amounts of marine debris found in the Southern California Bight (SCB) in July and August of 1994. Anthropogenic debris was most common in the central region, on the outer shelf, and in areas near publicly owned treatment works (POTWs). Fishing gear was the most common type of anthropogenic debris in the central region and in the outer shelf zone, whereas glass bottles and plastic were most common in POTW areas. Natural debris was more common close to shore in the inner shelf zone than anthropogenic debris. The deeper distribution of anthropogenic debris relative to natural debris, as well as the types of debris, suggest that the primary source of anthropogenic debris is marine vessel and fishing activity.

Moran, M.J., and P.C. Stephenson. 2000. Effects of otter trawling on macrobenthos and management of demersal scalefish fisheries on the continental shelf of north-western Australia. ICES Journal of Marine Science. Vol. 57(3):510-516.

Abstract: The effects of two types of otter trawl on macrobenthos (mainly sponges, soft corals, and gorgonians) were measured in an experiment involving repeated trawling of a marked area interspersed with video transects to estimate density of benthos. The gears tested were a demersal otter trawl and a semi-pelagic trawl fished approximately 15 cm above the seabed. Fishing with the semi-pelagic trawl had no measurable effect, whereas the standard demersal trawl reduced benthos density by 15.5% on each tow through the site. Only 4% of the benthos detached was actually retained in the net. Comparison with other studies indicates that macrobenthos mortality can vary greatly depending on how an otter trawl is rigged. The experimental estimate of one-pass mortality was combined with the frequency and distribution of commercial trawling to estimate patterns of annual mortality of macrobenthos in 6-min square blocks throughout the area where the fishery operates. The management response to the problem of benthos mortality in the trawl fishery has been to limit trawling for scalefish to a small proportion of the area of the continental shelf and to control the level and distribution of trawling effort.

Munro, C. 1992. An investigation into the effects of scallop dredging in Lyme Bay. Devon Wildlife Trust Report. 67 p.

North Carolina Division of Marine Fisheries. 1999. Shrimp and crab trawling in North Carolina's estuarine waters. Unpublished report to the North Carolina Marine Fisheries Commission. Morehead City, North Carolina. 121 p.

Summary: This report is the result of a request from the North Carolina Marine Fisheries Commission to prepare a report on trawling in estuarine waters, including bycatch and habitat impacts. The report does a very good job of detailing the potential impacts from trawling in North Carolina's estuarine waters. The report also includes recommendations for future research needs to adequately determine trawling impacts.

Otway, N.M., and W.G. Macbeth. 1999. Physical effects of hauling on seagrass beds. FRDC project no. 95/149 and 96/286. Report by FRDC and NSW Fisheries.

Pitcher, C.R., C.Y. Burridge, T. Wassenberg, G.P. Smith, R. O'Connor, P. Jones, N. Ellis, and G. Fry. 1997. Recovery of seabed habitat from the impact of prawn trawling in the far northern section of the Great Barrier Reef. Final Report to Great Barrier Reef Marine Park Authority on Year 1 Research. CSIRO Marine Research. 200 p.

Poiner, I., J. Glaister, R. Pitcher, C. Burridge, T. Wassenberg, N. Gribble, B. Hill, S. Blaber, D. Milton, D. Brewer, and N. Ellis. 1998. The environmental effects of prawn trawling in the far northern section of the Great Barrier Reef: 1991-1996. CSIRO Division of Marine Research. Cleveland, Queensland, Australia. 554 p.

Abstract: This report covers a five year study into the effects of trawling on seabed communities in the inter-shoal and inter-reef areas in the Far Northern Section of the Great Barrier Reef. The study arose from a GBRMPA convened scientific Workshop in 1989 to address the effects of fishing in the Great Barrier Reef region. The Workshop recommended that an experimental study of the effects of trawling should be carried out, taking advantage of the area closed to trawling (Marine National Park B) in the Far Northern Section of the Great Barrier Reef Marine Park. CSIRO and QDPI agreed to undertake the study, which was funded by these organizations as well as GBRMPA, FRDC and AFMA. Following the recommendation of the Workshop, the study was sited in an area known as the Green Zone between about 11° 15' and 11° 45'S that was closed to fishing in 1985 as well as in the areas immediately to the north and south of the Green Zone. The study had several components. 1) A collation and review of all known biological, oceanographic, and fisheries information available on the study area (Chapter 2). 2) A description of the study area. This included a survey of the sediments, epi-benthos (animals living on the seabed), fish and prawns in the region (Chapter 2). 3) Comparisons of the areas that are open to trawling with those that are closed to trawling (Chapter 3). 4) A Before-After-Control-Impact (BACI design) manipulative experiment comparing areas that were subjected to the Impact of a single trawl coverage with untrawled Control areas (Chapter 4). 5) A Repeat trawl experiment in which strips of seabed were trawled up to 13 times (Chapter 5). 6) A description of the composition of prawn trawl bycatch and the fate of discards from prawn trawling and a study of the interactions between seabirds and discards (Chapter 6). 7) The results are summarized here in 10 outcomes categories based on the original objectives of the work. In addition we have summarized a model describing the effects of differential impacts and recovery rates of the seabed fauna (Chapter 7). Finally, implications of the findings of the study for management of the GBR and for management of the East Coast prawn trawl fishery are discussed (Chapter 7).

Pranovi, F., O. Giovanardi, and G. Franceschini. 1998. Recolonization dynamics in areas disturbed by bottom fishing-gears. Hydrobiologia. Vol. 375/376:125-135.

Abstract: Results of two investigations on the effects of disturbance on benthic communities in lagoon and coastal areas, caused by bottom fishing-gears ("hydraulic dredge" for clams and "rapido", a kind of beam-trawl for soles and scallops employed in the Northern Adriatic sea), are given. Such gears, although characterized by different features and targets, have similar effects on the sea bottom: both produce deep furrows (7-13 cm for the "rapido", up to 20 cm for the "hydraulic dredge"), thus affecting the texture of the bottom. In 1992 ("hydraulic dredge") and in 1995 ("rapido") two different research projects were carried out; samples of benthos were collected immediately after the passage of the gears and at fortnightly-intervals, in treated and control areas. This allowed study of the modifications of the macrobenthic communities and investigation of the short and medium-term (dredge: 60 days, ''rapido'': 15 days) progression of the recolonization processes in the disturbed areas. These dynamics have been analyzed by giving emphasis to the species and to their time-space fluctuations. It has been found that characteristically "non-opportunistic" species can assume an opportunistic behaviour during the initial phase of the recolonization processes of the disturbed areas.

Pranovi, F., S. Raicevich, G. Franceschini, M. G. Farrace, and O. Giovanardi. 2000. Rapido trawling in the northern Adriatic Sea: effects on benthic communities in an experimental area. Journal of Marine Science. Vol. 57(3):517-524.

Abstract: The rapido is a towed gear used only in the Adriatic Sea for fishing scallops in sandy offshore areas and flatfish in muddy inshore areas. The gear is expected to have a high impact on the entire benthic community, mainly on epifauna and organisms living in the upper sediment layers. To obtain information on likely medium- to long-term effects of trawl fishing in the northern Adriatic Sea, an experiment on immediate/short-term effects was carried out in an undisturbed sandy area near a wreck. The rapido produced flat tracks on the bottom that were still clearly visible after a week by means of sidescan sonar. The trawl did not change the sediment grain size, although it did disturb the upper 6cm of sediment. Experimental trawling induced a modification in the macrobenthic community that was most evident immediately after the haul. Changes to the meiobenthic community were probably due to sediment disturbance and were recorded after 1 week. Comparison between an undisturbed control area and a neighboring commercially exploited area allowed some evaluation of long-term changes in the benthic community.

Ramsay, K., M.J. Kaiser, C.A. Richardson, L.O. Veale, and A.R. Brand. 2000. Can shell scars on dog cockles (*Glycymeris glycymeris* L.) be used as an indicator of fishing disturbance? Journal Of Sea Research. Vol. 43(2):167-176.

Abstract: The use of shell damage records as an *in situ* indicator of past fishing disturbance was investigated using the dog cockle *Glycymeris glycymeris* L. Shell sections of dog cockles collected from four areas subjected to varying levels of fishing disturbance were examined for the presence of damage records or shell 'scars'. Animals from a heavily fished area had significantly higher levels of scarring than those from three lightly fished areas.

From an estimation of the age of the shells (from internal growth lines and dating of each line), the year in which scarring occurred was determined and this was compared to yearly records of fishing effort. There was a weak but significant positive correlation between the frequency of shell scars per year and the intensity of fishing effort. Our data suggest that whilst scarring in shells of *G. glycymeris* cannot accurately be used to estimate past fishing intensity on a year-by-year basis, it can be used to differentiate between severely impacted and lightly fished areas of the sea bed.

Rogers, A.D. 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. International Review of Hydrobiology. Vol. 84(4):315-406.

Rose, C., A. Carr, D. Ferro, R. Fonteyne, and P. MacMullen. 2000. Using gear technology to understand and reduce unintended effects of fishing on the seabed and associated communities: background and potential directions. ICES Working Group on Fishing Technology and Fish Behavior report. ICES CM 2000/B:03.

Service, M., and B.H. Magorrian. 1997. The extent and temporal variation of disturbance to epibenthic communities in Strangford Lough, Northern Ireland. Journal of the Marine Biological Association of the United Kingdom. Vol. 77(4):1151-1164.

Abstract: Side-scan sonar and underwater video were used to determine the impact of a trawl fishery on an epibenthic community associated with the horse mussel, *Modiolus modiolus* in a Northern Ireland sea lough. The presence of marks caused by trawl otter-boards on the sediments could be clearly seen using side-scan sonar and changes to the epibenthos are described from the video survey. It is apparent from the side-scan sonar survey that changes have occurred in the structure of the superficial sediments on heavily trawled areas. However, there was no clear indication of temporal changes. The utility of side-scan sonar coupled with GIS techniques to detect temporal and spatial effects is discussed.

Shirley, T.C. 1997. Retrospective analysis of the effects of trawling on benthic communities in the Gulf of Alaska and Aleutian Island region. http://www.cifar.uaf.edu/fish97/trawling.html.

Summary: This short report details a study that investigated trawl fishing in the Gulf of Alaska and Aleutian Island region. The objectives were to describe the geographic patterns of trawling in the area from 1990 to 1996 by year and fishing district and to examine the same spatial and temporal framework changes in trawling effort by intensity and duration.

Stevens, B., I. Vining, S. Byersdorfer, and W. Donaldson. 2000. Ghost fishing of Tanner Crabs, *Chioneoecetes bairdi*, at Kodiak, Alaska: pot density and catch per trap as determined by sonar, submersible, and pot recovery. Fishery Bulletin. Vol. 98:389-399.

Abstract: Sidescan sonar was used to locate 189 putative lost crab pots in a 4.5 km^2 area of Chiniak Bay, near Kodiak, Alaska. Subsequent observations of 15 such objects by submersible and ROV verified that they were indeed crab pots. In 1995 and 1996, 147 pots were recovered from the surveyed and adjacent nonsurveyed areas by grappling, and their condition and contents were examined. Tanner crabs, *Chionoecetes bairdi*, were the most abundant organism, with 227 found in 24 pots (16% frequency of occurrence); sunflower sea stars (*Pycnopodia helianthoides*) were the most frequent (42%) occupant and second most abundant (189 in 62 pots). Octopuses (*Octopus dofleini*) were significantly associated with pots containing Tanner crabs. Occurrence of crabs in pots was primarily a function of background crab density and differed between the surveyed and nonsurveyed areas. Recently lost pots (< 1yr old) had significantly more male crabs, significantly larger male crabs, and contained seven times more total crabs than older pots (those lost two or more years prior to recovery). The proportion of pots with damaged webbing increased with pot age, but holes in pot webbing did not significantly affect catch per pot.

Tuck, I.D., N. Bailey, M. Harding, G. Sangster, T. Howell, N. Graham, and M. Breen. 2000. The impact of water jet dredging for razor clams, *Ensis* spp., in a shallow sandy subtidal environment. Journal Of Sea Research. Vol. 43(1):65-81.

Abstract: The effects of water jet dredging for *Ensis* spp. on the seabed and benthos were examined through experimental fishing. Immediate physical effects were apparent, with the dredge leaving visible trenches in the seabed. While these trenches had started to fill after five days, and were no longer visible after 11 weeks, the sediment in fished tracks remained fluidised beyond this period. The majority of the studied infaunal community is adapted morphologically and behaviourally to a dynamic environment, and other than initial removal through dispersal, is not greatly affected by the dredge at the site studied. Species that are likely to be affected (e.g. the heart urchin *Echinocardium cordatum, Arctica islandica* and other large bivalves) were very rare in infaunal samples, but present in dredge catches, where damage was noted, and ranged on average from 10 to 28% of individuals. Epifauna were scarce in the study area, and unaffected by the fishing, except that epifaunal scavenging species were attracted to the fished tracks. On the evidence of the present and previous studies, it would appear that there was little difference between the biological impact of hydraulic and suction dredging, although the latter may have a greater physical effect (larger trenches).

Tunnicliffe, V.J. 1980. Biological and physical processes affecting the survival of a stony coral, *Acropora cervicornis*. Ph.D. Dissertation. Yale University.

Watling, L., R.H. Findlay, L.M. Mayer, and D.F. Schick. 1997. Impact of scallop dragging on a shallow subtidal marine benthic community. Unpublished Report. Darling Marine Center, University of Maine. Walpole, Maine.

West, T.L., W.G. Ambrose, Jr., and G.A. Skilleter. 1994. A review of the effects of fish harvesting practices on the benthos and bycatch: implications and recommendations for North Carolina. Albemarle-Pamlico Estuarine Study, Raleigh, N.C., U.S. Environmental Protection Agency and N.C. Department of Health, Environment and Natural Resources. Report No. 94-06. 93 p.

Summary: This report is divided into two sections. The first examines the effects of fish harvesting methods on the benthos. The second examines bycatch in North Carolina marine and estuarine waters. Their management recommendations for fishing impacts on the benthos are: 1) Quantify trawling practices to determine a measure of trawling effort per unit area and time and determine turbidity levels generated by the gear type, and the rate of redeposition. 2) Determine the depth of penetration of trawling gear into sediments and the effect of trawling on sediment grain size distribution. 3) Sampling areas normally subjected to trawling in order to describe the local benthic communities. 4) Measure *in situ* rates of growth, mortality, and recruitment of selected species of benthic invertebrates exposed to trawling. 5) Measure *in situ* growth and survival of selected demersal predators in trawled and untrawled areas. 6) Evaluate the effect of trawling on primary production. 7) Evaluate secondary effects of turbidity caused by resuspension of sediments. 8) Compare the effects of trawling on water quality and the sediments with that caused by natural agents of disturbance such as storms.

Wynberg, R.P., and G.M. Branch. 1997. Trampling associated with bait-collection for sandprawns *Callianassa kraussi* Stebbing: Effects on the biota of an intertidal sandflat. Environmental Conservation. Vol. 24(2):139-148.

Abstract: Previous studies have inferred that the side effects of physical disturbance associated with bait-collecting for the sandprawn *Callianassa kraussi* are more deleterious than the actual removal of the prawns. The present study was specifically designed to disentangle the side-effects of trampling and disturbance associated with using suction pumps for bait-collecting. Separate areas were sucked over with a prawn pump at three different intensities, and the prawns collected from these areas subsequently returned to them. A parallel treatment involved trampling the sediment at levels comparable to the 'sucking' intensities, without removing the prawns. The responses of the meiofauna, macrofauna and microflora were assessed six weeks after this disturbance. Prawn densities were depressed six weeks following both sucking and trampling but recovered by 32 weeks. The meiofauna responded positively to some of the disturbance treatments; macrofaunal numbers on the other hand, declined in most treatment areas, and similarity analysis and multidimensional scaling showed that macrofaunal community composition in the most-disturbed areas was distinct from that in other areas. Chlorophyll levels were reduced at the more intensely-disturbed sites. The results corroborate the conclusion that trampling per se has almost the same effect as sucking for prawns, on both the prawns and on the associated biota. This has important implications in terms of managing the use of lagoonal and estuarine ecosystems.