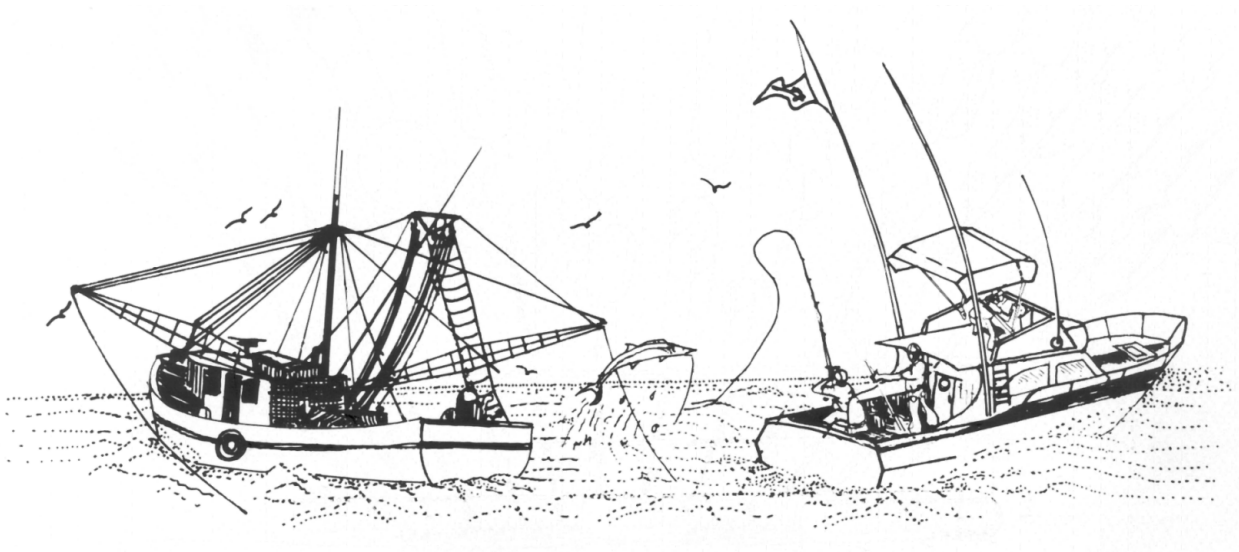
ANNOTATED BIBLIOGRAPHY OF FISHING IMPACTS ON HABITAT



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Introduction

The initial idea for this annotated bibliography arose in a March 1999 Gulf States Marine Fisheries Commission Habitat Subcommittee meeting. Fishery managers are now faced with examining and considering fishing impacts to habitat when managing fish populations. Habitat Subcommittee members felt that to address fishing impacts on habitat adequately, the scientific literature needed to be surveyed to determine the status of the knowledge. So began the task of compiling this bibliography. Due to the increasing amount of information on fishing impacts, it is hoped that updating this bibliography will be an ongoing process.

This bibliography 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.

No attempt has been made to review and analyze these papers. That will be the job of future researchers. An abstract, when available, was included with the reference for each paper. If the paper did not contain an abstract, a brief summary of the paper was composed and included. While an attempt was made to gather all papers listed, not all of the papers could be located and copied.

In these cases, the reference is listed but no abstract or summary is given. These papers therefore, might not be relevant for inclusion in the bibliography, but the title implied that it was pertinent to the subject.

It is the hope of the Gulf States Marine Fisheries Commission and the National Marine Fisheries Service that this annotated bibliography will assist researchers in their quest for a better understanding of how fishing activities affect habitat, the marine environment, and fish populations. Users of this document should feel free to contact the editor with comments, suggestions, and updated information. The information included in this document can be found on the Gulf States Marine Fisheries Commission web page at http://www.gsmfc.org.

Acknowledgments

A tremendous amount of work has gone into the compilation of this bibliography and without the help of several people, the bibliography would not have been possible. Cheryl Noble of the Gulf States Marine Fisheries Commission helped in the typing of abstracts and editing of the document. Joyce Shaw, Cathy Schloss, and Margie Williams of the Gunter Library at the Gulf Coast Research Laboratory and Claire Steimle of the Walford Library at the Northeast Fisheries Science Center were extremely helpful in locating and collecting articles for the bibliography. Mike Barnette of the National Marine Fisheries Service and Carla Brown of American Oceans Campaign also helped in collecting articles. Many other researchers provided assistance in collecting articles and sending reprints, and their help is appreciated.

This annotated bibliography is a product of the Joint Habitat Program of the Gulf States Marine Fisheries Commission and the Gulf of Mexico Fishery Management Council. Additional funding for the bibliography was provided by the National Marine Fisheries Service, Office of Habitat Conservation.

Adkins, B.E., R.M. Harbo, and R.M. Bourne. 1983. An evaluation and management considerations of the use of a hydraulic clam harvester on intertidal clam populations in British Columbia. Canadian Technical Reports of Fisheries and Aquatic Sciences. No. 1716.

Alcala, A.C., and E.D. Gomez. 1979. Recolonization and growth of hermatypic corals in dynamite blasted coral reefs in the Central Visayas, Philippines. Pages 645-661 *in* Proceedings of the International Symposium on Marine Biogeography and Evolution in the Southern Hemisphere, 17-20 July 1978, Auckland, New Zealand. DSIR Inf. Ser. 137 Vol. 2.

Abstract: Our data on percentage areal cover of live stony corals, number of colonies per unit area and sizes of individual colonies in reefs destroyed by dynamite-blasting some ten years ago in the Central Visayas area, Philippines indicate a recovery time (to 50% areal cover) of about 38 years. There is an indication that growth of certain species on firm, stable substrates is much more rapid than on coral rubble.

Alcala, A.C., and E.D. Gomez. 1987. Dynamiting coral reefs for fish: A resource-destructive fishing method. Pages 51-60 *in* Human Impacts on Coral Reefs: Facts and Recommendations. Antenne Museum, French Polynesia.

Abstract: Details are given of the methods involved in the use of explosives as a fishing method in coral reefs. Human hazards, underwater explosions and effects on marine organisms, corals and coral reefs are discussed. The use of dynamite, while a very efficient means of killing fish, is wasteful of marine resources because of generalized non-selective killing effects. Ecological damage results in reduced fish production, thus adversely affecting fishermen and others. Recommendations are given for proper management and legislative procedures.

Allen, P.L. 1995. An assessment of hydraulic cockle dredging on the macroinvertebrate faunas of Traeth Lafan, north Wales. Contract Science Report 64, Countryside Council for Wales. Contract FC 73-01-86. 85 p.

Allen, W.H. 1992. Increased dangers to Caribbean marine ecosystems. Cruise ship anchors and intensified tourism threaten reefs. BioScience. Vol. 42(5):330-335.

Summary: This article deals with anchor damage to coral reefs in the Caribbean from recreational vessels and fishing vessels.

Anderson, F.E., and D.S. McLusky. 1981. Physical recovery of an intertidal area disturbed by baitworm harvesting. Report to Natural Environment Research Council, Ref GR 3/4061. 52 p.

Anderson, F.E., and L.M. Meyer. 1986. The interaction of tidal currents on a disturbed intertidal bottom with a resulting change in particulate matter quantity, texture and food quality. Estuarine, Coastal and Shelf Science. Vol. 22(1):19-29.

Abstract: The purpose of this investigation was to determine if clam digging had an effect on the suspended sediment texture and composition in the intertidal zone. Surface sediment

and suspended particulate samples were collected prior to and after bottom perturbation similar to clam digging. The results indicated that the dug bottom sediments became coarser and contained lower amounts of organic matter. The coarser texture was due to increased winnowing on the rough bottom created in the digging process. Suspended sediment concentrations also increased after perturbation, especially over finer-textured areas. The resuspended particulates were well sorted with relatively low organic content. Resuspended bottom sediments contributed virtually no protein to the particulates brought in by the estuarine waters. Recovery rate both of the bottom sediments and the suspended particulates was slow, and seemed dependent on the microtopographic relief which could take weeks to months to return to normal.

Andrews, G. 1997. Development of Mafia Island Marine Park. Pages 241-254 *in* O. Linden, and C.G. Lundin, editors. The journey from Arusha to Seychelles: Successes and failures of integrated coastal zone management in Eastern Africa and Island States. The World Bank, Environmental Department, Washington, DC (USA).

Abstract: The Mafia Island region (Tanzania) contains estuarine, mangrove, coral reef and marine ecosystems. Habitats in the area of the Mafia Marine Park (MIMP, 400 km super(2)) include hard coral dominated reefs, soft coral and algal dominated reefs, sheltered back reef systems, intertidal flats with hard and soft substrate, mangrove and coastal forests, seagrass beds, algal, sponge and soft coral subtidal beds. The fisheries around Mafia provide much of the area's subsistence protein as well as a substantial income for the community. The productivity of Mafia's marine and coastal habitats are threatened by activities that include: destructive fishing techniques, particularly dynamite fishing; over-exploitation of fisheries resources and the access to that resource; excessive coral mining for aggregate and lime production; excessive harvesting of mangroves for building and fire wood; clearing of coastal forests for agriculture and unsustainable resource use; and unmanaged tourism development. Throughout Eastern Africa, integrated conservation management and policy development has generally concentrated on terrestrial ecosystem. However, the recognized economic and ecological importance of marine and coastal environments prompted the government of Tanzania to prepare a legislative base for marine protected area by passing the Marine Parks and Reserves Act in 1994. A management plan for the Mafia Island Marine Park (MIMP) was developed in 1993 and the park was officially gazetted in April 1995. The management systems and institutional capacity for Mafia Island Marine Park are addressed.

Anonymous. 1984. A review of the effects of fishing activities on the marine environment. Report prepared by Dobrocky Seatech for the Environmental Protection Service, Atlantic Region, Dartmouth, Nova Scotia. 61 p.

Anonymous. 1996. Detection of trawl marks on the sea floor by using side-scan sonar. Report Marine Geological Assistance, Merelbeke. 65 p.

Arcamo, S.V.R. 1994. Managing coastal resources in Ormoc Bay, Philippines. Pages 345-359 *in* Coastal Zone Canada '94, Cooperation in the Coastal Zone: Conference Proceedings. Volume 1. Coastal Zone Canada Association, Dartmouth, Nova Scotia.

Abstract: Ormoc Bay is one of the important fishing grounds in the Eastern Visayas Region. Recent resource and ecological assessments show that it may not yet be considered as an overexploited fishing ground; however, it is experiencing diminishing fisheries as evidenced by the substantial decline in fish catch and the disappearance of major resources like the milkfish (*Chanos chanos*) fry industry. The downtrend is attributed to significant management issues which include degradation of major coastal habitats like coral reefs; deteriorating water quality due to dumping of untreated domestic and industrial wastes; and siltation due to forest denudation, and sand and gravel extraction along rivers. Moreover, increasing human population amidst poor economic conditions have intensified exploitative pressures on the coastal zone oftentimes leading to the use of destructive fishing methods, i.e. blast fishing. Finally, fisheries and environmental laws are not properly enforced, and environmental consciousness in the area is relatively weak. An integrated coastal resource management plan is currently being developed to resolve the aforementioned issues and provide some strategies to attain sustainable resource use within the bay.

Arcement, E., and V. Guillory. 1993. Ghost fishing in vented and unvented blue crab traps. Proceedings of the Louisiana Academy of Sciences. Vol. 56:1-7.

Abstract: Ghost fishing mortality and other data were compared between blue crab traps with and without escape vents. Between October 10 and December 6, mortality of blue crabs was significantly less in vented (5.3/trap) than in unvented (17.3/trap) traps. Higher mortality was attributed to significantly greater numbers of small blue crabs in unvented traps. Average times of confinement for blue crabs escaping from vented and unvented traps were 5.8 and 9.3 days, respectively. Management implications of escape vent utilization are discussed.

Ardizzone, G.D., and P. Pelusi. 1983. Fish populations exposed to coastal bottom trawling along the Middle Tyrrhenian Sea. Rapp. Proc. Verb. Reun. CIESM. Vol. 28(5):107-110.

Summary: Italian law prohibits trawling within 3 miles of the coast or in waters less than 50 m deep. This study examines bathymetric fish distributions and determines that the zones most affected by trawling are the bottom area out to 12 m. From 12 m to 25m, the major damage by trawling is to *Posidonia oceanica* beds, whose condition influences the abundance of related fish species.

Ardizzone, G.D., and P. Pelusi. 1983. Regression of a Tyrrhenian *Posidonia oceanica* prairie exposed to nearshore trawling. Rapp. Comm. Int. Mer Medit. Vol. 28(3):175-177.

Summary: This study examines the reduction of *Posidonia oceanica* from the Tyrrhenian Sea off the coast of Italy. Illegal trawling has reduced shoot density to less than 50 shoots per square meter.

Ardizzone, G.D., and P. Pelusi. 1984. Yield and damage of bottom trawling on *Posidonia* meadows. Pages 63-72 *in* C.F. Bourdoresque, A. Jeudy de Grissac, and J. Oliver, editors. International Workshop on *Posidonia oceanica* Beds. GIS Posidonie Publication, France.

Ardizzone, G.D., P. Tucci, A. Somaschini, and A. Belluscio. 2000. Is bottom trawling partly responsible for the regression of *Posidonia oceanica* meadows in the Mediterranean Sea? Pages 37-46 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) The seagrass *Posidonia oceanica* is a marine angiosperm that is undergoing regression along Mediterranean coasts. Research in the last few years has demonstrated two possible main sources of damage: anthropogenic modification of sediment characteristics and the physical impacts of fishing gear. Trawl fisheries are considered to be one of the major factors leading to the deterioration of seagrass meadows. The aim of this study was to determine the physical and biological parameters that can be used to identify the reason for regression in different *Posidonia oceanica* meadows. 2) A total of 103 stations were sampled in two different areas in the Central Tyrrhenian Sea. The seagrass meadows in both areas are undergoing regression. The first area is strongly influenced by sedimentation and is untrawlable because of the presence of a hard and irregular seabed. In the second area, illegal trawling is known to have occurred for almost 20 years. 3) Regression analysis of environmental parameters on seagrass shoot density revealed that, in the untrawled area, the density of seagrass shoots is inversely proportional to the silt and clay content of the sediment, but independent of the depth gradient within the study area. At the same time, the percentage of dead 'matte' (a mat of dead seagrass roots and rhizomes) increases with higher proportions of silt and clay. This suggests that elevated levels of fine sediment may be one cause of the regression of *Posidonia oceanica*. Levels of silt and clay that exceed 10% of the sediment composition will cause a decline in seagrass beds. No relationship between sediment characteristics and meadow regression was found in the area that is trawled illegally. Thus, we conclude that fishing activities are the main cause of seagrass regression in this area. 4) While it is difficult to identify the possible sources of fine sediment inundation and thus ameliorate its effects on seagrass beds, illegal trawling can be controlled more readily through physical protection of the seabed using protective reefs or artificial seabed obstacles.

Arntz, W., E. Rachor, and S. Kuhne. 1994. Mid- and long-term effects of bottom trawling on the benthic fauna of the German Bight. p. 54-74. NIOZ Rapport 1994-11, Netherlands Institute of Fisheries Research, Texel.

Aschan, M.M. 1988. The effect of Iceland scallop (*Chlamys islandica*) dredging at Jan Mayen and in the Spitsbergen area. ICES, Shellfish Committee. ICES CM 1988/K:16. 8 p.

Abstract: In this paper the effect of dredging on the macrobenthos of *Chlamys islandica* fields will be presented. The study was conducted from the research vessel R/V *Johan Ruud* in the summer 1987 and 1988 in an area south of Jan Mayen at 60-120 m depth and at the northern and north-western side of Spitsbergen at 25-80 m depth. Data on the faunal composition was collected through use of dredging, photography and underwater video recording. Dominating species are, in addition to *Chlamys islandica*, *Astarte elliptica*, *Strongylocentrotus droebachiensis*, *Ophiopholis aculeata* and *Ophiura robusta.* At Jan Mayen the sea cucumber *Cucumaria frondosa* is common as well as the crustaceans *Sabinea septemcarinatus* and *Spirontocaris spinus*. In the Svalbard area, the crustaceans *Hyas* sp., *Sclerocrangon* sp., *Lebeus polaris* and *Balanus balanoides* often encrusting the scallops are

characteristic. In autumn 1987, the Jan Mayen field was closed for fishing because of over exploitation and the signs of recovery will be discussed. In the Svalbard areas, untouched scallop fields sited within the nature conservation area offer reference data. The damage on the bottom animals caused by the dredges and the processing and the short- and long-term effects will be discussed.

Aschan, M.M. 1989. Further results on the impact of scallop dredging on the benthos in the waters around the Jan Mayen and Spitsbergen area. Annex to the Eighth Report of the Benthos Ecology Working Group. ICES CM 1989/L:19.

Auster, P.J. 1997. The impacts of fishing gear on seafloor habitats. Sea Wind: Ocean Voice International. Vol. 10(4):20-22.

Summary: Short popular article on fishing gear impacts on the sea floor and the associated lack of knowledge regarding fishing gear impacts on the sea floor.

Auster, P. J. 1998. A conceptual model of the impacts of fishing gear on the integrity of fish habitats. Conservation Biology. Vol. 12(6):1198-1203.

Abstract: Fishing gear is used over large regions of continental shelves worldwide, but studies of the effects of fishing on seafloor habitats are generally conducted on a limited number of sediment types, making the wider application of particular studies difficult. Fishing gear can reduce habitat complexity by smoothing bedforms, removing emergent epifauna, and removing species that produce structures such as burrows. I developed a conceptual model of gear impacts across gradients of habitat complexity and levels of fishing effort to provide a more holistic understanding of the effects of fishing gear. Each habitat type, in an unaffected state, was categorized and scored numerically based on the components of habitat structure. Values for highly affected habitats, based on observations, were integrated into the model and represented the most affected state. The model predicts linear reductions in complexity based on linear increases in fishing effort. For example, the complexity value of pebble-cobble with emergent epifauna decreases linearly to half the unaffected value (i.e., 10 to 5) in the most affected condition. Research is needed to refine the model and develop improved predictive capabilities. For example, threshold effects may occur that depend on habitat type, fishing gear, and fishing effort. Adding feedback loops to the model, based on recovery rates of habitats, will greatly increase the value of such models to managers. The model can be used directly for management in the current iteration by adopting a well-conceived adaptive management strategy. The objective of such an approach must include both the sustainable harvest of fishes and the maintenance of biodiversity.

Auster, P.J., and R.J. Malatesta. 1995. Assessing the role of non-extractive reserves for enhancing harvested populations in temperate and boreal marine systems. Pages 82-89 *in* N. Shackell and J.H.M. Willison, editors. Marine Protected Areas and Sustainable Fisheries. Science and Management of Protected Areas Association. Wolfville, Nova Scotia.

Abstract: Habitat complexity in temperate and boreal low topography habitats is a combination of sedimentary features (e.g., gravel, rock, sand ripple) and biogenic structure

(e.g., emergent epifauna, amphipod tubes, biogenic depressions, shell, burrows). A framework for understanding the potential benefits of non-extractive reserves is based on the premise that habitat complexity will increase in areas which are not impacted by mobile fishing gear (e.g., increases in biogenic structure). Increased complexity would then result in increased survivorship of postlarval and early juvenile size classes, thus increasing recruitment to harvested populations. This approach requires development of survey protocols for habitat identification and mapping as well as understanding linkages between habitat level processes and population dynamics.

Auster, P.J., R.J. Malatesta, R.W. Langton, L. Watling, P.C. Valentine, C.L.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1995. The impacts of mobile fishing gear on low topography benthic habitats in the Gulf of Maine (Northwest Atlantic): A preliminary assessment. NAFO Science Council Research Document. Northwest Atlantic Fisheries Organization, Dartmouth Nova Scotia. No. 95/21. 16 p.

Abstract: Recent levels of fishing effort on the continental shelf of the Northeast U.S., by trawl and dredge gear, may have had profound impacts on the early life history in general, and survivorship in particular, of a variety of benthic species due to alterations of small-scale habitat. Studies conducted are summarized at three different locations in the Gulf of Maine which show measurable impacts of mobile fishing gear on habitat complexity and discuss the implications of fishing gear impacts on the sustainability of harvested species.

Auster, P.J., R.J. Malatesta, R.W. Langton, L. Watling, P.C. Valentine, C.L.S. Donaldson, E.W. Langton, A.N. Shepard, and I.G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): implications for conservation of fish populations. Reviews in Fisheries Science. Vol. 4(2):185-202.

Abstract: Fishing gear alters seafloor habitats, but the extent of these alterations, and their effects, have not been quantified extensively in the northwest Atlantic. Understanding the extent of these impacts, and their effects on populations of living marine resources, is needed to properly manage current and future levels of fishing effort and fishing power. For example, the entire U.S. side of the Gulf of Maine was impacted annually by mobile fishing gear between 1984 and 1990, based on calculations of area swept by trawl and dredge gear. Georges Bank was impacted three to nearly four times annually during the same period. Studies at three sites in the Gulf of Maine (off Swans Island, Jeffreys Bank, and Stellwagen Bank) showed that mobile fishing gear altered the physical structure (=complexity) of benthic habitats. Complexity was reduced by direct removal of biogenic (e.g., sponges, hydrozoans, bryozoans, amphipod tubes, holothurians, shell aggregates) and sedimentary (e.g., sand waves, depressions) structures. Also, removal of organisms that create structures (e.g., crabs, scallops) indirectly reduced complexity. Reductions in habitat complexity may lead to increased predation on juveniles of harvested species and ultimately recruitment of the harvestable stock. Because of a lack of reference sites, where use of mobile fishing is prohibited, no empirical studies have yet been conducted on a scale that could demonstrate population level effects of habitat-management options. If marine fisheries management is to evolve toward an ecosystem or habitat management approach, experiments are required on the effects of habitat change, both anthropogenic and natural.

Auster, P.J., and R.W. Langton. 1999. The effects of fishing on fish habitat. Pages 150-187 *in* L. Beneka, editor. Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Abstract: The 1996 Magnuson-Stevens Fishery Conservation and Management Act mandates that regional fishery management councils must designate essential fish habitat (EFH) for each managed species, assess the effects of fishing on EFH, and develop conservation measures for EFH where needed. This synthesis of fishing effects on habitat was produced to aid the fishery management councils in assessing the impacts of fishing activities. A wide range of studies was reviewed that reported effects of fishing on habitat (i.e., structural habitat components, community structure, and ecosystem processes) for a diversity of habitats and fishing gear types. Commonalities of all studies included immediate effects on species composition and diversity and a reduction in habitat complexity. Studies of acute effects were found to be a good predictor of chronic effects. Recovery after fishing was more variable depending on habitat type, life history strategy of component species, and the natural disturbance regime. The ultimate goal of gear impact studies should not be to retrospectively analyze environmental impacts but ultimately to develop the ability to predict outcomes of particular management regimes. Synthesizing the results of these studies into predictive numerical models is not currently possible. However, conceptual models can coalesce the patterns found over the range of observations and can be used to predict effects of gear impacts within the framework of current ecological theory. Initially, it is useful to consider fishes' use of habitats along a gradient of habitat complexity and environmental variability. Such considerations can be facilitated by a model of gear impacts on a range of seafloor types based on changes in structural habitat values. Disturbance theory provides the framework for predicting effects of habitat change based on spatial patterns of disturbance. Alternative community state models and type 1-type 2 disturbance patterns may be used to predict the general outcome of habitat management. Primary data are lacking on the spatial extent of fishing-induced disturbance, the effects of specific gear types along a gradient of fishing effort, and the linkages between habitat characteristics and the population dynamics of fishes. Adaptive and precautionary management practices will therefore be required until empirical data become available for validating model predictions.

Ball, B., B. Munday, and I. Tuck. 2000. Effects of otter trawling on the benthos and environment in muddy sediments. Pages 69-82 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) Undisturbed muddy sediments have a rich and diverse fauna that include large deep burrowing animals and erect epifauna. 2) Muddy sediments accumulate in high depositional areas where disturbance from currents and storms are uncommon. As such, they may act as sinks (accumulation areas) for toxic pollutants or biota (e.g. TBT, toxic algal spores) and are susceptible to eutrophication effects due to the depositional nature of sediments and associated high organic carbon content. 3) Such areas may be less capable of sustaining disturbance than more dynamic coarser sediments and accordingly have much longer recovery times. 4) The very stable nature of muddy sediment habitats makes them susceptible to disturbance from fishing in a number of ways, including the removal of target species and by catch from the grounds, mortality of animals discarded, and those damaged by the gear but not retained in the trawl. 5) Otterboard trawling causes visible physical

effects on the seabed that may still be discernible after 18 months, in sheltered areas. 6) Such physical disturbance also leads to community changes in the benthos. These include reduction in diversity, biomass and of individual organism size. The changes may persist for a long time (>18 months) and may be severe where trawling intensity is very high, even leading to an impoverished community that is in an alternative stable state adapted to regular fishing disturbance. 7) Remedial action and good management are often hindered by a lack of knowledge on the details of deterioration and recovery rates in fished muddy sediments.

Barber, C.V., and V.R. Pratt. 1998. Poison and profits: cyanide fishing in the Indo-Pacific. Environment. Vol. 40(8):4-9.

Abstract: Any live reef fish in captivity from the Indo-Pacific region was most probably caught with some form of cyanide. Since the 1960s, more than 1 million kilograms of cyanide have been sprayed onto coral reefs in the Philippines to stun and capture ornamental aquarium fish bound for the pet shops and aquariums of Europe and North America. More recently, the increasing demand for live reef fish as food in Hong Kong and other major Asian cities has vastly increased the incidence of the practice. The estimated annual retail value of the live reef fish trade in Southeast Asia is $1.2 billion, $1 billion of which consists of exports of food fish. The writer discusses, among other topics, the training of fishing communities in alternative fishing practices, and appropriate policy reform in both source countries and importing countries.

Barnette, M.C. 1999. Gulf of Mexico fishing gear and their potential impacts on essential fish habitat. NOAA Technical Memorandum. NMFS-SEFSC-432. 24 p.

Summary: This report details the fishing gear that is used in the Gulf of Mexico, and their potential impacts on habitat. It also details the types of habitat within the Gulf of Mexico, and the ways fishing gear can impact these important habitats.

Bech, G. 1995. Retrieval of lost gillnets at Ilulissat Kangia. Northwest Atlantic Fisheries Organization SCR document; 95/6. 5 p.

Abstract: During the last decade an unknown number of gillnets have been lost on the traditional inshore Greenland halibut fishing grounds in North Greenland. Lost gillnets are supposed to continue fishing (ghost nets) and thereby causing unnecessary losses to the local stock. In addition lost gillnets are a nuisance for other fishermen, who often loose their fishing gears when these are caught in the 'ghost nets'. Anecdotes from local fishermen in Greenland tells how the fish change behavior in areas with many 'ghost nets', and simply leave these areas. In July and December 1994 the Greenland Homerule Government, Ilulissat municipality and the local union of fishermen made a cooperative gillnet retrieval project at Ilulissat Kangia. The purpose of the project was to clean up lost gillnets from the traditional Greenland halibut fishing grounds off Ilulissat and in the icefjord. Greenland fisheries Research Institute participated as observer in this retrieval project.

Behnken, L. 1994. Southeast Alaska trawl closure: a case study in risk-averse management. Sea Wind: Ocean Voice International. Vol. 7(1):8-14.

Summary: This paper describes the effort to close an area off southeast Alaska to fishing. Longline fishermen were concerned about the impact trawlers were having on the area. Trawlers were thought to be impacting the area which is composed of ground unsuitable for trawling. Although there was considerable support for the closure, the North Pacific Fishery Management Council decided against closing the area.

Bell, L.A.J. 1985. Coastal zone management in Western Samoa. Pages 57-73 *in* Report of the Third South Pacific National Parks and Reserves Conference Held in Apia, Western Samoa, 1985. Volume 2, Collected Key Issue and Case Study Papers. South Pacific Regulatory Environment Programme, Noumea (New Caledonia).

Abstract: Following an account of the geography and history of Western Samoa, details are given of the country's fisheries. Sea tenure, limited access and traditional management are considered. Pressures on the coastal resources include: dynamite fishing, fish poisoning, manual destruction of corals, soil erosion, industrial and waste disposal and pesticides, crown-of-thorns starfish, over-fishing, cutting of mangrove trees, and dredging. A brief examination is made of fisheries-related regulations, marine reserves and mariculture.

Bennett, F. 1998. Changes to the sea floor in the Chatham area. Pages 115-116 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: A Commercial fisherman describes the changes in bottom habitat that he has noticed in his 30 years of fishing experience.

BEON (Beleidsgericht Ecologisch Onderzoek Noordzee). 1990. Effects of the beam trawl fishery on the bottom fauna in the North Sea. BEON Rapport No. 8. Netherlands Institute for Sea Research. Texel, The Netherlands. 57 p.

BEON (Beleidsgericht Ecologisch Onderzoek Noordzee). 1991. Effects of the beam trawl fishery on the bottom fauna in the North Sea II - The 1990 Studies. BEON Rapport No. 13. Netherlands Institute for Sea Research. Texel, The Netherlands. 85 p.

BEON (Beleidsgericht Ecologisch Onderzoek Noordzee). 1992. Effects of the beam trawl fishery on the bottom fauna in the North Sea III - The 1991 Studies. BEON Rapport No. 16. Netherlands Institute for Sea Research. Texel, The Netherlands.

Bergman, M.J.N., M. Fonds, M. Hup, and A. Stam. 1990. Direct effects of beam trawl fishing on benthic fauna in the North Sea. ICES CM 1990/Mini:11. 20 p.

Abstract: Direct effects of beam trawling on benthic species in the North Sea were determined by comparing faunal abundancies before and after commercial beam trawling on hard-sandy sediments. Threefold trawling resulted in a decrease in density (10-65%) of a number of species (echinoderms, polychaetes worms and molluscs). Mortality of a number of species which were caught in the nets and treated onboard the trawler, was estimated at 30 to 90%. Only the hermit crab *Eupagurus bernardus* and the starfish *Asterias rubens* have a good chance (resp. 100% and 80%) to survive after returning to the sea again. Of the

benthos escaping through the meshes the starfish, swimming crab and brittle star have a good chance of almost 100% to survive. Direct effects of beam trawling on the benthic fauna in the investigated area are clearly detectable, indicating that the structure of the benthic community in the area studied, which was intensively trawled in the past, already differs from a non-fished area. Direct effects of beam trawling on the densities of fish species in the studied area could not be detected by the methods used. Most fish caught in the trawl were dead or died soon after. During this experiment the amount of dead discard fish was estimated at 2-4 times the amount of marketable fish. This cannot be extrapolated to other seasons or areas. Of the fish escaping through the net, depending on the species 56% to 100% survived during this experiment. The presence of benthic infauna in catches of the beam trawl indicated that tickler chains and the ground chain most likely scraped off successive layers of sediment and reached at least 6 cm into the sediment. It is possible that this happened only in part of the trawled area.

Bergman, M.J.N., and M. Hup. 1992. Direct effects of beamtrawling on macrofauna in a sandy sediment in the southern North Sea. ICES Journal of Marine Science. Vol. 49:5-11.

Abstract: The presence of certain species of benthic infauna in catches from a beamtrawl indicated that tickler chains and the ground chain can scrape off successive layers of sediment and reach at least 6 cm into the sediment. Direct effects of beamtrawling on benthic species in the North Sea were determined by comparing faunal abundance before and after commercial beamtrawling on a hard-sandy sediment. In autumn 1989 three-fold trawling of the experimental area resulted in a decrease in density (10-65%) of a number of species of echinoderms, polychaetes and molluscs.

Bergman, M.J.N., and J.W. Van Santbrink. 1994. Direct effects of beam trawling on macrofauna in sandy areas off the Dutch coast. p. 179-208. NIOZ Rapport 1994-11, Netherlands Institute for Fisheries Research, Texel.

Bergman, M.J.N, M. Fonds, S. Groenewold, H.J. Lindeboom, C.J.M. Philippart, P. van der Puyl, and J.W. van Santbrink. 1997. Effects of trawl fisheries on the benthic ecosystem. Pages 58-60 *in* 1997 Annual Report of the Netherlands Institute for Sea Research.

Abstract: In the early 1900s the North Sea was already intensively fished by sailing vessels and steam trawlers using both passive gears and trawl nets. Technological advances intensified the fishing activity during this century. Nowadays, beam trawling is the most important fishery in Belgium and the Netherlands, and the most common demersal fishery in Germany. In the offshore part of the Dutch sector in the North Sea, where 12 m beam trawl fishery is the dominant type of trawling, every m^2 was trawled, on average, 1.2 times in 1994. The coastal zone and the Plaice-box were trawled with a similar frequency by the 4 m beam trawl fleet. In UK and Ireland, otter trawling is the most important fishing method. As a follow-up to the EU project IMPACT-1 (1992-1994), the IMPACT-project (1994-1997; AIR2-CT94-1664) has been carried out to study the effects of different types of fisheries on the North Sea and the Irish Sea benthic ecosystem. Subprojects focused on the physical and biological impacts of bottom trawling, and on short-term as well as long-term effects. The project was undertaken by the following institutes: RSZV (Belgium); AWI, BFA-ISH, IfM-Kiel (Germany); CEFAS, MLA-SOAEFD, UWB (UK); FRC, MRI (Ireland) and NIOO-

CEMO, NIOZ, RIVO-DLO, RWS-DNZ (The Netherlands). NIOZ and RIVO-DLO coordinated the project. The final report will be issued in 1998. The main conclusions are presented here.

Bergman, M.J.N., and J.W. Van Santbrink. 2000. Fishing mortality of populations of megafauna in sandy sediments. Pages 49-68 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) For a number of invertebrate species (gastropods, starfish, crustaceans and annelids) direct mortality due to the single passage of a trawl ranged from about 5% to 40% of the initial densities in the trawl track and varied from 20% to 65% for bivalve species. 2) The direct mortality of all the species studied was largely attributed to the physical damage inflicted by the passage of the trawl or indirectly owing to disturbance, exposure and subsequent predation. Mortality of animals caught in the net was of minor importance. 3) The annual fishing mortality of megafaunal populations (animals > 1 cm) in the Dutch sector of the North Sea ranged from 5% to 39% and the mortality of half of the species was > 20%. The 12-m beam trawl fishery caused greater annual fishing mortality than the combined action of the other fisheries acting in the same area. Differences in fishing mortality due to the 12-m and 4-m beam trawl fleets were less pronounced in coastal areas, whereas the 4-m beam trawl fleet might cause higher mortalities for some species that occur only within the 12-mile zone. 4) Generally, fragile infaunal and epifaunal species that live in reach of the groundrope and tickler chains suffer significant direct mortalities due to trawling. The long-term impact of fishing mortality on population structure and spatial distribution of faunal species, depends on their life-cycle characteristics (e.g. dispersal of eggs, survival of larvae and subadults, age of maturation and natural mortality). 5) Owing to trawling activities over the recent decades, several benthic species have decreased in abundance and some have disappeared in certain regions in the southern North Sea. To achieve an integrated approach to fisheries and ecosystem management, the following measures have to be considered: a significant reduction of trawling effort, development of gears less damaging for habitats and fauna, and designation of areas closed to fisheries for species and habitats that cannot be protected otherwise.

Berkeley, S.A., D.W. Pybas, and W.L. Campos. 1985. Bait shrimp fishery of Biscayne Bay. Florida Sea Grant College Program Technical Paper No. 40.

Summary: A small but valuable live bait shrimp fishery has existed in Biscayne Bay since at least the early 1950s. In recent years there has been increasing pressure from recreational fishing and environmental groups to eliminate this fishery from the Bay because the fishing activity is generally thought to be deleterious to the environment and/or destructive to juvenile game fish. This paper describes the fishery and gear used in the fishery.

Beukema, J.J. 1995. Long-term effects of mechanical harvesting of lugworms *Arenicola marina* on the zoobenthic community of a tidal flat in the Wadden Sea. Netherlands Journal of Sea Research. Vol. 33(2):219-227.

Abstract: More than half of the annual catch of about 30 million lugworms *Arenicola marina* from the Dutch Wadden Sea originates from digging machines which make 40-cm

deep gullies in a few restricted tidal-flat areas (Texel, Balgzand) in the westernmost part of the Wadden Sea. Four successive years (1978-1982) of frequent disturbance by a lugworm dredge of one of the 15 sampling stations involved in a long-term study of the dynamics of the macrozoobenthos on Balgzand allowed a study of long-term effects of mechanical lugworm digging. Within an area of about 1 km^2, a near-doubling of the annual lugworm mortality rate resulted in a gradual and substantial decline of the local lugworm stock from more than twice the overall Balgzand mean at the start of the 4-year digging period to a value close to this mean at the end of the period (when the dredge moved to a richer area). Simultaneously, total zoobenthic biomass declined even more by the almost complete extinction of the population of large gaper clams *Mya arenaria* that initially comprised half of the total biomass. Of the other, mostly short-lived, species only *Heteromastus filiformis* showed a clear reduction during the dredging period. Recovery of the biomass of the benthos took several years, particularly by the slow re-establishment of a *Mya* population with a normal size and age structure.

Blaber, S.J.M, D.T. Brewer, C. Burridge, D. Caeser, M. Connell, D. Dennis, G.D. Dews, J. Glaister, N. Gribble, B.J. Hill, D.A. Milton, R. Pitcher, I.R. Poiner, J.P. Salini, M. Thomas, S. Veronise, and T.J. Wassenberg. 1994. The Effects of Prawn Trawling in the Far Northern Section of the Great Barrier Reef. Final Report to the Great Barrier Reef Marine Park Authority on 1992-93 Research. 62 p.

Blaber, S.J.M, D.T. Brewer, C. Burridge, D. Caeser, M. Connell, G.D. Dews, J. Glaister, N. Gribble, B.J. Hill, D.A. Milton, R. Pitcher, I.R. Poiner, J.P. Salini, M. Thomas, S. Veronise, and T.J. Wassenberg. 1995. The Effects of Prawn Trawling in the Far Northern Section of the Great Barrier Reef. Final Report to the Great Barrier Reef Marine Park Authority on 1993-94 (Year 3) Research. Draft Version 1. 105 p.

Black, K.P., and G.D. Parry. 1994. Sediment transport rates and sediment disturbance due to scallop dredging in Port Phillip Bay. Memoirs of the Queensland Museum. Vol. 36(2):327-341.

Abstract: The first direct measurements of turbidity caused by scallop dredging are presented. The physical effects of scallop dredging on the sediment dynamics of an enclosed, heavily-fished bay in southern Australia are indicated and data are provided to assess potential biological impact. Transport and deposition of sediments were measured within and beyond the sediment plume behind a scallop dredge. Natural suspended sediment concentrations were recorded with a bottom-mounted instrumented frame; sediment disturbance behind dredges was determined using the same instrumentation mounted on a towed sled. Concentrations in the sediment plume 2-16 seconds after dredging were 2-3 orders of magnitude higher than natural concentrations. Plume concentrations were similar to the natural levels after c. 9 minutes. Thus, for typical currents of approximately 0.1 $m.s^{-1}$, suspended concentrations above natural levels were confined to a region within 54m of the dredge. However, the fine material remained in suspension longer, so dredging may be partially responsible for re-distribution of fine sediments in the bay.

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.

Boaden, P.J.S., and M.T. Dring. 1980. A quantitative evaluation of the effects of *Ascophyllum* harvesting on the littoral ecosystem. Helgoländer Meeresunters. Vol. 33:700-710.

Abstract: Little is known of the ecological effects of harvesting littoral algae although this is a worldwide commercial activity. In 1976 an attempt to establish harvesting in Strangford Lough, Northern Ireland, was opposed on mainly theoretical conservation grounds. The attempt began and stopped within a single small bay leaving a sharp boundary between cut and uncut areas. A subjective survey apparently confirmed the predicted loss of cryptic fauna, decline through predation and the resorting of interboulder sediment. In April 1979 the cut and uncut areas were examined in detail to determine whether any of these effects had persisted and were demonstrable scientifically. Beach and boulder transects and various other studies showed some increases in the cut area. There was significantly more *Fucus*, *Enteromorpha*, and *Ulva*; *Cirratulus* (inhabiting *Rhodochorton*-bound sediment on boulder surfaces) had a greater biomass. Some changes in *Littorina* colour morphs were apparent. Sediment in the cut area was coarser and had significantly more crustacean meiofauna. *Ascophyllum* internodal length and lateral branching were increased but it still provided 20% less shore cover than in the uncut area. There were significant decreases in the cover of *Cladophora* on the sides of boulders and of *Halichondria*, *Hymeniacodon* and *Balanus* on undersurfaces. Indeed on the habitable underside of boulders total animal cover had been reduced by nearly two-thirds and the average number of species per boulder by one-third. It is concluded that *Ascophyllum* harvesting has a significant and persistent effect on shore ecology. Littoral algae are a valuable commercial asset but it is important that some fairly large intertidal areas should be left unharvested for general conservation purposes.

Botsford, L.W., J.C. Castilla, and C.H. Peterson. 1997. The management of fisheries and marine ecosystems. Science. Vol. 277:509-515.

Abstract: The global marine fish catch is approaching its upper limit. The number of overfished populations, as well as the indirect effects of fisheries on marine ecosystems, indicate that management has failed to achieve a principal goal, sustainability. This failure is primarily due to continually increasing harvest rates in response to incessant sociopolitical pressure for greater harvests and the intrinsic uncertainty in predicting the harvest that will cause population collapse. A more holistic approach incorporating interspecific interactions and physical environmental influences would contribute to greater sustainability by reducing the uncertainty in predictions. However, transforming the management process to reduce the influence of pressure for greater harvest holds more immediate promise.

Bradshaw, C., L.O. Veale, A.S. Hill, and A.R. Brand. 2000. The effects of scallop dredging on gravelly seabed communities. Pages 83-104 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) Gravelly seabed communities around the Isle of Man, Irish Sea, are very heterogeneous in terms of both epi- and infauna, and vary over a wide range of spatial scales. This paper reviews the results of a large study which investigated the ecological effects of disturbance by scallop dredging at both a large (fishing grounds) and a small scale (experimental plots). 2) Commercial dredging for scallops and queen scallops is a significant factor in the structuring of benthic communities on gravelly substrata. 3) Community composition was related to the intensity of commercial dredging effort; this was also confirmed by dredging experiments undertaken in an area closed to commercial fishing. 4) The effect of scallop-dredge disturbance on a gravelly seabed may differ from that of bottom fishing on other soft sediments, owing to the extreme patchiness of animal distribution, sediment stability, greater abundance of epifauna and to the combined effect of the heavy, toothed scallop gear and stones caught in the dredges.

Bradshaw, V., C. Ryan, and C. Cooper. 1991. Experimental harvesting and processing of sea cucumber (*Cucumaria frondosa*) in Saint Mary's Bay, Nova Scotia, June, 1990. Project Report. Canadian Department of Fisheries and Oceans, Scotia-Fundy Region, Fisheries Development and Fishermen's Services Division. Vol. 161.

Abstract: The overall objectives of this study were: 1) to gain insight into the extent of the resource of sea cucumbers in Saint Mary's Bay; 2) to determine the bycatch of other commercially important species using different types of gear; 3) to determine the comparative catch rates of these gear types; and 4) to determine, if possible, the impacts of the gear on the local habitats of lobster, scallops and juvenile groundfish which are important in Saint Mary's Bay.

Bradstock, M., and D.P. Gordon. 1983. Coral-like bryozoan growths in Tasman Bay, and their protection to conserve commercial fish stocks. New Zealand Journal of Marine and Freshwater Research. Vol. 17:159-163.

Abstract: Mounds of 'coral' off Separation Point, Tasman Bay, which have recently been protected to conserve ecologically associated commercial fish species, are predominantly growths of Bryozoa. Two species (*Celleporaria agglutinans, Hippornenella vellicata*) make

up the bulk of these structures. Trawling through the 'coral' grounds has affected the fish populations to the extent that an area has been closed to trawling to conserve stocks.

Brambati, A., and G. Fontolan. 1990. Sediment resuspension induced by clam fishing with hydraulic dredges in the Gulf of Venice (Adriatic Sea). A preliminary experimental approach. Bollettino Di Oceanologia Teorica Ed Applicata. Vol. 8(2):113-121.

Abstract: So as to assess the impact of clam fishing with hydraulic dredges on the littoral zone of the Veneto Region, a simulation was done on sediment resuspension and deposition. The results have shown that considerable amounts of sediment are involved in these processes over most of the coastal areas of the Venice Lagoon, and that these processes cause erosion, with offshore suspension transport, also under calm conditions.

Brand, A.R., and S.J. Hawkins. 1996. Assessment of the effects of scallop dredging on benthic communities. Interim report to M.A.F.F. February 1996.

Breen, P.A. 1985. Ghost fishing by Dungeness crab traps: A preliminary report. Canadian Manuscript Reports of Fisheries and Aquatic Sciences. No. 1848:51-55.

Abstract: This is a preliminary report of a study to determine whether lost crab traps continue to catch and kill crabs, *Cancer magister*. Direct underwater observations of lost crab traps suggest that traps retain the capacity to fish for a considerable time, and that they do catch crabs as long as they are able. These studies, show that deaths within traps, and continuous entrance and escape make the actual fishing rate difficult to determine except by closely-spaced underwater observations.

Breen, P.A. 1987. Mortality of Dungeness crabs caused by lost traps in the Fraser River Estuary, British Columbia. North American Journal of Fisheries Management. Vol. 7:429-435.

Abstract: The loss of Dungeness crabs *Cancer magister* to "ghost fishing" (mortality caused by lost traps) was estimated from catches and mortalities in 10 simulated lost traps. Traps were originally baited and then left in place for 1 year at a 10-m depth in Departure Bay, British Columbia. Divers examined the traps at intervals and tagged all the crabs caught. In a year, the traps caught 169 Dungeness crabs, which were nearly all males, and about half of which died. Mortality rates of legal and sublegal size crabs were nearly the same. At the end of the study, the traps were all in good condition and continued to catch crabs. I also estimated an annual trap loss rate of 11% from a questionnaire survey of crab fishermen in the Fraser River estuary. From the estimated number of traps fished, loss rate, mortality rate per trap, and other values, I estimated that loss to ghost fishing might be equivalent in weight to 7% of the reported catch in the Fraser River District. This estimate is not directly applicable to other areas, but it is recommended that crab fishery management agencies develop and test inexpensive techniques, as well as regulations, that will prevent crab mortality from lost traps.

Breen, P.A. 1990. A review of ghost fishing by traps and gillnets. Pages 571-599 *in* R.S. Shomura and M.L. Godfrey, editors. Proceedings of the second international conference on marine

debris. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-SWFSC-154.

Abstract: Ghost fishing occurs when lost fishing gear continues to catch and kill animals. This paper reviews what is known about ghost fishing in trap and gillnet fisheries, how the information was obtained and how it has been used, how ghost fishing can be prevented, and what regulatory approaches have been taken to address the problem. Some standard terms are proposed to prevent confusion. Ghost fishing by traps can occur through several mechanisms. The problem is serious in several fisheries, minor in at least one, and remains unexamined for the majority of trap fisheries. Timed-release devices are simple, inexpensive, and effective at preventing ghost fishing by opening the trap some time after loss. In all Dungeness crab fisheries, such devices are required in crab traps, and other regulations attempt to minimize trap loss. In the American lobster fishery, only Connecticut and Maine address ghost fishing, which is known to be a problem. Ghost fishing by traps is poorly recognized as a problem outside North America. Ghost fishing by coastal gillnets has been documented in several locations and may persist for several years. For large pelagic gillnets the limited evidence suggests that lost nets form tangled nonfishing masses. More work, both descriptive and experimental, is required to document the nature, extent, and persistence of ghost fishing by gillnets, especially by pelagic gillnets if their use continues. It is not clear how to prevent ghost fishing by gillnets. Preventive measures suggested to date must be examined for possible side effects.

Brey, T. 1991. The relative significance of biological and physical disturbance: an example from intertidal and subtidal sandy bottom communities. Estuarine, Coastal and Shelf Science. Vol. 33:339-360.

Abstract: The effects of biological disturbance caused by the lugworm *Arenicola marina* (L.) on the abundance of the macrobenthic fauna were investigated at three subtidal stations (0.5 m, 12 m, and 19 m water depth) in Kiel Bay (western Baltic) and on an intertidal flat in the German Wadden Sea. Different effects of biological disturbance were observed (1) between funnel and cast of the lugworm burrow, (2) among stations, (3) between seasons, and (4) among taxa and groups of different living mode of the macrofauna. The strength of the impact of *A. marina* on the abundance of a certain macrobenthic species depends on three factors: (1) species behavior and living mode, (2) *A. marina* activity, and (3) hydrodynamic conditions. In general, the most distinct effects were observed at the intertidal station during summer, followed by the two deeper subtidal stations. At the very shallow station, only weak effects were detected.

Bridger, J.P. 1970. Some effects of the passage of a trawl over a seabed. ICES CM 1970/B:10. Gear and Behavior Committee, 10 p.

Summary: This report describes an investigation aimed at observing and recording the effect on the seabed of a trawl with various modifications to the tickler chain. Divers observed and photographed the seabed both in front of and immediately behind a moving trawl. The study found that the disturbance caused to the seabed was considerable even when using small otter boards, chains, and nets. The conclusion was that the effect on the seabed of any trawl will depend upon the trawl and the substrate where trawled.

Bridger, J.P. 1972. Some observations on penetration into the sea bed of tickler chains on a beam trawl. ICES CM 1972/B:7. Gear and Behavior Committee, 9 p.

Summary: The author uses direct measurements to determine how far a tickler chain penetrates the sea bed. The penetration of the chain varied between 0 and 27 mm, the latter was on very soft mud. The author concluded that except on very soft mud or silt, the effect of the tickler chain is likely to be confined to the top 10 mm of the bottom.

Brothers, G. 1992. Lost or abandoned fishing gear in the Newfoundland aquatic environment. Report of the Symposium on Marine Stewardship in the Northwest Atlantic, Department of Fisheries and Oceans, St. Johns, Newfoundland, Canada.

Brown, R.A. 1989. Bottom trawling in Strangford Lough: problems and policies. Pages 117-127 *in* C.C. ten Hallers and A. Bijlsma, editors. Third North Sea Seminar 1989.

Abstract: The marine life of Strangford Lough, Northern Ireland is internationally noted for its richness and diversity. Reflecting this, the lough is the subject of a major Wildlife Scheme run by the National Trust, whilst a large number of areas within the lough are protected by statutory designations. Discussions aimed at the creation of a Marine Nature Reserve are taking place between the Department of the Environment (Countryside & Wildlife Branch) and the Department of Agriculture (Fisheries Division). One of the most important benthic communities in the lough is that based on the Horse Mussel (*Modiolus modiolus* L.) which supports a very wide range of associated species, including the Queen Scallop (*Aequipecten opercularis* L.). This species has recently become the target for a bottom trawling fishery undertaken by vessels from outside the lough. The *Modiolus* population, and the associated species, are dependent on stable conditions allowing the survival of large, long lived mussels to support the community and to provide a slow recruitment of spat into the population. Trawling for Queen Scallops in the lough entails the removal of large quantities of non-commercial species and bottom debris. In the trawled areas, the *Modiolus* community has largely been destroyed with the exception of isolated clumps and some burrowing species. The fishery continues however, at present sustained by migration of scallops from the increasingly rare undamaged areas. Recovery of a *Modiolus* community from even small scale damage is known to be a slow process; the continuation of the fishery may cause permanent damage in some areas. The implications of this for the conservation value of the lough, and for the fishery are discussed.

Bryceson, I. 1978. Tanzanian coral reefs at risk. New Scientist. Vol. 80(1124):115.

Abstract: The greatest threat to coral reefs along the coast of Tanzania is the use of explosives for fishing, whereby dynamite charges are dropped in the vicinity of a clump of fish, which are killed or stunned, then scooped up by handnet. Apart from being inefficient, this method destroys large areas of coral (which provide a habitat for the fish) and is consequently threatening the livelihood of traditional fishermen. The practice continues despite press campaigns, parliamentary debates and public concern. Historically, little attention has been paid to artisanal fishing in Tanzania. Development programs are mainly aimed at foreign fishing countries, and the continuing rift between artisanal and industrial fisheries may contribute to the persistence of illegal dynamiting.

Brylinsky, M., J. Gibson, and D.C. Gordon, Jr. 1994. Impacts of flounder trawls on the intertidal habitat and community of the Minas Basin, Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 51:650-661.

Abstract: Four experimental trawls were made at highwater over the intertidal zone of the Minas Basin and the effects assessed when the tide was out to determine the physical and biological impacts of groundfish trawling on the benthos. The trawl doors made furrows 30-85 cm wide and up to 5 cm deep. The rollers compressed surficial sediments but did not scour a depression. The bridle caused no obvious disturbance. Door furrows and roller marks remained visible for 2-7 mo. No significant impacts were observed on either benthic diatoms or macrobenthos. The macrobenthos was dominated by polychaetes, some of which may have the ability to take evasive action as a trawl approaches. There were few molluscs, crustaceans, or echinoderms present; these taxa have been shown to be more susceptible to trawling damage in studies done elsewhere. Nematode numbers were initially depressed in the door furrows but did not recover with time. It is not known whether nematodes were killed or displaced but the latter is thought more likely. Overall, the impacts in this particular environment are judged to be minor, especially since the intertidal sediments of the Minas Basin are already exposed to similar natural stresses imposed by storms and winter ice.

Bullimore, B. 1985. An investigation into the effects of scallop dredging within the Skomer Marine Reserve. Unpublished report submitted to the Nature Conservancy Council by the Skomer Marine Reserve Subtidal Monitoring Project. SMRSMP Report No. 3. 39 p.

Burrell, V.G., Jr. 1975. Faunal studies of North and South Santee River prior to and after hard clam harvesting by hydraulic dredges. SCWMRD, MRD January report. 4 p.

Burrell, V.G., Jr. 1975. Recruitment studies of North and South Santee River after hard clam *Mercenaria mercenaria* harvesting by hydraulic escalator dredges. SCWMRD, MRD January report. 3 p.

Butcher, T., J. Matthews, J. Glaister, and G. Hamer. 1981. Study suggests scallop dredges causing few problems in Jervis Bay. Australian Fisheries. Vol. 40(9):9-12.

Summary: A study by New South Wales State Fisheries biologists suggests scallop dredges used in Jervis Bay are having little harmful effect on the marine environment. The authors took a series of dives that examined areas that were being fished for scallops and areas that were previously unfished. The authors concluded that the scallop dredges are having little or no effect on the Jervis Bay environment and damage to the sea floor is minimal and temporary. Turbidity caused by turbulence of the dredges is quickly dissipated due to the nature of the substrate.

Caddy, J.F. 1968. Underwater observations on scallop (*Placopecten magellanicus*) behaviour and drag efficiency. Journal of the Fisheries Research Board of Canada. Vol. 25(10):2123-2141.

Abstract: The efficiency of an 8-ft scallop drag was estimated from population density measurements by scuba divers. Density measurements had to be made with an enclosed quadrant because of scallop swimming activity. Scallops responded to approaching objects

by facing away from them and swimming. A steep rise usually preceded level swimming at a mean height of 0.4 m from bottom. Point-to-point swimming distances of up to 4 m were recorded with ground speeds in excess of 67 cm/sec. Few scallops over 100 mm could be induced to swim. Despite level bottom conditions, overall drag efficiency was low (2.1%) but increased progressively over the size range encountered (20-150 mm). Direct observations of drag function showed that swimming activity rather than selection by the drag was responsible for the low drag efficiency for the capture of scallops smaller than 100 mm. An indirect fishing mortality was established for recessed scallops buried by the drag. Dragging resulted in dislodgement of dead shell to the substrate surface, and aggregation of benthic predators in the drag tracks.

Caddy, J.F. 1973. Underwater observations on tracks of dredges and trawls and some effects of dredging on a scallop ground. Journal of the Fisheries Research Board of Canada. Vol. 30:173-180.

Abstract: Tracks of three types of fishing gear in bottom sediments were observed from a submersible in Chaleur Bay (Gulf of St. Lawrence). Tracks left by past otter trawling activities covered at least 3% of the bottom by area and were considered to have been made by trawl doors. Shallow tracks made by inshore and offshore scallop dredges during the course of the study could be distinguished from each other and from trawl tracks. Scallop dredging lifts fine sediments into suspension, buries gravel below the sand surface, and overturns large rocks embedded in the sediment, appreciably roughening the bottom. The inshore Alberton dredge is inefficient, dumping its contents back onto bottom at intervals during the tow. Dredging causes appreciable lethal and sublethal damage to scallops left in the track, this damage being greatest on rough bottom. Incidental mortalities to scallops with an offshore dredge of at least 13-17% per tow are of the same order of magnitude as estimates of harvesting efficiency made in earlier studies. Predatory fish and crabs were attracted to the dredge tracks within 1 hr of fishing and were observed in the tracks at densities 3-30 times those observed outside the tracks.

Cadée, G.C. 1977. Effect of bait-digging on the worm *Heteromastus*. Wadden Bulletin. Vol. 12:389-402.

Cadée, G.C., J.P. Boon, C.V. Fischer, B.P. Mensink, and CC. Ten Hallers-Tjabbes. 1995. Why the whelk (*Buccinum undatum*) has become extinct in the Dutch Wadden Sea. Netherlands Journal of Sea Research. Vol. 34(4):337-339.

Abstract: The disappearance of the whelk from the western Dutch Wadden Sea started in the mid 1920s with a gradual decline due to overfishing and lethal shell damage by fishing gear. When fishery stopped in the early 1970s, tributyltin-based (TBT) antifouling paints had become into use. Such paints caused imposex and possibly reproduction failure in the whelk leading to its local extinction. The whelk will disappear from larger parts of its present distribution area if fishery-free areas do not become effective, and if the use of TBT-based paints continues.

Calud, A., G. Rodriguez, R. Aruelo, G. Aguilar, E. Cinco, N. Armada, and G. Silvestre. 1989. Preliminary results of a study of the municipal fisheries in Lingayen Gulf. ICLARM Conference Proceedings No. 17:3-29.

Abstract: This paper presents a summary of preliminary results obtained during the course of the municipal fisheries and blast fishing studies in Lingayen Gulf covering the period May 1987 to April 1988. Information on gear design and specifications and catch rates of the various municipal gears (including blast fishing) are presented. Results of initial studies on lethal ranges of explosives used in blast fishing are also given. A preliminary attempt to estimate the magnitude of landings from municipal and blast fishing activities gives an aggregate of about 10,500 t/year. This indicates relatively high annual extraction rates of 10.1 t/km^2 of municipal fishing ground, and a yield-to-biomass ratio of 3.97. Recommendations center around the need for reduction in fishing effort and improved management of the fisheries.

Cameron, W.M. 1955. An investigation of a scallop drag operation with underwater television equipment. Unpublished report. National Research Council of Canada. Radio and Electrical Engineering Division. 3 p.

Abstract: The operation of the NRC Mark II Underwater Television Equipment in examination of the action of scallop drags on the sea bottom is described. The project was carried out during September-October, 1955, at the request of the Atlantic Biological Station (Fisheries Research Board). Peculiarities of scallop-drag operation were observed which account, at least in part, for the relatively light catch obtained in commercial operation.

Campbell, D.G. 1977. Bahamian chlorine bleach fishing: a survey. Pages 593-595 *in* Proceedings, Third International Coral Reef Symposium, Rosentiel School of Marine and Atmospheric Science, University of Miami. Miami, Florida.

Abstract: The problem of chlorine bleach fishing in the Bahamas is biologically difficult to define and socially complex. Bleach is applied to coral heads to drive commercially valuable species into range of spears and granges. A characteristic pattern of infection sets in on a bleached reef: annular zones of what appear to be *Oscillatoria submembranacea*, *Desulfovibir*o and *Beggiato*a travel over C1 stressed coral colonies from an initial point of infection. Reef community structure changes as well. Regeneration takes years.

Canadian Department of Fisheries and Oceans. 1991. Experimental sea cucumber fishery in St. Mary's Bay. Project Summary. Atlantic Fisheries Development Program Canada. Canadian Department of Fisheries and Oceans, Scotia-Fundy Region, Fisheries Development and Fishermen's Services Division. Halifax, Nova Scotia. 4 p.

Abstract: The intent of the experimental fishery was to investigate the distribution and abundance of sea cucumbers in St. Mary's Bay near Digby, Nova Scotia, and to gain some insight into the impact on the marine habitat of harvesting sea cumbers with different types of mobile fishing gear. In addition, information could be collected on catch rates, bycatch levels, processing and product yields.

Canadian Department of Fisheries and Oceans. 1993. Seabed disturbance from mobile fishing gear in the Bras d'Or Lakes. Atlantic Fisheries Development Program (Canada). No. 44. 4 p.

Abstract: The purpose of this study was to survey the seabed in the more heavily fished areas of the Bras d'Or Lakes in Cape Breton, Nova Scotia, in order to determine the distribution and physical characteristics of marks left on the seabed by various types of mobile fishing gear, in particular, by groundfish trawls, Danish seines and scallop rakes.

Canadian Department of Fisheries and Oceans. 1993. Seabed disturbances from fishing activities. Unpublished Report. Canadian Department of Fisheries and Oceans. Scotia-Fundy Region. Industry Services and Native Fisheries Branch. 4 p.

Abstract: The purpose was to review and document from existing data bases the physical and biological disturbances to the seabed within the Scotia-Fundy Region from bottom fishing trawls, scallop rakes and hydraulic clam dredges.

Canadian Fishing Industry Services, Aquaprojects Inc., and Groupe Poupart, de Blois Inc. 1992. Retrieval of lost gillnets and prevention of ghost fishing within the Atlantic fishery: action plans: revised draft. Unpublished Report. Submitted to Operations, Canadian Fishing Industry Services, Department of Fisheries and Oceans. 21 p.

Abstract: The present proposal is for a comprehensive strategy organized around three-year and five-year plans beginning simultaneously and designed to accomplish two principal goals. The proposed action plans will address the immediate problem arising from ghost fishing gillnets (three-year plan) and prevent the loss of gillnets in the future (five-year plan).

Cappo, M., D.M. Alongi, D. Williams, and N. Duke. 1998. A review and synthesis of Australian fisheries habitat research. Volume 2: Scoping Review, Issue 4: Effects of Harvesting on Biodiversity and Ecosystems. FRDC 95/055.

Summary: This report examines the effects of recreational and commercial fishing on ecosystems. It examines the scientific literature regarding these topics. The report then examines studies from Australia like bycatch, habitat damage, secondary effects of discards, indirect effects of the reduction of target species and habitat damage, and reducing the effects of fishing.

Carpenter, K.E., and A.C. Alcala. 1977. Philippine coral reef fisheries resources part II. Muro-ami and kayakas reef fisheries, benefit or bane? The Philippine Journal of Fisheries. Vol. 15(2):217-227.

Summary: This paper reviews the muro-ami and kayakas fisheries in regard to their production capabilities and effects on habitat. Some suggestions are made for increasing the long-term efficiency of the gears.

Carr, H.A. 1988. Long term assessment of a derelict gillnet found in the Gulf of Maine. Pages 984-986 *in* Proceedings, Ocean '88. The Ocean - An International Workplace. Halifax, Nova Scotia.

Abstract: A commercial, demersal gillnet, first found in 1984 was surveyed by submersible in June 1984, 1985, 1986 and by ROV in March 1988. We recorded our observations on a variety of parameters including vertical profile, epibenthic growth, and catch or marine life in the net. The most recent survey of a section of the net by ROV is highlighted because this is the period that groundfish, particularly cod, are present. We undertook four ROV dives and surveyed a 300 foot section of net during day, dusk, night and dawn. Extensive video recordings of the net characteristics and behavior of cod near the net were taken and are included in the presentation.

Carr, H.A., E.H. Amaral, A.W. Hulbert, and R. Cooper. 1985. Underwater survey of simulated lost demersal and lost commercial gill nets off New England. Pages 438-447 *in* R.S. Shomura and H.O. Yoshida, editors. Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. NOAA-TM-NMFS-SWFC-54.

Abstract: The increase in commercial and recreational fishing pressure in the New England ground fishery over the last decade has intensified the problems of gear conflict and preemption of prime fishing bottom by one particular gear. A major issue has been the demersal gill net, especially when it may be lost and ghost fishing. The Massachusetts Division of Marine Fisheries initiated two investigations on simulated ghost gill nets. The purpose of this effort was to establish methods to evaluate certain characteristics of a net set over an extended period of time, to evaluate net profile, and to monitor the catch rate and fate in the nets. One net was set in may 1982 and monitored periodically through June 1982. The catch, primarily spiny dogfish, *Squalus acanthias*, usually tangled in the net and depressed the height of the net. The second net was set mid-February 1983. Eleven dives were made on the net before its retrieval late April 1983. This commercial net had marked panels that assisted detailed assessment of the net profile and fate of fish caught in the net. The predominant species caught was Atlantic cod, *Gadus morhua*. Also caught were cunner, *Tautogolabrus adspersus*, sea raven, *Hemitripterus americanus*, and tautog, *Tautoga onitis.* In July 1984, the National Marine Fisheries Service and the Massachusetts Division of Marine Fisheries initiated a more thorough study of ghost gill nets using the submersible JOHNSON SEA-LINK II and the RV JOHNSON. Part of this 3-year study was to survey prime fishing sites for the frequency of lost nets and to determine the impact of these nets on the fishery resource. Fifteen submersible dives surveyed over 40.5 ha of bottom in the Gulf of Maine. We saw nine ghost gill nets, six balled up and rising off the bottom to heights up to 3.6 m; three stretched out horizontally but with reduced float line heights. Extensive video and still shots documented the nets and the catch in the nets. The catch, live or decaying, included Atlantic cod; Atlantic wolffish, *Anarhichas lupus*; spiny dogfish; winter flounder, *Pseudopleuronectes americanus*; American lobster, *Homarus americanus*; and crabs, *Cancer* spp. The ghost gill nets seen on these dives may be over 3 years old. We estimated the age of the nets observed through the marine invertebrates attached to the nets and by comparing eight of the nets to one net known to have been lost 3 years ago. Also discussed are the probable reason of the loss of these nets, the impact of these nets to the fishery resources, and future research to reduce any impacts.

Carr, H.A., and R.A. Cooper. 1987. Manned submersible and ROV assessment of ghost gillnets in the Gulf of Maine. Pages 622-624 *in* Proceedings, Ocean '87. The Ocean - An International Workplace. Halifax, Nova Scotia. September 28 - October 1, 1987.

Abstract: In 1984, a three year study began to determine the frequency and impact of lost demersal gillnets in two important fishing grounds in the Gulf of Maine. The surveys were undertaken using the submersibles JOHNSON SEA-LINK II and DELTA in June of each year. Twenty-four submersible transects averaging 0.5 nmi resulted in a survey of 186 acres on 64 nmi^2 of traditional commercial gillnet grounds of Jeffries Ledge and Stellwagen Bank. Ghost gillnets found were surveyed for net dimensions, vertical profile, fouling, vertebrate and invertebrate catch, and fate of catch. One ghost gillnet found in 1984 was surveyed again in subsequent cruises. Another net found in June 1986 was also surveyed in July 1986; the latter survey employed a Remote-Operated-Vehicle. Extensive video documentation was acquired.

Carr, H.A., A.J. Blott, and P.J. Caruso. 1992. A study of ghost gillnets in the inshore waters of southern New England. Pages 361-366 *in* MTS '92: Global Ocean Partnership. Marine Technology Society. Washington, D.C.

Abstract: The effect of lost (ghost) gillnets on fish stocks has been a concern of fisheries managers for some time. This study was designed to assess the impact of simulated ghost gillnets on inshore fish populations, and to look at modifications to nets which might solve the derelict net problem. A control and three experimental gillnets were set in southern New England inshore waters. They were observed by divers using still and video cameras over a two year period. Findings indicated that nets remaining on the bottom continue to fish even when the vertical profile has been reduced. However, the species makeup of the catch changes with a reduction in net height. The greatest reduction in fishing ability of lost gillnets seems to be due to the net's increased visibility to fish, which comes with fouling, physical destruction, and entanglement of the net.

Carr, H.A., and J. Harris. 1997. Ghost fishing gear: have fishing practices during the past few years reduced the impact? Pages 141-151 *in* J.M. Coe and D.B. Rogers, editors. Marine Debris, Sources, Impacts, and Solutions. Springer. New York. 432 p.

Summary: In this chapter, the authors describe six types of fishing gear, and their potential ghost fishing impact. The types of gear described are fish traps or pots, mobile trawling gear, demersal gillnets, demersal longlines, jigs, and fish weirs. The authors determine that pots, traps, and gillnets have the greatest potential for ghost fishing.

Carr, H.A., and H. Milliken. 1998. Conservation engineering: Options to minimize fishing's impacts to the sea floor. Pages 100-103 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: Authors describe innovations in mobile fishing gear and options to minimize the undesired effects of trawling.

Casey, J.F., and B. Daugherty. 1989. Evaluation of information on ghost (lost/abandoned) crab pots and methods of mitigating their effects on the resource. Maryland Department of Natural Resources, Unpublished Report.

Summary: This paper examines several studies that dealt with ghost fishing crab traps and lobster pots. It also makes recommendations on what methods can be employed to lower the incidence of ghost fishing by lost or abandoned traps. They are wide promotion of the effects of ghost pots and how much they cost the commercial crabbers in lost product, a bounty on each pot returned to a collection point no matter what its condition, when discarding the pot at sea, promote the removal of the expensive rebar weight and flattening the pot before discarding overboard, and after the crab season closes December 31st, declare any pot still in the water as officially abandoned and fair game for anyone who might want it.

Castilla, J.C., and L.R. Durán. 1985. Human exclusion from the rocky intertidal zone of central Chile: the effects on *Concholepas concholepas* (Gastropoda). Oikos. Vol. 45:319-399.

Abstract: The ecological role played by man as a top predator in a rocky intertidal environment of central Chile was studied. Human exclusion from a rocky intertidal stretch of coast (non-harvested area) at Punta El Lacho, for nearly two years, resulted in a substantial density increase of the economically important high trophic level predator muricid *Concholepas concholepas*. This was followed by a dramatic decline in the cover of the competitive dominant intertidal mussel *Perumytilus purpuratus*. According to current ecological theory the removal of the competitively superior primary space dominant species led to a pattern of increasing species diversity. We conclude that in the absence of human interference *C. concholepas* plays the role of a key species in central Chile rocky intertidal environments. We suggest that the interpretation of the structure and dynamics of intertidal landscapes should include the key role played by man. Comparison of monitoring programs between intertidal areas with and without human interference will prove critical to our understanding of such environments.

Causey, B.D. 1990. Biological assessments of damage to coral reefs following physical impacts resulting from various sources, including boat and ship groundings. Pages 49-57 *in* Diving for Science 1990. Proceedings of the American Academy of Underwater Sciences Tenth Annual Scientific Diving Symposium, October 4-7, 1990. University of South Florida, St. Petersburg, Florida.

Abstract: Physical damage to coral reefs from boat and ship groundings has been identified as a major impact to the coral reefs of the Key Largo and Looe Key National Marine Sanctuaries. Sanctuary regulations prohibit vessels from operating in such a manner as to strike or otherwise cause damage to the natural features of the sanctuary. Currently, the primary deterrent for this source of reef damage has been through civil procedures and penalties for vessel grounding cases. Litigation to recover damages to natural resources is also pursued in the case of large scale groundings. This legal process requires that the area impacted, or damaged, be accurately assessed for both biological damage and physical evidence to support the litigation. Methods for conducting such assessments are presented in this paper, along with recommendations on what observations are considered important. A review of assessment techniques and application of the information gathered during the assessment process are presented.

Cesar, H., C.G. Lundin, S. Bettencourt, and J. Dixon. 1997. Indonesian coral reefs- an economic analysis of a precious but threatened resource. Ambio. Vol. 26:345-350.

Abstract: An economic analysis of the coral reefs of Indonesia is presented. The coral reefs of Indonesia are presently being rapidly destroyed by human activities that include poison fishing, blast fishing, coral mining, sedimentation, pollution, and overfishing. An analysis of the private gains accrued by individuals from these activities and the related costs to society reveals that the social costs of these destructive activities far outweigh the short-term private gains. However, powerful forces, which vary from high-risk, high-payoff poison fishing to poverty-trap activities like coral mining, have a clear interest in maintaining the status quo of destruction. Appropriate policy responses to combat the destruction of Indonesia's coral reefs include local and national threat-based strategies, integrated coastal zone management, and the utilization of marine protected areas.

Chapman, C.J., J. Mason, and J.A.M. Kinnear. 1977. Diving observations on the efficiency of dredges used in the Scottish fishery for the scallop *Pecten maximus* (L.). Scottish Fisheries Research Reports. Vol. 10:1-16.

Abstract: The traditional, or standard, dredge used mainly on smooth substrata has a fixed tooth bar. In Scotland this has largely been replaced on rougher grounds by dredges fitted with a spring-loaded toothed bar which 'gives' when obstacles are encountered, thus reducing damage. The operation and efficiency of this dredge are described in this paper and compared with standard fixed bar dredges.

Chesapeake Bay Program. 1995. Guidance for protecting submerged aquatic vegetation in Chesapeake Bay from physical disruption. Annapolis, Maryland. 28 p.

Summary: This paper discusses ways to protect submerged aquatic vegetation in Chesapeake Bay; different physical disturbances that can negatively impact submerged aquatic vegetation and ways to limit their impact; and boating and fishing impacts on submerged aquatic vegetation.

Chopin, F.S., and T. Arimoto. 1995. The condition of fish escaping from fishing gears -- a review. Fisheries Research. Vol. 21:315-327.

Abstract: The capture of immature fish in many commercial fisheries is controlled by restricting the use of fishing gears or elements of fishing gears that prevent the escape of immature fish. Improving the selective characteristics of fishing gear is based on the assumption that fish escaping are not seriously damaged and able to make a complete recovery. If fish escape and die as a direct result of stress and injuries or indirectly due to disease and predation associated with gear damage, then increasing the opportunity for escape by improving selectivity may result in an increased level of unaccounted fishing mortality. This paper identifies the main fishing gear types used for harvesting marine and freshwater fish, a range of injuries, stress reactions and mortalities that can occur during capture and escape. It is concluded that immediate and delayed mortalities can occur in fish escaping from fishing gears and that the high variation in mortality rates within experiments is associated with a lack of information on how fish condition is affected by various fishing stressors and the type and severity of physical damage received. Improving selectivity

without reducing damage or stress incurred during capture and escape may not be the most appropriate way of protecting immature fish.

Chopin, F., Y. Inoue, and P. He. 1996. Future directions in conservation technology. Contributions Res. Fish. Eng. No. 2:59-67.

Abstract: In seeking a comprehensive fishing technology research strategy, it is necessary to look at a wide variety of technological solutions associated with fish capture. An examination is made of new research strategies in conservation harvesting technology associated with measuring fishing mortality. Sources of fishing induced mortality include discard mortality, escape mortality, and ghost fishing mortality. It is believed that significant strides in understanding conservation harvesting technology if adherence is made to a program of identification, quantification and elimination of sources of unaccounted fishing mortalities.

Chopin, F., Y. Inoue, Y. Matsushita, and T. Arimoto. 1996. Sources of accounted and unaccounted fishing mortality. Pages 41-47 *in* Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Program Report No. 96-03, University of Alaska Fairbanks.

Abstract: Discarding of nontarget species and sizes of fish by commercial fishing vessels is a common practice in many fisheries around the world and is currently estimated at 27 million tons globally. Efforts to reduce discarding through mechanical selection were started over 100 years ago and were the precursor to mesh selectivity research in many European countries. The release of fish through mechanical selection is now a preferred management tool in many fisheries. In recent years, research into fish mortality after escape has shown that mortalities vary by gear type and species, may be immediate or delayed, and may be due to injuries or stressors associated with capture-escape trauma. In addition to escape mortality, there are other unaccounted mortalities associated with different capture technologies. This paper reviews sources of unaccounted fishing mortality, presents a general model of the capture process, and proposes a set of conservation technology penalties for discards, ghost fishing, and escape mortalities for each gear type and fleet sector. An effective conservation philosophy for reducing resource waste must include a shift of research to the commercial sector and a review program to allow for penalty reductions when new technologies are introduced.

Chopin, F., D.L. Alverson, Y. Inoue, T. Arimoto, P. He, P. Suuronen, and G.I. Sangster. 1997. Sources of unaccounted mortality in fish capture technologies. Pages 149-156 *in* Developing and Sustaining World Fisheries Resources. The State of Science and Management. Commonwealth Scientific and Industrial Research Organization. Collingwood (Australia).

Abstract: With recent trends in fisheries management towards low risk or precautionary fishery management strategies, the need to identify significant sources of biological waste associated with commercial capture technologies is becoming increasingly important. In capture fisheries, reported catches are generally considered the only source of fishing-induced mortality. However, in addition to commercial reported catches, illegal, recreational and artisanal landings may be non-reported components of the landed catch.

There are also a number of discrete unaccounted technical sources of fishing mortality that can occur during the capture-escape process including discards, ghost fishing, escape, avoidance and drop-out mortality. Research to date has shown that for some gear types, the probability of mortality is a function of stresses and injuries received during the capture and/or escape process. This paper reviews sources of unaccounted fishing mortality and suggests that identifying, quantifying and reducing sources of biological waste should be an integral component of precautionary management requiring detailed investigation of fish-fishing gear interactions.

Christie, H., E. Rinde, S. Fredriksen, and A. Skadsheim. 1994. Ecological consequences of kelp trawling: Re-establishment of kelp forests, epiphytes and holdfast fauna after kelp trawling at the Rogaland coast. Nina-oppdragsmeld. Vol. 295:1-33.

Churchill, J.H. 1989. The effect of commercial trawling on sediment resuspension and transport over the Middle Atlantic Bight continental shelf. Continental Shelf Research. Vol. 9 (9):841-864.

Abstract: Numerous field observations have revealed that turbulence created in the wake of trawl doors can generate large and highly turbid clouds of suspended sediment. Time-averaged concentrations of sediment resuspended by trawls from various areas of the Middle Atlantic Bight continental shelf have been estimated using a simple mathematical model and National Marine Fisheries Service records of commercial trawling activity. Mean concentrations of sediment put into suspension by currents have also been computed using a modified form of the Glenn and Grant model. The results indicate that sediment resuspension by trawling can be a primary source of suspended sediment over the outer shelf, where storm-related bottom stresses are generally weak. The concentration estimates further suggest that sediment resuspended by trawls makes a sizeable contribution to the total suspended sediment load over the heavily trawled central shelf area of Nantucket Shoals during all times except winter and early spring. The level of trawling activity declines dramatically going seaward across the outer shelf. This decline coupled with cross-shore water motions in the area appears to result in a net offshore transport of sediment across the shelf edge. However, the estimated magnitude of this transport indicates that trawling does not produce significant short-term erosion of out shelf sediments.

Churchill, J.H. 1998. Sediment resuspension by bottom fishing gear. Pages 134-137 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: Author examines the role that mobile fishing gear has on shelf sediment movement.

Clark, B.M., B.A. Bennet, and S.J. Lamberth. 1994. A comparison of the ichthyofauna of two estuaries and their adjacent surf zones, with an assessment of the effects of beach-seining on the nursery function of estuaries for fish. South African Journal of Marine Science. Vol. 14:121-131.

Abstract: The ichthyofaunas of an estuary open intermittently (Zandvlei) and one permanently open (Eerste) and of the surf zones of beaches adjacent to their mouths. Muizenberg and Macassar respectively, were sampled quarterly by beach-seining. Fish densities in the Zandvlei and Eerste estuaries (5,0 and 3,2 fish per m^2) were considerably higher than those recorded in the adjacent surf zones (0,6 and 0,4 fish per m^2). Catches in all four localities were dominated by a few species, 2-3 species making up 92-97% of the total numbers of fish caught. Juvenile fish were abundant in all areas, numerically constituting 48 and 97% of the estuarine and surf-zone samples respectively. Statistical analyses of the density distribution of marine and estuarine fish in the surf zone indicate that, although these estuaries are extensively utilized by juveniles of many species, beach-seine hauls in the vicinity of estuary mouths are potentially no more harmful to these fish than those farther away.

Coen, L.D. 1995. A review of the potential impacts of mechanical harvesting on subtidal and intertidal shellfish resources. Unpublished Report. South Carolina Department of Natural Resources, Marine Resources Research Institute.

Abstract: This report was developed to address recent concerns expressed by the U.S. Army Corps of Engineers and other agencies regarding use of hydraulic/mechanical shellfish harvesters in South Carolina. The document reviews relevant issues and existing information on the use and potential impacts of subtidal and intertidal mechanical shellfish harvesters, with emphasis on subtidal escalator harvesters. Information included in this report summarizes all pertinent literature (both gray and primary) that could be located which provides direct or indirect information on concerns voiced by state, federal and private citizen groups, as well as extensive bibliography of the above mentioned literature. Specific recommendations regarding proposed research directions that address potential impacts are also provided. The document includes a brief summary of the types and location of shellfish harvesting activities that occur in South Carolina, and the environmental concerns related to those harvesting activities. General environmental issues related to these harvesting activities include: 1) resuspension/turbidity effects, 2) direct burial/smothering, 3) release of contaminants, 4) release of nutrients, 5) decreased water quality due to elevated BOD from #4, 6) direct disturbance or removal of infauna, 7) effects on economially important finfish and crustacean resources and 8) multiple use conflicts.

Collie, J. 1998. Studies in New England of fishing gear impacts on the sea floor. Pages 53-62 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: The author reviews studies on fishing gear impacts in the New England area. The main areas of study were Jeffreys and Georges Bank.

Collie, J.S., G.A. Escanero, L. Hunke, and P.C. Valentine. 1996. Scallop dredging on Georges Bank: Photographic evaluation of effects on benthic epifauna. International Council for the Exploration of the Sea. Mini-Symposium on Ecosystem Effects of Fisheries. ICES CM 1996/Mini:9. 14 p.

Abstract: Situated off the east coast of North America, the gravel sediment habitat on the northern edge of Georges Bank is an important nursery area for juvenile fish, and the site of a productive scallop (*Pecten maximus*) fishery. On recent cruises to this area, we collected dredge samples and photographs from sites of varying depths and with varying degrees of disturbance from otter trawling and scallop dredging. Colonial epifaunal species were conspicuously less abundant at disturbed sites. These differences were quantified by analyzing of still photographs of the sea bottom. In each photo, the percentages of the bottom covered by bushy, plant-like organisms and colonial worm tubes (*Filograna implexa*) were determined, as were the presence/absence and colors of encrusting bryozoa. Non-colonial organisms were also identified as specifically as possible, and sediment type was quantified. Significant differences between dredged and undredged areas were found for all variables tested except presence/absence of encrusting bryozoa. Emergent colonial epifaunal taxa provide a complex habitat for shrimp, polychaetes, brittle stars and small fish at undredged sites.

Collie, J.S., G.A. Escanero, and P.C. Valentine. 1997. Effects of bottom fishing on the benthic megafauna of Georges Bank. Marine Ecology Progress Series. Vol. 155(0):159-172.

Abstract: This study addresses ongoing concerns over the effects of mobile fishing gear on benthic communities. Using side-scan sonar, bottom photographs and fishing records, we identified a set of disturbed and undisturbed sites on the gravel pavement area of northern Georges Bank in the northwest Atlantic. Replicate samples of the megafauna were collected with a 1 m Naturalists' dredge on 2 cruises in 1994. Compared with the disturbed sites, the undisturbed sites had higher numbers of organisms, biomass, species richness and species diversity; evenness was higher at the disturbed sites. Undisturbed sites were characterized by an abundance of bushy epifaunal taxa (bryozoans, hydroids, worm tubes) that provide a complex habitat for shrimps, polychaetes, brittle stars, mussels and small fish. Disturbed sites were dominated by larger, hard-shelled molluscs, and scavenging crabs and echinoderms. Many of the megafaunal species in our samples have also been identified in stomach contents of demersal fish on Georges Bank; the abundances of at least some of these species were reduced at the disturbed sites.

Coleman, F.C., and D.H.S. Wehle. 1983. Caught by accident: The fishermen's unwanted harvest. Oceans. Vol. 16(4):65-69.

Abstract: Incidental capture and entanglement are different twists on the single theme, accidental capture. Incidental capture refers to the taking of animals other than those specifically sought in working nets. Entanglement, or ghost-fishing, describes the capture of aquatic animals in untended fishing gear. Through these two processes, virtually every fishery in every ocean contributes to the deaths of nearly a million marine birds and thousands of turtles and marine mammals each year.

Conner, W.G., and J.L. Simon. 1979. The effects of oyster shell dredging on an estuarine benthic community. Estuarine and Coastal Marine Science. Vol. 9:749-758.

Abstract: This paper describes the extent and nature of the effects on the benthos of physical disruptions associated with dredging fossil oyster shell. Two dredged areas and one

undisturbed control area in Tampa Bay, Florida, were quantitatively sampled before dredging and for one year after dredging. The immediate effects of dredging on the soft-bottom community were reductions in numbers of species (40% loss), densities of macroinfauna (65% loss), and total biomass of invertebrates (90% loss). During months 6-12 after dredging, the analysis used (Mann-Whitney U Test, $\alpha = 0.05$) showed no difference between dredged and control areas in number of species, densities, or biomass (except E_1). Community overlap (Czeckanowski's coefficient) between dredged and control areas was reduced directly after dredging, but after 6 months the pre-dredging level of similarity was regained.

Cook, W. 1991. Studies on the effects of hydraulic dredging on cockle and other macroinvertebrate populations 1989-1990. Lancaster University. Lancaster, United Kingdom. 30 p.

Cooper, R.A., H.A. Carr, and A.H. Hulbert. 1988. Manned submersible and ROV assessment of ghost gillnets on Jeffries and Stellwagen Banks, Gulf of Maine. Research Report 88-4. NOAA Undersea Research Program.

Abstract: In 1984, a three-year study began to determine the abundance and likely impact of lost (ghost) demersal gillnets on two important fishing grounds in the Gulf of Maine. The surveys were undertaken using the submersible JOHNSON SEA LINK II and DELTA in June of each year. The in situ methodology for this study was established in 1984 at known ghost gillnet sites. A quantitative survey to assess ghost net density was conducted in 1985 and 1986. Twenty-four submersibles transects averaging 0.5 nm resulted in a survey of 186 acres of traditional commercial gillnet fishing grounds of Jeffries Ledge and Stellwagen Bank. Ghost gillnets found were surveyed for net dimensions, vertical profile, fouling, vertebrate and invertebrate catch, and fate of catch. One ghost net found in 1984 was surveyed again in 1985 and 1986. Another net found in June 1986 was re-examined in July 1986 using a Remote Operated Vehicle (ROV). Extensive video documentation was acquired on each of these ghost gillnets.

Cornish, A.S., and D. McKellar. 1998. A history of fishing with explosives and poisons in Hong Kong Waters. Naga, the ICLARM Quarterly. Vol. 21(3):4-9.

Abstract: Fishing with explosives is still being practiced around Hong Kong. The first legislation against blast fishing was passed in Hong Kong in 1903. Since then, successive legislation has increased the penalties and fines on blast fishing and fishing with poisons. However, the problem has not been eliminated as enforcement puts pressure on the resources of the marine police. It would be more effective to educate the local communities on the destructive effects of these practices and make them more vigilant and responsible for controlling them.

Cotter, A.J.R., P. Walker, P. Coates, W. Cook, and P.J. Dare. 1997. Trial of a tractor dredger for cockles in Burry Inlet, South Wales. ICES Journal of Marine Science. Vol. 54:72-83.

Abstract: The effects on cockle (*Cerastoderma edule* L.) populations in Burry Inlet, South Wales of mechanical harvesting using a tractor dredger were investigated with an experimental trial conducted on 29 October 1992. Previously, only hand gathering methods

were used, and the trial was intended to assist a licensing decision for mechanical dredging. Six blocks of dredged and undredged (control) plots were set out in each of two areas, one having a low density of cockles, the other high. Approximately 82% of the dredged areas was lifted by the blade of the dredger. The catch consisted almost exclusively of adult cockles (≥ 2 years old) over 25 mm in length. Appreciable losses of spat and one-year-olds from the dredged plots were also observed even though they were not taken in the catch. Possible reasons are discussed. Counts of damaged individuals remaining on the plots on the day after dredging were generally low for all age groups. During the year following the trial, none of the year-classes showed further mortalities attributable to dredging, and changes to shell growth were either minor or absent. Spatfall success in 1993 was depressed by 11% on dredged plots compared to that on control plots in the low density area, but was increased slightly (not significant $p>0.05$) in the high density area. It is concluded that delayed effects of the dredging on cockle stocks were negligible.

Craeymeersch, J.A., G.J. Piet, A.D. Rijnsdorp, and J. Buijs. 2000. Distribution of macrofauna in relation to the micro-distribution of trawling effort. Pages 187-197 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) Information on the micro-scale distribution of fishing activities on the Dutch Continental Shelf was derived from automated position registration systems. This enabled a better assessment of their impact on the benthic fauna. 2) A direct gradient analysis points to a globally significant difference in species composition between intensively fished and less heavily fished locations. It is, however, very likely that the major part of these differences is not related to differences in trawling effort but to differences in environmental factors. 3) Differences in fishing effort between areas best explained the differences that occurred in spionid worm densities.

Cranfield, H.J., K.P. Michael, and I.J. Doonan. 1999. Changes in the distribution of epifaunal reefs and oysters during 130 years of dredging for oysters in Foveaux Strait, southern New Zealand. Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 9(5):461-483.

Abstract: 1) Foveaux Strait, a narrow seaway that is exposed to heavy wave action and strong tidal currents, has been the subject of an oyster fishery for over 130 years. Before the oyster fishery commenced the seafloor was extensively covered by epifaunal reefs that were tidally-oriented, linear aggregations of patch reefs. 2) Patch reefs are formed by the bryozoan *Cinctipora elegans* cemented by encrusting bryozoa, ascidians, sponges, and polychaetes. The molluscan epifauna is dominated by the oyster, *Tiostrea chilensis* and bysally attached bivalves. Mortality of oysters is probably lower and recruitment and growth may be higher within the reef habitat. 3) Fishers found commercial densities of oysters occurred only on epifaunal reefs. Fishers exploited local groups of reefs. These groups form the patchily distributed oyster beds characteristic of this fishery. 4) Dredging for oysters progressively modified reefs until oysters were the only epifauna remaining. Dredges caught oysters more efficiently after the catch bag no longer became saturated with other epifauna. This heightened efficiency allowed fishers to rapidly reduce oyster density to commercial extinction. Oyster density has not rebuilt on oyster beds abandoned by fishers. 5) The rate of modification of epifaunal reefs was slower during the early years of the fishery but has accelerated, especially over the last 37 years. Frequency of disturbance increased as the

numbers of vessels fishing grew and fishers developed speedier dredging methods. Intensity of disturbance also increased as heavier dredges were introduced and allowed focused fishing of reefs. 6) Oysters became reduced to low densities in the eastern and central areas that fishers then abandoned. The commercially exploited area subsequently expanded to the limits of Foveaux Strait. 7) With accelerated modification of oyster habitat, disease mortality has become more important. 8) Attempting to rebuild the fishery by oyster enhancement may be more successful conjoined with habitat restoration.

Crawford, R.E. 1998. Measuring boating effects on turbidity in a shallow coastal lagoon. *In* R.E. Crawford, N.E. Stople, and M.J. Moore, editors. The environmental impacts of boating; proceedings of a workshop held at Woods Hole Oceanographic Institution, December 7-9, 1994. Technical Report. WHOI-98-03.

Summary: This paper is part of a presentation made at a workshop on the environmental impacts of boating in 1994. This study was conducted in Waquoit Bay, Massachusetts and was seeking a predictive formula to help evaluate the potential impact of boats to shallow marine ecosystems. The study found that when boats pass over an area, turbidity increases momentarily. Within 10-15 minutes after the boat has passed, light levels returned to levels that support the growth of eelgrass.

Creed, J.C., and G.M. Amado Filho. 1999. Disturbance and recovery of the macroflora of a seagrass (*Halodule wrightii* Ascherson) meadow in the Abrolhos Marine National Park, Brazil: An experimental evaluation of anchor damage. Journal of Experimental Marine Biology and Ecology. Vol. 235(2):285-306.

Abstract: Anchor damage due to tourist visitation is becoming increasingly intense in the Abrolhos Marine National Park, Brazil, and is probably detrimental to the biota associated with the seagrass beds. In this study the effects of anchor damage on an algal dominated seagrass (*Halodule wrightii*) bed in the national park were measured and assessed. The mean size of anchor scars was 0.16 m^2, and it was estimated that 0.5% of the seagrass beds were damaged per year by boat anchoring. The short term effect of simulated anchor damage (over 4 d) was a reduction in seagrass density, in the standing stock of *Laurencia obtusa* (Hudson) Lamouroux growing epiphytically on *Udotea flabellum* (Ellis and Solander) Lamouroux, and in the total macrophyte (seagrass + algae) standing stock. The longer-term (5, 9 and 13 month) ability of the seagrass and macroalgae to recover from damage, and possible seasonal differences in recovery ability, were determined. *H. wrightii* reoccupied experimentally cleared 0.25 m^2 areas by vegetative elongation, and in 9 mo short shoot, rhizome and root biomass, and short shoot and rhizome densities were similar to controls. The ability of the seagrass to recover appeared not to be seasonal, and seasonality was only found in short shoot density. Recovering seagrass sent up more short shoots per length of rhizome than plants in undamaged areas. The most abundant macroalga was the rhizophytic *Udotea flabellum*; other algae grew on it as epiphytes or unattached. *U. flabellum* could recover quickly from simulated anchor damage, though other common algae (*Dictyota mertensii* (Martius) Küetz., *D. cervicornis* Kutzing, *Padina* spp. and *Laurencia obtusa*) showed more complex patterns of recovery that were seasonally or species dependent. A perturbation such as an anchoring has an effect on the algal flora more than a year later, although most algae species and *H. wrightii* can recover more quickly. Notably large areas

devoid of macrophytes within the seagrass bed may have been created by the fusion of anchor scars.

Currie, D.R., and G.D. Parry. 1994. The impact of scallop dredging on a soft sediment community using multivariate techniques. Memoirs of the Queensland Museum. Vol. 36(2):315-326.

Abstract: Changes to benthic infauna caused by scallop dredging in Port Phillip Bay were examined experimentally using a BACI (Before, After, Control, Impact) design. Analysis of 150x0.1 m^2 grab samples obtained from 2 pre-dredging and 3 post-dredging periods are described. A diverse fauna of 204 invertebrate species and 49,044 individuals were surveyed. Bray-Curtis community dissimilarities were used to assess changes to community structure following dredging. Pair-wise comparisons of community dissimilarity between the control and dredge plots through time enabled a test of the statistical significance of change following dredging. Multi-dimensional scaling (MDS) was used to describe patterns of change following dredging. Statistically significant ($0.05<p<0.10$) changes to community structure were detected following dredging; ecological significance of these changes requires further analysis.

Currie, D.R., and G.D. Parry. 1996. Effects of scallop dredging on a soft sediment community: A large-scale experimental study. Marine Ecology Progress Series. Vol. 134(1-3):131-150.

Abstract: Changes to benthic infauna caused by scallop dredging at a site in Port Phillip Bay, southeastern Australia, were examined experimentally using a BACI (before, after, control, impact) design. The experimental dredging was undertaken by commercial fishermen and was typical of normal commercial operations in its spatial extent, intensity and duration. Changes to benthic community structure following dredging were monitored using grab samples taken on 3 occasions pre-dredging and 6 occasions post-dredging. The significance of changes was assessed using ANOVA for the more abundant species and, for pooled groups of species, Bray-Curtis community dissimilarities and multidimensional scaling (MDS). The abundance of 7 of the 10 most common species changed significantly (ANOVA $p < 0.10$) after dredging; 6 species decreased in abundance while 1 species increased. The size and persistence of dredging impacts varied between species, but most species decreased in abundance by 20 to 30%. Dredging impacts became undetectable for most species following their next recruitment. Most species recruited within 6 mo of the dredging impact, but a small number of species still had not recruited after 14 mo. These latter species appeared to cause a persistent change in community structure which was still detectable after 14 mo using Bray-Curtis dissimilarities. MDS ordination indicated that changes to community structure caused by dredging were smaller than those that occur between seasons and years.

Currie, D.R., and G.D. Parry. 1999. Changes to benthic communities over 20 years in Port Phillip Bay, Victoria, Australia. Marine Pollution Bulletin. Vol. 38 (1):36-43.

Abstract: Changes to the structure of benthic communities in Port Phillip Bay, Victoria, were determined by comparing results of a survey of 86 sites in 1969-72 with a survey of 13 sites in 1991-92. The species composition of communities differed significantly between surveys. Since the earlier study a further three exotic species (*Sabella spallanzanii, Corbula*

gibba, Euchone limnicola) have become abundant and these are contributing to long-term and probably irreversible changes to the ecology of Port Phillip Bay. Other changes may reflect real change or differences between habitats sampled in both studies. The ambiguity of conclusions from comparisons between these studies emphasizes the need for an adequate time-series of benthic monitoring to better define the extent of change and to identify their causes.

Currie, D.R., and G.D. Parry. 1999. Impacts and efficiency of scallop dredging on different soft substrates. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 56:539-550.

Abstract: Impacts of scallop dredges and their efficiency were examined experimentally in three areas with different soft substrates in Port Phillip Bay, southeastern Australia. Physical and biological changes were measured on large (600 x 600 m) experimental plots that were dredged with an intensity and duration similar to normal fishing operations. Dredges were most efficient on soft, flat, muddy sediments (51-56% of commercial-sized scallops caught) and least efficient on firm, sandy sediments with more topographic variation (38-44%). Dredging flattened all plots, but changes to topography were most apparent on plots dominated initially by callianassid mounds. Dredges caught predominantly the scallop *Pecten fumatus*, and damage to bycatch species was slight, except for high mortality rates (>50%) of spider crabs and the probable mortality of many discarded ascidians. Changes to benthic community structure caused by scallop dredging were small compared with differences between study areas, and even marked reductions in the size and longevity of scallops over the last two decades may not be due entirely to dredging. The recent cancellation of all scallop dredging licences offers a unique opportunity to determine the contribution of scallop dredging to ecological changes in the bay over the past 30 years.

CWSS. 1992. Mussel fishery in the Wadden Sea. Common Wadden Sea Secretariat, Working Document 1992. Wilhelmshaven.

Daan, N. 1991. A theoretical approach to the evaluation of ecosystem effects of fishing in respect of North Sea benthos. ICES CM 1991/L:27. 6 p.

Abstract: So far, evaluations of the potential impact of trawling gears on North Sea benthos are based on extrapolations from limited observations of discards or detailed *in situ* studies. This paper presents a top-down approach based on P/B ratios of benthos, and estimates of estimated fishing mortalities on benthos based on the spatial distribution of beam trawl effort. The results indicate that on a southern North Sea wide scale fisheries have a relatively small impact on the biomass of benthos compared to sources natural mortality. Problems might only be expected in a very restricted number squares or for particular long-lived species.

Dahl, K., T. Borchardt, N. Dankers, and H. Farke. 1994. Status, trends, regulation and ecological effects of the Wadden Sea fishery. Ophelia. Supplement 6:87-97.

Abstract: Fishery in the Wadden Sea area attained a lot of interest at the 6th Trilateral Governmental Conference in November 1991. This paper describes the development and present status of the Wadden Sea fishery and its ecological effects. Furthermore an

assessment is made of the implementation of the decisions made at the conference regarding fishery.

Dahlstrom, W.A. 1975. Report of lost crab trap recovery. Unpublished Report. California Department of Fish and Game, Marine Resources Region, Processed Report, Sacramento.

Summary: Condition and catch of a Dungeness crab trap estimated to have been lost for 10 months are discussed. Catch rates of legal and nonlegal crabs by the lost pot are compared to test gear fished in the same location with escape openings wired shut.

Dare, P.J. 1974. Damage caused to mussels (*Mytilus edulis* L.) by dredging and mechanized sorting. Journal for the Conservation and International Exploration of the Sea. Vol. 35(3):296-299.

Abstract: Up to 13% of mussels which had passed through a rotary sorting machine experienced shell damage and many apparently suffered some internal damage which impaired their long-term survival out of water. These injuries were superimposed upon others when harvesting was done with large dredges. Sublittoral mussels had a significantly higher shell-damage rate than intertidal mussels of comparable age; they also survived less well out of water. Relaying sublittoral stock into the low intertidal zone, for at least 6 months, increased resistance to sorting damage and to lengthy exposure in air. At least 90% of sorted mussels survived for 8 days out of water in winter in North Wales, and survival for at least 36 days was recorded with a few unsorted individuals.

Dare, P.J. 1992. A review of the effects of molluscan dredge fisheries upon benthos and substrates. ICES Study Group 1992. 10 p.

Dare, P.J., D. Key, and P.M. Conner. 1993. The efficiency of spring-loaded dredges used in the western English Channel fishery for scallops, *Pecten maximus* (L.). ICES CM 1993/B:15. 8 p.

Abstract: Three experiments were conducted to measure the overall efficiency of commercial dredges used to survey scallop stocks. Marked animals were laid on four plots located in the Cornish fishery on inshore and offshore grounds ranging from smooth, sandy or muddy gravels to rougher, stony substrates. Efficiency at catching each 5mm size (shell height) class of scallop was estimated by comparing mean numbers of releases and recaptures per 1000 m^2 of seabed. The gear was highly size-selective and of low efficiency overall with substrate-dependent variations. For these commercial dredges, with spring-loaded toothbars and 75mm belly and back meshes, mean efficiency at catching legally fishable (>90mm) scallops ranged from 6% (rough ground) to 41% (smooth muddy gravel). On the most widespread offshore ground type (sand and fine gravels) efficiency on two plots averaged 22%, but it fell rapidly with decreasing scallop size to 1.4% at 65mm and to only 0.2% at 45mm. Dredge efficiency is the resultant not only of a two-stage selection and retention process (by toothbar and meshes) but of complex interactions between the gear, the seabed, hydrodynamic forces and the behavior of scallops themselves. Overall, spring-loaded dredges retain rather few juvenile scallops and, although most effective on moderately soft grounds, their efficiency generally is low.

Davis, G.E. 1977. Anchor damage to a coral reef on the coast of Florida. Biological Conservation. Vol. 11:29-34.

Abstract: Twenty percent of an extensive staghorn coral, *Acropora cervicornis*, reef has recently been damaged by boat anchors in Fort Jefferson National Monument, Dry Tortugas, Florida, USA. It is suggested that this type of damage may occur in other coral reef sanctuaries unless anchor-sensitive areas are identified and closed to anchoring. Alternatively, mooring buoys should be provided by sanctuary managers.

Dayton, P.K. 1998. Reversal of the burden of proof in fisheries management. Science. Vol. 279(5352):821-822.

Abstract: Traditional management of fisheries aims to optimize the catch of certain economically important species by commercial fishing boats, but this goal often eventually results in the collapse of the targeted species itself. We have excellent long-term data documenting this process for some fisheries. But what is happening to the hundreds of noncommercial species taken incidentally or by poaching or ghost fishing by lost or abandoned gear? There is virtually no information. In addition, thousands of square kilometers of benthic habitat and invertebrate communities have been obliterated by trawling, and recreational fishing and poaching have massively altered many coastal marine communities. If society's environmental needs are to be protected so that future generations can also enjoy, learn, and profit from marine ecosystems, this legal burden of proof must be applied to our marine resources so that those hoping to exploit them must demonstrate no ecologically significant long-term changes. If the public hopes to preserve our marine environment, they must act quickly to change the relevant regulations and reverse the burden of proof.

Dayton, P.K., S.F. Thrush, M.T. Agardy, and R.J. Hofman. 1995. Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 5:205-232.

Abstract: 1) Some effects of fisheries on the associated biological systems are reviewed and management options and their inherent risks are considered. 2) In addition to the effects on target species, other sensitive groups impacted by fishing are considered including marine mammals, turtles, sea birds, elasmobranchs and some invertebrates with low reproductive rates. 3) Other impacts discussed include the destruction of benthic habitat, the provision of unnatural sources of food and the generation of debris. 4) Management options are considered including the designation of marine protected areas, risk aversion, and the burden of proof. 5) A balanced consideration of the risks and consequences of "Type I" and "Type II" errors is advocated.

DeAlteris, J., L. Skrobe, and C. Lipsky. 1999. The significance of seabed disturbance by mobile fishing gear relative to natural processes: a case study in Narragansett Bay, Rhode Island. Pages 224-237 *in* L. Beneka, editor. Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Abstract: Seabed disturbance by mobile bottom-fishing gear has emerged as a major concern related to the conservation of essential fish habitat. Unquestionably, dredges and trawls

disturb the seabed. However, the seabed is also disturbed by natural physical and biological processes. The biological communities that utilize a particular habitat have adapted to that environment through natural selection, and, therefore, the impact of mobile fishing gear on the habitat structure and biological community must be scaled against the magnitude and frequency of seabed disturbance due to natural causes. Fishers operating in the mouth of Narragansett Bay, Rhode Island use trawls to harvest lobsters, squid, and finfish and dredges to harvest mussels. These mobile fishing gears impact rock, sand, and mud substrates. Side-scan sonar data from 1995 with 200% coverage were available from the National Oceanic and Atmospheric Administration for the mouth of Narragansett Bay. Analysis of these data indicates that evidence of bottom scarring by the fishing gear is restricted to deeper waters with a seabed composition of soft cohesive sediments, despite the observation that fishing activity is ubiquitous throughout the bay mouth. A quantitative model has been developed to compare the magnitude and frequency of natural seabed disturbance to mobile fishing gear disturbance. Wave and tidal currents at the seabed are coupled with sediment characteristics to estimate the degree of seabed disturbance. Field experiments designed to compare the longevity of bottom scars indicate that scars in shoal waters and sand sediments are short-lived, as compared to scars in deep water and mud sediments, which are long-lasting. Finally, the model results are compared to the recovery time of sediments disturbed by the interaction of the fishing gear with the seabed. The impact of mobile fishing gear on the seabed must be evaluated in light of the degree of seabed disturbance due to natural phenomena. The application of this model on a larger scale to continental shelf waters and seabed sediment environments will allow for the identification of problematic areas relative to the degradation of essential fish habitat by mobile fishing gear.

De Clerck, R., and P. Hovart. 1972. On the effects of tickler chains. ICES, Gear and Behavior Committee. ICES CM 1972/B:15.

Summary: This report examines the use of tickler chains on the benthos off the Belgian coast. The study concluded that the use of 2 to 4 tickler chains increased catch rates 1.5 to 2 times for sole. The authors also used a anti-stone chain gear and found that the amount of mud and pebbles was higher when using this gear than without. The authors also found no change in catch rate with or without additional anti-stone chains.

Degange, A.R., and T.C. Newby. 1980. Mortality of seabirds and fish in a lost salmon driftnet. Marine Pollution Bulletin. Vol. 11:322-323.

Abstract: Large numbers of seabirds have been killed in offshore salmon driftnets. Mortality of seabirds occurs not only in the nets being fished but also in lost or discarded gear. In 1978, we recovered ninety-nine seabirds of five species, two salmon sharks, one ragfish and over two hundred chum and silver salmon from a lost salmon driftnet in the western North Pacific. Our observations indicate that such nets may be a hazard to marine organisms for extended periods of time.

De Graaf, U.H., and J.F. De Veen. 1973. *Asteria rubens* and the influence of the beam trawl on the bottom fauna. ICES, Shellfish and Benthos Committee. ICES CM 1973/K:37.

Summary: This report examines injuries to starfish. The authors conclude that most starfish injuries are due to fishing. The difference in the percentage of regenerating animals can possibly give an indication of the magnitude of the influence of fishing on the bottom fauna, but other factors such as temperature and condition of the substrate also need to be considered.

de Groot, S.J. 1972. Some further experiments on the influence of the beam trawl on the bottom fauna. ICES CM 1972/B:6.

Summary: In this study, the author trawled areas with a double 6-meter beam trawl. He then used a sonar to examine the trawl tracks. He noted that the tracks disappeared quickly in a mud bottom environment. The author concluded that the disturbance of the bottom by the trawl depends mainly on the type of bottom and current velocity.

de Groot, S.J. 1984. The impact of bottom trawling on benthic fauna of the North Sea. Ocean Management. Vol. 9:177-190.

Abstract: This paper reviews the impact of bottom trawling (beam or groundtrawl) on animals of the sea bed. The area of study is restricted to the North Sea, however, the final conclusions have a far wider application. Protests against the use of trawls date back to the period of their introduction; for northwest Europe this was the thirteenth century, and it still evokes protests up to the present day. Trawling does affect benthic life, the trawl penetrates up to 30 mm into the soil, depending on the substrate. All types of trawls are basically similar in their action on the bed. Beam trawls with tickler chains catch much more benthos than do ground trawls without tickler chains. Some groups of animals suffer far more damage than others, e.g. echinoderms. It is not unlikely that in the long-term a shift in species and numbers may occur along the same lines such as has been found in the German Wadden Sea where polychaetes are on the incline and molluscs and crustaceans on the decline.

de Groot, S.J. 1995. On the penetration of the beam trawl into the sea bed. ICES CM 1995/B:36. 5 p.

Abstract: After a short historical review of real and supposed harmful effects attributed to beam trawling, the paper reviews the now available data on the penetration of depth of ticklers and chain arrays of the beam trawl. Depending on the bottom type and structure ticklers penetrate 1.5-7 cm deep in the bottom, not always however, as the gear moves over the bottom with speeds of 6-7 knots.

de Groot, S.J., and J.M. Apeldoorn. 1971. Some experiments on the influence of the beam trawl on the bottom fauna. ICES CM 1971/B:2.

Summary: This paper examines the Dutch beam trawl fishery, and its use of tickler chains. It examines the beam trawl and tickler chain's effect on bottom invertebrates and fish. The research shows that an increase in the number of tickler chains used on a beam trawl increases the catch of different species at different rates.

de Groot, S.J., and H.J. Lindeboom. 1994. Environmental impact of bottom gear on benthic fauna in relation to natural resources management and protection of the North Sea. NIOZ-Rapport 1994-11 RIVO-DLO Report CO26/94. 257 p.

Demestre, M., P. Sánchez, and M.J. Kaiser. 2000. The behavioural response of benthic scavengers to otter-trawling disturbance in the Mediterranean. Pages 121-129 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) The behaviour of scavengers and predators was studied in response to otter-trawling disturbance in muddy sediments in the north-west Mediterranean. 2) Repeated trawling with a commercial fishing gear over the same plotted coordinates depleted the abundance of commercially important species such as hake. However, smaller scavenging and predatory species increased in abundance significantly with time. 3) As in previous studies, the aggregative response of scavengers was short-lived and lasted no more than several days, which indicated that additional food resources made available by the trawling activities were rapidly consumed.

De Moor, G., J. Lanckneus, and L. van de Linde. 1992. Detection of trawl marks on the seafloor of the southern North Sea: Analysis of a time series of side-scan sonar recordings. Part I and Part II. Report of the Marine Geomorphology Research Unit. University of Ghent. 38 p.

Demory, D. 1971. Abandoned crab pots near Cannon Beach, Oregon. Fish Commission of Oregon, Research Division, Shellfish Investigation Information Report 70-6. Portland, Oregon.

Summary: Over 100 Dungeness crab pots were found unattended and were confiscated. Number, size, sex, and shell condition of the crabs retrieved were documented. Consequences of leaving the pots on the fishing grounds were discussed in terms of the onset of molt and probable cannibalism that would have resulted.

Dennis, G.D., and T.J. Bright. 1988. The impact of a ship grounding on the reef fish assemblage at Molasses Reef, Key Largo National Marine Sanctuary, Florida. Pages 213-218 *in* Proceedings of the Sixth International Coral Reef Symposium, Townsville, Australia, 8-12 August 1988. Volume 2: Contributed Papers.

Abstract: Reef fish recolonization of a coral reef area damaged by a ship grounding was monitored by diver visual census for 2 years (November 1984 to November 1986). During this time impacted and control areas tended to become more similar, though they still differed detectably in species composition, community structure, and biomass as late as two years after the grounding. These differences can be attributable to damage from the grounding and not just spatial variability, as control areas were never significantly different. Further recovery of the epifaunal assemblage and an increase in spatial complexity, especially in the severely impacted area, may be necessary for the reef fish assemblage to recover to pre-impact levels. This may take several more years based on epifauna recovery rates of corals and alcyonarians.

De Sylva, D.P. 1954. The live bait shrimp fishery of the Northeast Coast of Florida. State of Florida Board of Conservation Technical Series No. 11.

Abstract: 1) This investigation was undertaken from June to September 1953, by the Marine Laboratory of the University of Miami for the Florida State Board of conservation. Its purpose was to study biological and economic aspects of the live bait shrimp fishery of the northeast coast of Florida. 2) The sport fishery of the area depends to a large extent on live shrimp as bait. 3) Three species of shrimp are included in the fishery. The relative importance of these varies with locality, as does the method of fishing. 4) The complex life history of the white shrimp is outlined. It is emphasized that the female bait shrimp species does not carry its eggs attached to its body and that the small shrimp caught in the bait fishery with egg masses on the abdomen are a different species. Also, the bait shrimp do not spawn in the shallows, but offshore in deep water. 5) The economic importance of this industry is shown by the shrimp sales in these areas from July 1952 to July 1953, which amounted to nearly $700,000. It is estimated that about 1300 people make their living solely from the shrimp industry from Oak Hill to Jacksonville Beach. Catches, prices and other economic data pertaining to the industry are presented. 6) Methods of holding and transporting live shrimp are described. 7) Included in this project were studies on the fishery methods and gear and the identification of shrimp and fishes caught. The two principal gears used are the pushnet and the dipnet. In addition, castnets and trawls are employed. 8) Each of seven shrimp-producing areas on the northeast coast of Florida is considered in relation to the important species of shrimp it produces, the gear used, the catch composition and the ecology of the area. 9) The catch composition of pushnet catches is presented. Few fish of sports or economic importance are caught. It is believed that the pushnets (and the other gears) have little or no harmful effects on the shrimp or fish stocks or on the habitat. 10) It is concluded that the law prohibiting the use of pushnets was not justified on the basis of conservation or economics.

De Vlas, J. 1987. Effects of cockle fisheries on the macrobenthos in the Wadden Sea. Proceedings of the 5th International Wadden Sea Symposium. Biologiske Meddelelser. Vol. 31:215-228.

Dickson, J.O. 1996. Country report -- The Philippines. Research and development projects in fishing technology. Contrib. Res. Fish. Eng. No. 2:28-30.

Abstract: An outline is given of research and development projects conducted during 1994-1995 in the Philippines regarding fishing technology. The studies focused mainly on gear impact on the resources, mesh size selectivity, and gear efficiency.

Drew, S.C., and R.E. Larsen. 1994. Worldwide trawl and dredge study. Unpublished Report. Marine Data Systems. Plymouth, Massachusetts. 8 p.

Summary: This study was designed to determine how deeply bottom fishing gear penetrates the bottom so that cable burial depth requirements can be established. The researchers also determined where bottom trawl and dredge fisheries are conducted worldwide. They concentrated their effort in water depths greater than 30 m. They conclude that seabed penetration varies with the characteristics of the fishing gear, the hardness of the substrate and other factors. The study also lists penetration depths for beam trawls, otter trawls, scallop dredges, mussel dredges, clam dredges, and mechanized dredges.

Drobeck, K.G., and M.L. Johnston. 1982. Environmental impact of hydraulic escalator dredging on oyster communities. UMCEES Report 82-5 CBL. University of Maryland, Chesapeake Biological Laboratory. Solomons, Maryland. 51 p.

Durako, M.J., M.O. Hall, F. Sargent, and S. Peck. 1992. Propeller scars in seagrass beds: an assessment and experimental study of recolonization in Weedon Island State Preserve, Florida. Pages 42-53 *in* F.J. Webb, editor. Proceedings of the Nineteenth Annual Conference on Wetland Restoration and Creation, Hillsborough Community College, Plant City, Florida.

Abstract: Seagrass recolonization of experimentally-scarred areas was monitored for 421 days within adjacent monospecific beds of turtle grass, *Thalassia testudinum* Banks ex Konig, and shoal grass, *Halodule wrightii* Aschers in Weedon Island State Preserve in Tampa Bay. *Thalassia* recovery data were fitted to a first order regression ($y = 0.146x+8.18$, $r^2 = 0.84$) that indicated it would take approximately 3.6 - 6.4 years for these scars to achieve natural short-shoot densities (ca. 200-350 short-shoots 0.5 m^2). Regrowth data for experimental scars in the *Halodule* bed fell into two distinct groups, depending on the location of the scars. The regression for data from the first group of subplots ($y=1.17x+17.0$, $r^2 = 0.85$), which were located near the fringe of the bed, indicated that natural short-shoot densities (ca. 1000-2000 short-shoots 025 m^2) would be achieved after 2.3 - 4.6 years, whereas short shoots in the second group of subplots ($y = 3.03x-40.3$, $r^2 = 0.84$) which were located in the interior of the bed, would take only 0.9 - 1.8 years to reach natural densities. Photogrammetric analyses of 1:2,400-, and 1:12,000-, and 1:24,000-scale aerial photographs indicated that 1:24,000-scale photographs, taken under ideal conditions of water clarity, provided adequate resolution for identifying the areas damaged worst by propeller scars within the preserve. Seven hundred individual propeller scars were delineated using the 1:2,400-scale photography. The greatest concentration of propeller scars within the preserve occurred at the passes, and the maximum length of a single scar was approximately 800 m long.

Dyekjaer, S.M., J.K. Jensen, and E. Hoffman. 1995. Mussel dredging and effects on the marine environment. ICES CM 1995/E:13. 19 p.

Abstract: With the increased dredging for mussels in Limfjorden (Denmark) a growing concern about the impact of this fishery on the environment has evolved. During dredging, sediment plumes are released, and particles, nutrients, and oxygen-consuming substances are transported from the sediment to the water phase. It has been argued that this might have a serious impact on the general environment in the fiord. In this study the amount of released particles per m^2 dredged was quantified on four occasions through full scale *in situ* measurements around a dredging vessel. The pool of dissolved and loosely sorbed nutrients in the upper sediment layers has been quantified through extraction experiments, and the pool of oxygen-consuming substances was calculated through measurements of oxygen consumption of suspended sediment. These experiments have given an indication of the potential release during dredging. Preliminary estimates of the release of particles and nutrients during mussel dredging are given and calculations based on simple rough estimates are used to compare the effects of mussel dredging with other factors such as wind-induced resuspension and the load of nutrients to the fiord from external sources. The total annual

release of suspended particles during dredging is relatively unimportant compared with the total annual wind-induced resuspension, and so is the total annual release of nutrients compared with the load from land. The effect of mussel dredging both locally and in the fiord as a whole is discussed.

Dyrynda, P., and K. Lewis. 1995. Ecological studies within the Crymlyn Burrows SSSI (Swansea Bay, Wales): impacts of mechanized cockle harvesting. Marine Environment Research Group, University of Wales, Swansea. 15 p.

Eckmayer, W.J. 1977. Oyster reef cultivation for cultch material. Alabama Marine Resources Bulletin. Vol. 12:23-30.

Abstract: A modified oyster dredge was used as a method of utilizing existing buried shell for cultch. SCUBA and random m^2 quadrats were used before and after dredging to sample Bayou Cour Reef, Kings Bayou Reef, and Shellbank Reef in Mobile Bay and Bon Secour Bay, Alabama. The reefs were dredged at a rate of 6.4 km/hour covering 0.4 ha in one hour and 15 minutes. The modified dredge was found to destroy half-shell while exposing the half-shell resulting in an increase in shell weight. The bottom was disrupted and the exposed shell appeared to settle into the bottom with a subsequent loss of relief followed by an accumulation of silt. Spat set increased following dredging, but loss of relief makes this method unsatisfactory for reefs over a soft substrate. Man-made or rehabilitated oyster reefs on hard substrate may benefit from this method.

Ecological Consultancy Services Ltd. 1998. Coral reefs in Irish waters. http://www.ecoserve.ie/projects/coral. 5 p.

Summary: This article discusses the occurrence of two coral species, *Lophelia pertusa* and *Madrepora oculata*, off the west coast of Ireland. The article states that these coral reefs have been damaged by deep water trawling for about 30 years. The article also stresses that more research needs to be done on these reefs to assess their importance.

EEC. 1990. Scientific and Technical Committee for Fisheries, Special Meeting of November 1990. Chapter 11 - Effects of beam trawling on the sea bed. Commission of the European Communities. SEC(90)2498, p. 18-23.

Efanov, S.F. 1981. Herring of the Gulf of Riga: the problem of escapement and mechanical impact of the trawl. ICES CM 1981/J:7. 16 p.

Abstract: In the process of trawling a lot of small-sized fish escape from the trawl. The majority of these fish are viable. Thus, for the Baltic herring that have passed through codends of 24.0, 28.0 and 32.0 mm death from wounds was equal to 35.3, 15.6 and 10.1%, accordingly. The impact of trawling on exploited herring concentrations in the Gulf of Riga was determined taking into consideration trawl catchability, biomass of the fish which were caught and escaped through the front part of the trawl and codend, and also death of fish from wounds.

Eldredge, L.G. 1987. Poisons for fishing on coral reefs. Pages 61-66 *in* Human Impacts on Coral Reefs: Facts and Recommendations. Antenne Museum, French Polynesia.

Summary: This article describes the use of both plant poisons and commercial poisons on coral reefs and coral reef fish. The author describes the effects of the poisons and possible impacts.

Eleftheriou, A., and M.R. Robertson. 1992. The effects of experimental scallop dredging on the fauna and physical environment of a shallow sandy community. Netherlands Journal of Sea Research. Vol. 30:289-299.

Abstract: An experimental dredging operation was carried out in a small sandy bay in Scotland, with the aim of quantitatively assessing the effects of scallop dredging on the benthic fauna and the physical environment. An area within the 10-m depth contour was selected; a 1.2-m modified scallop dredge was operated at frequencies of 2, 4, 12 and 25 dredges, carried out over a period of nine days. The effects on the bottom topography, the physical characteristics of the sediment and the fauna were investigated by grab and core sampling, and direct observations were carried out by a diving team. Observed changes in bottom topography were not translated into changes in the disposition of the sediments, their grade distribution and the organic carbon and chlorophyll content, all of which showed no effects. The infaunal community, which consisted of bivalve molluscs and peracarid crustaceans, both taxa adapted morphologically and behaviourally to a dynamic environment, did not show any significant changes in abundance or biomass. Sessile forms such as polychaetes showed a noticeable decrease, and the burrowing spatangid *Echinocardium* was substantially reduced from the dredged area. Corresponding changes in the biomass of the different taxa were also evident but not significant. However, the most important effect of this experiment was on the epifaunal and large infaunal organisms recorded by the divers. Large numbers of molluscs (*Ensis*), echinoderms (*Asterias*) and crustaceans (*Cancer*) were killed or damaged by the dredging operations. Very large concentrations of the burrowing sand eel *Ammodytes* were also destroyed. The overall conclusion to be drawn from this experimental dredging operation is that its effect was limited to the selective elimination of a fraction of the fragile and sedentary components of the infauna, and the destruction of the large epifaunal and infaunal organisms.

Engel, J.D. 1998. Potential impacts of commercial trawling on a benthic community in Monterey Bay National Marine Sanctuary. M.S. thesis. Moss Landing Marine Laboratories/San Francisco State University. San Francisco.

Engel, J., and R. Kvitek. 1998. Effects of otter trawling on a benthic community in Monterey Bay National Marine Sanctuary. Conservation Biology. Vol. 12(6):1204-1214.

Abstract: Bottom trawling is one of the most disruptive and widespread human-induced physical disturbances to seabed communities and has become a global environmental concern. We used a comparative approach to test the hypothesis that persistent otter trawling decreases bottom habitat complexity and biodiversity, increases the abundance of opportunistic species, and benefits prey important in the diet of some commercially valuable fish. We compared two similar and adjacent fishing areas at 180 m off central California in

Monterey Bay National Marine Sanctuary: one inside the three-mile coastal zone of restricted fishing with light levels of trawling and one beyond the three-mile limit with high levels of trawling. Differences in fishing effort between the two areas were confirmed and quantified by means of data and tow number statistics from Pacific Fishery Management Council (PFMC) Trawl Logbook records. We used still photography, video footage, bottom grab samples, and experimental trawling to compare the physical and biological parameters of the two areas. The area with high levels of trawling had significantly more trawl tracks, exposed sediment, and shell fragments and significantly fewer rocks and mounds and less flocculent material than the lightly trawled area. Most invertebrate epifauna counted were significantly more abundant in the lightly trawled area. The density of the amphinomid polychaete, *Chloeia pinnata*, as well as that of oligochaetes, ophiuroids, and nematodes, were higher every year in the highly trawled area, and there were significantly fewer polychaete species every year in the highly trawled area. Content analysis of fish guts showed that *C. pinnata* was a dominant prey item for some of the commercially important flatfishes in both lightly and heavily trawled areas. Our study provides evidence that high levels of trawling can decrease bottom habitat complexity and biodiversity and enhance the abundance of opportunistic species and certain prey important in the diet of some commercially important fishes. Our work also illustrates how constraints currently imposed on fisheries research by the near universal absence of true unfished control sites severely limit our ability to determine appropriate levels of harvest pressure for maintaining sustainable fisheries and marine biodiversity. Valid research in these areas will require marine reserves in which fishing effort and methods can be manipulated in collaborative studies involving fishers, researchers, and resource agencies.

Eno, N.C., D.S. MacDonald, and S.C. Amos. 1996. A study on the effects of fish (crustacea/mollusc) traps on benthic habitats and species. In *Report to European Commission Directorate General XIV*, Studies Contract 94/076. 43 p.

Erzini, K., C.C. Monteiro, J. Ribeiro, M.N. Santos, M. Gaspar, P. Monteiro, and T.C. Borges. 1997. An experimental study of gill net and trammel net 'ghost fishing' off the Algarve (southern Portugal). Marine Ecology Progress Series. Vol. 158:257-265.

Abstract: Four 100 m lengths of both monofilament gill nets and trammel nets were deployed at depths between 15 and 18 m off the coast of the Algarve (south of Portugal) between April 1995 and June 1996. The nets were set on a natural rocky bottom with one end cut loose to simulate lost nets. Changes in net structure (net height, effective fishing area, movement, colonization, wear and tear) and their catches (species, sizes, numbers, and biomass) were monitored by divers. Similar patterns were observed in all the nets, with a sharp decrease in net height and effective fishing area, and an increase in visibility within the first few weeks. Net movement was negligible except in the case of interference from other fishing gears. Catch rates were initially comparable to normally fished gill nets and trammel nets in this area, but decreased steadily over time. No sea birds, reptiles or mammals were caught in any of the 8 nets. Catches were dominated by fish (89% by number, at least 27 species), in particular by sea breams (Sparidae) and wrasses (Labridae). Under the conditions experienced throughout the study the fishing lifetime of a 'lost' net is between 15 and 20 wk. Based on an exponential model, we estimated that 100 m lengths of gill net and trammel net will catch 314 and 221 fish respectively over a 17 wk period. However, we

consider this to be an underestimate due to high rates of predation and scavenging by octopuses, cuttlefish, moray eels, conger eels, and other fish such as the wrasse *Coris julis*. When the nets were surveyed in the following spring, 8 to 11 mo after being deployed, they were found to be completely destroyed or heavily colonized by algae and had become incorporated into the reef.

Estrella, B.T. 1989. The impact of bottom trawling on American lobsters off Duxbury Beach, Massachusetts. Massachusetts Division of Marine Fisheries. Boston, Massachusetts. 14 p.

Summary: This study investigates the extent and frequency of damage to lobsters captured in a trawl compared to lobsters passed over by a trawl. It also studies the impact of trawling on habitat in Massachusetts. Finally it determines if the inshore bottom trawl used in resource surveys, effectively samples lobsters in its path to yield representative population parameters adequate for lobster resource assessments.

ESGEMAR. 1995. Assessment of the effect of trawling on *Posidonia oceanica* grounds in relation to the benthic and demersal communities. Final Report EC-DG XIV Study Contract No. TR/MED921/012. 110 p.

Fanelli, G., S. Piraino, G. Belmonte, S. Geraci, F. Boero. 1994. Human predation along Apulian rocky coasts (SE Italy): desertification caused by *Lithophaga lithophaga* (Mollusca) fisheries. Marine Ecology Progress Series. Vol. 110:1-8.

Abstract: The date mussel *Lithophaga lithophaga* is a Mediterranean boring mollusc living in calcareous rocks. Its populations are intensely exploited by SCUBA divers, especially in southern Italy. Collection carried out by demolition of the rocky substratum, so that human predation on date mussels causes the disappearance of the whole benthic community. The impact of this activity along the Apulian coast was evaluated by 2 surveys carried out by SCUBA diving inspection of the Salento peninsula. The Ionian coast of Apulia, from Taranto to Torre dell'Orso (Otranto), was surveyed in 1990 and in 1992 by 2 series of transects (from 0 to 10 m depth, 2 km from each other), covering 210 km. Observations were transformed into an index of damage, ranging from 0 (no damage) to 1 (complete desertification). 159 km of the inspected coast are rocky. The first survey (1990) allowed us to estimate that a total of 44 km was heavily affected by this human activity (the index of damage ranging between 0.5 and 1), whereas the second survey showed heavy damage along a total of 59 km. This increase in length was accompanied by a high increase in the index of damage along parts of coast that were less intensely exploited in 1990 than in 1992. The second survey (1992) was extended to 90 km of the Adriatic coast of Apulia (from Otranto to Torre S. Sabina, Brindisi), with 47 km of rocky coast and a total of 10 km heavily affected by the date mussel fishery. Date mussel collection is one of the most destructive human activities along the Apulian coast and it has long-term effects because sea urchin grazing probably prevents recolonization of barren areas. Rarefaction of the resource due to overexploitation and habitat destruction caused rapid 'evolution' of the techniques of predation, with an increase in searching efficiency achieved by the use of underwater vehicles. Similar impacts of date mussel collection have been recorded in other parts of the Italian coast, especially Campania and Sardinia, and it is possible that such situations are common, but still undetected, in other areas of the Mediterranean.

Fiege, D., V. Neumann, and J. Li. 1994. Observations on coral reefs of Hainan Island, South China Sea. Marine Pollution Bulletin. Vol. 29(1-3):84-89.

Abstract: Two recent expeditions to Hainan Island provided the opportunity to survey coral reefs at various locations, including some which had been studied during earlier investigations. Since 1987 the reefs have apparently recently suffered from additional human impact. Dynamite fishing poses the major threat and large sections of the reefs are severely damaged. Increasing tourism with hotels built directly on the beach is also putting the coastal marine fauna at risk. Conservation measures and especially the enforcement of existing laws are urgently required.

Fisheries and Marine Institute, Memorial University of Newfoundland. 1993. Prevention of ghost fishing in Atlantic Canada: phase 1. Fisheries and Marine Institute of Memorial University of Newfoundland in cooperation with Fisheries Management, Canadian Department of Fisheries and Oceans. 231 p.

Fisheries Resource Conservation Council. 1997. A report on gear technology in eastern Canada: report of the Gear Technology Subcommittee. Fisheries Resource Conservation Council (Canada). Gear Technology Subcommittee. Ottawa, Canada. 25 p.

Abstract: This report considers the various fishing gears being used in the Atlantic groundfish fisheries and reviews the characteristics of the different gears that are relevant to the conservation of the resources and ecosystems. The document contains general and gear specific recommendations on means to address concerns about possible adverse impacts of fishing gear on resource yields and sustainability, and on the need to carry out further investigation of a number of the conservation concerns and of the means of addressing them.

Flint, R.W., and J.A. Younk. 1983. Estuarine benthos: long-term community structure variations, Corpus Christi Bay, Texas. Estuaries. Vol. 6(2):126-141.

Abstract: A study of the benthic communities in Corpus Christi Bay was carried out between 1974 and 1979 to identify both natural and human-induced variations in community dynamics of the benthos over a long time period of monthly sample collection. General results of the investigation were comparable to previous shorter-term studies of this estuary in respect to species list of dominant fauna, total densities and species diversity measures. The present study emphasized two habitats: a channel 15 m deep and a shoal less than 3.5 m deep. Channel stations exhibited lower species numbers, densities, and species diversity than shoal sites but in contrast showed more even distributions of population numbers between species (equitability) than shoal sites. Hierarchical classification procedures identified community structure patterns that were associated with a major disturbance to the area, dredging, as well as minor, more frequent disturbances associated with large ship traffic and shrimp trawling activities in the channel. The community variables of species number and total density were also related to changes in salinity patterns in the study area. The results of this long-term study illustrated the resilience of benthic communities to disturbance. They also provided supportive evidence to hypotheses concerning the high resistance of communities to disturbance in inconstant environments and the source of colonists in these environments after a major disturbance to the bottom.

Floderus, S., and L. Pihl. 1990. Resuspension in the Kattegat: impact of variation in wind climate and fishery. Estuarine, Coastal and Shelf Science. Vol. 31:487-498.

Abstract: The recurrence of various agents of fine sediment resuspension in the Kattegat Sea, notably wind-induced wave action and demersal trawling, and their seasonal variation and long-term trends have been estimated. A comparison between the sediment-water interface and the spatial distribution of theoretical wind/wave impact indicated that the sediment is resuspended by further agents at depths below the permanent halocline between 10 and 20 m depth. The climatic deterioration in 1940-70 had a significant influence on the recurrence of wind-induced resuspension, although this was mostly limited to a 10-30% shortening of the recurrence period. On the other hand, a quantification of the effect of demersal trawling in the same period suggests a total shortening of recurrence at bottoms below the halocline by 75-85% in the autumn and winter, and with one order of magnitude (90%) in spring and summer, compared with the effect of waves only in the 1930s; resuspension caused by near-bottom unidirectional currents was not quantified. At these deeper bottoms, resuspension conditions have approached those prevailing at shallow bottoms above the halocline.

Fogarty, M.J., and S.A. Murawski. 1998. Large-scale disturbance and the structure of marine systems: fishery impacts on Georges Bank. Ecological Applications. Vol. 8(1):S6-S22, Supplement.

Abstract: Georges Bank, a shallow submarine plateau located off the New England coast, has supported valuable commercial fisheries for several centuries. The region is characterized by high levels of primary productivity and, historically, high levels of fish production. Within the last four decades Georges Bank has been subjected to major perturbations that have profoundly altered levels of catch, abundance, and species composition. The arrival of distant water fleets during the early 1960s resulted in dramatic increases in effective fishing effort and the subsequent commercial collapse of several fish populations. Total fish biomass is estimated to have declined by >50% on Georges Bank during the period of operation of the distant water fleets. The implementation of extended jurisdiction (the 200-mile [370.4-km] limit) in 1977 was followed by modernization and increased capacity of the domestic fleet, resulting in a second perturbation to the system that resulted in further declines in groundfish populations to historically low levels. A subsequent increase in the abundance of species of low commercial value was documented, with an apparent replacement of gadoid and flounder species by small elasmobranchs (including dogfish sharks and skates). Examination of feeding guild structure suggests that this switch in species dominance may have linked to a competitive release. The small elasmobranchs, notably dogfish sharks, also prey on species of commercial importance (primarily small pelagics, including herring and mackerel). The cumulative impacts on the groundfish populations as a result of intense exploitation and predation pressure may have been further exacerbated by effects of fishing gear on the physical structure of the habitat. Implications for the development of an ecosystem-based management approach are described.

Fonds, M., and S. Groenewold. 2000. Food subsidies generated by the beam-trawl fishery in the southern North Sea. Pages 130-150 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) The intensive beam-trawl fishery for sole and plaice in the southern North Sea produces large amounts of discard materials and much larger amounts of damaged fauna on the seabed. This material is rapidly consumed by opportunistic scavenging species, such as birds, crabs, starfish and fish. Damaged and exposed benthos is mainly consumed by fish, while discarded fish are mainly consumed by invertebrate scavengers. Trawling results in an increased rate of recycling of macro-benthic fauna and fish through the food web. 2) The balance between food generated by beam trawling and the potential food consumed by local populations of benthic carnivores and demersal fish was estimated for four different areas in the southern North Sea. On average, beam trawling an area once in the summer may generate *c.* 127 g afdw (ash-free dry weight) 100 m^{-2}. This can be compared with a potential daily food consumption by benthic carnivores of *c.* 13.2 g afdw 100 m^{-2}, 10.8 g by benthic invertebrates and 2.4 g by demersal fish. In winter, food production by beam trawling and potential daily food consumption by benthic carnivores is estimated to be lower: *c.* 87 g generated compared with *c.* 3.5 g consumption. 3) On average, beam trawling may generate *c.* 180 g afdw 100 $m^{-2}year^{-1}$ damaged benthos and approximately 15-38 g afdw 100 $m^{-2}year^{-1}$ of discard fish, compared with a potential annual food demand of *c.* 2450 g afdw 100 $m^{-2}year^{-1}$ for benthic invertebrate carnivores and 550 g afdw 100 $m^{-2}year^{-1}$ for demersal fish. 4) The annual amount of food supplied by beam trawling is approximately 7% of the maximum annual food demand of all common benthic predators considered together, which may help to maintain these populations but is insufficient to support further population growth. 5) While beam trawling undoubtedly increases food subsidies in the marine environment, it also removes large predators from the ecosystem. This may have led to higher growth rates of some fish and caused increases in the populations of small fish species such as dragonets, solenettes, scaldfish, lesser weever and gobies.

Fonseca, M.S., G.W. Thayer, A.J. Chester, and C. Foltz. 1981. The impact of scallop harvesting on eelgrass (*Zostera marina* L.) meadows. Unpublished manuscript. Southeast Fishery Center Beaufort Lab, National Marine Fisheries Service, NOAA, Beaufort, North Carolina. 15 p.

Fonseca, M.S., G.W. Thayer, A.J. Chester, and C. Foltz. 1984. Impact of scallop harvesting on eelgrass (*Zostera marina*) meadows: implications for management. North American Journal of Fisheries Management. Vol. 4:286-293.

Abstract: Eelgrass (*Zostera marina*), an important component of estuarine areas from Nova Scotia to North Carolina, is the primary habitat for the economically important bay scallop *Argopecten irradians*). The bay scallop fishery in North Carolina is extensive yet precarious in its dependence on seagrass systems. A balance between habitat integrity and scallop harvest is necessary to sustain the fishery. In this study, we examined the effect of scallop dredging on eelgrass meadows. When the eelgrass was in its vegetative stage, 15 and 30 dredgings were carried out in a hard sand substrate and a soft mud substrate and the results compared to an area of no dredging. Impact was assessed by analyzing the effects of scallop harvesting on eelgrass foliar dry weight and on the number of shoots. The hard bottom had

significantly greater overall biomass of eelgrass ($P<0.01$, ANOVA) than the soft bottom but fewer differences were apparent for eelgrass shoot density ($P<0.10$). Increased dredging led to significantly reduced levels of eelgrass biomass and shoot number ($P<0.01$) on both hard and soft bottoms. Harvesting of bay scallops in North Carolina occurs at a time of seasonally low eelgrass foliar biomass, peak abundance of commercially harvestable scallops, and settlement of post-larval scallops that require eelgrass leaves for attachment. Our data demonstrated potentially negative impacts on the scallop fishery that would result from harvest-related damage to existing eelgrass meadows.

Fonteyne, R. 2000. Physical impact of beam trawls on seabed sediments. Pages 15-36 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) The first data on the physical impact of beam trawling on the seabed were obtained during the 1970s, and consequently relate to rather light gears compared with those currently used. This paper deals with the impact on the seabed of modern, heavy beam trawls. It concentrates on the pressure exerted by the gears and on the changes to seabed topography and sediment characteristics. A 4-m beam trawl equipped with a chain matrix was used in all experimental work. This gear is typical for 'Eurocutters' operating in coastal areas. 2) An instrumented trawl head was developed to measure directly the pressure of the trawl heads on the seabed. This device also allowed a description of the mechanical behaviour of the gear in contact with the seabed. The effect of gear and vessel size on gear pressure was modelled. The changes to the seabed topography were observed by side-scan sonar, and changes in sediment characteristics were measured using the RoxAnn seabed classification system. 3) The pressure exerted on the seabed by beam trawls is strongly related to the towing speed. As the speed increases, the lift of the gear increases and the resultant pressure force decreases. At higher speeds, the weight of the gear is fully compensated, and the trawl lifts off the bottom. 4) For the 4-m beam trawl studied, the pressure exerted by the trawl heads varied from 17 to 32 hPa at towing speeds of 4-6 kn. Bottom contact was lost at a towing speed of 7 kn. 5) Although larger vessels use heavier gears, this is compensated for by larger sole-plate dimensions and higher towing speeds, hence the pressure exerted is roughly equal to the 4-m beam trawl. 6) Beam trawls leave detectable marks on the seabed. The length of time that the beam trawl marks remain visible depends on the upper sediment layer. On a seabed consisting of mainly coarse sand, the tracks remained visible for up to 52 h, whereas on sediments with mainly finer particles, the tracks had completely faded after 37 h. The penetration depth could not be deduced from the side-scan sonar recordings, since the traces were too weak. 7) The movement of the gear causes the resuspension of the lighter sediment fraction. The changes are most pronounced in areas with finer sand. The suspended particles, however, settle down within a few hours.

Fowler, S.L. 1989. Nature conservation implications of damage to the seabed by commercial fishing operations. UK Nature Conservancy Council, Contract Report No. 79. 33 p.

Franklin, A. 1972. The cockle and its fisheries. MAFF, Laboratory Leaflet. No. 26. 33 p.

Summary: This report examines the cockle, *Cardium edule*. It describes the biology, life history, and fishery for cockles. The report also describes the types of gear used in the fishery and their possible impacts.

Franklin, A., and G.D. Pickett. 1978. Studies on the indirect effects of fishing on stocks of cockles, *Cardium edule*, the Thames Estuary and Wash. MAFF, Fishery Research Technical Reports. No. 42. 9 p.

Summary: This report examines the hydraulic cockle dredge, and its effects on the bottom and the damage done to undersize cockles. The impact on the bottom was determined to be well defined tracks several centimeters in depth and equal in width to the size of the dredge blade (0.6 m). The tracks were found to be visible several months after fishing, though they disappeared quickly following bad weather.

Freese, L., P.J. Auster, J. Heifetz, and B.L. Wing. 1999. Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. Marine Ecology Progress Series. Vol. 182:119-126.

Abstract: Short-term effects of bottom trawling on a 'hard-bottom' (pebble, cobble and boulder) seafloor were studied on the outer continental shelf in the eastern Gulf of Alaska. Eight sites were trawled in August 1996; then, from a research submersible we videotaped each trawl path and a nearby reference transect to obtain quantitative data. Boulders were displaced, and large epifaunal invertebrates were removed or damaged by a single trawl pass. These structural components of habitat were the dominant features on the seafloor. There was a significant decrease in density, and an increase in damage, to sponges and anthozoans in trawled versus reference transects. Changes in density, or damage to most motile invertebrates were not detected. Delayed mortality, of apparently undamaged invertebrates, may have resulted in greater impact than we detected. Alternatively, over time, some invertebrates may have recovered from any damage previously suffered. A subsequent survey at these sites will address these questions.

Frid, C.L.J., and S.J. Hall. 1999. Inferring changes in North Sea benthos from fish stomach analysis. Marine Ecology Progress Series. Vol. 184:183-188.

Abstract: In this study we formulated *a priori* hypotheses for the changes in the benthos that would be expected as a result of the direct impacts of trawl fisheries. These were tested using a data set comprising stomach contents for dab *Limanda limanda* collected in March and August in the early 1950s and a matched sample from 1996-97. Changes in samples taken in August were consistent with the hypothesized effects of fishing, with an increased prevalence of scavengers and decreased occurrence of sedentary polychaetes in the diet. There were also marked differences between the 1950s and 1996-97 for March samples due to the high prevalence of fish remains in the contemporary samples. While our results must be treated with caution, they are consistent with the hypothesis that there have been widespread long term changes in benthic communities due to fishing.

Frid, C.L.J., R.A. Clark, and J.A. Hall. 1999. Long-term changes in the benthos on a heavily fished ground off the NE coast of England. Marine Ecology Progress Series. Vol. 188:13-20.

Abstract: Long-term monitoring of 2 benthic stations off the Northumberland coast, NE England, at 80 and 55 m depth, has been carried out since 1971. The 80 m station is located within a *Nephrops norvegicus* fishing ground, while the 55 m station is located outside of the main fished area. In this study we compare the fauna of the heavily fished site with that of the shallower site over a period during which fishing effort changed. Changes in macrofaunal abundance at the station outside the fishing ground reflected changes in organic input. This was also the case at the fished station except during the period of highest fishing activity when this relationship broke down. This suggests that the dynamics of the macrobenthos at this station were influenced by fishing activity. Individual taxa were categorized *a priori*, based on literature accounts of their response to fishing. At the site outside the fishing ground the proportion of individuals predicted *a priori* to increase and that predicted to decrease in response to the direct effects of fishing did not vary. At the heavily fished station the increase in fishing effort in the early 1980s did not alter the abundance of the taxa predicted to decline, but the abundance of individuals in taxonomic groups predicted to increase did change in the predicted direction. The differences in the dynamics of the 2 stations, which differed in their fishing intensity, provide some evidence for a role of direct effects of fishing in determining the abundance and composition of coastal macrofauna.

Frid, C.L.J., and R.A. Clark. 2000. Long-term changes in North Sea benthos: discerning the role of fisheries. Pages 198-216 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) Fishing occurs at the scale of ocean basins and has been going on for millennia. The scale and intensity of fishing has expanded in the last 100 years with the mechanization of the fleet and the development of better navigational and vessel technology. 2) Fishing activities interact with the benthos through direct mortality of benthos as by-catch and net damaged organisms and inputs of organic matter in the form of carcasses and offal, and indirectly through alterations in sediment characteristics, altered sediment-water column fluxes, and changes in predation rates through changed abundance and size structure of populations of predatory fish. 3) Separating the effects of fishing from other long-term sources of variation in benthic communities is difficult. However, application of a precautionary approach to ecosystem management would suggest that action needs to be taken when there is sufficient weight of evidence. 4) Current data suggest reduced abundances of long-lived bivalves and increased abundances of scavenging crustacea and sea stars in the German Bight, and altered benthic community composition on at least some fishing grounds. There are also likely to have been major changes in the predation pressure applied by fish to the benthos. This suggests that both direct and indirect effects are manifested in the most intensively fished areas of the North Sea. 5) Managers must recognize that a healthy ecosystem is a requirement and aim of existing international agreements and a prerequisite for healthy fish populations. To date, fisheries management has failed adequately to protect the target species, we should now seek methods that also provide protection to the wider ecosystem and its functions.

Friedlander, A.M., G.W. Boehlert, M.E. Field, J.E. Mason, J.V. Gardner, and P. Dartnell. 1999. Sidescan-sonar mapping of benthic trawl marks on the shelf and slope off Eureka, California. Fishery Bulletin. Vol. 97:786-801.

Abstract: The abundance and orientation of trawl marks was quantified over an extensive portion (>2700 km^2) of the Eureka, California, outer shelf and slope, an important commercial bottom trawling ground for such high-value species as rockfish, sole, and sablefish. Fishing logbook data indicate that the entire reporting area was trawled about one and a half times on an average annual basis and that some areas were trawled over three times annually. High-resolution sidescan-sonar images of the study area revealed deep gouges on the seafloor, caused by heavy steel trawl doors that act to weigh down and spread open the bottom trawls. These trawl marks are commonly oriented parallel to bathymetric contours and many could be traced for several kilometers. Trawl marks showed a quadratic relationship in relation to water depth, with the greatest number of trawl marks observed at ~400 m. There was a significant positive correlation between the number of trawl marks observed on the sidescan images and the number of annual trawl hours logged within reporting areas. This finding indicates that acoustic remote sensing is a promising independent approach to evaluate fishing effort on a scale consistent with commercial fishing activities. Bottom trawling gear is known to modify seafloor habitats by altering benthic habitat complexity and by removing or damaging infauna and sessile organisms. Identifying the extent of trawling in these areas may help determine the effects of this type of fishing gear on the benthos and develop indices of habitat disturbance caused by fishing activities.

Froglia, C. 1989. Clam fisheries with hydraulic dredges in the Adriatic Sea. Pages 507-521 *in* J.F. Caddy, editor. Marine Invertebrate Fisheries: Their Assessment and Management. Wiley and Sons, Inc. New York.

Fuller, S., and P. Cameron. 1998. Marine benthic seascapes: fishermen's perspectives. Marine Issues Committee Special Publication. Vol. 3. Ecology Action Centre. Halifax, Nova Scotia. 64 p.

Abstract: Fishermen from Nova Scotia and southwest New Brunswick were interviewed to collect their knowledge of the sea floor, changes to the sea floor and perceptions of sensitive habitat. Valuable information about bottom type, species associations, and characteristics of specific geographical areas was collected. Natural changes and the impact of human activity on the sea floor, from the perspectives of fishermen was examined. The importance and effects of damage to the sea floor as described by fishermen, was related to type of gear fished, the length of time they had been in the fishery and whether or not they were retired. In general, fishermen felt that the greatest threat to benthic habitat was fishing gear. Destruction of habitat included removal of epifaunal species, reducing and flattening topographical features and altering bottom substrate. Natural changes were not a threat and were not considered to be permanent. The effects of other human activities were considered minimal, except by those directly affected by coastal activities. Fishermen were reluctant to discuss sensitive areas in fear their information would be used to restrict areas where they can fish. The most commonly suggested conservation measure for benthic habitat was to use low impact gear, such as hook and line in areas determined to be essential habitat. The knowledge collected in this study belongs to the fishermen who participated. Fishermen provide valuable information about the marine environment. This knowledge can be used for conservation and management purposes. All respondents showed concern for the future of the fishing industry. In order to protect benthic habitat, measures must be taken to limit and monitor human activities that destroy or disturb these areas.

Futch, C.R., and D. S. Beaumariage. 1965. A report on the bait shrimp fishery of Lee County, Florida. Florida Board of Conservation Marine Laboratory Maritime Base, Bayboro Harbor, St. Petersburg, Florida. FBCML No.: 65-1.

Summary: A survey of the bait shrimp fishery in Lee County, Florida was conducted to determine if any damage was done to the fish nursery area where the fishery takes place, to determine if small shrimp and fish are being killed by trawling operations, and to propose recommendations pertaining to the bait shrimp fishery. This paper also gives a brief history of the fishery, a description of the gear used, and the fishing methods used in the fishery.

Galvez, R.E. 1991. Blast fishing and government response in Lingayen Gulf. ICLARM Conference Proceedings No. 22:430.

Abstract: The use of explosives in fishing is illegal and punishable with stiff fines and prison terms. Nevertheless, it persists in a number of coastal villages in Lingayen Gulf (Philippines). This paper is an ethnographic study of a fishing village in the gulf area based on primary and secondary data gathered from April 1987 to March 1988. It describes (1) how blast fishing is practiced in the village; (2) the perception of the village residents regarding the illegal practice; (3) the factors that affect its continued use; and (4) the measures taken by government agencies to check its use.

Galvez, R.E., and M.S.M. Sadorra. 1988. Blast fishing: A Philippine case study. Tropical Coastal Area Management. Vol. 3(1):9-10.

Summary: The authors examine the primary social causes of blast fishing, including the social benefits, how blast fishermen avoid enforcement officials, and how blast fishing can be reduced.

Galvez, R.E., T.G. Hingco, C. Bautista, and M.T. Tungpalan. 1989. Sociocultural dynamics of blast fishing and sodium cyanide fishing in two fishing villages in the Lingayen Gulf area. ICLARM Conference Proceedings. No. 17:43-62.

Abstract: The use of explosives and poisons in fishing is illegal and punishable with stiff fines and prison terms. Nevertheless, the use persists in a number of coastal villages in the Lingayen Gulf area. This paper gives the results of ethnographic studies in two fishing villages in the gulf area based on data/interviews covering the period May 1987 to April 1988. It describes: (1) how blast fishing and sodium cyanide fishing are practiced in the villages; (2) the factors which affect their continued use; (3) the level of perception of village residents regarding these illegal practices; and (4) the need for education campaigns to increase awareness of the destructive effects of these illegal practices.

Ganz, A. 1980. Otter trawl induced lobster damage evaluation. Final Report to Department of Commerce, NOAA, NMFS, Commercial Fishery Research Development Act, R.I. Project. 3-279-R.

Summary: This report examines trawl damage to lobsters in Narragansett Bay in Rhode Island. The author found that 11% of lobsters sampled sustained injury within a short time

of capture. These injuries were assumed to be trawl related. Ninety-one percent of the lobsters caught were sublegal size. The 11% injury rate is compounded when lobsters are caught numerous times. Injury is also more severe immediately following molting periods.

Garrison, G. 1997. St. John, U.S. Virgin Islands fish trap study, 1992-1994. Unpublished Report. Biological Resources Division, USGS, Virgin Islands National Park.

Abstract: The Virgin Islands' multigear, artisanal fishery harvests over 100 species of reef-associated and open water fishes, with fish traps the most commonly used gear since at least the 1930s (Fiedler and Jarvis 1932; Idyll & Randall 1959; Dammann 1969). The gear is non-selective, efficient and requires little capital investment or expertise to use (Fiedler and Jarvis 1932; Idyll & Randall 1959; Dammann 1969). The traditional arrowhead trap in the Virgin Islands, once made of mangrove wood frames and hand-woven hoop vine mesh, is now commonly constructed of rebar and "chicken wire." Many fishers now construct large rectangular traps of welded rebar, vinyl clad wire mesh and zinc anodes because the traps last years longer and are believed to be more efficient.

Garrison, G. 1998. Reef fishes of St. John, U.S. Virgin Islands. Pages 325-327 *in* M.J. Mac, P.A. Opler, C.E. Puckett Haecker, and P.D. Doran, editors. Status and trends of the nation's biological resources. U.S. Department of the Interior, U.S. Geological Survey. Washington, D.C.

Summary: Author discusses the decline of reef fish in the U.S. Virgin Islands due to natural and human activities. Also, the author briefly discusses direct impacts to habitats from fishing operations.

Gaspar, M.B., C.A. Richardson, and C.C. Monteiro. 1994. The effects of dredging on shell formation in the razor clam *Ensis siliqua* from Barrinha, southern Portugal. Journal of the Marine Biological Association United Kingdom. Vol. 74:927-938.

Abstract: Shell growth of the razor clam *Ensis siliqua* (Mollusca: Bivalvia) from southern Portugal has been analyzed using both surface growth rings and internal shell microgrowth patterns. The growth rate estimated from an analysis of the growth rings is slower (von Bertalanffy growth, constant K=0·27) than that determined from the annual narrowing of the internal microgrowth patterns present in shell sections (K=0·65), although both methods predict a similar asymptotic length, L∞/ of 144·8 and 139·6 mm, respectively. The Barrinha razor clam population occurs in a heavily dredged area and an analysis of shell sections reveals the presence of a series of shell margin breaks consisting of deep clefts in the outer shell layer in which sand grains are embedded. It is suggested that these disturbances to shell growth are the result of repeated dredge damage. The frequency of the clefts increases with the size and age of the razor clams, and thus the shells provide a record of the intensity and frequency of unsuccessful capture or retrieval attempts. Cleft formation also occurred seasonally with the deposition of a small cleft during June, but these annual clefts were much less pronounced than those caused by dredge damage.

Gell, B. 1998. Bottom trawling on hard substrates. Pages 85-86 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: A commercial fisherman describes his fishing gear and its perceived effects on habitat.

Gerrodette, T., B.K. Choy, and L.M. Hiruki. 1987. An experimental study of derelict gillnets in the central Pacific Ocean. SWFC, NMFS, Honolulu Laboratory, Administrative Report H-87-18.

Gerrodette, T., B.K. Choy, and L.M. Hiruki. 1990. An experimental study of derelict gillnet fragments in the central Pacific Ocean. Pages 600-614 *in* R.S. Shomura and M.L. Godfrey, editors. Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFSC-154.

Abstract: An experiment designed to investigate the behavior and fate of derelict gillnet fragments was initiated in August 1986 in the central Pacific Ocean. Four fragments of high-seas squid gillnet, varying in length from 50 to 1,000 m, were observed closely for 3 days and subsequently tracked for up to 10 months by satellite. The net fragments changed length, shape, heading, and location under the influence of wind and current. The time a net remained open in a fishing configuration varied from hours to weeks, depending on its initial length. The nets drifted at an average speed of 15 km/day, but with frequent changes in direction, they remained in the general vicinity of the Hawaiian Archipelago. The complex movement of the net fragments means that predicting the drift of marine debris is an oceanographic problem that requires detailed knowledge of surface currents and wind.

Getmanenko, V.A., E.G. Yanovsky, and G.G. Grote. 1996. The impact of semi-automatic dredge trawling on zoobenthos of the East Sivash (the Azov Sea). Journal of Hydrobiology. Vol. 32(1):54-60.

Abstract: The influence of semi-automatic dredges used for fishing of the Black Sea flounder (*Platichthys flesus luscus*) on bottom biocenoses of the East Sivash (Azov Sea) were studied during 1985-1987. It was found that the impact on the flounder food organisms (zoobenthos) was insignificant as bottom sediments of the East Sivash are predominantly soft (silty). Average biomass of zoobenthos did not change markedly after dredging made 4 to 6 times a day.

Gibbs, P.J., A.J. Collins, and L.C. Collett. 1980. Effect of otter prawn trawling on the macrobenthos of a sandy substratum in a New South Wales estuary. Australian Journal on Marine and Freshwater Resources. Vol. 31:509-516.

Abstract: The effect of the use of otter trawling gear (of the type commonly employed for prawn fishing in New South Wales estuaries) on the macrobenthos of a sandy substratum was studied. The effect was assessed by direct quantitative sampling of the macrobenthos at three treatment sites and one control site on three occasions: before and after intensive

trawling, prior to the opening of the commercial prawning season, and again at the close of the commercial season. Underwater observations of otter trawl nets were also made. The similarity of sites was examined using numerical clustering techniques as a preliminary step to statistical comparisons of epifaunal, infaunal and 'whole' faunal community indices (No. of individuals, No. of species and Shannon species diversity) by analysis of variance. From both the quantitative sampling and underwater observations, it was shown that the otter prawn trawling gear used did not cause any detectable changes in the macrobenthic fauna of the trawl grounds.

Gilkinson, K., M. Paulin, S. Hurley, and P. Schwinghamer. 1998. Impacts of trawl door scouring on infaunal bivalves: results of a physical trawl door model/dense sand interaction. Journal of Experimental Marine Biology and Ecology. Vol. 224(2):291-312.

Abstract: The physical interaction of otter trawl doors with the seabed and the associated damage to infaunal bivalves were simulated in a laboratory test tank using a full-scale otter trawl door model. A scour test was performed in a sand testbed constructed to simulate a seabed on the northeastern Grand Banks of Newfoundland. As it scoured the testbed, the trawl door model created a 2 cm deep furrow, the pre-determined scouring depth of the trawl door shoe, and an adjacent berm of displaced frontal spoil along the trailing edge of the trawl door. Bivalves in the scour path at the sediment-water interface in two replicate experimental blocks were displaced to the berm, and 58% and 70% of displaced specimens which were originally buried were completely or partially exposed at the testbed surface. Out of a total of 42 specimens which had been placed in the scouring zone, two showed major damage. We propose a mechanism to explain the apparent anomaly of bivalve displacement with little associated damage based on sediment mechanics, and size and life position of infaunal bivalve species living on this bottom type.

Gislason, H. 1994. Ecosystem effects of fishing activities in the North Sea. Marine Pollution Bulletin. Vol. 29(6-12):520-527.

Abstract: The North Sea harbors an intensive fishery which removes between 30 and 40% of the biomass of exploited fish species each year. In addition fishing causes mortality of non-target species of benthos, fish, seabirds and mammals. Heavy towed gears disturb the uppermost layer of the seabed and cause mortality of benthos, while gillnets accidentally entangle seabirds and marine mammals. Unwanted catch is usually returned to the sea where it is eaten by scavenging species, such as seabirds. Since the North Sea ecosystem is highly complex and exhibits a high natural variability, it has proved difficult to isolate the longer term consequences of these impacts. Until more is known about the environmental impact of fisheries management, action (or no action) will have to be agreed upon in the light of considerable scientific uncertainty.

Gittings, S.R., T.J. Bright, and B.S. Holland. 1990. Five years of coral recovery following a freighter grounding in the Florida Keys. Pages 89-105 *in* Diving for Science 1990. Proceedings of the American Academy of Underwater Sciences Tenth Annual Scientific Diving Symposium, October 4-7, 1990. University of South Florida, St. Petersburg, Florida.

Abstract: Coral community recovery has been followed for five years since the destruction of a portion of Molasses Reef, Key Largo National Marine Sanctuary, by a 122 meter freighter, which ran aground in August 1984. Underwater repetitive and random photographic methods, visual counts, and artificial substrates were used between 1984 and 1989 to assess coral populations, cover, recruitment, and the fate of coral colonies damaged by the grounding. We report here on data and results from random photographic methods and underwater visual censuses. Coral abundances had redeveloped in 1989 from virtually 0% in an area of major impact to a level approximately 65-78% of supposed pre-impact populations though colonies were very small. Cover of hard corals in 1989 was 22% of pre-impact cover, and gorgonian cover approximately 40% of pre-impact cover and tend to have high rates of recruitment. Coral recruitment has been dominated by species which brood larvae. These species are also numerical dominants in mature surrounding communities. Though recovery would occur naturally over an extended period of time, transplantation could be used as a way to increase the relative abundance of species which only rarely have been found as coral recruits. These include primarily the large massive corals conspicuous in typical mature reef communities. Most of these species are broadcast spawners, which have long planktonic stages, low recruitment rates, and low relative abundances in mature communities. Transplantation also restores the habitat complexity essential to the development of the associated invertebrate and fish assemblages characteristic of these diverse ecosystems.

Glémarec, M., Y. LeFaou, and F. Cuq. 1996. Long-term changes of seagrass beds in the Glenan Archipelago (South Brittany). Oceanologica Acta. Vol. 20(1):217-227.

Abstract: Aerial photographs and *in situ* data of the Glenan archipelago permit the establishment of a cartography of its *Zostera marina* seagrass beds. Due to the exceptionally clear water, it was possible to distinguish submerged structures, such as rocks, sand dunes, maerl beds and seagrass meadows on the photographs. The distribution of *Zostera* meadows was incorporated into a geographical information database through scanning, and then compared with historical data. Ten aerial photographic surveys, made over a sixty-year period from 1932 to 1992, were available. The earliest of these surveys showed the seagrass beds to be in good condition. Low cover in 1952 suggests that the *Zostera* meadows within the studied area were subject to severe destructions, presumably due to the "wasting disease", which caused a general breakdown of the North-Atlantic populations during the 1930s. During the 1970s, the distribution of *Zostera* beds increased; this was followed by a gradual decline during the 1980s and early 1990s. For the investigation of the environmental circumstances under which *Zostera* beds are fluctuating, the Glenan site is unique. This site being relatively remote from direct anthropogenic disturbances (light irradiance decline, sewage inputs), the causes of such fluctuations during this 60-year period can be more easily identified. *Z. marina* is a boreal species naturally affected by climate changes and in particular by global warming, which was at a maximum during the 1940s and 1950s. Various human activities, such as scallop dredging, maerl exploitation, yachting and anchoring, should also be considered. However, these anthropogenic disturbances were of limited importance in comparison with the dramatic decline and recovery of the seagrass beds as a result of climate fluctuations.

Glude, J.B. 1954. Observations on the effect of a Maryland soft clam dredge on the bottom. U.S. Fish and Wildlife Service, Manuscript. 4 p.

Glude, J.B., and W.S. Landers. 1953. Biological effects on hard clams of hand raking and power dredging. USFWS Special Science Reports on Fisheries, 110:1-43.

Abstract: The Division of Fish and Game of the Rhode Island Department of Agriculture and Conservation has the responsibility of enforcing laws regulating areas which may be fished by dredging as well as the dredging catch limit of 30 bushels per day. Difficulties in enforcing these laws, the dredgers' demands for additional areas, and controversies between power and hand diggers resulted in a request by the Division of Fish and Game that the Fish and Wildlife Service investigate the problem. Since this controversy has been encountered in other States, it was decided that the Service should undertake an experiment to determine the relative biological effect of power-dredging and hand-raking upon a population of hard-shell clams.

Glynn, P.W. 1994. State of coral reefs in the Galapagos Islands: natural versus anthropogenic impacts. Marine Pollution Bulletin. Vol. 29(1-3):131-140.

Abstract: Before the 1982-1983 El Niño disturbance event low diversity coral communities and small, actively accreting coral reefs were present on Galapagos shallow shelves in areas protected from strong upwelling. Prolonged El Niño 1982-1983 sea warming resulted in 95-99% coral mortality, virtually eliminating corals throughout the archipelago. The population size of an ubiquitous, large sea urchin species (*Eucidaris thouarsii*) was unaffected by the warming event. Urchins later showed increased abundance on dead coral colonies and frameworks, and caused bioerosion that exceeded the net calcification capacity of disturbed reefs. Known human impacts on corals result mainly from anchor damage, the collection of corals for sale as curios, and mechanical damage resulting from the activities of fishermen. An evaluation of natural and anthropogenic damage to Galapagos coral communities indicates that natural disturbances, especially strong ENSO episodes, are of greatest concern. However, rapidly increasing human pressures could exacerbate the recovery capacity of naturally perturbed coral communities.

Godcharles, M.F. 1971. A study of the effects of a commercial hydraulic clam dredge on benthic communities in estuarine areas. State of Florida Department of Natural Resources Marine Resources Laboratory Technical Series No. 64.

Abstract: A Maryland soft-shell escalator clam dredge, the R/V *Venus* was used in a systematic sampling program to study its effects on representative bottom types (habitats) in Tampa Bay and to conduct clam exploration in Tampa and Boca Ciega Bays, the Cedar Keys area, and Tarpon Springs vicinity. Six experimental stations established in Tampa Bay were visually inspected and sampled with trynet before dredging and at various intervals after dredging. Benthic plug samples were taken at the final sampling. Sediment samples were also taken to assess textural changes by particle size analyses. Collected fauna were identified, counted, and in most instances, measured. After more than a year no recolonization of sea grasses, *Thalassia testudinum* and *Syringodium filiforme*, occurred in any dredged area. Some regrowth of *Caulerpa prolifera* was observed 86 days after

dredging. No increase of clam set was detected during the study. Analyses of trynet hauls showed no faunal variations between dredge and control plots at any time after dredging and benthic plug samples revealed marked faunal differences at only one station. Redredging with the R/V *Venus* revealed no faunal declines except for a marked decrease in quahogs, *Mercenaria campechiensis*, at one station. Dredgehead water jets penetrated the substrate 18 inches and uprooted all vegetation. Dredge tracks remained visible from one to 86 days and some spots remained soft for over 500 days. Two stations showed a decrease of silt/clay particles immediately after dredging but only one showed a sustained decrease. The greatest density of clams, *Mercenaria campechiensis*, was found in Tampa Bay and considerable numbers of surf clams, *Spisula raveneli*, were found on the Gulf side of Mullet Key. The greatest production of clams (*M. campechiensis*) in the Cedar Key survey occurred at the Suwannee Reef and in the Tarpon Springs survey north of Honeymoon Island. Two modifications to the harvester are recommended to increase efficiency and retard substrate damage. It is also recommended that these harvesters be permitted to operate in Florida on a permit basis and be prohibited in grassy areas.

Gomez, E.D., A.C. Alcala, and H.T. Yap. 1987. Other fishing methods destructive to coral. Pages 65-75 *in* Human Impacts on Coral Reefs: Facts and Recommendations. Antenne Museum, French Polynesia.

Summary: This article describes the muro-ami and kayakas fishing technique, and their possible impacts on corals. It also describes the use of fish traps, and their impacts. Finally, the article makes recommendations to limit damage to coral reefs from these destructive fishing practices.

Gomez, E.D., P.M. Alino, H.T. Yap, and W.Y. Licuanan. 1994. A review of the status of Philippine reefs. Marine Pollution Bulletin. Vol. 29(1-3):62-68.

Abstract: Since 1979, the status of Philippine reefs has been periodically updated. While conditions of the reefs during the early surveys were assessed in terms of live coral cover *per se*, the 'coral mortality index' was applied to the sets of data collected during the past 7 years which may be a better gauge in determining the health of the reefs. Generally, most reefs surveyed are in fair condition. Major destructive factors described are sedimentation and siltation from coastal development and activities inland, illegal and destructive methods of fishing, and overfishing. If the reefs are to continue to provide for the present and future users, the ecological processes that render them productive must be maintained through integrated approaches of coastal area management.

Goñi, R. 1998. Ecosystem effects of marine fisheries: an overview. Ocean and Coastal Management. Vol. 40(1):37-64.

Abstract: Most fisheries literature avoids speaking about ecosystem impacts of fishing, either because impacts are not demonstrated or because a causal relationship between impacts and fishing cannot be formally established with the available information. However, there is mounting evidence that fishing has undesired effects in the marine ecosystems. This overview examines the wide ecosystem effects of fishing, describing and illustrating the potential unintended effects of the main fisheries of the world. An operational framework

for classifying the effects of fishing in terms of the mechanisms generating the effects is provided. The focus and, to a large extent, the recourse to examples is on those fisheries for which the impacts of fishing have been best studied such as those in the North Atlantic and the Northeast Pacific. Ecosystem effects are divided into direct and indirect: direct effects include the fishing mortality exerted on target populations (overfishing), the fishing mortality sustained by non-target populations (bycatch), and the physical impacts caused by towed gears on benthic organisms and on the seabed. Indirect effects include impacts mediated by biological interactions, the environmental effects of dumping discards and organic detritus (offal), and the mortality caused by lost gear (ghost fishing).

Goodwin, L. 1978. Some effects of subtidal geoduck (*Panope generosa*) harvest on a small experimental plot in Puget Sound, Washington. Washington Department of Fisheries. Progress Report No. 66. 21 p.

Goodwin, L. 1997. Revision of the Environmental Impact Statement of the Puget Sound Commercial Geoduck Fishery, 1985. Washington State Departments of Fish and Wildlife of Natural Resources. 66 p. plus appendices and tables.

Goodwin, L., and W. Shaul. 1978. Studies of the mechanical escalator harvester on a subtidal clam bed in Puget Sound, Washington. Washington Department of Fisheries. Progress Report No. 53. 23 p.

Goodwin, L., and W. Shaul. 1980. Studies of the mechanical escalator harvester on an intertidal beach near Port Townsend, Washington. State of Washington, Department of Fisheries, Progress Report No. 119. 26 p.

Gordon, D.C., Jr., P. Schwinghamer, T.W. Rowell, J. Prena, K. Gilkinson, W. P. Vass, and D.L. McKeown. 1998. Studies in eastern Canada on the impact of mobile fishing gear on benthic habitat and communities. Pages 63-67 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Abstract: Since 1990, the Department of Fisheries and Oceans has been conducting an experimental program on the impacts of mobile fishing gear on benthic ecosystems in Atlantic Canada. Much of the initial effort went into developing the imaging and sampling technology needed to conduct controlled disturbance experiments on continental shelf benthic ecosystems. The major accomplishment to date has been a three-year experiment (1993-1995) on the effects of otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland (120-146 m depth). Each year, three 13-km corridors were trawled 12 times with an Engel 145 otter trawl equipped with rock-hopper footgear, which created a disturbance zone on the order of 120 to 250 m wide. Side scan sonar, RoxAnn™, DRUMS™, and video imagery observations clearly indicated that the experimental trawling changed physical habitat structure, but sediment grain size was not affected. The biomass of epibenthic organisms in the trawl bycatch decreased significantly with repeated trawling, and an influx of scavenging snow crabs was observed after six trawl sets (approximately 10-12 h). Total biomass of invertebrates, as sampled by an epibenthic sled, was on average 25 percent lower in trawled corridors than in adjacent, untrawled reference corridors, and this

difference was statistically significant. The biomass of snow crabs, sand dollars, soft corals, and brittle stars was significantly lower in trawled corridors. In addition, sand dollars, sea urchins, and brittle stars showed significant levels of physical damage. No significant effects of trawling were apparent in the four dominant mollusc species collected by the epibenthic sled. An extensive series of grab samples was also collected, and data are currently being analyzed. Two new mobile gear experiments are being planned for the Scotian Shelf. The first will be another otter trawling experiment on a gravel bottom area on Western Bank. The second will be a hydraulic clam dredging experiment on Banquereau Bank.

Gorzelany, J.F. 1998. Unusual deaths of two free-ranging Atlantic bottlenose dolphins (*Tursiops truncatus*) related to ingestion of recreational fishing gear. Marine Mammal Science. Vol. 14(3):614-617.

Abstract: While fishing gear entanglement by cetaceans has been well documented, limited records exist related to fishing gear ingestion. In a survey of major institutions involved in the collection of stomach content information from stranded cetaceans, only 43 cases of debris ingestion by 16 different species were documented from 1,790 stomachs examined; of these, few involved the ingestion of fishing gear by free-ranging dolphins. In five documented cases where fishing gear ingestion was described, the foreign material (primarily fish hooks) was not implicated as the cause of death. Similar findings have been documented in Texas (nine cases of foreign material ingestion, including fishing gear, out of 1,542 stomachs examined, Haubold et al. 1994). Evidence of fishing gear (loose fish hooks) was found in only a small percentage (<0.02%) of more than 700 bottlenose dolphin stomachs collected between 1973 and 1996 from the southeastern United States (N. Barros, personal communication). Some cases may have been reported in more than one of the summaries described above; thus the proportion of documented cases involving fishing gear ingestion is extremely small. In contrast, two cases of fishing gear ingestion, leading directly or indirectly to the death of two of 23 dead-stranded Atlantic bottlenose dolphins examined during 1995, were documented along the central Florida west coast. On 27 August 1995 an adult female (239 cm, 36 yr old) bottlenose dolphin, MML9514, was discovered floating dead in Sarasota Bay, Florida. The animal was freshly dead and in good nutritional condition. Internal examination revealed a distention of the esophagus and a partially digested sheepshead (Archosargus probatocephalus) at the entrance to the forestomach. Further examination revealed a fishing hook (size equivalent = 1/0) embedded in the left side of the fish.

Goudey, C.A., and G. Loverich. 1987. Reducing the bottom impact of Alaskan groundfish trawls. Pages 632-637 *in* Proceedings Oceans '87. The Ocean -An International Work Place. Halifax, Nova Scotia. September 28 - October 1, 1987.

Abstract: The impact on the Alaskan Crab resources of groundfish trawls used in the Bering Sea Yellowfin Sole fishery has recently become a controversial issue. Excessive crab by-catch and suspected high rates of mortality have threatened the continuation of this important trawl fishery. To address the problem, scale models of the trawl gear in present use were tested in the 22 foot wide circulating water channel and the 52 foot wide tow tank at the David Taylor Naval Ship R&D Center. This paper describes how these scale model experiments were used to study the effect of trawl design and rigging adjustments on bottom-

tending performance. Through the proper selection, rigging, and operation of trawl system components, it was found that sustained contact with the bottom of most portions of the gear can be minimized.

Graham, M. 1955. Effect of trawling on animals of the sea bed. Papers in Marine Biology and Oceanography, Supplement to Vol. 3 of Deep-Sea Research. p. 1-6.

Abstract: Damage to fish food species trawled over in the main area of the North Sea plaice, cannot be serious; otherwise there would be a noticeable difference where trawling is impossible, as close to light vessels or among the under-water sand dunes. Direct attack, covering the ground some five or six times over on the average, did break full-grown Heart Urchins, *Echinocardium cordatum*, and possibly swimming or paddler crabs (*Portunus depurator*), but appeared not to damage *Ophiura albida*, nor any of the fragile-shelled plaice food animals: razor shells, *Mactra* or *Tellina*. Those forms were not very abundant, but all the 15 specimens taken of fragile animals (other than urchins and paddlers) were undamaged. Such large urchins as were damaged were not plaice food. Doubtless *Sabellaria* habitations (ross) would be broken and laid low, but they would probably soon be reconstructed. Trawling, even with a tickler chain, seems again to escape the so viable indictment.

Greene, L.E., and J.M. Shenker. 1993. The effects of human activity on the temporal variability of coral reef fish assemblages in the Key Largo National Marine Sanctuary. Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 3(3):189-205.

Abstract: A visual assessment method, called Discrete Group Censussing, was used to assess and monitor five coral reef fish assemblages in the Key Largo National Marine Sanctuary, Florida, USA. Samples were obtained quarterly from Winter 1988 to Autumn 1990 to investigate a possible relation between the variability of reef fish assemblages and human disturbance. Two types of disturbance were studied: a ship grounding that occurred 4 years previous to the study, and intensive, recreational snorkel and SCUBA diving. These disturbances appeared to have no short-term effect on the temporal variability of the reef fish assemblages during the study period. Furthermore, the assemblages at all five study sites appeared to be extremely stable over the 2 year period of the study. These results support the theory that coral reef fish assemblages are highly ordered and stable over relatively large spatial scales. The Discrete Group Censussing visual assessment method was found to be a valuable and easily applied tool for the nondestructive *in situ* monitoring of reef fish assemblages on coral reefs.

Greenstreet, S.P.R., F.B. Spence, A.M. Shanks, and J.A. McMillan. 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. II. Trends in fishing effort in the North Sea by UK registered vessels landing in Scotland. Fisheries Research. Vol. 40:107-124.

Abstract: North Sea fishing effort data (expressed as hours fishing) for UK vessels landing in Scotland over the period 1960-1994 are analyzed. Long-term temporal, spatial and seasonal trends in the use of particular gears are described. Pelagic fishing effort trends were clearly related to changes in the target species. Pelagic effort, mainly pair-trawling targeted at sprats in the 1960s and early 1970s, declined markedly in the late 1970s. In the early

1980s pelagic fishing effort increased again, but was predominantly purse-seining targeted at herring. The spatial distribution of pelagic effort shifted northwards, and changed from winter to summer. Demersal fishing effort varied little over three decades, but marked changes in the type of gear used were apparent. The use of seine nets decreased, particularly in the northwestern North Sea, and otter trawl fishing increased. The spatial distribution of demersal effort is now more widespread than in earlier years, but there has been little change in seasonal patterns.

Gruffydd, L.L.D. 1972. Mortality of scallops on a Manx scallop bed due to fishing. Journal of the Marine Biological Association United Kingdom. Vol. 52:449-455.

Abstract: In 1965/6, Manx scallop dredgers removed about one third of the population of the bed being investigated. At least another 10%, possibly as many as 56.5% died through natural mortality and indirect fishing mortality. A rough estimate puts the efficiency of the dredges at about 15%. Mortality in the laboratory of scallops damaged during capture was up to 13 times greater than the mortality of undamaged individuals. An improved dredge design to minimize damage would reduce such mortalities which must occur amongst undersized discards.

Guard, M., and M. Masaiganah. 1997. Dynamite fishing in southern Tanzania, geographical variation, intensity of use and possible solutions. Marine Pollution Bulletin. Vol. 34(10):758-762.

Abstract: The use of dynamite to kill marine fish has been reported in Tanzania since the 1960s. Today it is one of the most common methods used and because of its high intensity virtually all coral reefs along the coast of Tanzania are now being degraded at an unprecedented and alarming rate. One of the main reasons attributed to its continual use is local poverty. However, in reality it is not the fishermen who make large amounts of money but the dealers and unknown boat owners who by providing dynamite at a relatively low cost are able to ensure its use is sustained. This problem is further underpinned by ineffective law enforcement, inadequate legislation, insufficient regulation of dynamite supplies and a prevailing opinion that corruption will prevent any effective action being taken. Nevertheless, what is required is immediate action otherwise in the near future many Tanzanian coastal communities will experience severe declines in reef biodiversity and fish stocks such that local incomes will dwindle still further and a major food source could be lost.

Gucinski, H. 1982. Sediment suspension and resuspension from small craft induced turbulence. EPA 600/3-82-084. 61 p.

Abstract: The objective of this study was to determine if small vessels, operating in shallow waters, have any measurable effects in producing increased turbidities by the resuspension of fine sediments which may affect submerged aquatic vegetation (SAV). A two-phase approach was used, consisting of field tests in a suitable sub-estuary of the Chesapeake Bay, and laboratory measurements of propeller effects. During field trials, two different vessel types were used to make passes at set speeds over known water depths. Before and after measurements of light extinction, transmission, and gravimetric suspended sediment

determinations were used to identify effects. Laboratory experiments were conducted to delineate propeller contribution to possible resuspension; this was done using laser-doppler anemometry to map the turbulence field produced by propeller action.

Guillén, J.E., A.A. Ramos, L. Martínez, and J.L. Sánchez-Lizaso. 1994. Antitrawling reefs and the protection of *Posidonia oceanica* (L.) Delile Meadows in the western Mediterranean Sea: demand and aims. Bulletin of Marine Science. Vol. 55(2):645-650.

Abstract: In the westem Mediterranean Sea, *Posidonia oceanica* meadows have a great ecological and fishing interest; in spite of this fact, in several areas, meadows have been deteriorated due to multiple factors, illegal trawling fishing being one of the most relevant causes. To work out the already mentioned problem, an antitrawling artificial reef was installed in the Marine Reserve of Tabarca (Spanish SE) in 1989, which has eliminated illegal trawling, and thus it has produced a slight recovery of the meadow. Similarly, following the example of Tabarca, another antitrawling reef was placed in El Campello, where about 45% of the total area of *P. oceanica* meadow had been disturbed by illegal trawling. The reef consists of 358 concrete modules giving protection to 540 ha of the meadow.

Guillory, V. 1993. Ghost fishing by blue crab traps. North American Journal of Fisheries Management. Vol. 13:459-466.

Abstract: Ghost fishing by abandoned or lost traps for blue crab *Callinectes sapidus* was evaluated experimentally in the Timbalier Bay estuary, Louisiana. An average of 12.8 blue crabs per trap were captured by the initial baiting, and an additional 34.9 blue crabs later entered each subsequently unbaited trap; of the total captured, 25.8 died and 21.7 escaped per trap. The turnover of blue crabs was fairly rapid; two-thirds of blue crabs entering the trap either died or escaped within 2 weeks. The number of blue crabs per trap varied seasonally and was a function of the comparative rates of ingress, mortality, and escapement. Small blue crabs (<120 mm carapace width) were more likely to escape, whereas large individuals (>140 mm) tended to remain in the traps and eventually die. Management measures to ameliorate the adverse effect of ghost fishing on the blue crab resource include escape vents and biodegradable panels.

Hall, S.J. 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. Oceanography and Marine Biology: an Annual Review. Vol. 32:179-239.

Abstract: This review examines the physical and biological processes which move marine intertidal and subtidal sediments and considers available information on the consequences of physical disturbance for benthic communities. The agents examined include waves and currents, bioturbation, fishing and dredging and the intensities and scales upon which the various processes operate is considered. The inter-relationships between the various disturbance processes are also examined.

Hall, S.J. 1999. The Effects of Fishing on Marine Ecosystems and Communities. Blackwell Science. Oxford, United Kingdom. 274 p.

Summary: This book is a very detailed exploration of fishing effects on marine ecosystems and communities. Chapters include trends in world fisheries and the essence of the problem, bycatch and discards, effects of trawling and dredging on the seabed, fishing at the coastal margins, the response of predators, prey, and competitors to the removal of target species, three case studies of demersal fish populations, ways of looking at system level responses, ecosystem health, function and stress, and mitigating effects of fisheries management.

Hall, S.J., D.J. Basford, and M.R. Robertson. 1990. The impact of hydraulic dredging for razor clams *Ensis* sp. on an infaunal community. Netherlands Journal of Sea Research. Vol. 27(1):119-125.

Abstract: The impact of fishing for razor clams (*Ensis* sp.) by hydraulic dredging on the associated infaunal community has been examined in a manipulative field experiment executed in autumn in a Scottish sea loch at 7 m depth. Infaunal samples from replicate fished and unfished plots were examined after 1 and 40 days. Major effects on the total number of individuals were observed immediately after fishing and sign test revealed a reduction in the abundance of a significant proportion of species in fished areas. However, after 40 (mostly stormy) days no effects of fishing could be detected and no visible signs of fishing remained on the sea bed. We hypothesize that active migration into the water column and passive suspension during wind- and tide-induced sediment transport dilute localized effects and conclude that, given the restricted depth at which fishing is possible at present, hydraulic dredging is unlikely to have persistent effects on most of the infaunal community in most habitats. The effects on long-lived bivalve species could, however, be more serious.

Hall, S.J., M.R. Robertson, D.J. Basford, and S.D. Heaney. 1993. The possible effects of fishing disturbance in the northern North Sea: an analysis of spatial patterns in community structure around a wreck. Netherlands Journal of Sea Research Vol. 31 (2):201-208.

Abstract: The spatial patterns in benthic community structure have been examined around a wreck located in a heavily fished area of the northern North Sea. Marked spatial structures in both sediment characteristics and the infaunal community were detected. The pattern observed is consistent with the presence of either linear waves of coarse and fine sediment or with concentric bands with the wreck at the center. Whichever of these alternatives apply, such results are unlikely to be the result of fishing disturbance. Infaunal community structure showed a close relationship with grain size and organic carbon content but, in contrast to most other studies, individuals and taxa were more abundant in coarser sediments. This reversal of the usual relationship with grain size and the consistency of the relationship with organic carbon content suggest that it is food availability, rather than particle size that is a primary determinant of community structure in this habitat. The utility of wreck studies for examining the effects of fishing on benthic communities is discussed in the light of our results.

Hall, S.J., and J.M. Spencer. 1995. Evaluation of the direct and indirect impact of fishing gears on the substratum and on the benthos. Final project report to DGXIV (Directorate General). European Commission, Brussels, Belgium. PEM\93\08.

Hall, S.J., and M.J.C. Harding. 1997. Physical disturbance and marine benthic communities: the effects of mechanical harvesting of cockles on non-target benthic infauna. Journal of Applied Ecology. Vol. 34:497-517.

Summary: 1) The effects of physical disturbance processes on marine benthic communities remain an issue of considerable theoretical and practical importance, particularly with respect to the impact of fisheries activity and possible conflict with wildlife conservation objectives. One area where particular concern has been raised is with respect to the effects of mechanical harvesting of cockles (*Cerastoderma edule*) on non-target benthic infauna in intertidal communities. 2) This paper describes the results of manipulative field experiments which examine the effects of disturbance by two mechanical cockle harvesting methods, hydraulic suction dredging and tractor dredging. 3) Although the suction dredge experiment revealed some statistically significant effects, taken as a whole the results indicated that the faunal structure in disturbed plots recovered (i.e. approached that of the un-disturbed controls) by 56 days. This occurred against a background of consistent increases in the abundance of many taxa in both treatments, which we interpret as the normal seasonal response of the community. 4)The tractor dredge experiment revealed fewer statistically significant effects than the suction dredge experiment, and recovery from disturbance occurred against a background of general seasonal decline in the abundance of the fauna. From the available evidence the most likely mechanism of recovery was through the immigration of adults into disturbed areas. 5) We conclude that mechanical harvesting methods impose high levels of mortality on nontarget benthic fauna, but that recovery of disturbed sites is rapid and the overall effects on populations is probably low. Although our results suggest that tractor dredging has less effect than suction dredging, this result is most likely to be a consequence of the different times of year in which the experiments were conducted. Thus, for this location, we do not believe that a distinction can be made between the effects of the two methods. Although experimental manipulations cannot be conducted on comparable spatial scales to real fishing activity, we believe these results probably do not represent a major under-estimate of recovery times for intertidal habitats similar to the one chosen for his study.

Hall-Spencer, J.M., C. Froglia, R.J.A. Atkinson, and P.G. Moore. 1999. The impact of Rapido trawling for scallops, *Pecten jacobaeus* (L.), on the benthos of the Gulf of Venice. ICES Journal of Marine Science. Vol. 56:111-124.

Abstract: Rapido trawls are used to catch sole around the coast of Italy and to catch scallops in the northern Adriatic Sea but little is known about the environmental impact of this gear. Benthic surveys of a commercial scallop ground using a towed underwater television (UWTV) sledge revealed an expansive area of level, sandy sediment at 25 m characterized by high population densities of scallops (2.82 m^{-2} *Aequipecten opercularis* but fewer *Pecten jacobaeus*) together with ophiuroids, sponges, and the bivalve *Atrina fragilis.* Rapido trawls were filmed in action for the first time, providing information on the selectivity and efficiency of the gear together with its impact on the substratum and on the benthos. The trawls worked efficiently on smooth sand with ca. 44% catch rate for *Pecten jacobaeus*, of which 90% were >7 cm in shell height. Most organisms in the path of the trawl passed under or through the net; on average by-catch species only formed 19% of total catch by weight. Of the 78 taxa caught, lethal mechanical damage varied from <10% in resilient taxa such as

hermit crabs to >50% in soft-bodied organisms such as tunicates. A marked plot surveyed using towed UWTV before, then 1 and 15 h after fishing by Rapido trawl showed clear tracks of disturbed sediment along the trawl path where infaunal burrow openings had been erased. Abundant, motile organisms such as *Aequipecten* showed no change in abundance along these tracks although scavengers such as *Inachus* aggregated to feed on damaged organisms. There were significant decreases in the abundance of slow-moving/sessile benthos such as *Pecten*, *Holothuria*, and *Atrina*. Juvenile pectinids were abundant on the shells of *Atrina*. The introduction of a scheme of areas closed to trawling would protect highly susceptible organisms such as *Atrina* and enhance the chances of scallop recruitment to adjacent areas of commercial exploitation.

Hall-Spencer, J.M., and P.G. Moore. 2000. Impact of scallop dredging on maerl grounds. Pages 105-117 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) The single passage of Newhaven scallop dredges can bury and kill 70% of the living maerl in their path and extract *c.* 85% of the scallops present. 2) On a dredge track, most of the flora and megafauna to a depth of 10 cm beneath the maerl sediment surface is damaged. Only small, strong-shelled animals are resistant to damage within that stratum. 3) For every 1 kg of scallops caught, 8-15 kg of other organisms are captured from maerl habitats. 4) Dredge tracks remain visible for up to 2.5 years in maerl habitats. 5) Scallop dredging has indirect effects through sediment redistribution, altered habitat structure and modified predator/prey relationships. 6) Maerl is a 'living sediment'; it is slow to recover from disturbance by towed gear due to infrequent recruitment and extremely slow growth rates. 7) Maerl has an associated deep-burrowing megafauna that is resistant to towed gear impact. 8) Pristine maerl communities are highly susceptible to scallop dredging with long-term (>4 year) reductions in the population densities of epibenthic species and decadal consequences for the maerl itself. 9) Previously impacted maerl beds support modified benthic communities that recover more quickly from scallop dredging (1-2 years).

Hamon, D., P. Berthou, and S. Fifas. 1991. A study of the effects of fishing towed gears in the coastal zone. Case trawling in the Bay of Saint-Brieuc (Western Channel). ICES CM 1991/B:27. 15 p.

Abstract: This study is a component of a multidisciplinary programme initiated by IFREMER (Institut Francais de Recherche pour l'Exploitation de la Mer), in 1990 to assess effects of bottom fishing gears (shellfish dredges and bottom trawls) on benthic communities and harvested available resources. The bay of Saint-Brieuc has been choosen as an experimental site of this program. This area is concerned by intensive shellfish dredging (especially for scallop fishing) and trawling activities. A first experiment was carried out to evaluate the catchability of an otter trawl similar to those used in the Bay of Saint-Brieuc on some different seabeds. Furthermore, immediate harmful effects induced by beam trawling have been estimated by benthos sampling and submarine observations (diving, underwater video) in an experimental zone. Preliminary results suggest: the ability of the gear to fish scallops in a great quantity; a low short-term mortality of scallops even on juveniles (size between 20 and 80 mm); a fishing catch essentially represented by juveniles or fish less than the minimum authorized size, during survey (end of March to beginning of April).

Harris, A.N., and I.R. Poiner. 1991. Changes in species composition of demersal fish fauna of Southeast Gulf of Carpentaria, Australia, after 20 years of fishing. Marine Biology. Vol. 111(3):503-519.

Abstract: The changes in a tropical demersal fish community in the southeast Gulf of Carpentaria, Australia, were examined by comparing the results of a survey undertaken in 1964 before the area was fished, with two surveys in 1985 and 1986 after 20 yr of commercial trawl fishing. The numerical abundance of 52 of the 82 fish taxa had not changed significantly, but that of 18 had decreased while 12 had increased. One taxon (*Paramonacanthus* spp.) had decreased by more than 500 times and another (*Saurida micropectoralis*) had increased substantially in abundance. The changes occurred throughout the area surveyed, but the largest changes were offshore. In the pre-trawling community most taxa were caught mainly during the night, while in the post-trawling community most were caught in the same numbers during day and night. In 10 of the 30 taxa that changed in abundance, changes were within a family and could not be explained. For the remaining 20, the changes could be related to their position in the water column: benthic taxa decreased and bentho-pelagic taxa increased. The changes were assessed in relation to fishing effort, and changes in the mud content of the substrate in the study area. Although the changes did not correlate with the fishing effort among three zones in the study area, it is suggested that fishing effort and discarding of the by-catch caused the change in 18 taxa. The magnitude of the decreases of some species might be related to changes in the sediment or possibly other long-term environmental change. There was also a change in the diel behaviour in the fish community that perhaps may be related to the effects of fishing on a tropical multispecies fish community.

Harrison, P.H., K.W. Strong, and K.A. Jenner. 1991. A review of fishery related seabed disturbance on the Grand Banks of Newfoundland. Final contractors report to the Department of Fisheries and Oceans from Maritime Testing (1985) Ltd., Dartmouth, Nova Scotia.

Abstract: This report summarizes information on fishery-related seabed disturbance collected from sidescan sonograms of the seabed of the Grand Banks of Newfoundland. All of the data bases examined were originally obtained for other purposes. All of the observed fishing disturbances was attributable to groundfish trawls and was best preserved on areas of featureless seabed or, on bedforms located in low energy environments. Very little disturbance was observed in regions where the seabed environment was sufficiently energetic to allow the development of bedforms. No information could be collected on rates of degradation of gear tracks nor could any data be obtained on the biological impact of such sources of disturbance. As well, the data base did not permit any estimations of percent of seabed actually disturbed by fishing gear on either a spatial or annual basis. Such information is required before any potential impacts of seabed disturbance by fishing activity can be addressed.

Hartge, P. 1998. Boating induced turbidity. *In* R.E. Crawford, N.E. Stople, and M.J. Moore, editors. The environmental impacts of boating; proceedings of a workshop held at Woods Hole Oceanographic Institution, December 7-9, 1994. Technical Report. WHOI-98-03.

Summary: This paper is part of a presentation given at a workshop on the environmental impacts of boating. The subject of the presentation was on the regulations that the Maryland Department of Natural Resources placed on boating which include closing certain areas to boating and placing speed limits in other areas. These regulations have benefitted waterways by reducing the amount of sediment that is resuspended thus benefitting seagrass.

Haskin, H.H., and E.S. Wagner. 1986. Assessment of mortalities in surf clam due to dredging, sorting and discard. Grant in Aid Completion Report, National Marine Fisheries Service, Gloucester, Massachusetts.

Hastings, K., P. Hesp, and G.A. Kendrick. 1995. Seagrass loss associated with boat moorings at Rottnest Island, Western Australia. Ocean and Coastal Management. Vol. 26:225-246.

Abstract: Loss of seagrasses caused by mooring damage at Rottnest Island, Western Australia, was studied using aerial photographs taken between 1941 and 1992. The temporal decline of seagrass beds damaged by moorings was studied by comparing areal coverages of seagrasses and sand patches, and increases in the length of the exposed seagrass edge within seagrass beds. The study concentrated on Rocky Bay and Thomson Bay where the bulk of permanent moorings are located. Rocky Bay is more exposed to the prevailing westerly swell direction and Thomson Bay is a protected east facing bay. The loss of seagrasses associated with moorings in Rocky Bay has been dramatic, with 18% of seagrass area lost between 1941 and 1992, and 13% between 1981 and 1992. The exposed edge of the beds increased by 230% between 1981 and 1992. Sand patches associated with moorings have coalesced in the shallow central west part of the bay. The change from single weighted swing moorings to three chained cyclone moorings has resulted in greater loss of seagrasses. Single cyclone moorings produce three circular holes in the seagrass bed. The areal loss recorded from Thomson Bay was less than 5%, yet the exposed edge of the seagrass beds doubled between 1941 and 1992. Fragmentation of the bed was visible near heavy use areas. Some regrowth was recorded to the north of the main ferry jetty where the sedimentary environment is depositional. The effects of moorings on seagrasses at Rottnest Island varied from devastating in Rocky Bay to small in Thomson Bay. The differences seem to be related to exposure to prevailing swell and whether the environments are erosional or depositional. Thus a single management protocol, such as cyclone moorings versus swing moorings, is inappropriate. Physical environments need to be assessed before determining the number and types of moorings allowable in bays at Rottnest Island.

Havon, D.S. 1970. A study of hard and soft clam resources of Virginia. USFWS, Commercial Fishery Research Development, Act. Ann. Rep., Contribution No. 3-77-R-1. 69 p.

Heesen, H.J.L. 1988. Fishery effects. Pages 538-550 *in* W. Salomons, E.K. Duursma, B.L. Bayne, and U. Forstner, editors. Pollution of the North Sea: An Assessment. Springer-Verlag, Berlin.

Abstract: The North Sea ecosystem is very complex, and within this system innumerable interactions exist. The fisheries somehow influence the ecosystem, but is themselves influenced by technical developments, socio-economic circumstances and natural variations in the fish stocks. Against the very complex background of all possible interactions, it often

proves extremely difficult to conclude what exactly is the cause of certain changes, and thus that it is also difficult to distinguish between natural variation and the changes induced or maintained by human activities.

Heifetz, J. 1997. Workshop on the potential effects of fishing gear on benthic habitat. NMFS AFSC Processed Report 97-04. 17 p.

Summary: This report contains abstracts from a workshop that was held in September 1996 on the potential effects of fishing gear on benthic habitat. The workshop was held to review the progress and preliminary results of studies that began in 1996. Participants also discussed future approaches and priorities for fishing gear research.

Hess, N.A., C.A. Ribic, and I. Vining. 1999. Benthic marine debris, with an emphasis on fishery-related items, surrounding Kodiak Island, Alaska, 1994-1996. Marine Pollution Bulletin. Vol. 38(10):885-890.

Abstract: Composition and abundance of benthic marine debris were investigated during three bottom trawl surveys in inlet and offshore locations surrounding Kodiak Island, Alaska, 1994-1996. Debris items were primarily plastic and metal regardless of trawl location. Plastic bait jars, fishing line, and crab pots were the most common fishery-related debris items and were encountered in large amounts in inlets (20-25 items per km^2), but were less abundant outside of inlets (4.5-11 items per km^2). Overall density of debris was also significantly greater in inlets than outside of inlets. Plastic debris densities in inlets ranged 22-31.5 items per km^2, 7.8-18.8 items per km^2 outside of inlets. Trawls in inlets contained almost as much metal debris as plastic debris. Density of metal debris ranged from 21.2 to 23.7 items per km^2 in inlets, a maximum of 2.7 items per km^2 outside of inlets. Inlets around the town of Kodiak had the highest densities of fishery-related and total benthic debris. Differences in benthic debris density between inlets and outside of inlets and differences by area may be due to differences in fishing activity and water circulation patterns. At the current reduced levels of fishing activity, however, yearly monitoring of benthic debris appears unnecessary.

High, W.L. 1981. Wreck-netters capture more fish than they know. National Fisherman. November 1981. p. 122.

Summary: This short article warns of the problems associated with setting nets next to wrecks. The author discusses the potential loss of fish due to the ghost fishing of the lost nets.

High, W.L. 1985. Some consequences of lost fishing gear. Page 430-437 *in* R.S. Shomura and H.O. Yoshida, editors. Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. NOAA-TM-NMFS-SWFC-54.

Abstract: Directed studies and incidental observations of derelict crab pots, longline gear, and sunken gill nets show some long term damage to living marine animals. More than 30,000 crab pots have been lost in the western Gulf of Alaska since 1960. About 20% of legal size and 8% of sublegal king crab in these pots at the time of loss, fail to escape. The

king crab which escape pots after a 10-day or more confinement, reenter the fishery at a very low rate, suggesting that relatively short-term confinement contributes to high mortality. Crab which dies in a pot tend to repel other crab. Bright, bare hooks on halibut longline gear occasionally take fish, but plated hooks quickly rust or snag on sea floor objects. Although the nylon ground lines and gangions remain intact for several years, the hooks quickly cease to function. Three salmon gill net segments lost by Washington State fishermen have been observed for several years. The deployed segments ranged from 5.5 to 18.3 m (18 to 60 ft.) below the surface. Each continued to fish for more than 2 years, taking a variety of fish, invertebrates, and seabirds. Underwater studies of the sunken gill net fishery for Pacific cod, *Gadus macrocephalus*, showed that only about 14% of the entangled cod escape before the net was retrieved. Consequently, most cod gilled, or otherwise tangled in sunken gill nets lost by fishermen remain until they die. Because set net fisheries are often concentrated on rough sea floor areas and among sunken man-made objects, significant loss of nets do occur. Some fishing gears are modified to quickly reduce their fishing capacity when lost.

High, W.L. 1998. Observations of a scientist/diver on fishing technology and fisheries biology. NOAA, NMFS, AFSC Processed Report 98-01. 47 p.

Summary: While this paper mainly focuses on the techniques divers use to observe fishing gear, it does mention some gear interactions with the bottom. It describes a trawl net, and the impact it has on the bottom, and it also mentions different animals' reactions to fishing gear.

High, W.L., and D.D. Worlund. 1979. Escape of king crab, *Paralithodes camtschatica*, from derelict pots. NOAA Technical Report NMFS SSRF-734. 11 p.

Abstract: Loss of 10% per season of pots (traps) in the Alaskan fishery for the king crab, *Paralithodes camtschatica*, has raised the question of possible loss of crabs and fishes to the derelict, or lost, pots which continue to fish. We conducted a series of experiments during 1974 and 1975 in which tagged king crab were placed in several types of pots and returned to the bottom (soaked) for periods of 1-16 days. As controls, we released some tagged king crab in Chiniak Bay, Kodiak Island, Alaska. Tagged crab missing from the pots at time of recovery were credited with escape. The experiments demonstrated that 92% of undersize and 80% of legal-size crab readily escaped the derelict pots. Mortality among crab held in pots for various experiments ranged up to 12%. Crab that escaped within 1-4 days were recovered by commercial fishermen at about the same rate as those released in Chiniak Bay near the experiment site. However, those released after a 10- to 16-day confinement were returned at a much lower rate. Some commercially valuable fishes such as Pacific halibut, *Hippoglossus stenolepis,* were also caught in the experimental pots.

Higman, J.B. 1952. Preliminary investigation of the live bait shrimp fishery of Florida Bay and the Keys. Report to the Florida State Board of Conservation. Marine Laboratory, University of Miami. 8 p.

Summary: This paper describes the shrimp fishery in Florida Bay. It gives the value of the fishery, describes the three types of gear used in the fishery, and determines the gear impact

on seagrass and *Sargassum* habitat. The author states that the current fishery is not harming fish habitat in Florida Bay.

Higman, J.B. 1955. Observations on the live bait shrimp industry of Pasco and Pinellas Counties, Florida. Report to the Florida State Board of Conservation. Marine Laboratory, University of Miami. 4 p.

Hill, A.S., A.P. Brand, L.O. Veale, and S.J. Hawkins. 1997. Assessment of the effects of scallop dredging on benthic communities. Final Report to MAFF. Contract CSA 2332. University of Liverpool, Liverpool.

Summary This report summarizes the investigation into the effects of scallop dredging on benthic communities carried out by the Port Erin Marine Lab, University of Liverpool. The main objectives of the study were to1) compare the efficiency of French and spring-tooth dredge types and the effects of each gear type upon the epibenthos, and the behaviour of benthic scavengers and predators in response to discarded bycatch and the wake of dredges, 2) study the bycatch caught by dredges on the Manx commercial scallop ground, 3) esitmate commercial fishing effort, estimate the number of animals killed by commercial fishing and mortality rates of the major bycatch species, 4) assess the effects of dredging on particulate concentrations and examination of the effects of elevated particulate levels on selected benthic species, 5) describe the benthic communities of commercially fished grounds which are subject to variable fishing intensity, 6) examine an area closed to commercial fishing since 1989, 7) analyze historical data describing benthic community structure prior to commercial dredging activity, and compare this with the current status of benthic communities in corresponding areas, and 8) compare the effects of beam trawls and scallop dredges on epifaunal communities.

Hill, A.S., L.O. Veale, D. Pennington, S.G. Whyte, A.R. Brand, and R.G. Hartnoll. 1999. Changes in Irish Sea benthos: possible effects of 40 years of dredging. Estuarine, Coastal and Shelf Science. Vol. 48(6):739-750.

Abstract: From 1946 to 1951 Dr N. S. Jones sampled the benthos around the south of the Isle of Man from over 200 sites. Multivariate methods have been used here to compare subsets of this historical data with recent data from the same locations: of these locations some have been subject to heavy scallop dredging over the intervening 40 plus years and some to little dredging. Clear changes were apparent regardless of scallop dredging intensity. Some of the changes in the heavily dredged areas were those expected to result from extreme physical disturbance-an increased polychaete mollusc ratio, loss of some fragile species, and an increase in the predominance of scavenger/predator species. However, changes in the lightly dredged areas also included the loss of a number of species including some potentially fragile tube-dwellers. Reasons for these changes were not apparent.

Hingco, T.G., and R. Rivera. 1991. Aquarium fish industry in the Philippines: toward development or destruction? ICLARM Conference Proceedings. No. 22:249-253.

Abstract: Aquarium fish collection in the Philippines is a multimillion peso industry whose growth has been interrupted by major slumps over the last decade. These were attributed to

the bad reputation of Philippine aquarium fish in the international market arising from the use of sodium cyanide in collecting them. This study gives an overview of the industry in Bolinao, a major source of aquarium fish. It also focuses on the different reasons for the persistent use of sodium cyanide. It reports that the efficiency of collection and economic incentive systems support the continued use of sodium cyanide in aquarium fishing. It points out that fishermen are able to befriend law enforcers and/or avoid them. It recommends that marketing arrangements be established that will encourage the sale of fish caught with nets and that community education facilitate the process of change. It also suggests cutting off the supply of sodium cyanide.

Hoffman, E. 1994. A marine ecosystem and an economic and ethnological analysis of the consequences of utilizing its biological resources. ICES Council Meeting Papers. 12 p.

Abstract: During the last two decades, the Danish marine fjord system Limfjorden has changed concurrently with an increased load of nutrients. Increased phytoplankton biomass, anoxia, bottom inversion, reduced fishery, diminished light penetration, large-scale occurrence of annual macroalgae, and a reduced depth extension of rooted vegetation are some results of this eutrophication. Since the early 70s, primary phytoplankton production has more than doubled. Today this forms the basis of a sizeable production of blue mussels (*Mytilus edulis*), with a total landing of some 110,000 tons net weight in 1993. From an economic viewpoint, the most important fishery in Limfjorden today is mussel dredging. Such high catches and the visible effect of dredges on the environment in the form of upwelling of bottom sediment, along with destruction of bottom animals and eel-grass, has stimulated great interest in the impact of mussel dredging on the ecosystem. Demands have been made for quotas, closed areas, and even total abandonment of mussel fishery. These demands are based on fear of a negative effect of dredging on the ecosystem in the form of increased oxygen utilization, macrophytes destruction, increased nutrient remineralization, reduced commercial and part time landings of eel, herring and flatfishes. However, other interest groups also draw on the fjord's resources. Characteristically, the different life modes (user groups) compete in order to keep their position in the total social use of the fjord. Thus, a number of socio-economic problems must be taken into account when applying different managing methods. In light of the above, a strategic research project has been established to carry out an integrated analysis of the Limfjord's biological structures and functions, together with an ethnological and economic analysis of the consequences of utilizing its biological resources. The strategic objective is to acquire that part of the scientific knowledge necessary to take qualified decisions, and thereby ensure that this policy is based on realistic objectives. This project was launched in January 1994 and will continue through 1996.

Holland, F. 1997. Reef wreckers. New Scientist. Vol. 156(2105):5.

Abstract: The first global survey of coral reefs has found that about 95 percent of the world's coral reefs have suffered from overfishing, dynamiting, poisoning, pollution, or ship anchor damage. Fish and shellfish that were once common in Caribbean, Indo-Pacific, and Red Sea reefs are now much rarer. No lobsters were found at 81 percent of the reef sites surveyed and only 26 Napoleon or humphead wrasse were found in all the Indo-Pacific reefs surveyed.

Holmes, B. 1997. Destruction follows in trawlers' wake. New Scientist. No. 2086:4.

Summary: This article reviews the conclusions from the Society for Conservation Biology meeting held in British Columbia.

Howell, R. 1985. The effect of bait-digging on the bioavailability of heavy metals from the surface of intertidal marine sediments. Marine Pollution Bulletin. Vol. 16(7):292-295.

Abstract: Extensive bait-digging has been apparent for the last few months at a site on the northeast coast of England known from previous work to be relatively unpolluted by heavy metals. Recent analyses of surface sediment and components of the meiofauna have indicated that there has been a sudden and dramatic rise in the total concentration and bioavailability of metals at this site and evidence is presented that indicates that this is due to the activities of bait-diggers.

Hsiao, Y.M., J.E. Easley, Jr., and T. Johnson. 1987. Testing for harmful effects of clam and scallop harvesting techniques in the North Carolina Bay scallop fishery. North American Journal of Fisheries Management. Vol. 7:187-193.

Abstract: An open-access fishery model incorporating negative effects from harvesting techniques was developed to derive a bionomic equilibrium harvest rate. The model was applied to the bay scallop fishery in North Carolina. The results suggested that clam kicking and clam raking have had significant negative effects on the bay scallop recruitment process.

Huber, M.E. 1994. An assessment of the status of the coral reefs of Papua New Guinea. Marine Pollution Bulletin. Vol. 29(1-3):69-73.

Abstract: Papua New Guinea's coral reefs are of global significance in extent and diversity. They are very poorly studied. The primary human uses are subsistence and artisanal commercial fisheries. While the reef fishery resources are underutilized on a national scale, localized overfishing has occurred where there has been access to cash markets. PNG reefs are thought to be relatively undisturbed, but there are insufficient data for objective assessment of their status. Major threats include sedimentation due to forestry, agriculture and mining, and damage from blast fishing. Mining has caused reef damage in at least one location, and mangrove deforestation is accelerating. Eutrophication and other pollution may be a problem in localized areas, especially near urban centres.

Hudson, J.H., and R. Diaz. 1988. Damage survey and restoration of M/V Wellwood grounding site, Molasses Reef, Key Largo National Marine Sanctuary, Florida. Pages 231-236 *in* Proceedings of the Sixth International Coral Reef Symposium, Townsville, Australia, 8-12 August 1988. Volume 2: Contributed Papers.

Abstract: Grounding of the M/V Wellwood on Molasses Reef in the Key Largo National Marine Sanctuary on August 4, 1984, resulted in massive destruction to living corals and underlying reef framework. A precision survey of grounding damage to the reef was done with a light weight aluminum frame subdivided with elastic cord into 1-m^2 "search" grids that enabled divers to examine and photograph each m^2 of disturbed substrate. Accuracy was

controlled by tightly stretched nylon transect lines spaced 4 m apart across the long axis of the grounding site. The survey revealed that a 1,282-m^2 area of the reef had sustained a 70-100 percent loss of live coral cover as a result of the grounding. Within this major damage zone, 644 m^2 of underlying reef framework had been fractured by the great weight of the 400-ft- long (122 m) ship. Pilot studies were undertaken at the grounding site to test the feasibility of transplanting hard and soft corals, stabilizing widespread fracturing, and rebuilding reef topography with dislodged, massive corals. All 3 mitigation experiments have proven to be a practical means of restoring a coral reef area severely damaged by a ship grounding.

Hutchings, P. 1990. Review of the effects of trawling on macrobenthic epifaunal communities. Australian Journal of Marine and Freshwater Research. Vol. 41:111-120.

Abstract: This review summarizes the available information on the macrobenthic epifaunal communities in tropical areas of Australia, with regard to species composition and seasonal changes in these communities. A synopsis is given of the information available on their growth rates and reproduction, together with a consideration of the role they play within tropical marine communities. Little is known about this role. Changes in the composition of these communities that occur as a result of trawling are discussed, together with the factors that must be considered before plans of management can be drawn up and implemented. There is a paucity of information on macrobenthic epifaunal communities and their role in Australian tropical marine ecosystems.

ICES. 1973. Effects of trawls and dredges on the seabed. ICES, Gear and Behavior Committee. ICES CM 1973/B:2.

Summary: This short report summarizes the knowledge of the ICES Gear and Behaviour Committee on the effects of trawls and dredges on the seabed. Seventeen points were made on the status of the knowledge with a brief discussion following each point.

ICES. 1987. Sixth report of the Benthos Ecology Working Group. ICES CM 1987/L:26.

Summary: This report details the meeting of the Benthos Ecology Working Group. It contains brief reports on studies investigating the impact of dredging and bottom fishing gear.

ICES. 1988. Report of the study group on the effects of bottom trawling. ICES CM 1988/B:56. 30 p.

ICES. 1988. Seventh report of the Benthos Ecology Working Group. ICES CM 1988/L:15.

ICES. 1989. Eighth report of the Benthos Ecology Working Group. ICES CM 1990/L:19.

ICES. 1990. Ninth report of the Benthos Ecology Working Group. ICES CM 1990/L:95.

ICES. 1991. Report of the Study Group on Ecosystem Effects of Fishing Activities, Lowestoft, 11-15 March 1991. International Council for the Exploration of the Sea. Study Group on Ecosystem Effects of Fishing Activities. ICES CM 1991/G:7. 66 p.

Summary: This report details the quantification of the direct impacts of fishing activities, trends in fishing effort and type of fishing, influences of anthropogenic activities other than fishing, species interaction effects and other long-term effects of fishing activities, and possible management conflicts and compromises. One section to note is the section that compares direct impacts of fishing with the impacts of other anthropogenic influences and natural processes.

ICES. 1992. Report of the Study Group on Ecosystem Effects of Fishing Activities, Copenhagen, 7-14 April, 1992. International Council for the Exploration of the Sea. Study Group on Ecosystem Effects of Fishing Activities. ICES CM 1992/G:11. 144 p.

Summary: This report contains an overview of long-term changes to bottom habitat, quantification of the direct impacts of fishing activities, influences of anthropogenic activities other than fishing, long-term effects of fishing activities, and possible management objectives, conflicts, and solutions.

ICES. 1993. Report of the Working Group on Ecosystem Effects of Fishing Activities. International Council for the Exploration of the Sea. Working Group on Ecosystem Effects of Fishing Activities ICES CM 1993/G:4. 9 p.

ICES. 1994. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 1994/Assess/Env:1.

ICES. 1994. Sensitivity of species to physical disturbance of the seabed - preliminary report. ICES, Benthos Ecology Working Group meeting. ICES CM 1994/L:4, Annex 8.

Summary: This is a report prepared by the Benthos Ecology Working Group to compile a list of indicator species that are sensitive to physical disturbance. The Working Group summarizes the types and sources of seabed disturbance, the species characteristics that make species vulnerable, and these species documented vulnerability. The Working Group concludes that species should be assessed on the basis of life history characteristics, physical fragility/robustness of the species, and habitat and behavioural characteristics.

ICES. 1995. Report of the Study Group on Ecosystem Effects of Fishing Activities, Copenhagen, Denmark, 7-14 April, 1992. ICES Cooperative Research Report No. 200. 120 p.

Summary: This report contains information on the ecosystem effects of fishing in the North Sea area. The contents include a summary for the North Sea Task Force, an overview of long-term changes in the North Sea, a quantification of the direct impacts of fishing activities, the influence of anthropogenic activities other than fishing, a comparison of the direct effects of fishing with the effects of other anthropogenic influences and natural processes, the long-term effects of fishing activities, and possible management objectives, conflicts, and solutions.

ICES. 1996. Report of the working group on ecosystem effects of fishing activities. ICES Headquarters, 13-21 March 1996. ICES CM 1996/Assess/Env:1 Ref.: Session G.

Summary: This report mainly discusses the ecosystem effects of fishing on communities and assemblages and non-target populations. Although, it examines the vulnerability of species to fishing and reviews the effects of reducing fishing mortality by examining ongoing research projects throughout the world. Finally, it estimates discards and their utilization in the ecosystem.

ICES. 1999. Report of the working group on fishing technology and fish behaviour. ICES, Fisheries Technology Committee. ICES CM 1999. 51 p.

Summary: A special section of this report deals with technical measures to fishing gears and operations to reduce their biological and physical impacts on benthos and benthic substrates, and methodologies for studying such impacts. This section includes abstracts of the presentations made at the meeting. It also includes group discussion on each presentation.

Industrial Science Division. 1990. The impact of commercial trawling on the benthos of Strangford Lough. Interim Report No. TI/3160/90. Industrial Science Division, 17 Antrim Road, Lisburn, Co., Antrim B128 3AL.

Ismail, N.S. 1985. The effects of hydraulic dredging to control oyster drills on benthic macrofauna of oyster grounds in Delaware Bay, New Jersey. Internationale Revue der Gesamten Hydrobiologie. Vol. 70(3):379-395.

Abstract: This study describes the extent and nature of the effects of hydraulic dredging to control oyster drills (*Urosalpinx cinerea* and *Eupleura caudata*, Family Muricidae, Order Neogastropoda) on benthic macrofauna and sediments of the oyster grounds in Delaware Bay, New Jersey. The immediate effects of hydraulic dredging were reductions in numbers of species as well as in total numbers of animals on the three oyster grounds selected. However, oyster drills were most affected. Benthic populations have recovered three to ten months after dredging. The sediments of the dredged grounds can be described as muddy sands. Immediately after dredging, additional mud was brought up from subsurface layers which reduced the median grain size on Ground 154 test plot. On Ground 515 test plot, however, there was a slight loss in the mud which increased the median grain size.

Jaap, W.C., and J. Wheaton. 1975. Observations on Florida reef corals treated with fish-collecting chemicals. Florida Marine Research Publications. No. 10. 18 p.

Summary: This paper examines the effect of fish collecting chemicals like quinaldine, tricaine methanesulfonate, cresol, urethane, antimycin 'A', sodium hypochlorite, sodium cyanide, and rotenone on coral reef. These chemicals are used by tropical fish collectors to collect specimens for the tropical fish industry.

Jackson, M.J., and R. James. 1979. The influence of bait digging on cockle, *Cerastoderma edule*, populations in North Norfolk. Journal of Applied Ecology. Vol. 16:671-679.

Abstract: The population of cockles *Cerastoderma* (=*Cardium*) *edule* (L.) declined drastically in the late 1950s and 1960s concurrent with intensification of digging for lug and rag worms. At Blakeney Point, where bait digging is slight, cockles remained common. A field experiment showed that digging caused heavy mortality of cockles and probably acted more severely on smaller ones of each age group. Laboratory experiments confirmed that few cockles buried at 10 cm could regain their near surface positions and that many died. Predator exclusion did not affect cockle numbers.

Jameson, S.C., M.S.A. Ammar, E. Saadalla, H.M. Mostafa, and B. Riegl. 1999. A coral damage index and its application to diving sites in the Egyptian Red Sea. Coral Reefs. Vol. 18(4):333-339.

Abstract: A coral damage index (CDI) is provided, to screen sites to obtain a perspective on the extent and severity of physical damage to coral. Sites are listed as "hot spots" if in any transect the percent of broken coral colonies (BCC) is greater than or equal to 4% or if the percent cover of coral rubble (CR) is greater than or equal to 3%. To demonstrate its utility, the CDI is applied to a real-life management situation off Hurghada and Safaga, Egypt in the Red Sea. The extent of coral damage covered all four diving sites. Forty percent of all the transects were "hot spots" that required management action. Thirty-one percent of the 16 "hot spot" transects were identified by both broken coral and ruble criteria, 25% by only broken coral criterion and 44% by only coral rubble criterion of the CDI, suggesting that past breakage was responsible for most of the observed damage. Sixty-three percent of the "hot spot" transects were at 4 m depth versus 37% at 8 m depth, suggesting that most of the damage was caused by anchors dragging across the reef in shallow water. The severity of coral damage, reflected by CR, was the greatest at Small Giftun in transect 5 at 4 m depth (333% above the CDI). El Fanous experienced the most severe degree of broken coral damage (325% above the CDI) at 8 m depth along transect 2. Estimates of the number of dives per year show diving carrying capacities for El Fanous, Gotta Abu Ramada, Ras Abu Soma and Small Giftun being exceeded by large amounts. The CDI can be used globally to; gauge the severity and extent of damage, focus managers on areas that need mooring buoys and associated dive site management programs, and provide a starting point from which to focus more detailed coral reef assessments and restoration programs.

Jamieson, G.S., M. Etter, and R.A. Chandler. 1981. The effect of scallop fishing on lobsters in the western Northumberland Strait. Unpublished CAFSAC Research document. 8 p.

Abstract: Damage to lobsters by commercial scallop dragging in Egmont Bay and off Miminegash, PEI, was minimal with present seasonal scallop fisheries restrictions. During May, when commercial scallop fishing was occurring, lobster abundance was low in areas of profitable scallop exploitation. These areas were generally smooth and most lobsters were able to avoid the gear. Of the lobsters observed to be in the drag path, 12.1 and 2.5% were injured or retained by the drag in the areas studied having no commercial scallop fishing and commercial scallop fishing, respectively. Lobster abundance in July in the areas commercially exploited for scallops in May and June was significantly greater than in May, but whether this was the result of a natural seasonal movement of lobsters or was influenced by the cessation of scallop fishing is unclear.

Jamieson, G.S., and A. Campbell. 1985. Sea scallop fishing impact on American lobsters in the Gulf of St. Lawrence. Fishery Bulletin. Vol. 83(4):575-586.

Abstract: Damage to American lobsters, *Homarus americanus*, in Egmont Bay and off Miminegash, Prince Edward Island, is minimal from the drags of the seasonal sea scallop, *Placopecten magellanicus*, fishery. During May 1981, when commercial sea scallop fishing was occurring, American lobster abundance was low in areas of profitable scallop exploitation. Sea bed substrate in these areas was generally smooth and most lobsters were able to avoid the gear. In the areas with and without commercial scallop fishing, 1.3% and 11.7% of observed lobsters, respectively, were injured or retained by the drag. Lobster abundance in the areas commercially exploited for scallops in May and June was significantly greater in July than in May, but whether this was a result of a natural seasonal movement of lobsters or the cessation of scallop fishing is unclear.

Jenner, K., K.W. Strong, and P. Pocklington. 1991. A review of fishery related seabed disturbance in the Scotia-Fundy Region. Project Report 166. Canadian Department of Fisheries and Oceans, Scotia-Fundy Region, Industry Services and Native Fisheries Branch.

Abstract: This report summarizes information on fishery-related seabed disturbance collected from sidescan sonar records and videotapes of the seabed of the Scotia-Fundy Region. Less than 2% of the seabed surveyed by sidescan sonar contained any evidence of fishing activity from either groundfish trawls, scallop rakes or clam dredges. Almost all of the remains of observed disturbance was confined to areas of featureless seabed. Virtually no remains of disturbance was observed in regions where seabed environments were sufficiently energetic to allow the development of bedforms. Because of their widespread use, groundfish trawls were responsible for most of the observed disturbance. However, hydraulic clam dredges disrupted more sediment per unit of area utilized than either scallop rakes or groundfish trawls. No information could be collected on rates of degradation of gear tracks nor could any data be obtained on the biological impact of such sources of disturbance. As well, the data base did not permit any estimations of percent of seabed actually disturbed by fishing gear on a temporal basis. Such information is required before potential impacts of seabed disturbance by fishing activity can be addressed fully.

Jennings, S., and N.V.C. Polunin. 1996. Impacts of fishing on tropical reef ecosystems. Ambio. Vol. 25:44-49.

Abstract: Fishing is the most widespread human exploitative activity on tropical reefs and the survival of many coastal societies is dependent on the productivity of their fisheries. Existing fishery management strategies focus primarily on target fish populations, but they may not be appropriate when fishing initiates shifts in the reef ecosystem. Such shifts may not be reversible, and can impair the processes which guarantee future fish production. We describe a number of alternative approaches to management and consider which of these may help to maximize yield whilst minimizing the probability of unwanted ecosystem shifts. One of these approaches is already adopted by a number of island societies but, ironically, it has proved to be incompatible with many fishery development programs.

Jennings, S., and N.V.C. Polunin. 1997. Impacts of predator depletion by fishing on the biomass and diversity of non-target reef fish communities. Coral Reefs. Vol. 16:71-82.

Abstract: An understanding of the indirect effects of fishing on predator-prey relationships is required for the development of valid multispecies yield models for reef fisheries and for determining the factors governing fish community structure at larger scales. We used an underwater visual census technique to examine the indirect effects of fishing on the biomass and diversity (species richness) of reef fishes in a series of ten traditional Fijian fishing grounds (*qoliqoli*) subject to a range of fishing intensities. All members of the families Chaetodontidae (butterflyfishes), Labridae (wrasses), Lutjanidae (snappers), Mullidae (goatfishes), Scaridae (parrotfishes) and the sub-family Epinephelinae (groupers and coral trout) which could be reliably identified were censussed. Each species censussed was assigned to one of three trophic groups: herbivore, invertebrate feeder or piscivore. The biomass of all piscivorous fishes and of large (> 30 cm) piscivorous fishes differed significantly between *qoliqoli* and was significantly correlated with fishing intensity. However, the biomass of piscivorous fishes was not correlated with the biomass or diversity of their potential prey (which were not targeted by the fishery). This suggested that the indirect effects of fishing did not have an important bearing on fish diversity or biomass and that predation by the target species did not play an important role in structuring these Fijian reef fish communities. The results contrast with those from a number of studies at smaller scales and provided further indications that the structure of reef fish communities is not governed by a single dominant process, but by a range of processes which operate on different scales in different circumstances.

Jennings, S., and M.J. Kaiser. 1998. The effects of fishing on marine ecosystems. Advances in Marine Biology. Vol. 34:201-352.

Abstract: We review the effects of fishing on benthic fauna, habitat, diversity, community structure and trophic interactions in tropical, temperate and polar marine environments and consider whether it is possible to predict or manage fishing-induced changes in marine ecosystems. Such considerations are timely given the disillusionment with some fishery management strategies and that policy makers need a scientific basis for deciding whether they should respond to social, economic and political demands for instituting or preventing ecosystem-based management. Fishing has significant direct and indirect effects on habitat, and on the diversity, structure and productivity of benthic communities. These effects are most readily identified and last longest in those areas that experience infrequent natural disturbance. The initiation of fishing in an unfished system leads to dramatic changes in fish community structure. As fishing intensity increases the additional effects are more difficult to detect. Fishing has accelerated and magnified natural declines in the abundance of many forage fishes and this has lead to reduced reproductive success and abundance in birds and marine mammals. However, such donor-controlled dynamics are less apparent in food webs where fishes are the top predators since their feeding strategies are rather more plastic than those of most birds and mammals. Fishers tend to target species in sequence as a fishery develops and this leads to changes in the composition of the fished communities with time. The dramatic and apparently compensatory shifts in the biomass of different species in many fished ecosystems have often been driven by environmental change rather than the indirect effects of fishing. Indeed, in most pelagic systems, species replacements would have

occurred, albeit less rapidly, in the absence of fishing pressure. In those cases when predator or prey species fill a key role, fishing can have dramatic indirect effects on community structure. Thus fishing has shifted some coral reef ecosystems to alternate stable states because there is tight predator-prey coupling between invertebrate feeding fishes and sea urchins. Fishing has reduced, and locally extirpated, populations of predatory fishes. These reductions do not have a consistent effect on the abundance and diversity of their prey: environmental processes control prey populations in some systems, whereas top-down processes are more important in others. By-catch which is discarded during fishing activities may sustain populations of scavenging species, particularly seabirds. We conclude by identifying the circumstances in which new research is needed to guide managers and stress the importance of unfished control sites for studies of fishing effects. We discuss the advantages and disadvantages of closed area management (marine reserves) and the conditions under which such management is likely to provide benefits for the fishery or ecosystem.

Jennings, S., J. Alvsvag, A.J.R. Cotter, S. Ehrich, S.P.R. Greenstreet, A. Jarre-Teichmann, N. Mergardt, A.D. Rijnsdorp, and O. Smedstad. 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. III. International trawling effort in the North Sea: an analysis of spatial and temporal trends. Fisheries Research. Vol. 40:125-134.

Abstract: This paper describes trends in beam and otter trawling effort in the North Sea from 1977 to 1995. Data are presented as total hours fishing by English, German, Norwegian, Scottish and Welsh vessels for the period 1977-1995, and by Danish, Dutch, English, German, Norwegian, Scottish and Welsh vessels for the period 1990-1995. Analyses of temporal trends indicated that total international trawling effort in the entire North Sea has increased slowly since 1977 and that it is currently (1995) 2.25 million h yr^{-1} of which 55% is due to beam trawling. Spatial analyses indicate that the proportion of beam trawling effort increases from north to south. Plots of annual fishing effort by ICES statistical rectangle (211 boxes of 0.5° latitude x 1° longitude) indicate that the majority of fishing effort in the North Sea are concentrated in a very few rectangles. Thus mean annual total fishing effort (1990-1995) was less than 2000 h in 29% of rectangles and less than 10000 h in 66% of rectangles. Total effort exceeded 40000 h in 4% of rectangles. The results indicate that assessments of the average area swept by trawls in the North Sea give a poor indication of the direct impacts of trawling on the biota. Some areas are intensively fished but many others are not. Our dataset is likely to underestimate trawling effort in the southern North Sea (ICES Area IVc) because data for Belgian and French vessels were not available. However, the absence of French and Belgian data would not significantly alter total trawling effort estimates from the central (IVb) and northern (IVa) North Sea.

Jennings, S., and A.J.R. Cotter. 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. I. Introduction. Fisheries Research. Vol. 40:103-106.

Abstract: Traditionally, fisheries scientists were concerned with the effects of fishing on the dynamics of exploited stocks. In recent years, however, interest in the wider effects of fishing on community structure, diversity, ecosystem processes and the abundance of non-

target fishes, invertebrates, birds and marine mammals has burgeoned. In this Special Issue of Fisheries Research we present an introduction to effects of fishing on marine ecosystems followed by six related papers that describe patterns in fishing effort, diversity and community structure in northeast Atlantic shelf seas. The papers describe the patchiness of fishing effort in space and time, the relative roles of fishing and biogeography in explaining fish community structure, potential biases when trawl samples are used to determine long-term trends in fish communities and the effects of fishing on the diverse invertebrate assemblages associated with tube worms.

Johnson, S.W. 1990. Distribution, abundance, and source of entanglement debris and other plastics on Alaskan beaches, 1982-88. Pages 331-348 *in* R.S. Shomura and M.L. Godfrey, editors. Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS, NOAA-TM-NMFS-SWFSC-154.

Abstract: Sixty kilometers of outer coast beaches at 25 locations in Alaska were surveyed from 1982 to 1988 to determine distribution, composition, quantity, deposition, and source of plastic debris washed ashore. Approximately 67% of all plastic debris found was fishing gear (e.g., net fragments, rope, floats) and 33% was packaging material (e.g., plastic bags, bottles). Debris found which could entangle marine mammals, seabirds, and fish included trawl web, rope, packing straps, and monofilament gillnet. Monofilament gillnet was not abundant (usually <5 pieces/km) on beaches, but trawl web was found on beaches throughout Alaska and exceeded 10 fragments/km at more than 50% of the locations sampled. Foreign fisheries were the source of most (98%) of the monofilament gillnet washed ashore; the source of trawl web is shifting from foreign to domestic fisheries. Trends in composition and abundance of plastic debris were monitored at three sites: Amchitka Island, Middleton Island, and Yakutat. Amchitka Island had similar quantities (~300 items/km) of total plastics in 1982 and 1987, although the amount of trawl web at this site continued to increase. Quantities of plastic debris on Middleton Island remained similar from 1984 to 1987 (average 860 items/km), with the exception of an approximate 33% decline in 1985 from the 4-year average. Near Yakutat, the quantity of trawl web deposited ashore increased from 8.8 to 10.1 fragments/km/year from 1985 to 1988. Continuing the surveys of these benchmark beaches will help determine whether recent mitigating legislation is effective in reducing the disposal of entanglement debris and other plastics at sea.

Jolley, J.W., Jr. 1972. Exploratory fishing for the sunray venus clam, *Macrocallista nimbosa*, in northwest Florida. Florida Department of Natural Resources Technical Series No. 67:1-42.

Abstract: Exploratory fishing to locate commercially significant beds of the sunray venus clam, *Macrocallista nimbosa* (Solander), and to survey benthic fauna from 68 ft shoreward was conducted with a 48-in. hydraulic Nantucket clam dredge. Sampling was dependent on mild weather and was usually confined to sandy substrates. One hundred seventy-three stations were established from the Alabama-Florida boundary line to Cedar Keys with five additional stations in southwest Florida. *Macrocallista nimbosa* was the most abundant and frequently caught clam; 95% were taken in 10 to 40 ft and catch per unit effort was highest at 10 to 15 ft. It was caught predominantly in sandy substrates and most productive stations were in Area B, near Panama City, and in Area E, near Cedar Keys. Although these areas

yielded smaller catches than those at the commercial grounds on Bell Shoal, they warrant further investigation. Offshore investigations in 41 to 68 ft showed no evidence of other potentially commercial clam stocks. Paucity of small sunrays (<126 mm) tends to substantiate the hypothesis that subadults may move from inshore to offshore areas. More than 140 species of fish and invertebrates were identified from catches; faunal associations varied with depth in some areas. Several benthic species were found commonly associated with sunrays, and a predatory relationship is suggested for two species. Results at Cedar Keys indicated that the hydraulic Nantucket dredge should not be used in areas where grass beds are an important part of the environment.

Jones, J.B. 1992. Environmental impact of trawling on the seabed: a review. New Zealand Journal of Marine and Freshwater Research. Vol. 26(1):59-67.

Abstract: Fishers have been complaining about the effects of bottom trawl gear on the marine environment since at least the 14th century. Trawl gear affects the environment in both direct and indirect ways. Direct effects include scraping and ploughing of the substrate, sediment resuspension, destruction of benthos, and dumping of processing waste. Indirect effects include post-fishing mortality and long-term trawl-induced changes to the benthos. There are few conclusive studies linking trawling to observed environmental changes since it is difficult to isolate the cause. However, permanent faunal changes brought about by trawling have been recorded. Research has established that the degree of environmental perturbation from bottom trawling activities is related to the weight of the gear on the seabed, the towing speed, the nature of the bottom sediments, and the strength of the tides and currents. The greater the frequency of gear impact on an area, the greater the likelihood of permanent change. In deeper water where the fauna is less adapted to changes in sediment regimes and disturbance from storm events, the effects of gear take longer to disappear. Studies indicate that in deep water (> 1000 m), the recovery time is probably measured in decades.

Jones, M.M. 1995. Fishing debris in the Australian marine environment. Marine Pollution Bulletin. Vol. 30(1):25-33.

Abstract: The loss and disposal of fishing gear has been recognized internationally as a major environmental issue for several decades. This paper reviews the available data on fishing debris in the Australian marine environment. In some regions debris from deep-water trawl, longline and rock lobster fisheries has harmed marine wildlife and littered beaches. The highest documented incidence of wildlife entanglement by fishing debris is for the Australian fur seal in Bass Strait and off southern Tasmania, where over the period 1989-1993 approximately 1.5-2% of seals were found with neck collars. Data collected by Australian observers on board foreign vessels fishing within the Australian Fishing Zone, indicate that in 1992 and 1993 at least one-third of these vessels did not comply with the MARPOL regulations on the disposal of plastics. Approaches used to reduce debris have included education programmes, development of plastic-free gear, and clean-up programmes.

Jones, R.J., and A.L. Steven. 1997. Effects of cyanide on corals in relation to cyanide fishing on reefs. Marine and Freshwater Research. Vol. 48(6):517-522.

Abstract: Small fragments of the zooxanthellate corals *Pocillopora damicornis* and *Porites lichen* were subjected to a range of cyanide concentrations for various times (i.e. to various cyanide doses). Doses encompassed those likely to be experienced by corals as a result of various cyanide fishing practices. Following the highest doses, corals died; after medium doses, they lost their zooxanthellae (symbiotic algae) resulting in a discoloration or 'bleaching'; and after the lowest doses they lost zooxanthellae but not in sufficient numbers to cause noticeable discoloration. Respiratory rates of *P. damicornis* were inhibited by 10-90% following exposure to cyanide but recovered to pre-exposure levels within 1-2 h after transfer to clean sea water.

Jones, R.J., T. Kildea, and O. Hoegh-Guldberg. 1999. PAM chlorophyll fluorometry: a new *in situ* technique for stress assessment in scleractinian corals, used to examine the effects of cyanide from cyanide fishing. Marine Pollution Bulletin. Vol. 38(10):864-874.

Abstract: Sodium cyanide is being used on reefs in the Asia-Pacific region to capture live fish for the aquarium industry, and to supply a rapidly growing, restaurant-based demand. The effects of cyanide on reef biota have not been fully explored. To investigate its effects on hard corals, we exposed small branch tips of *Stylophora pistillata* and *Acropora aspera* to cyanide concentrations estimated to occur during cyanide fishing. Pulse amplitude modulation (PAM) chlorophyll fluorescence techniques were used to examine photoinhibition and photosynthetic electron transport in the symbiotic algae (zooxanthellae) in the tissues of the corals. These measurements were made *in situ* and in real time using a recently developed submersible PAM fluorometer. In *S. pistillata*, exposure to cyanide resulted in an almost complete cessation in photosynthetic electron transport rate. Both species displayed marked decreases in the ratio of variable fluorescence (F_v) to maximal fluorescence (F_m) (dark-adapted F_v/F_m), following exposure to cyanide, signifying a decrease in photochemical efficiency. Dark-adapted F_v/F_m recovered to normal levels in ~6 d, although intense tissue discoloration, a phenomenon well-recognized as coral 'bleaching' was observed during this period. Bleaching was caused by loss of zooxanthellae from the coral tissues, a well-recognized sub-lethal stress response of corals. Using the technique of chlorophyll fluorescence quenching analysis, corals exposed to cyanide did not show light activation of Calvin cycle enzymes and developed high levels of non-photochemical quenching (q_N), signifying the photoprotective dissipation of excess light as heat. These features are symptomatic of the known properties of cyanide as an inhibitor of enzymes of the Calvin cycle. The results of this *in situ* study show that an impairment of zooxanthellar photosynthesis is the site of cyanide-mediated toxicity, and is the cue that causes coral to release their symbiotic zooxanthellae following cyanide exposure. This study demonstrates the efficacy of PAM fluorometry as a new tool for *in situ* stress assessment in zooxanthellate scleractinian corals.

Kaiser, M.J. 1996. Effects of trawling on marine ecosystems. Environmental Conservation. Vol. 23:366-367.

Kaiser, M.J. 1996. Starfish damage as an indicator of trawling intensity. Marine Ecology Progress Series. Vol. 134:303-307.

Abstract: Two species of starfish, *Asterias rubens* and *Astropecten irregularis*, were collected from areas in the Irish Sea that are subjected to different intensities of commercial beam trawling. A side-scan sonar survey revealed that the observed abundance of trawl marks correlated with the reported levels of fishing at the sampling locations. The incidence of starfish, of both species, with damaged or regenerating arms increased with increasing fishing intensity. The severity of damage, i.e. the number of regenerating arms, also increased with fishing intensity. The proportion of starfish with damaged or regenerating arms may provide a useful short-term (1 to 2 yr) biological indication of physical disturbance by demersal fishing gears.

Kaiser, M.J. 1998. Significance of bottom-fishing disturbance. Conservation Biology. Vol. 12(6):1230-1235.

Abstract: Since the early 1970s there has been increasing interest in the ecological effects of bottom-fishing activities on the benthic ecology of the seas of northern Europe. The majority of studies have examined the short-term effects of disturbance on benthic fauna. Some areas, however, such as the southern North Sea, have been subjected to fishing disturbance for over 50 years, which complicates predictions of long-term ecological change inferred from recent experimental studies. I highlight the importance of evaluating the ecological relevance of fishing disturbance versus natural perturbations, which varies among different habitats. Most experimental studies have shown that it is possible to detect short-term changes in community structure in response to fishing disturbance. Evidence suggests that long-term changes are probably restricted to long-lived fragile species or communities found in environments that are infrequently disturbed by natural phenomena. Understanding the relative ecological importance of physical disturbance by fishing verses natural events would provide a basis for predicting the outcome of fishing activities in different marine habitats. I suggest approaches that may refine attempts to correlate fishing intensity and frequency with community change, such as the use of tracking devices fitted to trawlers and surveys of fauna, such as bivalves and echinoderms, that record disturbance events of the past in their shells or body structure.

Kaiser, M.J. 2000. The implications of the effects of fishing on non-target species and habitats. Pages 383-392 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: This chapter summarizes the book within which it is contained. The topics included are the distribution of fishing effort and physical interaction with the seabed, effects of fishing on benthic fauna and habitats, fishing as a source of energy subsidies, long-term changes associated with fishing, conservation methods, issues and implications for biodiversity, and socio-economic implications and mechanisms for reducing fisheries impacts.

Kaiser, M.J., and B.E. Spencer. 1993. A preliminary assessment of the immediate effects of beam trawling on a benthic community in the Irish Sea. ICES CM 1993/B:38. 9 p.

Abstract: After an experimental box had been fished 10 times with a 4-m commercial beam trawl, the density of sessile animals such as *Alcyonium digitatum* and hydroids decreased by

ca. 50%. The density of more mobile animals, such as fishes, crabs and *Palaemon* spp. remained constant or increased. Assessment of the survival of animals caught in the codend indicated large variation between species. Echinoderms with flexible tests, e.g. *Asterias rubens*, showed low mortality, whereas those with brittle tests, e.g. *Psammechinus miliaris*, were readily damaged leading to high mortality. The extent of fish mortality, as a result of being caught and landed, was related to the presence or absence of phenotypic features such as scales, spines, boney plates and slime. After 120 h in tanks of running seawater, between 68 to 97% of *Callionymus* spp. and 34 and 38% of *Pleuronectes platessa* and *Raja naevus* died. Those animals which have predatory or scavenging feeding behaviour, and are able to survive the trauma of being caught in the codend and handled on deck (e.g. *A. rubens*), may increase in abundance as a result of fishing activities.

Kaiser, M.J., and B.E. Spencer. 1993. Opportunistic feeding on benthos by fishes after the passage of a 4-m beam trawl. ICES CM 1993/G:27. 13 p.

Abstract: When a beam trawl passes over the seabed, benthic animals may be disturbed or killed by the action of the tickler chains and beam shoes. These animals are potentially available for scavenging/predation by fish that move into the trawl tracks after fishing. To test this hypothesis, two species of gurnard, *Eutrigla gurnardus* (L.) and *Aspatrigula cuculus* (L.), and lesser-spotted dogfish, *Scyliorhinus canicula* (L.) were collected, identified and weighed to determine whether feeding had altered after fishing. The catch rate of dogfish was significantly lower 3 h after the previous fishing bout, whereas the catch rate of gurnards did not alter significantly. A comparison of the species found in the stomach contents of fish with the available benthic fauna, indicated that fish were feeding selectively. Gurnards fed exclusively on crustaceans and fish, whereas dogfish fed on a mixed diet of crustaceans, fish, molluscs and polychaetes. Gurnard stomachs also contained significantly more shrimps and amphipods and dogfish stomachs contained significantly more amphipods after intensive fishing. It is deduced that predatory fish capitalise on animals killed or disturbed from their burrows, or other smaller predators that move into a recently trawled area. Furthermore, a side-scan sonar survey of beam trawl tracks 3 h after fishing showed that there were 3.8 times as many shoals of fish over the trawl tracks compared with the adjacent unfished area. Food generated by beam trawling could provide a significant component of the diets of certain opportunistic fish species in some areas subject to intensive beam trawl activity.

Kaiser, M.J., and B.E. Spencer. 1994. Fish scavenging behavior in recently trawled areas. Marine Ecology Progress Series. Vol. 112:41-49.

Abstract: The diets of gurnards *Aspitrigla cuculus* and *Eutrigla gurnardus*, lesser-spotted dogfish *Scyliorhinus canicula* and whiting *Merlangius merlangus* were examined to determine whether they migrated into recently trawled areas to feed on animals that may be damaged or dislodged by the action of a 4 m beam trawl. Gurnards and whiting increased their intake of prey after an area had been fished. In particular, they increased the proportion of the amphipod *Ampelisca spinipes* in their diets. Beam trawling damaged the purple burrowing heart urchin *Spatangus purpureus*, scallop *Aequipecten opercularis*, *Ensis* spp. and *Laevocardium* sp., exposing internal tissues which were then eaten by whiting. Some mobile invertebrate scavengers, such as *Pandalus* spp., only occurred in diets after the area had been fished, suggesting that these animals were also scavenging over the trawl tracks.

Observations of the seabed using a side-scan sonar revealed a greater concentration of fish marks around the trawl tracks than in adjacent unfished areas. Our results indicate that fish rapidly migrate into beam trawled areas to feed on benthic animals which have been either damaged or disturbed by fishing or on scavenging invertebrates. In areas where certain benthic communities occur, beam trawling intensity may be such that it creates a significant food resource for opportunistic fish species. This is a possible mechanism whereby long-term community structure could be altered by fishing activity.

Kaiser, M.J., B. Bullimore, P. Newman, K. Lock, and S. Gilbert. 1996. Catches in 'ghost fishing' set nets. Marine Ecology Progress Series. Vol. 145(1-3):11-16.

Abstract: Both trammel and gill nets are used to catch marine fishes and crustaceans around the British Isles. Their use is controversial in areas where there is a risk of incidental catches of seabirds or marine mammals. An additional concern is the fate and fishing capabilities of nets when they are lost either as a result of bad weather or when they are damaged by mobile fishing gear. Few, if any, studies have ascertained for how long or effectively these lost nets continue to fish, more commonly termed 'ghost fishing'. Two types of fixed gear, a gill and trammel net, were set by a commercial fisherman ca 1000 m offshore from a rocky coastal area in southwest Wales, UK. One end of each net was cut free to simulate net loss. The nets were then allowed to fish continually for 9 mo, during which time they were surveyed by divers recording catches by direct observation, still photography and video camera survey. Several hours after both nets had been set, a large number of dogfishes were caught, causing the nets to collapse. Within 1 d, 2 commercial crustacean species, spider crabs *Maja squinado* and brown crabs *Cancer pagurus*, were attracted to the dead and decomposing fishes. Many of these animals also became trapped in the netting and were fed upon by their conspecifics and other scavengers. Some of these crustaceans also became entangled and died, producing a sequence of captures throughout the observation period. Catch rate began to decline within a few days of the initial deployment, probably related to a decline in the effective fishing area. The results indicate that lost nets could continue to catch commercial crustacean species for at least 9 mo after initial loss.

Kaiser, M.J., D.B. Edwards, and B.E. Spencer. 1996. Infaunal community changes as a result of commercial clam cultivation and harvesting. Aquatic Living Resources. Vol. 9:57-63.

Abstract: Manila clams, *Tapes philippinarum* (Adams and Reeve) are cultivated beneath plastic netting, to protect them from excessive predation, and harvested after approximately two years. Both the on-growing and harvesting process have the potential to alter benthic communities. In order to study these effects, we surveyed a clam lay and uncultivated areas at a site of commercial clam cultivation in south-east England. Surveys were undertaken at the end of the growing stage, immediately after harvesting by suction dredge and seven months later. Infaunal abundance was greatest within a net covered clam lay than in proximate and distant control areas, but the total number of species encountered was similar in all areas (20-22). These differences were not attributable to variation in sediment structure or environmental variables between the areas sampled. Tube-building polychaetes, such as *Lanice conchilega* and *Euclymene lumbricoides*, were particularly abundant within the cultivated area as was the errant polychaete, *Syllis gracilis*. Harvesting by suction dredge altered sediment composition by removing the larger sand fractions down to the underlying

clay substratum, consequently there was a large reduction in the density of all individuals and the total number of species. Seven months later, no significant difference was found between the infaunal community in the harvested clam lay or either of the control areas and sedimentation had nearly restored the sediment structure. These observations indicate that the practice of clam cultivation does not have long-term effects on the environment or benthic community at this site.

Kaiser, M.J., A.S Hill, K. Ramsay, B.E. Spencer, A.R. Brand, L.O. Veale, K. Pruden, E.I.S. Rees, B.W. Munday, B. Ball, and S. J. Hawkins. 1996. Benthic disturbance by fishing gear in the Irish Sea: A comparison of beam trawling and scallop dredging. Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 6(4):269-285.

Abstract: 1) The distribution of effort for the most frequently used mobile demersal gears in the Irish Sea was examined and their potential to disturb different benthic communities calculated. Fishing effort data, expressed as the number of days fished, was collated for all fleets operating in the Irish Sea in 1994. For each gear, the percentage of the seabed swept by those parts of the gear that penetrate the seabed was calculated. 2) For all gears, the majority of fishing effort was concentrated in the northern Irish Sea. Effort was concentrated in three main locations: on the muddy sediments between Northern Ireland and the Isle of Man (otter and *Nephrops* trawling); off the north Wales, Lancashire and Cumbrian coast (beam trawling); the area surrounding the Isle of Man (scallop dredging). 3) In some areas, e.g. between Anglesey and the Isle of Man, the use of scallop dredges and beam trawls was coincident. A comparative experimental study revealed that scallop dredges caught much less by-catch than beam trawls. Multivariate analysis revealed that both gears modified the benthic community in a similar manner, causing a reduction in the abundance of most epifaunal species. 4) Although beam trawling disturbed the greatest area of seabed in 1994, the majority of effort occurred on grounds which supported communities that are exposed to high levels of natural disturbance. Scallop dredging, *Nephrops* and otter trawling were concentrated in areas that either have long-lived or poorly studied communities. The latter highlights the need for more detailed knowledge of the distribution of sublittoral communities that are vulnerable to fishing disturbance.

Kaiser, M.J., K. Ramsay, and B.E. Spencer. 1996. Short-term ecological effects of beam trawl disturbance in the Irish Sea: a review. ICES CM 1996/Mini:9. 5 p.

Abstract: In this paper we review the results obtained from a long-term experiment that was begun in spring 1992 to examine the ecological effects of beam trawling on benthic communities. The main effects of beam trawling studies were i) changes in sediment structure, ii) changes in infaunal and epifaunal community structure, iii) survival of animals retained by the codend and those escaping through the meshes of the codend, and iv) the feeding behaviour of predators and scavengers that aggregate on trawled areas.

Kaiser, M.J., and B.E. Spencer. 1996. Behavioural responses of scavengers to beam trawl disturbance. Pages 116-123 *in* S.P.R. Greenstreet and M.L. Tasker, editors. Aquatic Predators and Their Prey. Blackwell Scientific Publications, Oxford.

Abstract: 1) Beam trawling may contribute to long-term changes in benthic communities. Most studies have concentrated on the direct effects of fishing on animals intimately associated with the seabed. However, the role of scavengers of animals damaged or disturbed by trawling is poorly understood. 2) We investigated the behavior of potential scavengers, at time intervals before and after fishing an area with a 4 m beam trawl, using a combination of replicate 2.8 m beam trawl tows, diver operated video surveys and extended camera observations of bait. 3) After fishing with the commercial beam trawl, the density of dabs and gurnards increased significantly. Dabs dispersed within 48 h, whereas gurnard numbers remained high. Although the density of hermit crabs was lower immediately after fishing, they increased to the prefishing level after 24 h. Diver observations indicated that some scavengers aggregated on the trawled area within 1 h and were patchily distributed. After 24 h, common starfish and whelks were observed in greater numbers on the trawl track and were feeding on animals that had been damaged by the beam trawl. 4) Within 30 min, dabs and whiting were attracted to a baited bag attached to a camera frame located in close proximity to the trawled area. Hermit crabs arrived after 40 min, with peak numbers occurring between 3 to 14 h after the baited camera reached the seabed. Whelks started to arrive after 7 h, peaked at 12 h and then began to disperse. Starfish continued to arrive at the bait bag for up to 17 h. 5) Beam trawling seems to provide a food supply for a variety of scavenging species. It is conceivable that, in some areas, scavenger abundance could be related to trawling intensity and frequency, and may indicate the scale of intensity. In heavily trawled areas, communities may eventually become dominated by high abundances of a few scavenging species.

Kaiser, M.J., and B.E. Spencer. 1996. The effects of beam-trawl disturbance on infaunal communities in different habitats. Journal of Animal Ecology. Vol. 65(3): 348-358.

Abstract: 1) Beam-trawling is a source of physical disturbance to marine sedimentary communities in areas less than 50 m deep, on the western European continental shelf. Chains attached between the beam-trawl shoes are designed to penetrate the upper few cm of the sediment which leads to the damage or removal of some infaunal and epifaunal species. In some areas, beam-trawling may be frequent and intense, leading to speculation that it may generate long-term changes in the local benthic fauna. 2) As part of a larger MAFF study examining the ecological effects of beam-trawling, we investigated its local impact on an infaunal community in the north-eastern Irish Sea. Studies of this type are complicated by the heterogeneity of the environment, hence we adopted a replicated, paired control and treatment design to maximize the chances of detecting any effects due to trawling. 3) A side-scan sonar survey revealed that the experimental area was characterized by mobile megaripples in the south-eastern sector of the experimental area and stable sediments with uniform topography in the north-western sector. Multivariate analysis of the species abundances from the control areas separated the fauna into two distinct communities which corresponded to the different substratum characteristics. Data from the two regions were therefore treated separately when testing for the effects of trawling. 4) In the north-western sector, trawling led to 58% decrease in the mean abundance of some taxa and a 50% reduction in the mean number of species per sample. Multivariate analysis revealed that differences between control and fished sites were largely due to the reduction or removal of less common species. These effects were less apparent in the mobile sediments of the south-eastern sector, which had a naturally impoverished fauna and high level of heterogeneity.

5) Univariate variables, such as abundance and the total number of species per sample, indicated that the variation between replicate samples increased as a result of trawling disturbance. However, examination of the community data using an index of multivariate dispersion revealed no difference between fished and unfished areas. This suggests that the effects of fishing disturbance are consistent between replicate samples. 6) Fishing with demersal gears modifies communities in relatively stable sediments. Frequent and repeated physical disturbance by fishing gears may lead to long-term changes in the benthic community structure of these habitats.

Kaiser, M. J., and J.W. Horwood. 1997. Damage limitation on the sea bed. New Scientist. Vol. 156:55.

Summary: The writers maintain that bottom trawling does not always result in the predicted damage to seabed life. Unintentionally misleading reports on the extent and ecological importance of the predicted disturbance caused by bottom fishing are sometimes presented. Fishermen tend to distribute their effort patchily and this may be an effective method of conservation, reducing the extent of physical disturbance. The fact that the target species return to the same grounds every year indicates that they are recolonizing these areas.

Kaiser, M.J., and K. Ramsay. 1997. Opportunistic feeding by dabs within areas of trawl disturbance: possible implications for increased survival. Marine Ecology Progress Series. Vol. 152:307-310.

Abstract: As demersal fishing gears are towed across the seabed they dig up or damage infauna. Dab *Limanda limanda* L. are known to aggregate in areas disturbed by trawls. We demonstrate that dab alter their diet and increase their food intake when feeding in these areas. Although dabs are frequently caught in large numbers as part of the by-catch of commercial flatfish fisheries, and a large proportion of these die, they remain the most abundant flatfish species in the North Sea. Fisheries have selectively removed species that prey upon or compete with dab. Furthermore, fishing activity increases feeding opportunities for dabs. These factors may have contributed to the observed increase in the abundance of dab in the North Sea.

Kaiser, M.J., D.B. Edwards, P.J. Armstrong, K. Radford, N.E.L. Lough, R.P. Flatt, and H.D. Jones. 1998. Changes in megafaunal benthic communities in different habitats after trawling disturbance. ICES Journal of Marine Science. Vol. 55:353-361.

Abstract: As part of a long-term study to examine the ecological effects of beam-trawling, we investigated the immediate impact of fishing on the megafaunal component of a benthic community and the extent to which it had recovered 6 months later. A quantitative dredge was used to collect megafaunal samples following a replicated, paired control and treatment design to maximize the chances of detecting any effects due to trawling. There were two different habitats with distinct communities in the experimental area, one with stable sediments and a rich fauna, the other with mobile sediment and a relatively impoverished fauna. Immediately after fishing the composition of the community in the stable sediments was significantly altered. While the abundance of some species decreased (e.g. sea mice *Aprodita aculeata*), others apparently increased (e.g. hermit crabs *Pagurus bernhardus*).

Variation between samples from the fished areas was higher than those from the control areas. This suggests that the effects of trawling were not uniform, even though the treatment area was entirely swept at least once. The effects of fishing were not detectable in the mobile sediments. Six months later, seasonal changes had occurred in both communities and the effects of the trawling disturbance were no longer evident.

Kaiser, M.J., K. Cheney, F.E. Spence, D.B. Edwards, and K. Radford. 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. VII. The effects of trawling disturbance on the fauna associated with the tubeheads of serpulid worms. Fisheries Research. Vol. 40:195-205.

Abstract: We report the effects of beam trawling on the diverse fauna associated with tubeheads formed by serpulid worms. Despite an experimental regime of biannual fishing, no changes in the number or size of serpulid tubeheads was apparent throughout the course of the study, and no significant changes were detectable in the composition of the tubehead fauna that could be attributed to fishing disturbance. A laboratory study revealed that tubeheads were unlikely to resettle on the seabed in an orientation similar to that prior to disturbance. Serpulids are known to be opportunistic species and may rapidly recolonise disturbed areas, such that we were unable to detect these changes within our sampling regime. Serpulid tubeheads provide an important microhabitat, a total of 73 taxa (50 species) being associated with them. Other similar studies indicate that these associated organisms are important food for small fish. In addition to increasing benthic biodiversity, they provide a potentially important habitat for juvenile commercial species, providing shelter and food.

Kaiser, M.J., S.I. Rogers, and J.R. Ellis. 1999. Importance of benthic habitat complexity for demersal fish assemblages. Pages 212-223 *in* L. Beneka, editor. Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Abstract: Major amendments in 1996 to the Magnuson-Stevens Fishery Conservation and Management Act require fisheries managers to define "essential" fish habitat and address the impact of fishing gear in their management plans. However, before considering what might qualify as essential fish habitat, it is necessary to first understand the association between fish and their habitat. Some studies have already revealed subtle relationships between fishes and sediment type; however, this approach does not quantify habitat complexity. We undertook a large-scale survey of demersal fish populations and benthic communities in the southern North Sea and eastern English Channel. As in other studies, water depth was closely linked to the main dichotomy in assemblage composition. Flatfishes occurred in shallow water, whereas roundfishes and small shark species were found in deeper habitats. Within each of these two sample station groupings, the assemblages dichotomised further on the basis of habitat type and benthic faunal associations. Three further groupings were identified within the deepwater habitat. These groupings were characterized by the presence of rocks, broken shells, or a large biomass of sessile epibenthos. Small shark species were almost exclusive to habitats with shelly substrata. In contrast, the shallow-water habitats were topographically less complex with sessile epibenthos of a smaller biomass. Flatfishes that were visual predators were most closely associated with habitats with some sessile epibenthos, whereas sole *Solea solea*, which largely locate their prey using chemosensory cues, were more closely associated with the least complex habitat. Although these flatfish habitats are intensively

fished by bottom trawls, the characteristic sessile epifauna are relatively fast growing and are probably able to withstand such disturbance. In contrast, the deepwater sessile communities had sessile epifauna of a greater biomass with some slow-growing species that would be more vulnerable to fishing disturbance. However, these habitats are seldom fished using invasive techniques.

Kanehiro, H., T. Tokai, and K. Matuda. 1995. Marine litter composition and distribution on the seabed of Tokyo Bay. Fish. Eng. (Japan)/Suisan Kogaku. Vol. 31(3):195-199.

Abstract: A survey, via beam trawl, of the abundance, type (plastics, fishing gear, textile and other) and distribution of litter was conducted on the seabed of an area in the central portion of Tokyo Bay. Over 4 years period (1989-1991 and 1993) of the litter, plastics (synthetic polymer resin) made up 80-85% of the total, with 60% of these plastics being of low specific gravity (range 0.86-1.1). These substances, due to them being relatively inert and widely distributed, pose a significant pollution threat to fishing grounds and the nearshore marine environment. Litter from fishing activities although quantitatively small were also significant and pose potential damage to resources via 'ghost fishing' after being discarded.

Kauwling, T.J., and G.J. Bakus. 1979. Effects of hydraulic clam harvesting in the Bering Sea. Unpublished Report submitted to the North Pacific Fishery Management Council. Tetra Tech Report TC3324. 183 p.

Kelley, G.H. 1990. A review of fish trapping. A non-thesis option paper submitted in partial fulfillment of the requirements for the degree of Master of Science in Ocean Science with a speciality in: Marine Biology. Nova University. 61 p.

Kenchington, T.J. 1991. Some effects of bottom trawling on the availability of cod biomass to an inshore longline fishery: a discussion. Northwest Atlantic Fisheries Organization SCR document; 91/10. 21 p.

Abstract: A fundamental assumption of fisheries science holds that fishing effort is the only significant variable control on the abundance of typical marine commercial fish resources, such as Atlantic cod, that acts after the age of recruitment. Such effort is supposed to affect the resources only via the fishing mortality that it imposes. This simplified conceptual model is not shared by commercial fishermen, who believe that a much wider range of factors influence abundance. In this paper, a subset of fishermen's views, specifically those advanced by Nova Scotian longline fishermen concerning the effects of bottom trawling on cod abundance, are examined. Most of these ideas have been considered and dismissed in past scientific reviews and, in many cases, those rejections are supported here. I do, however, suggest that trawling may have adverse effects on cod production and availability through either or both of the destruction of specific, preferred bottom habitats off Nova Scotia and the physical disturbance of the fish's behaviour patterns. I therefore suggest that a wider range of mechanisms linking fishing effort to the depletion of cod resources should be considered in fisheries management. Further, while the longline fishermen's arguments against trawling that are based on population dynamics do not bear critical examination, I suggest that there are two mechanisms by which trawling may have a disproportionate effect on the abundance of cod available to longlining. These mechanisms are examined by

modeling of the cod fishery in western NAFO Division 4Vn. The first of them, the spatio-temporal concentration of trawling effort on those components of the resource that are available to longlining, does not appear to be significant for this fishery. However, the difference in partial recruitment vectors of the two years, which allows the trawlers to exploit heavily a year class before it is markedly available to longlining could have important consequences for management. I therefore suggest that, even where fishing effort impacts on the resource via fishing mortality, a more complex view of that mechanism should be incorporated into stock assessments and, particularly, management practices.

Kenchington, T.J. 1995. A summary of the published evidence relating to habitat modification by fish draggers. Pages 109-116 *in* The Canadian Maritimes Fishing: Let's Fix It, An Action Plan. SW Nova Fixed Gear Association. Shelburne, Nova Scotia, Canada.

Summary: This paper summarizes the current scientific knowledge on the effects of trawling on the seabed. The author argues that although there has been little scientific research done on trawling impacts, that it has at least some negative impact. He further states that fishery managers should consider trawling effects during the formulation of their management plans.

Kendall, J. 1998. Scallop dredge fishing. Pages 90-93 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: A commercial fisherman describes his fishing gear and its perceived effects on habitat.

Ketchen, K.S. 1947. An investigation into the destruction of grounds by otter trawling gear. Fisheries Research Board of Canada Progress Report. 73:55-56.

Summary: This study drug an otter trawl over a beach at high tide, and the effects were examined at low tide. The author found that the path taken by the otter trawl boards were traceable over most of the route. He found no evidence to indicate that damage to the bottom was caused by the net.

Kimani, E.N. 1995. Coral reef resources of east Africa: Kenya, Tanzania and the Seychelles. Naga, the ICLARM Quarterly. Vol. 18(4):4-7.

Abstract: Coral reefs are widespread along the East African coast and Seychelles Islands. Their roles in island building and coastal protection are often underestimated, they are also important fishery habitats and major tourist attractions. The East African marine fishery production, estimated at 1.4-4.9 tonnes per km^2, is principally a result of artisanal fishing. Siltation, trampling, and destructive fishing methods are the main cause of coral reef degradation along the East African coast and associated islands. Legislation has been implemented to protect coral reefs by establishing marine parks and reserves. However, poaching and anchor damage are widespread on these protected reefs. Legislative provision to increase the benefit to fishing communities may reduce poaching. The establishment of

exclusive nature reserves may be on way to ensure preservation of some coral reefs in the region.

Kimker, A. 1994. Tanner crab survival in closed pots. Alaska Fishery Research Bulletin. Vol. 1(2):179-183.

Abstract: Lost and delinquent commercial and sport fishing gear has gained public notoriety recently because of documented waste of fish and shellfish resources. Shellfish and groundfish pots have contributed to the problem. Although escape mechanisms have been developed to allow egress of captured species from pots, imprecise release time of these devices has generated debate exacerbated by inexact estimates of the survival of captured species. To gain information on Tanner crab *Chinoecetes bairdi* survival in pots, we capture large, adult male Tanner crabs and held them in cod pots in the outer portion of Kachemak Bay, Alaska. The pot tunnels were secured shut so the crabs had no chance to escape. No external source of food was provided. The pots were pulled periodically over a 119-d period. A total of 52 (39%) of the original 132 crabs died during the experiment.

Kingsford, M.J., A.J. Underwood, and S.J. Kennelly. 1991. Humans as predators on rocky reefs in New South Wales, Australia. Marine Ecology Progress Series. Vol. 72:1-14.

Abstract: Multifactorial sampling designs were used to describe the activities of humans on rocky reefs. Intensive studies around Sydney and broad scale surveys along 1000 km of the coast of New South Wales (NSW), Australia, recorded the amount of fish and exploitation of intertidal organisms by humans. Sparid and girellid fish were taken in large numbers by fishermen. Intertidal ascidians, crabs, and gastropods were primarily used by fishermen taken as bait. The activity of humans affecting the shore was greatest from late morning to dusk on weekdays and weekends of school holidays. No major effects of tide were detected. Numbers of people affecting or not affecting the shore (e.g. sunbathers and walkers) were greatest in summer. The distribution of fishermen was patchy on scales of 50 and 100 m and the effects of fishing and gathering bait may therefore be concentrated in particular small areas. Broad-scale surveys along the coast of NSW in summer and winter detected no differences, in numbers of people affecting the shore, between widely separated locations at varying distances from highly populated areas. People in NSW are probably sufficiently mobile to create this pattern. Large differences were found among sites separated by 1 to 10 km at each location along the coast of NSW. Humans have a potentially important direct effect on populations of organisms and indirect effects on structure of inshore assemblages of species. Multiple sanctuaries are recommended to determine the effect of exploitation by humans. Moreover, additional information is required on the ecology of species particularly subject to predation by humans.

Klemanowicz, K.J. 1985. Effects of a mechanical oyster harvester on macrofaunal community structure. MS Thesis, The College of Charleston. Charleston, South Carolina. 102 p.

Klemanowicz, K.J., and G.H. Steele. 1984. Effects of a mechanical oyster harvester on macrobenthic community structure. Journal of Shellfish Research. Vol. 4:92.

Abstract: The ecological effects of mechanical harvesting on the intertidal benthic invertebrate community associated with oyster beds in Beaufort County, SC, is being studied. At a harvest site macrobenthos that inhabit oyster beds in the high and low intertidal zones are being monitored before and after harvesting and at seasonal intervals over an annual cycle. In order to assess changes in community structure that may be effected by the harvester, a nearby control will be sampled on the same schedule as the harvested site. For each sampling period, 16-m^2 circular quadrat is being used to collect 5 replicate samples from both high and low intertidal areas in the harvested and control sites. A quantitative assessment of motile and noncolonial macrobenthos is being made, whereas only the species composition of colonial and encrusting organisms is noted. Biomass is determined for all live oysters in a sample in addition to other molluscs (including shell) and decapod crustaceans. Changes in diversity, species composition, and relative density are being analyzed for the macrobenthic community inhabiting intertidal strata at each site. Information gained will be used to determine whether the integrity of the benthic community is disturbed by use of the mechanical harvester.

Koslow, J.A., and K. Gowlett-Holmes. 1998. The seamount fauna off southern Tasmania: benthic communities, their conservation and impacts of trawling. Final report to Environment Australia and the Fisheries Research Development Corporation. FRDC Project 95/058.

Summary: In 1995, a 370 km^2 area off Tasmania was closed to trawling for three years. The objects of the study were to assess the uniqueness of the benthic fauna of the region, the potential impacts of the deepwater trawl fishery on the fauna, and measures required to conserve the fauna. The study found that trawl operations significantly impacted the most heavily fished areas where the reef aggregate has been mostly removed from the slopes or turned to rubble.

Kröencke, I. 1995. Long-term changes in North Sea benthos. Senckenbergiana Maritima. Vol. 26(1-2):73-80.

Abstract: The existing literature on long-term benthic data sets in the North Sea south of 58 degree North is reviewed. There is evidence that changes found in benthic communities are caused by anthropogenic rather than by natural impact. Eutrophication, pollution and fisheries impact are the main reasons for changes in the benthic environment.

Krost, P., M. Bernard, F. Werner, and W. Hukriede. 1990. Otter trawl tracks in Kiel Bay (Western Baltic) mapped by side-scan sonar. Meeresforschung. Vol. 32:344-353.

Abstract: Tracks of bottom trawling gear, in particular of otter boards, have been mapped from side-scan sonar records. The extent of disturbance per unit area was quantified by relating the area covered by trawl to the total area. Frequency classes were defined and related to sediment type and water depth. The density of trawl tracks is highest below 20 m and in mud areas. Taking into account fishing effort data, it can be concluded that some areas are ploughed at least once a year by the boards alone.

Krost, P., and H. Rumohr. 1990. Effects on the benthos of physical disturbance of the sea bed. Annex to the Ninth Report of the Benthos Ecology Working Group. ICES CM 1990/L:95. p. 75-77.

Summary: This report examines the effects of bottom trawling on the benthos and the nutrient release from the sediment in Kieler Bucht. A small scale comparison was made between the abundance and biomass of the benthos in a fresh trawling track and in an undisturbed control area to study the effects of an otter trawl on benthic species. A large scale comparison was made between regions known to be intensely trawled with areas that were not trawled to determine long-term changes of benthic species. Lastly, a study to determine the degree and patterns of damage to benthic organisms by trawls was preformed.

Kruer, C. 1998. Boating impacts on seagrass habitats in Florida. *In* R.E. Crawford, N.E. Stople, and M.J. Moore, editors. The environmental impacts of boating; proceedings of a workshop held at Woods Hole Oceanographic Institution, December 7-9, 1994. Technical Report. WHOI-98-03.

Summary: This paper is part of a presentation made at a workshop on the environmental impacts of boating in 1994. The presentation described prop scarring and other boating impacts on seagrass in the Florida Keys. The author also presents ways to limit boating damage to seagrass. These include restricting their use to certain areas and better marking of channels.

Kyte, M., P. Averill, and T. Hendershott. 1975. The impact of the hydraulic escalator shellfish harvester on an intertidal soft-shell clam flat in the Harraseeket River, Maine. Department of Marine Research, Augusta, Maine. Project Completion Report. 54 p.

Kyte, M.A., and K.K. Chew. 1975. A review of the hydraulic elevator shellfish harvester and its known effects in relation to the soft-shell clam, *Mya arenaria.* Washington Sea Grant Publication Report No. WSG 75-2. University of Washington, Division of Marine Sciences. Seattle, Washington. 32 p.

Laist, D.W. 1996. Marine debris entanglement and ghost fishing: a cryptic and significant type of bycatch. Pages 33-39 *in* Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Program Report No. 96-03, University of Alaska Fairbanks.

Abstract: Lost fishing gear and gear scraps are the most hazardous types of marine debris pollution for marine life. Lost gillnets and traps can remain intact and catch marine life for well over a decade. The amount of gear lost annually probably increases with increased fishing effort and, in some areas, derelict gear may outnumber active gear units. Most entangled seals, seabirds, and turtles are reported caught in small fragments of trawl net, gillnet, and monofilament line. However, some of the highest mortality levels may involve commercial fish and shellfish caught in lost gear while it is still relatively intact. Ghost fishing of some commercial stocks has been estimated to catch amounts equal to 5% - 30% of the annual landing levels. These estimates only consider ghost fishing by gear lost in the associated fishery (e.g. mortality of lobster in lost lobster pots). If ghost fishing by all types of lost gear is considered, impacts on some fishery resources, especially crabs and lobsters,

could be much greater than levels estimated to date. Highest priority needs are for designing and verifying the effectiveness of time-sensitive gear disabling mechanisms (e.g., escape panels for traps), providing services for the disposal of old fishing gear, developing technology and approaches to minimize gear loss, and research on the rates and causes of gear loss, and the catch by different types of derelict gear over the long term.

Laist, D.W. 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. Pages 99-139 *in* J.M. Coe and D.B. Rogers, editors. Marine Debris, Sources, Impacts, and Solutions. Springer. New York. 432 p.

Summary: In this chapter, the author compiles a very exhaustive list of marine animals that have been entangled in lost fishing gear. The list details the animals captured, the ghost fishing gear, the location captured, and the study that documents the capture.

Laist, D.W., T.E. Bigford, G.W. Robertson, and D.R. Gordon. 1986. Management of corals and coral ecosystems in the United States. Coastal Zone Management. Vol. 13(3-4):203-239.

Abstract: Corals and coral communities provide substantial societal benefits by virtue of their recreational and esthetic appeal, the habitat provided for commercially harvested fish and shellfish, the structural foundation provided for productive coastal ecosystems, and the market value of harvested coral specimens. Coral resources are subject to adverse effects from pollution, dredging, specimen collecting, anchor damage, commercial fishing, overharvesting, and activities related to offshore petroleum development. Management programs which protect coral resources in the United States comprise a patchwork of separate federal and state programs. They attempt to adapt broad regulatory authorities for parks, fisheries, offshore mineral resources, and other subjects for the purpose of coral conservation. These programs embody species-specific, area-specific, and generic approaches to coral management. This paper traces the evolution of U.S. coral management programs and comments on their respective strengths and weaknesses. Alternative approaches for strengthening management systems could include new coordinating committees, legislation, memoranda of agreement between involved agencies, and others.

Lambert, J., and P. Goudreau. 1996. Performance of the New England hydraulic dredge for the harvest of Stimpson's surf clams (*Mactromeris polynyma*). Canadian Industry Report of Fisheries and Aquatic Sciences. Vol. 235. 28 p.

Abstract: The New England hydraulic dredge has been used recently in the commercial harvest of Stimpson's surf clams in the Gulf of St. Lawrence. We undertook a study to determine the harvesting efficiency of this fishing gear and its immediate impact on the mollusc populations.

Langton, R.W. 1994. Fishing effects on demersal fish habitats. Pages 7-8 *in* R.W. Langton, J.B. Pearce, and J.A. Gibson, editors. Selected Living Resources, Habitat Conditions, and Human Perturbations of the Gulf of Maine: Environmental and Ecological Considerations for Fishery Management. NOAA Technical Memo. NMFS-ME-106. Woods Hole, MA.

Summary: Author briefly reviews recent studies on the effects of trawling and dredging on fish habitat. He also reviews the effects of bycatch and processing discards, lost gear, and gives a brief fishing effects overview.

Langton, R.W. 1998. The effect of dredge harvesting on eastern oysters and the associated benthic community. Pages 108-110 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: Author studies the effect of dredge harvesting on oysters on the boundary between New Hampshire and Maine. The results of this study indicate that this type of mobile fishing gear did not cause negative impacts on either the habitat or the targeted species.

Langton, R.W., and W.E. Robinson. 1990. Faunal associations on scallop grounds in the western Gulf of Maine. Journal of Experimental Marine Biology and Ecology. Vol. 144:157-171.

Abstract: Benthic photographic transects were made during 1986-1987 across productive scallop beds on Jeffreys and Fippennies Ledges, western Gulf of Maine, from a manned submersible at depths of 56-84 m. Three megafaunal invertebrates dominated at each site: the sabellid worm *Myxicola infundibulum* (Renier) mean densities ranging from 3.3±4.2 to 7.1 ± 9.6 m^{-2}); the burrowing cerianthid anemone *Cerianthus borealis* Verrill (1.0 ± 1.2 to 2.0 - .05m^{-2}); and the sea scallop *Placopecten magellanicus* (Gmelin) 0.2 ± 0.5 to 1.0 ± 2.2m^{-2}). All three species exhibited contagious distributions (i.e., occurred in large scaled clusters or patches), which could be modeled by negative binomial functions. On Fippenies Ledge, where little scallop dredging occurred in 1986, but, where appreciable fishing was conducted in 1987, sea scallops were positively associated with *M. infundibulum* and negatively associated with *C. borealis* in both years. In contrast, the association between *M. infundibulum* and *C. borealis* changed from a significant negative association in 1986 to random in 1987. The marked increase in scallop dredging on Fippennies Ledge between 1986 and 1987 was apparently the cause of a significant decline in the mean densities of all three megafaunal species (70% decline in sea scallops; 25-27% decline in cerianthids and myxicolids), although the pattern of faunal association with the sea scallops remained intact. On Jeffreys Ledge, where intensive dredging had occurred prior to our 1986 sampling, the pattern of faunal association described for Fippennies Ledge was absent. Thus, natural faunal associations may be severely impacted by fishing operations. We propose that *C. borealis* controls the spatial distribution and patch size of both *M. infundibulum* and *P. magellanicus* by preying on the larvae of the latter two species.

Langton, R.W., P.J. Auster, and D.C. Schneider. 1995. A spatial and temporal perspective on research and management of groundfish in the northwest Atlantic. Reviews in Fisheries Science. Vol. 3(3):201-229.

Abstract: Fish populations have been exploited along the northeastern coast of North America for over 500 years. During this period, an extensive knowledge of fish distributions and habitat has developed both as anecdotal and scientific literature. Despite this knowledge, catches and stocks have fluctuated widely. As a result of a large decline in the fish stocks

that is primarily attributed to overfishing, the region is currently experiencing the implementation of extreme management initiatives to allow the exploited stocks to recover. As our scientific knowledge of fish populations increases, the question arises as to how we integrate our knowledge of fish and fishers, at multiple scales, and produce a management structure that maintains stocks at sustainable levels. This article addresses that question by reviewing patterns and processes exhibited by both fishers and fish through a hierarchy of temporal and spatial scales. Large-scale population surveys, for example, document the persistence of patterns in the structure and geographic range of fish populations. In contrast to regional-scale patterns in population structure, both fish and fishers interact and react at the scale of a fishing ground. Similarly, the large industrial fleets concentrate on aggregations of fish because the profitability of larger trawlers depends more on the concentration of the resource than the distance from the home port. Research has also demonstrated that fish distributions can be attributed to variability in small-scale physical (i.e., habitat) features. The impact of fishing and the behavior of animals at the fishing ground and habitat scales is cumulative at the population level where current management plans operate. Management actions must, however, be considered not only at the population level, but also at smaller scales in order to have predictable effects. It is essential to integrate the different scales that operate throughout the fishery into a management scheme that incorporates both the perspective of the fishers and the targeted resource.

Langton, R.W., and P.J. Auster. 1999. Marine fishery and habitat interactions: to what extent are fisheries and habitat interdependent. Fisheries. Vol. 24(6):14-21.

Abstract: The scientific literature unequivocally supports the premise that fisheries affect an ecosystem by altering the flow of ecological capital. This article reviews the ecological rules that define this flow and discusses the consequences of current fishery practices on habitat integrity and fish production in marine systems. The impact of fishing is a function of its intensity and severity relative to other perturbations in the oceans. Its impact also has to be explained at appropriate temporal and spatial scales and, unfortunately, there is often a mismatch between fisheries data and many ecological processes. Groundfish, in particular, depend on the benthos for their shelter and sustenance, so feedback loops inevitably exist between fish production and the biological community within which fish are both predators and prey. The difficulty for fishery managers is to predict the direction, let alone the magnitude, of fishing-induced changes on these feedback mechanisms. The challenge for habitat researchers is to develop a quantitative predictive capability given a particular management protocol, but until this is accomplished, it is incumbent on managers and scientist alike to apply the precautionary approach to all management decisions by using current ecological theory to guide this process.

Laurenson, L.J.B., P. Unsworth, J.W. Penn, and R.C.J. Lenanton. 1993. The impact of trawling for saucer scallops and western king prawns on the benthic community in coastal waters off Southwestern Australia. Report 100. Fisheries Department of Western Australia. Fisheries Research. Perth, Western Australia. 93 p.

Leach, M. 1998. Bottom longline fishing. Pages 96-98 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: A commercial fisherman describes his fishing gear and its perceived effects on habitat.

Legaspi, N. 1999. Balancing environmental, social, and economic sustainability in the Lingayen Gulf. http://darwin.bio.uci.edu/~sustain/suscoasts/nlegaspi.html. 27 p.

Abstract: The Philippines contain one of the most diverse coral reef systems in the world within the Lingayen Gulf. However, this biodiversity is threatened by anthropocentric activities such as overfishing, pollution, tourism, and a multitude of other direct and indirect problems. In order for the ecosystems of the Lingayen Gulf to coexist with humanity, planning for sustainability must be initiated. While it may be convenient to view the Lingayen Gulf from the standpoint of environmental sustainability, socioeconomic sustainability must also be taken into account. A balance between environmental, economic, and social sustainability is the key to planning success. Improved regulations, better education, and alternative livelihoods for the people will allow successful environmental sustainability, while maintaining socioeconomic sustainability. While the potential is present, the Philippines still has a long way to go before a sustainable Lingayen Gulf is reached.

Lenihan, H.S., and C.H. Peterson. 1998. How habitat degradation through fishery disturbance enhances impacts of hypoxia on oyster reefs. Ecological Applications. Vol. 8(1):128-140.

Abstract: Oysters are ecosystem engineers that create biogenic reef habitat important to estuarine biodiversity, benthic-pelagic coupling, and fishery production. Prevailing explanations for the dramatic decline of eastern oysters (*Crassostrea virginica*) during the last century overlook ecosystem complexity by ignoring interactions among multiple environmental disturbances. To explain oyster loss, we tested whether (1) mortality of oysters on natural oyster reefs varies with water depth (3 m vs. 6 m), (2) harvesting by oyster dredges reduces the height of oyster reefs, and (3) bottom-water hypoxia/anoxia and reduction in reef height through fishery disturbance interact to enhance mortality of oysters in the Neuse River estuary, North Carolina, USA. The percentage of oysters found dead (mean ± 1 SD) during a survey of natural reefs in May 1993 was significantly greater at 6-m (92 ± 10%) than at 3-m (28 ± 9%) water depth. Less than one season's worth of oyster dredging reduced the height of restored oyster reefs by ~ 30%. During stratification of the water column in summer, oxygen depletion near the seafloor at 6 m caused mass mortality of oysters, other invertebrates, and fishes on short, deep experimental reefs, while oysters and other reef associates elevated into the surface layer by sufficient reef height or by location in shallow water survived. Highly mobile blue crabs (*Callinectes sapidus*) abandoned burrows located in hypoxia/anoxic bottom waters but remained alive in shallow water. Our results indicate that interaction of reef habitat degradation (height reduction) through fishery disturbance and extended bottom-water hypoxia/anoxia caused the pattern of oyster mortality observed on natural reefs and influences the abundance and distribution of fish and invertebrate species that utilize this temperate reef habitat. Interactions among environmental disturbances imply a need for the integrative approaches of ecosystem management to restore and sustain estuarine habitat.

Levin, L.A. 1984. Life history and dispersal patterns in a dense infaunal polychaete assemblage: community structure and response to disturbance. Ecology. Vol. 65(4):1185-1200.

Abstract: The effects of differing life histories on the dynamics of dispersal, recruitment, and population maintenance were investigated for a dense infaunal polychaete assemblage on the Kendall-Frost mudflat in Mission Bay, California. Polychaete life history features provided the framework for investigations of small-scale dispersal mechanisms, infaunal response to disturbance, and the spatial and temporal predictability of species' abundances. Field and laboratory studies revealed the *Rhynchospio arenincola* Hartman, *Streblospio benedicti* Webster, *Exogone lourei* Hartman, *Fabricia limnicola* Hartman, and *Capitella* spp. shared many life history traits which limited the range of dispersal. These included small adult size, brood protection, small brood size, and planktonic larval stages which were reduced or absent. *Pseudopolydora paucibranchiata* Okuda, and *Polydora ligni* Webster exhibited initial brood protection but had larger brood sizes and longer lived larvae. Small-scale dispersal was examined by studying patterns of larval availability, recruitment into settling cartons, and colonization of defaunated sediments. The role of dispersal in response to disturbance was examined for two levels of perturbation. Small-scale disturbance, commonly generated on the mudflat by ray foraging and human digging, was studied by artificially defaunating small (0.4-m^2) sediment patches. A severe storm and consequent raw sewage spill created an episodic large-scale perturbation in the middle year of the 3-yr study. Analyses of species' responses revealed colonization ability at recruitment to be distinct from dispersal (migratory) ability. Rates and mechanisms of colonization were governed by larval development, settlement, and mobility patterns and varied with the scale of perturbation. For *R. arenincola*, *S. benedicti*, *E. lourei*, and *F. limnicola*, factors such as brood protection, reduced planktonic larval phases, and postlarval movements, particularly by brooding adults, confer small-scale dispersal abilities which permit rapid colonization of disturbed patches and result in maintenance of high infaunal densities (>200,000 individuals/m^2). *P. paucibranchiata* and *P. ligni* posses long-lived larvae whose planktonic abundances are highly seasonal and variable from year to year. The timing of disturbance must coincide with periods of peak larval availability for successful colonization by these species. In general, the annual life cycles and flexible small-scale mobilities of most species enable persistence in the face of frequent fine-grained disturbance.

Lewis, A.R. 1998. Effects of experimental coral disturbance on the population dynamics of fishes on large patch reefs. Journal of Experimental Marine Biology and Ecology. Vol. 230 (1):91-110.

Abstract: The effects of disturbance to coral on the abundances of fishes were investigated experimentally on the Great Barrier Reef. Fishes on ten large (108-267 m^2) isolated patch reefs or 'bommies' were monitored at 1-2 month intervals for a year. The hard corals on five of these were disturbed by breaking the colonies into small pieces with a mallet. Fishes were counted for the next year. Cover of coral on the damaged bommies decreased from approximately 66% to approximately 29% by the end of the study, but increased by 5% at the control bommies. Linear mixed-effects models were used to examine the numbers of 53 species of fishes (from a total pool of 150 species). Significant declines in abundance were detected in five species, all of which associate closely with live coral: an apogonid (*Cheilodipterus artus*), a chaetodontid (*Chaetodon rainfordi*) and three pomacentrids (the

species complex *Chromis atripectoralis-viridis*, *Dascyllus reticulatus*, and *Pomacentrus moluccensis*). One herbivorous pomacentrid (*Pomacentrus grammorphynchus*) significantly increased in abundance. Each of the affected species showed a different temporal response to the disturbance, ranging from emigration and local extinction within one month, to changes in recruitment six months later. This study shows that many species of fishes are robust to physical disturbances which substantially reduce cover of coral and modify the fine-scale (1 m) heterogeneity provided by the veneer of live corals on the surface of a reef. The few negatively affected species frequently sheltered in live coral; the one positively affected species was herbivorous. Many coral-associated species and many herbivores were not affected, so it is not yet possible to make precise predictions about which species will be affected by disturbance to coral.

Lindeboom, H.J., and S.J. De Groot. 1998. Impact II. The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems. NIOZ Rapport 1998-1. 404 p.

Summary: This report is a compilation of information studying fishing effects in the North Sea and Irish Sea. Several organizations came together to report on eight study topics. These topics are the size of the bottom trawling fleets in the North Sea and Irish Sea area, fishing gears used by these fleets, the physical impact of the fishing gears, catch efficiency of commercial trawls, direct mortality due to trawling, scavenger responses to trawling, comparison of undisturbed and disturbed areas, and long term trends in demersal fish and benthic invertebrate populations.

Lindholm, J.B. 1999. Habitat-mediated Survivorship of Juvenile Atlantic Cod (*Gadus morhua*): Fish Population Responses To Fishing-induced Alteration of the Seafloor in the Northwest Atlantic and Implications for the Design of Marine Protected Areas. Dissertation Abstracts International Part B: Science and Engineering. Vol. 59(12):6168.

Abstract: Much scientific research has focused on large-scale planktonic egg and larval mortality as a factor contributing to annual fluctuations in year-class strength of fishes. Significantly less attention has focused on small-scale, localized processes affecting survivorship of early benthic- phase juvenile fish, although mortality during this life history stage is sufficient to significantly modify population size. The sustainability of Atlantic cod (*Gadus morhua*) populations, a species with ecological, economic and cultural significance for New England, is dependent on the continued productivity of off- shore nursery grounds currently at risk from alteration by fishing activity. Key questions in this regard are: (1) the role of seafloor habitat in mediating the survivorship of early benthic-phase cod; and (2) the implications of predator-prey-habitat interactions for the design and allocation of marine protected areas (MPAs) for fish conservation and management in the northwest Atlantic. Laboratory experiments quantify the effect of fishing impacts to seafloor habitat on mortality rates for juvenile cod. Results indicate that the presence of emergent epifauna (habitat undisturbed by fishing) resulted in a significant decrease in juvenile cod mortality when compared to flat sand (habitat disturbed by fishing) and that density of emergent epifauna is more significant than epifaunal height in reducing juvenile cod mortality. A computer model, parameterized with lab-derived mortality rates and spatial variation in habitat type from seafloor mapping, captures non-linearities in the responses of fish populations to seafloor habitat alteration given variations in fish movement rates, fish densities and MPA

size. Comparison of the existing National Marine Sanctuaries to the National Parks, Forests and Wildlife Refuges illuminates a significant disparity in the designation of protected areas between marine and terrestrial systems with respect to the size of protected areas, their number, and the total area and the proportion of U.S. land and waters currently under protection. Primary conclusions include: (1) fishing alteration of the seafloor has a significant deleterious impact on associated Atlantic cod populations; (2) there is a need to incorporate seafloor habitat protection in the designation of MPAs for fish management; and (3) habitat-specific MPAs should be designated in the northwest Atlantic to buffer against environmental and managerial uncertainty.

Lindholm, J.B., P.J. Auster, and L.S. Kaufman. 1999. Habitat-mediated survivorship of juvenile (0-year) Atlantic cod *Gadus morhua*. Marine Ecology Progress Series. Vol. 180:247-255.

Abstract: Fishing activity can impact fish populations in 2 ways. The first is the immediate effect on population demographics by the removal of fish. Second is the impact of fishing (e.g. bottom trawls and dredges) on the seafloor which can reduce habitat structure and thus increase the vulnerability of juvenile fish to predation by older conspecifics and other predators. We conducted laboratory experiments to investigate the role of variability in seafloor habitat structure on the survivorship of post-settlement juvenile (0-year) Atlantic cod *Gadus morhua*. Groups of 0-yr cod were exposed to a foraging predator (3+ cod) over 5 seafloor habitats of varying complexity (sand, cobble, minimum density short sponge, maximum density short sponge, and tall sponges). These habitats were selected to mimic the range of impacts of mobile fishing gear given a gradient in fishing effort. Emergent epifauna resulted in a significant decrease in 0-yr mortality when compared to flat sand, the least complex habitat. Epifaunal density was shown to be more significant than epifaunal height in reducing 0-yr mortality. Predator reaction distance decreased with increasing habitat complexity, presumably due to the obstruction of visual cues by complex relief. Latency to first and second capture did not differ statistically between habitats. Alteration of seafloor habitat by fishing activity in the northwest Atlantic could magnify the effects of overfishing by limiting juvenile survivorship.

Lindley, J.A., J.C. Gamble, and H.G. Hunt. 1995. A change in zooplankton of the central North Sea (55° to 58° N): a possible consequence of changes in the benthos. Marine Ecology Progress Series. Vol. 119:299-303.

Abstract: The mesozooplankton taken in continuous plankton recorder samples from the central North Sea has changed from being numerically dominated by holoplanktonic calanoid copepod species from 1958 to the late 1970s to a situation where pluteus larvae of echinoid and ophiuroid echinoderms have been more abundant than any single holoplanktonic species in the 1980s and early 1990s. The abundance of the echinoderm larvae as a proportion of the zooplankton taken in the samples has followed a continuous increasing trend over the Dogger Bank, but off the eastern coast of northern England and southern Scotland the increase did not become obvious until the 1980s. This trend is consistent with reported increases in abundance of the macrobenthos. It is proposed that changes in the benthos have influenced the composition of the plankton.

Low, L.L, R.E. Nelson, Jr., and R.E. Narita. 1985. Net loss from trawl fisheries off Alaska. Pages 130-153 *in* R.S. Shomura and H.O. Yoshida, editors. Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. NOAA-TM-NMFS-SWFC-54.

Abstract: The most dominant fisheries off Alaska in terms of geographical extent, seasonal duration, and volume of catch is the trawl fishery for groundfish. This fishery began in earnest in 1954, mainly by foreign nations which now number seven, and only recently has been joined by domestic trawlers. The number of foreign trawlers increased rapidly to more than 400 vessels by 1963 and fluctuated around 300 vessels until 1975. Since then, the number of foreign vessels has decreased gradually. Domestic trawlers have remained small by comparison in numbers and physical size. However, expansion of the domestic trawl fleet has been rapid, from just a few vessels in 1979 to 93 in 1984. The total fleet size has, therefore, remained above 300 vessels. This paper traces the progression of these trawl fisheries by two regions--the Bering Sea-Aleutians region and the Gulf of Alaska region. Estimates are made of the number of boats and fishing effort. Effort is measured by number of vessel-months of operations. Since these trawling activities contribute to entanglement of marine mammals in active fishing gear as well as passive lost or discarded gear, the extent of net loss as a source of marine debris is estimated. These estimates are derived from data collected by the Foreign Fisheries Observer Program.

MacDonald, D.S. 1993. Ecological studies on the effects of scallop dredging on the benthos of the North Irish Sea. Ph.D. thesis. University of Liverpool, United Kingdom.

MacDonald, D.S., M. Little, N.C. Eno, and K. Hiscock. 1996. Disturbance of benthic species by fishing activities: A sensitivity index. Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 6(4):257-268.

Abstract: 1) Preliminary estimates of the relative sensitivity of sea bed types and benthic species to physical disturbance, particularly fishing activity, have been made in order to identify areas where further studies are required and to help formulate management plans for sites of marine conservation importance. 2) Physical disturbance is considered in the context of a single encounter with fishing gear followed by a recovery period during which there is no fishing, but with a view to qualifying, in the future, the effect of multiple fishing events. Disturbance is considered in terms of the physical action of the gear on the sea bed and the unit area over which this action occurs. 3) The effects of a wide range of gears are considered. Static gears, which can be employed on a variety of substrata, generally result in low level impacts for single fishing events and impacts are localized compared with the effects of mobile gears, which can extend over considerable areas. 4) The theoretical sensitivity of individual species is assessed on the basis of how well they cope with an encounter with fishing gear and on their likely recovery from destruction in terms of their reproductive strategies. 5) Species considered of key importance in the structuring of communities are suggested and examples of particularly sensitive species, which are therefore likely indicator species of physical disturbance, are listed. 6) Fragile, slow recruiting animals are considered to be most susceptible to disturbance, while the least sensitive species are generally fast growing and have good recruitment.

MacKenzie, C.L., Jr. 1982. Compatibility of invertebrate populations and commercial fishing for ocean quahogs. North American Journal of Fisheries Management Vol. 2:270-275.

Abstract: The objective of this study was to determine whether fishing for ocean quahogs (*Arctica islandica*) with hydraulic dredges on the continental shelf off the coast of northeastern United States alters the abundance or species composition of associated benthic macroinvertebrates. Invertebrate populations in three types of ocean quahog beds were sampled with a Smith-McIntyre grab (0.1 m^2) in October 1978, at the end of the reproductive season of most invertebrates. The beds differed in that one had been fished for about a year and then abandoned in May-June 1978, another had been fished for about 2 years and was actively fished during the sampling, and the third bed had never been fished and served as a control. Differences in the mean numbers of total invertebrates and species were not statistically significant and differences in the abundance-weighted species composition were not evident among the beds. Thus, hydraulic dredging for ocean quahogs did not appear to alter the invertebrate populations in these beds off the coast of New Jersey. This finding is important because many of the invertebrates found here serve as food for crabs and fish.

Maclean, J.L. 1988. Blast fishing and poisoning threaten the Philippines' last undersea wilderness area. Naga. Vol 11(4):14-15.

Summary: Observations made during diving visits to the Tubbataha Reefs regarding damage caused by blasting, being used as a method for capturing fish, are described. The use of cyanide to stun fish, to be then sold as aquarium fish, is also discussed briefly. The need for education of the local fisherman in order for them to understand the harmful effects of both kinds of illegal fishing methods is stressed.

MacPhail, J.S., and J.C. Medcof. 1962. Fishing efficiency trails with a hydraulic clam (*Mya*) rake. Fisheries Research Board of Canada Manuscript Report. No. 724. 16 p.

Madin, L. 1998. Possible effects of propeller shearing on zooplankton. *In* R.E. Crawford, N.E. Stople, and M.J. Moore, editors. The environmental impacts of boating; proceedings of a workshop held at Woods Hole Oceanographic Institution, December 7-9, 1994. Technical Report. WHOI-98-03.

Summary: This paper is part of a presentation made at a workshop on the environmental impacts of boating in 1994. This study speculates on the effects of boat propellers on zooplankton.

Maggorrian, B.H. 1995. The impact of commercial trawling on the benthos of Strangford Lough. Ph.D. dissertation. The Queen's University of Belfast, Northern Ireland.

Abstract: In recent years conflict has arisen between conservation groups and commercial fishing interests over perceived trawl damage to the benthic communities in Strangford Lough. Data from a number of survey techniques were combined to assess the impact of trawling on the benthos of the Lough, principally on the diverse communities associated with the horse mussel, *Modiolus modiolus* beds. The target species of the otter trawl fishery is the queen scallop, *Auquipecten opercularis*. Fisheries data were recorded and a quantitative

species bycatch list was compiled. The fishery is confined to a small number of local-based vessels and existing regulations seem adequate. Otter trawls with rollers (separated by discs) on the footrope were found to collect less bycatch, including notably fewer *M. modiolus*, than trawls with a plain, continuous footrope. The major bottom types and associated benthic communities present in the Lough were mapped out using an acoustic bottom classification system, RoxAnn, in conjunction with underwater cameras. Visual data were statistically analyzed to quantify the effects of trawling and certain benthic species were found to be significantly associated with *M. modiolus*. Trawling was found to remove emergent epifauna and to reduce the structural complexity of the mussel bed, giving an overall fattened appearance. Grab sampling was used to further investigate the effects of trawling on benthic community structure, particularly the infaunal component of the benthos. Side-scan sonar was employed to locate areas of the Lough bed physically impacted by trawling. Otter boards were found to imprint distinct trawl marks on the Lough bed and were identified on side-scan records. During the surveys a Geographical Information System (GIS) was successfully employed as a data management tool. Based on this study, possible strategies for future management of the queen scallop fishery and Strangford Lough as a Marine Nature Reserve have been discussed.

Maier, P.P., P.H. Wendt, W.A. Roumillat, G.H. Steele, M.V. Levisen, and R. Van Dolah. 1998. Effects of subtidal mechanical clam harvesting on tidal creeks. South Carolina Department of Natural Resources, Marine Resources Division. 38 p.

Summary: This study had three objectives which were to measure turbidity levels and the extent of turbidity plumes during harvesting activities, measure impacts to the abundance, diversity and species composition of benthic (bottom-dwelling) invertebrate communities, and evaluate impacts to the abundance, diversity and species composition of fish and crustacean communities that use these habitats. The results showed that while it is possible that high turbidity levels created by these harvesting operations may have short-term effects on the distribution and movement of estuarine biota, the bottom-dwelling invertebrate and finfish assemblages suggest that these effects were not significant. The study also found that there were no differences in species composition, abundance, and diversity attributable to the escalator harvester effects.

Main, J., and G.I. Sangster. 1979. A study of bottom trawling gear on both sand and hard ground. Scottish Fisheries Research Report No. 14. 15 p.

Abstract: The area chosen allowed a fourteen minute tow at 1.54 m/s (3 knots). This covered rough ground with boulders of a variety of sizes up to 2 metres in height, with clear smooth sand at each end. Water depth ranged from 24 to 28 m (12 to 14 fm). The two nets compared were the new Aberdeen 4-panel "Lossie J" trawl, designed to cope with rough ground and the Boris 'Mystic', an accepted commercial net used by many Scottish fishermen. Both nets and their rigging specifications are described in detail. The four types of trawl board used during the performance experiments were rectangular flat, rectangular cambered, oval cambered slotted (polyvalent) and Vee. Their dimensions are shown and their design specifications described in the FAO Fishing Manual.

Main, J., and G.I. Sangster. 1981. A study of sand clouds produced by trawl boards and their possible effects on fish capture. Scottish Fisheries Research Report No. 20. 19 p.

Abstract: From a towed underwater vehicle a direct observation study by diving scientists was made of the behaviour and geometry of the sand clouds produced by Vee, polyvalent flat and cambered trawl boards. The sand clouds spread inwards along the bridles due to turbulence caused by the boards. The rate and extent of lateral movement is different for the inner and outer edges of the sand clouds produced by each type of board. The sand clouds from the polyvalent and cambered boards are narrower in comparison to those of the flat and Vee. With the data from these experiments, bridle angles can be predicted to ensure that the sand clouds pass through the wing-ends of the net. The predicted bridle angles represent practical arrangements with shorter sweeps but not with the longer sweeps tested.

Manning, J.H. 1957. The Maryland soft shell clam industry and its effects on tidewater resources. University of Maryland, CBL Reference No. 11. 25 p.

Summary: A thorough report on the soft shell clam industry including dredging techniques, the history and use of the clam fishery in Maryland, and the effects of the hydraulic clam dredge on tidewater resources including seagrass and oysters.

Manning, J.H., and E.A. Dunnington. 1955. The Maryland soft-shell clam fishery: a preliminary investigational report. Proceedings of the National Shellfisheries Association. Vol. 46:100-110.

Summary: This report describes the new (in the 1950s) Maryland soft shell clam fishery. It attempts to answer questions concerning the impact of the hydraulic clam dredge on estuarine resources, the renewability of the soft shell clam resource, and the effects of the dredge on oyster reefs. Definitive answers to these questions are not answered in this paper but issues for future studies are identified.

Manning, J.H., and K.A. McIntosh. 1960. Evaluation of a method of reducing the powering requirements of soft-shelled clam dredging. Chesapeake Science. Vol. 1(1):12-20.

Abstract: The *JOHN A. RYDER*, clam dredging research vessel of the Maryland Department of Research and Education, was converted from dual-engine to single-engine powering of the pumping and propulsion systems through use of a controllable-pitch propeller designed for the specific application by Electric Boat Division of General Dynamics Corporation. The dredge pump is driven by mechanical power take-off from the propulsion engine at any desired speed, and optimal thrust is obtained by adjustment of the controllable-pitch propeller. Tests conducted by the Department of Research and Education before and after conversion included (1) cruising speed and fuel consumption at cruising speed, (2) dredging rates, and (3) fuel requirements of dredging. Performance of the controllable-pitch propeller at cruising speed compares favorably with that of the fixed propeller formerly used. Fuel savings of about one-third are realizable with the single engine powering system, with no sacrifice of necessary flexibility of operation.

Manzi, J.J., Burrell, V.G., Jr., Lemanowicz, K.J., N.H. Hadley, and J.A. Collier. 1985. Impacts of a mechanical harvester on intertidal oyster communities in South Carolina. Final Report: Coastal Energy Impact Program, Contract # CEIP-83-06, Governor's Office, Columbia, South Carolina.

Mapstone, B., C. Davies, and J. Robertson. 1997. The effects of line fishing on the Great Barrier Reef: available evidence and future directions. Pages 178-194 *in* The Great Barrier Reef-Science, Use and Management. A National Conference. Proceedings. Volume 1. Invited Papers, 25-29 November 1996. Great Barrier Reef Marine Park Authority. Townsville, Australia.

Margetts, A.R., and J.P. Bridger. 1971. The effect of a beam trawl on the sea bed. ICES Council Meeting. 1971/B:8.

Summary: The aim of this study was to make direct observations of the bottom over which a trawl with tickler chain passed and of the untrawled area next to it. This experiment did not examine the effect of trawling on the benthos. The authors determined that the disturbance of the trawl varies with the nature of the bottom.

Massachusetts Department of Natural Resources. 1964. Restricting the use of the beam or otter trawls. Special Report of the Department of Natural Resources to the Senate and House of Representatives of the State of Massachusetts. No. 3703. 103 p.

Summary: This report reviews the use and subsequent outlawing of beam and otter trawls in Massachusetts' waters. It also contains a section on the effect of dragging on bottom life and on the bottom. This sections reviews the literature on the effects of trawling on bottom habitat.

Matishov, G.G., and L.G. Pavlova. 1994. Degradation of ecosystems of the north European seas under the effects of fishing and pathways for their recovery. Izvestiya Akademii Nauk Seriya Biologicheskaya. Vol. 1:119-126.

May, A.W. 1967. Effects of offshore fishing on the inshore Labrador cod fishery. International Commission, Northwest Atlantic Fisheries Research Bulletin. Vol. 4:67-75.

Mayer, L.M., D.F Schick, R.H. Findlay, and D.L Rice. 1991. Effects of Commercial Dragging on Sedimentary Organic Matter. Marine Environmental Research. Vol. 31:249-261.

Abstract: The effect of commercial dragging on sedimentary organic matter was examined in two field experiments using different types of gear. A heavy scallop dredge caused two types of organic matter translocation--some of the surficial organic matter was exported from the drag site and the remaining material was mixed into subsurface sediments. Phospholipid analysis indicated decreases in various classes of microbiota, with relative increases in the contribution of anaerobic bacteria to the microbial community. An other trawl that largely remained above the sediment--water interface caused little change in organic matter profiles, although ^{7}Be profiles suggest an export of the surficial horizon. Sediment mixing by some

types of gear will likely result in burial of labile organic matter and hence may shift sediment metabolism toward microbial and anaerobic food chains.

McAllister, D.E. 1988. Environmental, economic and social costs of coral reef destruction in the Philippines. Galaxea. Vol. 7:161-178.

Abstract: During the last two decades the biotically diverse and productive reefs of the Phillippines have been subject to extensive destruction by sedimentation from deforestation, destructive fishing methods, pollution, poor agricultural practices, and quarrying for reefs. An estimated 150,000 kg (330 U.S. tons) of sodium cyanide is used on the coral reefs each year to catch fishes for the aquarium and live fish food trades. At least 10% of small fishers use explosives to catch food fishes throughout the year. The coral reef destruction has grave environmental and economic consequences. Lost each year are conservatively estimated harvests of 160 million kg of fishes worth 1,600 million pesos ($80 million U.S.) and at least 127,000 small-scale fishing jobs leaving over 637,000 family members without support. Multiplier employment effects suggest that over one million persons are affected. The commercial food fishery, aquarium fish, sports diving and tourist trades have also suffered from coral reef destruction. The sociological effects are deep and far reaching. More than 5 million Filipinos are deficient in proteins, vitamins and minerals which could have been derived from seafood. Up to 59% of children in coastal communities suffer from malnutrition. This and the poverty associated with reef destruction leads to illness, early death, stress on the nation's health care system, and migration of people to the slums of the cities. The quality of human life is seriously diminished. Destruction of coral reefs is a major contributor to poverty in coastal communities. The economic independence of fisherfolk is lessened as income levels fall. From 1966 to 1986, while the productivity of the coral reefs dropped by at least one third, the population of the Phillippines almost doubled and is expected to double again in 40 years. These two changes have meant that the square kilometer of reef that in 1966 helped support 900 persons, in 1986 had to support 2,631 persons. Habitat destruction and population increase have been the primary causes of exceeding sustainable yields, overfishing is a secondary consequence. Practical short-term and long-term alternatives exist to most of the problems that are causing the destruction of one of the country's primary resources, the productive and beautiful coral reefs. Habitat destruction equals or exceeds in importance the secondary problem of overfishing, and resources need to be made available to restore the coral reefs, one of the nation's most important natural resources. Sea reform is needed as badly as land reform.

McAllister, D.E. 1991. Questions about the impact of trawling. Sea Wind: Ocean Voice International. Vol. 5(2):28-32.

Summary: This paper discusses the impacts of otter and beam trawling. It is limited to the environmental aspects of trawling. The paper examines the mowing effects, plowing/leveling effects, sedimentation effects, and turbidity effects. The author recommends that trawl designs be modified to reduce habitat impact and lower bycatch, and more studies should be undertaken to study the effects of trawling on habitat and the environment.

McAllister, D.E., and G. Spiller. 1994. Trawling and dredging impacts on fish habitat and bycatch. Pages 1709-1718 *in* Coastal Zone Canada 1994, Cooperation in the Coastal Zone. Conference Proceedings, Volume 4. Coastal Zone Canada Association, Dartmouth, Nova Scotia.

Abstract: Trawling and dredging for fishes, shrimp and shellfish have major impacts on habitat and, through bycatch, fish populations of fishing banks. Tracks of trawlers and dredges swept tracks of over 4.3 million kilometers in 1985. The gear, drawn by powerful vessel engines, shears off bottom vegetation and protruding invertebrate animal life including sea anemones, sponges, sea squirts, crinoids and many others. These miniature forests provide shelter for small species and young of large species from predators and harbour food for fish. Removal of this shelter exposes fish to predation and reduces food supply. The trawls/dredges also shear off higher hummocks, fill in low spots, changing the configuration of the bottom, removing areas more exposed to or protected from the current, exposing shellfish, worms and other sediment dwelling species to predation. Trawling/dredging also stirs up clouds of mud and other sediment that plug gills and similar structures of filter feeders. Bycatch of trawling gear commonly averages 50% by weight of the catch. The bycatch, commonly thrown overboard unutilized, is often dead, dying or injured; a few hardy species survive the process. Discarded bottom invertebrates beam trawled in the North Sea suffer mortalities of 30-90%. Thus a significant part of the bottom-living biomass is killed immediately or has its life-span shortened. The bycatch includes young of commercial species, forage species, and species of no direct use to humans but which play a role in ecosystems. Habitat impacts and bycatch affect stocks of commercial fishes, the natural biodiversity and the ecological services provided. The industrialization of fishing moves the distribution of benefits from individual fishers and fishing communities to larger ports and distant stockholders. It may also extend the periods of time that fishermen are separated from their families. Fishing nations should: (1) undertake regular monitoring of impacts of fishing gear on habitat and non-target species, commercial and non-commercial; (2) undertake ecological studies of sea life in bottom habitats disturbed and undisturbed by different types of fishing gear so as to better understand gear impact; (3) establish near-shore continental shelf and slope protected areas to protect representative ecosystems and species, provide control areas for the study of impacts of fishing gear, areas for scuba diving and submersible tours by ecotourists; (4) switch to fishing gear which has low habitat impact and bycatch; (5) consider the impact of fishing gear on marine biodiversity as well as on commercial fishing stocks; and (6) take into account social as well as environmental factors, equitable distribution of benefits and the quality of life of fishers and fishing communities.

McCandless, D.T. 1992. Impact of bottom fishing on the benthos. M.S. thesis. University of Wales, Bangor, United Kingdom.

McKenna, J.E., Jr. 1997. Influence of physical disturbance on the structure of coral reef fish assemblages in the Dry Tortugas. Caribbean Journal of Science. Vol. 33(1-2):82-97.

Abstract: Visual counts of fish within fringing coral reef habitat in the Dry Tortugas were used to determine the impact of physical disturbance on species assemblages. Visual observations of fish assemblages inhabiting a large ship grounding site and three other reef areas within the protected Dry Tortugas system revealed a diverse fauna. Species richness

within a site ranged from 26 to 46. Diversity (H') at the most disturbed grounding sites averaged 1.23, while that at Pulaski Shoal averaged 2.60. Analyses consistently identified three distinctly different assemblages of fish among the sampled sites. Small wrasses (especially *Halichoeres bivittatus*) and juvenile parrotfish (especially *Scarus croicensis*), which are closely associated with the bottom, dominated the assemblages at the grounding site. A variety of schooling species (e.g., *Coryphopterus personatus* and juvenile Haemulidae) and those with a more pelagic disposition (e.g., *Caranx ruber*) dominated the assemblages at the least disturbed sites. Relatively undisturbed areas near the grounding site were characterized by high diversity (2.27) and intermediate species assemblages. Differences in diversity between sites was consistent with predictions of the Intermediate Disturbance Hypothesis. Differences in three-dimensional structure, depth, and the natural level of disturbance were implicated as factors determining the assemblage of fish found at a given reef site. Further analyses and observations are needed to determine how changes in these factors may affect change in the biological community.

McKeown, D.L., and D.C. Gordon, Jr. 1997. Grand Banks otter trawling impact experiment: II. Navigation procedures and results. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 2159. 79 p.

Abstract: In 1990 a collaborative research program between the Maritimes and Newfoundland Regions of Fisheries and Oceans Canada (DFO) was established to study the potential impacts of mobile fishing gear on benthic marine ecosystems in Atlantic Canada. It was decided early on that the best approach was to conduct carefully controlled field experiments in areas protected from fishing activity employing mobile gear in contact with the seafloor. These experiments would include initial seafloor surveys using different kinds of sensing and sampling equipment, intentional disturbance with a given type of mobile fishing gear, and follow-up seafloor surveys to assess the extent and duration of disturbance on both physical habitat and biological communities. In order to meet the operational requirement of this approach it is absolutely essential to have precise navigation information on both the location of the seafloor disturbance and the relative position of all sensing and sampling equipment. The first offshore experiment in this program was conducted on the Grand Banks from 1993 to 1995 using an otter trawl. This report describes the navigational equipment (dGPS, Trackpoint II AGCNav) and procedures that were used, summarizes data processing procedures, presents selected results, and explores the quality of the position fixes and methodologies employed. It is concluded that the accuracy of ship position using dGPS is on the order of 3 to 4 m at the Grand Banks experimental site. The position of the otter trawl as well as sensing and sampling equipment (sidescan sonar, BRUTIV, epibenthic sled, and video grab) relative to the ship was determined using Trackpoint II, and it is concluded that the accuracy of positions is on the order of 4 m near the ship and less than 20 m at a distance of 600 m. Therefore, it is possible to plot with a high degree of accuracy both the zone of disturbance and the location of samples. Analysis of the results confirms that all samples collected during the 3-yr experiment were obtained from disturbed or control areas as intended.

McLoughlin, R.J., P.C. Young, R.B. Martin, and J. Parslow. 1991. The Australian scallop dredge: estimates of catching efficiency and associated indirect fishing mortality. Fisheries Research. Vol. 11:1-24.

Abstract: The catching efficiency of the Australian scallop "mud" dredge was examined in two experiments on plots seeded with scallops (*Pecten fumatus*) of known size and abundance. Catching efficiency was found to be low: on average only 11.6% of the reseeded scallops in the tow path were caught. Size selectivity ranged from 1% for scallops of 57 mm shell height, to 28% for scallops of 86 mm shell height. The efficiency of the dredge was not affected by either the dredge mesh size, or the direction of tow with respect to orientation of ripples and sandwaves on the sea-bed. To determine the mortality of scallops resulting from the use of this dredge, changes in the relative proportions of live, damaged and dead scallops on the Banks Strait grounds before and after the start of the 1986 fishing season were measured by assigning scallops from subsamples of catches to one of the three categories. At the start of fishing, both scallop density and levels of shell damage due to dredging were high. Although the proportion of damaged scallops in catches declined over time, a high mortality rate of scallops continued after commercial fishing had ceased. This rate was such that almost all the remaining scallops on the bed were dead within 8 months of the closure of the grounds. A general theoretical model describing changes in the proportions of live, damaged and dead scallops as a consequence of dredging is presented. The model indicates that only 12-22% of the initial stock in Banks Strait was landed as catch, with the rest of the stock wasted through direct and indirect mortality resulting from dredging.

McLusky, D.S., F.E. Anderson, and S. Wolfe-Murphy. 1983. Distribution and population recovery of *Arenicola marina* and other benthic fauna after bait digging. Marine Ecology Progress Series. Vol. 11:173-179.

Abstract: Effects of bait digging on distribution and population recovery of *Arenicola marina*, *Hydrobia ulvae* and *Macoma balthica* have been investigated on trial plots at Blackness, Forth estuary (Scotland). *A. marina* rapidly recolonized the basins created by digging, but had reduced populations on the dug mounds. Its populations were dislocated for over 3 mo after digging. *H. ulvae* and *M. balthica* showed enhanced populations on the mounds for up to 2 wk, but were otherwise unaffected by digging. Factors influencing the mode of population recovery are discussed; it is suggested that enhanced basin populations of recolonizing *A. Marina* are due substantially to above-surface migration of worms into areas with increased levels of organic matter.

McManus, J.W. 1988. Coral reefs of the ASEAN region: status and management. Ambio. Vol. 17(3):189-193.

Abstract: Coral reef provide a substantial part of the protein intake in Southeast Asia. Reefs and nonreef coral communities within 15 km of shore are generally overfished, while offshore subsurface atolls and pinnacle reefs are often beyond the reach of small-scale fishermen. Major destructive forces include excessive sedimentation, related to deforestation, and various forms of destructive fishing, especially blast fishing. Current attempts to manage these areas through coastal-zone plans, fishery restrictions, and the development of marine parks have been effective in only a few isolated cases. The most promising approaches involve management and evaluation at the municipal level. This concept can be extrapolated to an adaptive management scheme involving community-based development specialists, cross-trained in environmental and fishery monitoring, who assist municipalities in the development of regulations concerning local reefs and associated

ecosystems. Reef management can be expedited in many areas with the establishment of alternative livelihood programs to alleviate excessive demands on the reef resources.

McManus, J.W., R.B. Reyes, Jr., and C. Nañola, Jr. 1997. Effects of some destructive fishing methods on coral cover and potential rates of recovery. Environmental Management. Vol. 21(1):69-78.

Abstract: Effects of fishing with explosives (blastfishing) and sodium cyanide and of anchor damage on live coral were investigated on a heavily exploited fringing reef in Bolinao, Philippines from 1987 to 1990. A simple balance-sheet model indicated that approximately 1.4%/yr of the hermatypic coral cover may have been lost to blasting, 0.4%/yr to cyanide, and 0.03%/yr to coral-grabbing anchors, the potential coral recovery rate reduced by about one third from 3.8%/yr in the absence of disturbances to 2.4%/yr. These figures are subject to considerable uncertainty due to compounding of errors during computation. Reefs with patchy coral cover are more susceptible to damage from blastfishing because of targeting by fishers. Reefs with smaller corals may have greater resilience, because each unit of radial colony growth contributes a greater per cent increase in areal cover. Blastfishing in particular may reduce resilience to natural perturbations, leading to assemblages of small, sparse corals and reduced patchiness.

McManus, L., and L.A. Menez. 1989. Status of coralline resources in Lingayen Gulf. ICLARM Conference Proceedings. No. 17:63-70.

Abstract: Nine sites were surveyed along the western coast of Lingayen Gulf to assess the status of coral reefs in the area. The study showed the reefs to be in relatively poor to fair condition, having 18%-47% living coral cover. Reefs are degraded by both naturally occurring factors and man-induced stresses (such as poor land management, which brings about siltation, and destructive fishing techniques). Blast fishing and the use of sodium cyanide for catching aquarium fish are rampant in the area. The destruction of the reefs could cause a breakdown of their community structure, as well as those of associated coral-dominated communities. Various management schemes designed to forestall the destruction of the reefs and ease the fishing pressure on the resources are presented. Critical information gaps are identified.

McShane, P. 1981. The effect of scallop dredging on macrobenthos of a muddy environment in Port Phillip Bay. Marine Science Laboratories, Queenscliff Technical Reports. Vol. 4:1-16.

Summary: The author conducted a study that examined the effects of scallop dredging on organisms in Port Phillip Bay, Australia. The sediment in Port Phillip Bay is sandy-silt and silty-clay. The author concludes that scallop dredging had no immediate effect upon the macrobenthos. The author further compared existing benthic survey data to data prior to the start of scallop dredging and determined that no major change has occurred in the benthic communities of Port Phillip Bay due to scallop dredging.

Medcof, J.C. 1959. Effect of a hydraulic escalator harvester on under-size soft-shell clams. Proceedings of the National Shellfish Association. Vol. 50:151-161.

Abstract: A modified Maryland-type hydraulic escalator shellfish harvester was used at high tide on intertidal beaches in Nova Scotia to determine its effect on soft-shell clams less than 2 inches long. The boat was equipped with a propeller guard to prevent bottom scouring and three types of experiments were carried out with small, marked clams: (1) Dead clams were released in the scoop to determine their scatter pattern after passing through the harvester. (2) Plots of planted dead clams were dug through to discover breakage rates and distribution. (3) Plots of planted living clams were dug through to see how the harvester affects their distribution and ability to reestablish themselves. Results were observed on the dry beach at low tides. Most of the small clams sifted through the mesh of the escalator belt before they reached the surface of the water. In spite of strong currents from harvester jets and the boat propeller, 90% of the clams were returned to the harvester track within 75 or 100 feet of the place where they entered the harvester. Soil is heavy and settled first in the track. Clams are lighter and were deposited on the soil surface, not buried and smothered. The harvester broke 7 to 10% of the living clams but the rest dug in again quickly. Because damage was so small compared with that caused by conventional clam hoes we think production would be improved if hydraulic escalator harvesters were used.

Medcof, J.C., and J.S. MacPhail. 1964. Fishing efficiency of clam hacks and mortalities incidental to fishing. Proceedings of the National Shellfish Association. Vol. 55:53-72.

Abstract: The conventional clam hack is a reasonably efficient tool for harvesting soft-shell clams (*Mya arenaria*). With it the average digger harvests 60% of the market-size stock from the soil he turns. But it is very destructive. At each turning of the soil it kills nearly 50% of the unharvested clams. Each digging brings about a total reduction (harvesting and smothering) of 80% of the stock of market-size clams and a reduction of 50% of the stock of under-size clams. Frequently repeated digging of the same ground was probably the main cause of the decline in clam production in the Maritime Provinces in the 1950's. Fishing effort seems to have decreased since then and we cannot explain why the decline is continuing.

Medcof, J.C., and N. Bourne. 1971. Causes of mortality of the sea scallop, *Placopecten magellanicus*. Proceedings of the National Shellfisheries Association. Vol. 53:33-50.

Abstract: Causes of natural mortality include summer water temperatures too low for spawning or for larval development, flushing of basins by "tropic tides," lethal saltations in summer water temperature, predators, and shell pests. Mass mortalities due to pathogenic micro-organisms are not known. Causes of fishing mortality include bottom damage by dragging, damage by turbulence in drags, dumping on deck, culling, shoveling, air exposure, and shucking. Fouling of beds by discarded rims, and pressure changes, probably are not causes of mortality. Natural mortality has been estimated as 10% for adult scallops but there is no reliable figure. Present methods destroy 10% of discards (scallops returned to the bottom) off Digby, Nova Scotia, and 2 to 20% on Georges Bank due to practices resulting in long air exposure and much mechanical damage. Dickie (1955) estimated that 20% of the scallops of Digby, N.S., were removed each year by fishing (dragging). There is no satisfactory estimate of direct fishing mortality for Georges Bank.

Medcof, J.C., and J.F. Caddy. 1971. Underwater observations on the performance of clam dredges of three types. ICES CM 1971/B:10.

Abstract: When towing speeds, warp lengths and water pressures were skillfully controlled, the two types of "wet" (hydraulic) dredge were nearly 100% efficient in catching ocean clams (*Artica islandica*) on sandy bottom. The shells of more than 80% of uncaught clams were broken. However, because of high dredge efficiency, there were few uncaught clams. Breakage in catches was generally less than 20%. The "dry" (non-hydraulic) dredge was less than 1% efficient on sand and broke the shells of 80% of uncaught clams and of 50% of the clams caught. The edges of wet dredge tracks in sand crumbled soon after the dredge passed, but the tracks were deep and filled in slowly. The dry dredge left a shallow track that soon disappeared. Several species of demersal fish and bottom invertebrates congregated in dredge tracks and fed on broken clams and other exposed materials. This study involved scuba diving and observations from submersibles. Submersibles were advantageous in several respects.

Medcof, J.C., and J.F. Caddy. 1974. Underwater observations on performance of clam dredges of three types. Fisheries Research Board of Canada, Manuscript Report Series. Vol. 1313:9.

Abstract: When towing speeds, warp lengths and water pressures were skillfully controlled, the two types of "wet" (hydraulic) dredge were nearly 100% efficient in catching ocean clams (*Arctica islandica*) on sandy bottom. The shells of more than 80% of uncaught clams were broken. However, because of high dredge efficiency, there were few uncaught clams. Breakage in catches was generally less than 20%. The "dry" (non-hydraulic) dredge was less than 1% efficient on sand and broke the shells of 80% of uncaught clams and of 50% of the clams it caught.

Messieh, S.N., T.W. Rowel, D.L. Peer, and P.J. Cranford. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research. Vol. 11(8-10):1237-1263.

Abstract: This paper presents an overview of current knowledge on the effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. The impact of trawling and dredging for fish and shellfish on marine habitats has recently attracted international attention among fisheries and environmental scientists. In Atlantic Canada, trawling and dredging are the principal methods of harvesting groundfish and scallops and ocean clams, respectively. It is estimated that fish trawlers and scallop dredges have swept tracks, cris-crossing the Canadian continental shelf, approximately 4.3 million km in length in 1985. In the past few years several studies were carried out by scientists from Canada, the United States and Europe to assess the impacts of trawling and dredging but results were inconclusive. Some studies showed physical damage as well as biological effects, whereas others indicated that the adverse effects were not considered to be serious. Fishermen are not the only potential users of the resources of the continental shelf. There is an increasing demand for good-quality sand and gravel aggregate and the ocean seabed is being seen as a possible source. The eastern Canadian continental shelf also exhibits hydrocarbon potential and operational and accidental discharges are an environmental concern. Increased marine transportation and expansion of the fishing fleet have resulted in a greater need for harbor

dredging. Dredging and dredge spoil disposal were controlled by the Ocean Dumping Control Act and now the Canadian Environmental Protection Act which places restrictions on the composition of material that can be disposed of in the sea. Nevertheless some harbors contain contaminant concentrations exceeding the maximum allowable limits. It is concluded that the impacts of human activities on the continental shelf seabed environment are inevitable and the long-term effects, while difficult to determine, must be assessed. The sub-lethal effects of increased suspended sediment loads on benthic organisms and potential changes to benthic community structure are major concerns and should be the focus of further research.

Meyer, D.L., M.S. Fonseca, P.L. Murphey, M.W. LaCroix, P.E. Whitfield, D.R. Colby, and G. W. Thayer. 1991. Impact of bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, Florida. Unpublished Report submitted by NMFS, Southeast Fisheries Center, Beaufort Laboratory to Florida Department of Natural Resources, Marine Research Institute. DNR Contract #C4488. 28 p.

Abstract: Sampling trips were conducted during August and November 1990, to evaluate the effect of live bait shrimp trawling on seagrass habitat and fish by-catch mortality in Tampa Bay, Florida. In the seagrass component of this study, nine study sites per collection date were selected in *Thalassia testudinum* beds in the Tarpon Key area of lower Pinellas County, Florida. Fishing gear used throughout the operation consisted of a commercial live bait shrimp boat with two 3.38 m wide stainless steel roller trawls. Within each site the initial condition of the *T. testudinum* was surveyed, with additional surveys conducted after 1, 3, 9, and 18 trawls. For the fish by-catch component of this study, night trawling was conducted in *T. testudinum* beds at an area southwest of Tierra Verde, near the mouth of Tampa Bay, using this same fishing gear. Fifteen, five minute tows were conducted on two separate nights, a total of 30 tows for each collection date. Fish by-catch from each trawl was placed in separate holding pens and checked periodically for fish mortality for up to 36 hours. Data indicate that 1-time acute trawling with commercial live bait shrimp roller trawls in *T. testudinum* beds (up to 18 time per unit area of bed) has no significant (alpha=0.05) impact on above- or belowground standing crop or morphometrics. There was an indication that species-specific mortality of fish by-catch varies widely with some species more susceptible to mortality due to bait shrimp trawling than were other species. Smaller individuals of certain species more susceptible to trawl mortality than larger individuals.

Meyer, D.L., M.S. Fonseca, P.L. Murphey, R.H. McMichael, Jr., M.M. Byerly, M.W. LaCroix, P.E. Whitfield, and G. W. Thayer. 1999. Effects of live-bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, Florida. Fishery Bulletin. 97(1):193-199.

Abstract: The use of live shrimp for bait in recreational fishing has resulted in a controversial fishery for shrimp in Florida. In this fishery, night collections are conducted over seagrass beds with roller beam trawls to capture live shrimp, primarily pink shrimp, *Penaeus duorarum*. The shrimp are culled from the catch on sorting tables and placed in onboard aerated "live" wells. Our study objectives were 1) to determine effects of a roller beam trawl on turtlegrass biomass and morphometrics during intensive (up to 18 trawls over a turtlegrass bed), short-term (3-hour duration) use and 2) to examine the mortality of bycatch finfish following capture by a trawl.

Meyer, R.M. 1971. A study concerning the problem of derelict pots in the king crab fishery. Unpublished Report. U.S. Department of Commerce, NOAA, NMFS, Kodiak, Alaska.

Summary: This study concerns the problem of lost crab pots in the Bering Sea crab fishery. The pots can still fish for 3 to 8 years and can retain up to 100 crabs per pot. Field experiments to determine if king crabs can escape from a pot, if crabs will enter an unbaited pot, and deterioration rate of pot web materials were conducted in Kodiak, Alaska. King crabs were found to escape and enter unattended pots.

Meyer, T.L., R.A. Cooper, and K.J. Pecci. 1981. The performance and environmental effects of a hydraulic clam dredge. Marine Fisheries Review. Vol. 43(9):14-22.

Abstract: The efficiency of a 1.2 m hydraulic clam dredge in a surf clam, *Spisula solidissima* (Dillwyn), population was demonstrated by diver scientists to be sensitive to factors such as: speed of towing, scope of tow line and water hose, and distance between cutting blade and water manifold. When these operational specifications were near optimum, the dredge removed 91 percent of the available clams: when below optimum, efficiency was 80 percent. When dredge performance was low, larger clams, which burrowed deeper into the sediment, suffered mortalities as high as 92 percent: when high, mortalities decreased to 30 percent. In high clam density areas (>1,000/m^2), the dredge filled with clams after approximately 10 m of towing. Once filled, the dredge action was analogous to a snowplow as it pushed and blew clams and sediment to the sides. Initially, the dredge track was conspicuous with a smooth track shoulder, sharply angled walls, and a flat floor. The track rapidly deteriorated through slumping and biological activity until by 24 hours it appeared more like a series of shallow depressions. Predators were more abundant inside the dredge track than outside and were divided into two categories: 1) Ones which fed on the remains of damaged clams, and 2) those which preyed on undamaged clams. The most abundant predator feeding on damaged clams was the lady crab, *Ovalipes ocellatus*, which reached a density of 1,500/100 m^2. The starfish, *Asterias forbesi*, was the most abundant predator of undamaged clams, reaching a density of 30/100 m^2. After 24 hours, predator density had returned to predredging levels except for the moon snail, *Lunatia hero*, which was the only predator to increase in abundance after the 2-hour estimate.

Millner, R.S. 1985. The use of anchored gill and tangle nets in the sea fisheries of England and Wales. Laboratory Leaflet. Directorate of Fisheries Research. Lowestoft, England. No. 57. 27 p.

Summary: This leaflet describes general features of the construction and operation of fixed nets. Its primary purpose is to examine the relation of fixed net fisheries to other fisheries, particularly in the context of stock conservation and fisheries management. The mode of action of gill nets and tangle nets is given, especially their selectivity. The effect on traditional fishing is also mentioned, relations between trawlers and netters, effects on salmon fishing and angling, "ghost fishing" by lost nets and mesh size regulations. Regional fisheries are described including the Grinsby wreck-net fishery, north-east, east, south southwest and Irish Sea coasts. Fixed nets are a well-established means of fishing by small inshore boats, less than 19m long, but if operating costs remain lower than for conventional trawls, there could be a steady expansion in future, for larger vessels, and to expand the range

of small inshore boat operators. The widespread use by part-time and leisure fishermen is likely to continue.

Millner, R.S., and C.L. Whiting. 1996. Long-term changes in growth and population abundance of sole in the North Sea from 1940 to the present. ICES Journal of Marine Science. Vol. 53:1185-1195.

Abstract: Sole stocks in the North Sea have shown a threefold variation in abundance over the past 50 years, largely as a result of fishing activity and variability in recruitment. Natural fluctuations in abundance have also occurred as a result of sever winter mortality as in 1962/1963 when the spawning stock biomass was reduced by more than half. Analysis of historical growth changes provides a means of assessing the causes of these variations in abundance. Changes in growth of female sole since the early 1940s were examined using back-calculated length increments from otoliths. Growth was lowest in the decade following the war and increased during the 1960s at a time of declining stock size. Growth of individual year classes appeared to be affected by the reduction in stock abundance in 1963. The extent to which these changes are related to eutrophication, beam trawl activity, and density-dependent factors are discussed.

Mirarchi, F. 1998. Bottom trawling on soft substrates. Pages 80-84 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: A commercial fisherman describes his fishing gear and its perceived effects on habitat.

Moore, C.G., G.R. Saunders, and D.B. Harries. 1998. The status and ecology of reefs of *Serpula vermicularis* L. (Polychaeta: Serpulidae) in Scotland. Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 8(5):645-656.

Abstract: The distribution and abundance of reefs of *Serpula vermicularis* was examined in Loch Creran, the only known remaining site of reefs of this species in Scotland. In view of the decline in populations elsewhere, the aims included assessment of the importance of the Scottish population in terms of conservation of the reef habitat and the establishment of a baseline against which future changes could be gauged. A further objective was to determine appropriate conservation management of the reefs by examining the influence of both natural and anthropogenic factors. Reefs were largely restricted to a depth range of 1-13 m. Factors controlling the depth distribution are discussed. *Serpula vermicularis* reefs colonized a variety of substrata, but predominantly grew on lamellibranch shells on a seabed of muddy sand. There was some evidence that reef abundance was influenced by the availability of suitable substrata. A belt of scattered reefs fringed much of the coastline of the loch with profuse reef development at two sites, where reef coverage exceeded 10% of the seabed. In terms of total abundance of *Serpula vermicularis* reefs, Loch Creran represents the major world site for reef development. It is concluded that the reefs of Loch Creran are of significant nature conservation importance and grounds for the establishment of conservation management are discussed. Reef development is apparently curtailed in areas of strong currents and high flushing rate. There is evidence that human activity has

adversely influenced reef growth through the discharge of organic factory effluent and the physical disturbance caused by mooring ground tackle. Scallop dredging also represents a significant threat to the persistence of serpulid reefs. Methods of minimizing damage to this rare and fragile feature are discussed.

Moore, D.R., and H.R. Bullis, Jr. 1960. A deep-water coral reef in the Gulf of Mexico. Bulletin of Marine Science of the Gulf and Caribbean. Vol. 10 (1):125-128.

Abstract: The Fish and Wildlife Service M/V OREGON discovered by the depth recorder a peculiar structure on the continental slope 40 miles E. of the Mississippi River mouth, at depths of 230-280 fathoms. A drag across the area brought up about 300 lbs. of the deep water colonial coral, *Lophelia prolifera*, that had formed an extensive reef over half a mile long and up to 180 feet thick. This species is known to form deep water reefs in the northeastern Atlantic but this is the first *Lophelia* reef to be reported from the Americas.

Moore, G., and S. Jennings. 2000. Commercial Fishing: the Wider Ecological Impacts. Blackwell Science. 72 p.

Summary: This book examines different types of fishing gear and their operation. Gear examined include pelagic drifting gear, bottom set gear, pelagic mobile gear, and bottom mobile gear. The authors examine ghost fishing and the effects of fishing litter on animals and habitat. They also examine the vulnerability of mud, sand, gravel, maerl, coral, coralligene and rocky reef habitats, seagrass meadows, kelp forests, and sea mounts to fishing impacts. Finally, the authors provide conservation recommendations to lessen the fishing impact on habitat.

Moore, J. 1990. Experimental studies of the impact of hydraulic cockle dredging on intertidal sediment flat communities. Field Studies Council Research Report, FSC/RC/2/90.

Moore, J. 1991. Studies of the impact of hydraulic cockle dredging on intertidal sediment flat communities. Final Report. Nature Conservancy Council, CSD Report No. 1256, Peterborough. 46 p.

Moore, K.A., and R.J. Orth. 1997. Evidence of widespread destruction of submerged aquatic vegetation (SAV) from clam dredging in Chincoteague Bay, Virginia. Unpublished Report to the Virginia Marine Resources Commission. 5 p.

Summary: This report examines the destruction of submerged aquatic vegetation from clam dredging in Chincoteague Bay, Virginia. The researchers examined aerial photographs to detect the presence of dredge scars. The study states that over 300 acres of submerged aquatic vegetation were destroyed in 1997 alone.

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.

Morell, T. 1998. Lobster trap fishing. Pages 94-95 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: A commercial fisherman describes his fishing gear and its perceived effects on habitat.

Moreno, C.A., J.P. Sutherland, and H.F. Jara. 1984. Man as predator in the intertidal zone of southern Chile. Oikos. Vol. 42:155-160.

Abstract: From 1978 to 1982, man was excluded from a 6000 m^2 reserve near Mehuin, Chile (39°24'S, 73°13'W). During this time there was an increase in the abundance of *Fissurella* spp. coupled with a dramatic decline in the abundance of mid-intertidal macroalgae, principally *Iridaea boryana*. Macroalgal abundance increased to near 100% cover from 1978 to 1979 on a rock in the reserve where herbivores were removed. Outside the reserve, areas closest to large fishing villages had a higher cover of *I. boryana* and a lower abundance of *F. picta*. Mid-intertidal macroalgae are abundant only where human predation on herbivores is severe.

Moreno, C.A., K.M. Lunecke, and M.I. Lépez. 1986. The response of an intertidal *Concholepas concholepas* (Gastropoda) population to protection from man in southern Chile and the effects on benthic sessile assemblages. Oikos. Vol. 46:359-364.

Abstract: In this paper we document the changes experienced by the carnivorous *Concholepas concholepas* snail population after the establishment of a marine reserve in May 1978. Our data indicate that the release from human predation results in a striking change of the *Concholepas* population structure, due to the increment of individuals larger than 40-50 mm peristomal length. This evidence strongly indicates that the usual absence of larger size classes from the intertidal is not a consequence of physiological limitations of the muricid, as was previously thought. Significant density differences were detected only in 1984, but they were due to substantial reduction of the snails in the harvested control area. The reduction experienced by *Concholepas* prey species (barnacles and *Perumytilus purpuratus*) in the marine reserve are during the same period, indicates that the carnivore has an important role in the organization of the intertidal benthic sessile assemblage. Altogether, our results support the idea that in the absence of human intervention the intertidal community structure differs from the usual, previously considered "natural" structure.

Morgan, M.J., E.M. DeBlois, and G.A. Rose. 1997. An observation on the reaction of Atlantic cod (*Gadus morhua*) in a spawning shoal to bottom trawling. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 54 (Supplement 1):217-223.

Abstract: The reactions of Atlantic cod (*Gadus morhua*) in spawning condition to a single pass with an otter trawl were observed by repeatedly transecting the trawl track through a cod shoal with a 38-kHz echosounding system. The shoal consisted of a 5-km-wide band of fish extending approximately 25 km along the 390-m isobath and occupying the bottom 10 m at varying densities averaging 0.004 fish·m^{-3} (maximum 0.488·m^{-3}). The shoal comprised cod of a mean size of 41 ±6.1 cm. Following passage of the trawl, a 300-m-wide "hole" in the

aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl. Densities were very low in and near the trawl track and increased up to a distance of 200-400 m on each side of the track (a total distance of 400-800 m). This study is the first to observe large-scale changes in the structure of a shoal of cod in spawning condition, attributable to otter trawling, and indicates that such responses can result in persistent disturbances within the shoal over relatively large distances.

Morton, B. 1996. The subsidiary impacts of dredging (and trawling) on a subtidal benthic molluscan community in the southern waters of Hong Kong. Marine Pollution Bulletin. Vol. 32(10):701-710.

Abstract: The macrobenthic fauna of the southern waters of Hong Kong were surveyed in April 1992, notably with regard to the Mollusca. Subsequently, parts of the area were extensively suction dredged for major construction projects. Commercial trawling continued alongside the dredging. In October 1994, with dredging close to finishing, six of the original 50 stations were resurveyed using the same gear, and the Mollusca again re-examined. This study demonstrates that close to dredged sites, i.e. within 2 km, species and individual numbers of both the Gastropoda and Bivalvia had declined by approximately two thirds in the intervening period. With regard to the Gastropoda, most of the species losses were of specialist neogastropod predators. Post-dredging, the gastropod fauna was virtually dominated by opportunistic scavengers, notably *Nassarius siquijorensis*, *Bursa rana* and *Murex trapa*. These, however, were also dominant predredging and this lends support to an earlier argument that disturbed inshore marine sediments favour the presence of such species. The bivalve fauna was dominated by a few species that are resistant to disturbance, such as *Placamen calophylla*, *Corbula crassa* and *Minnivola pyxidatus*. These species are of no commercial value and the former two have solid shells that are resistant to trawl damage and which are, actually, adaptations to avoid predation. Possibly, *Veremolpa micra* and *Paphia undulata* are new colonizers of the perturbated sea-bed, but this remains to be substantiated. This study postulates that settling silt plumes associated with dredging activity have exacerbated the problems of a sea-bed already disturbed as a result of trawling and pollution.

Murawski, S.A., and F.M. Serchuk. 1989. Environmental effects of offshore dredge fisheries for bivalves. ICES CM 1989/K:27. 12 p.

Abstract: During 1986 and 1987 we conducted submersible observations and associated experiments studying offshore dredge fisheries for scallops and clams in the mid-Atlantic region off the northeast USA. Objectives of the project were to: 1) evaluate the effects of commercial fishing operations on incidental mortality (gear-induced damage) of sea scallops (*Placopecten magellanicus*), ocean quahogs (*Arctica islandica*) and surf clams *(Spisula solidissima*); 2) assess the acute mortality rates of these species when dredged by commercial vessels and subsequently discarded as undersized; and 3) observe the general environmental effects of the offshore dredge fisheries for these shellfish. We conclude that, in the Mid-Atlantic region, harvest efficiency of commercial dredges is generally high, there is variable damage among species encountered by the dredges but not retained, and there are variable survival rates of small clams and scallops returned to the sea bed as undersized. Environmental effects of the dredges are likely sediment-type dependent.

Myers, R., and G. Gilbert. 1993. Fishing-related bottom disturbance study Bras d'Or Lakes. Unpublished Report. Prepared by Canadian Seabed Research Ltd. Submitted to Canadian Department of Fisheries and Oceans, Industry Services and Native Fisheries Branch.

Naughton, J. 1985. Blast fishing in the Pacific. South Pacific Commission Fisheries Newsletter. Noumea. No. 33:16-20.

Abstract: The use of dynamite and other explosives for fishing is commonplace throughout the tropical Pacific, although usually illegal. Detrimental impacts of blast fishing are examined. The problem of enforcement is discussed, education being a major factor involved.

Nickerson, R.B., and T.J. Brown. 1979. The effects of an experimental hydraulic harvester on marginal and submarginal razor clam (*Siliqua patula*) habitat on the Cooper River Delta, Cordova, Alaska. Informational Leaflet. Alaska Department of Fish and Game, 179. 19 p.

Nielsen, A. 1990. Coupon Bight Aquatic Preserve management plan. Florida Department of Natural Resources. Contract NA89AA-D-CZ-228. 188 p.

Abstract: Coupon Bight Aquatic Preserve, located off Big Pine Key in Monroe County, covers approximately 9,000 acres of an outstanding Florida Keys marine habitat. The preserve consists of a shallow water bay covered with dense seagrass beds and other associated marine communities, and it includes a portion of near-shore Atlantic waters containing a large assemblage of marine corals. Coupon Bight Aquatic Preserve is one of two aquatic preserves located in the Florida Keys. It is unique as the only preserve in the state containing significant living coral communities. The resources of the preserve are being adversely impacted from increased development of adjoining uplands and from boating impacts on seagrasses. In particular, damages to the coral formations from boat anchorages is an immediate concern. Various resource restoration studies have been conducted in the preserve.

Norse, E.A., and L. Watling. 1999. Impacts of mobile fishing gear: the biodiversity perspective. Pages 31-40 *in* L. Beneka, editor. Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Abstract: The increasing concern about impacts of bottom trawling, scallop dredging, and other mobile fishing methods has focused primarily on effects on commercial fisheries, but these fishing activities also act more broadly on benthic biological diversity. Because the seabed is erroneously envisioned as a featureless, nearly lifeless plain, impacts of commercial fishing gear have long been underestimated. Structures on and in the seabed, including biogenic structures (reef corals, kelp holdfasts, shells, tubes, and tunnels), create a diversity of habitat patches. They provide refuges from predation and feeding places for demersal fishes and other species. Benthic structural complexity is positively correlated with species diversity and postsettlement survivorship of some commercial fishes. Mobile fishing gear disturbs the seabed, damaging benthic structures and harming structure-associated species, including commercially important fishes, although some other commercial fish species can persist where seabed structures have been removed. Bottom trawling is therefore similar to

forest clear-cutting, but it is far more extensive and is converting very large areas of formerly structurally complex, biologically diverse seabed into the marine equivalent of low-diversity cattle pasture. In contrast with the U.S. National Forest Management Act, which governs use of living resources in federally owned forestlands, the 1996 Magnuson-Stevens Fishery Conservation and Management Act does not prevent ecosystem "type conversion" and ignores the need to maintain biological diversity. Preventing further loss of marine biodiversity and key fisheries will depend on our willingness to protect marine areas from effects of mobile fishing methods.

Nzali, L.M., R.W. Johnstone, and Y.D. Mgaya. 1998. Factors affecting scleractinian coral recruitment on a nearshore reef in Tanzania. Ambio. Vol. 27(8):717-722.

Abstract: A 12-month study was conducted on recruitment patterns in two locations on Taa Reef, northern Tanzania. Since one of the sites had been severely damaged by dynamite fishing, the central aim was to examine any impact that this might have had on coral recruitment. Results showed a strong seasonality in recruitment with a peak recruitment occurring in April at both sites. The peak in recruitment coincided with the peak in water temperature, and low sedimentation rate. A significant difference was observed between sites experiencing different degrees of coral damage, with higher recruitment occurring at the least disturbed site suggesting that recruitment rate was influenced by coral cover. Significant differences were also observed in the distribution of recruits between the upper and lower surfaces of the settling tiles used in the study, with coral larvae preferring to settle on the lower surfaces. Overall, dynamite fishing at Taa Reef appears to have had a major impact due to the removal of viable seed populations of corals. This has decreased the supply of recruits for recolonization of the damaged areas. In addition to recruitment levels, other factors such as sedimentation rates and competition for space with other organisms were also examined, but these did not appear to play a major role in determining recruitment levels at the study sites.

O'Brien, D.W.F. 1997. Fish bombing in Hong Kong-investigation and detection. Pages 68-78 *in* Proceedings of the First International Symposium on Marine Conservation. Hong Kong Marine Conservation Society.

Öhman, M.C., A. Rajasuriya, and O. Lindén. 1993. Human disturbances on corals reefs in Sri Lanka: a case study. Ambio. Vol. 22:474-480.

Abstract: The degradation of coral reefs in Sri Lanka has increased substantially over the last decades. Human activities causing this degradation include: mining for lime production, sewage discharges, discharges of oil and other pollutants in connection with shipping and port activities, destructive fishing practices, land and mangrove destruction, tourism and the collecting of fauna such as fish, shells and corals. In this study, three adjacent coral reefs, Bar Reef, Talawila Reef, and Kandakuliya Reef, which are widely scattered patch reefs off Kalpitiya Peninsula, northwestern Sri Lanka, were surveyed and compared in terms of their fish and coral diversity and abundance as well as human and natural disturbances. Information was gathered by snorkeling in visual overview surveys and by scuba diving in detailed transect surveys. When each reef was ranked according to the extent of live coral cover, and chaetondontid diversity, the results indicated that Bar Reef was in excellent

condition, Talawila Reef was intermediate, and Kandakuliya Reef was in poor condition. The diversity of coral genera, the topographic relief and the proportion of coral rubble, did not follow the same pattern. The number of coral genera found was 49, while 283 fish species belonging to 51 families were recorded. Human disturbance factors on the reefs were found to be net fishing, boat anchoring and ornamental fish collection for the aquarium trade. Bottom-set nylon nets in particular were found to have a very destructive impact on the bottom fauna.

Orth, R.J., K.A. Moore, D.J. Wilcox, and J.R. Fishman. 1998. Chincoteague Bay, Virginia: effectiveness of the SAV sanctuary and revegetation of SAV habitat disturbed by clam dredging. Unpublished Report to the Virginia Marine Resources Commission. 6 p + figures.

Summary: Scientists from the Virginia Institute of Marine Science alerted staff from the Virginia Marine Resources Commission on the destruction of submerged aquatic vegetation beds that had apparently been caused by clam dredging. The scientists reviewed aerial photographs that show an increase in the number of circular scars. Virginia enacted a submerged aquatic vegetation sanctuary that prohibited clam and crab dredging within the sanctuary. This study concludes that the sanctuary has been effective in preventing further destruction of submerged aquatic vegetation beds.

Pace, D.R. 1982. Development and evaluation of a roller-belt harvester for Irish moss in Atlantic Canada. Project Report. Canadian Department of Fisheries and Oceans. Scotia-Fundy Region. Fisheries Development Branch. Vol. 31. 25 p + tables.

Abstract: There are several potential advantages of the roller-belt harvester over the dragrake. It requires less physical effort to operate, it causes relatively little damage to the substrate and presumably the associated flora and it is potentially less damaging to lobsters because it is towed at a much slower speed and covers a much reduced portion of the seabed on each pass. The objective of the present study was to evaluate the roller-belt harvester in terms of these promises and to determine its harvest efficiency throughout a range of commercially productive locations. The study was divided into three phases. Phase I would concentrate on achieving maximum harvest efficiency and minimum biological impact within a single location. Phase II would define operable range and performance level throughout the two regions. Phase III would involve demonstration to potential users when satisfactory performance levels were achieved.

Pajaro, M, C.M. Nozawa, and R. Purgatorio. 1995. Preliminary findings on the conservation status of some tropical marine aquarium fishes. Third National Symposium in Marine Science of the Philippine Association of Marine Science, Philippine Scientist.

Abstract: Exploitation of tropical marine aquarium fishes in the Philippine coastal waters has been going on for more than thirty years. The existence of these fish species has been continually threatened with the destruction of their habitat and unabated use of destructive fishing methods such as sodium cyanide and dynamite fishing, which kills even the young. Several people from Luzon who are involved in the aquarium trade, such as gatherers, screeners and exporters, also perceived a declining trend in the supply of certain species of fishes over the last ten years. Based on interviews, catch records and records of sale, it

appears that the population of some species of Pomacanthids, blue tangs (*Paracantharus hepatus*) and a few butterflies may have been affected by over exploitation. Further studies on the extent of their exploitation is needed. Recommendations for the conservation of these resources are presented.

Parrish, F.A., and T.K. Kazama. 1992. Evaluation of ghost fishing in the Hawaiian lobster fishery. Fishery Bulletin. Vol. 90:720-725.

Abstract: Mortality due to retention of lobsters in derelict traps was evaluated over a 2-year period using two approaches. First, a string of eight empty, single-chamber, plastic traps was deployed at 40 m depth off Oahu, Hawaii, and monitored periodically by scuba during a 6-month period in 1990. The traps were stable and remained intact despite adverse oceanic conditions. Numerous entries and exits of lobsters were recorded. For the second test, the ability of lobsters to exit traps was tested in a series of field and laboratory trials of trap strings stocked with Hawaiian spiny lobster *Panulirus marginatus* and slipper lobster *Scyllarides squammosus*. The number of lobsters that died in stocked traps was less than 4% of the test population and differed significantly from zero only in the laboratory evaluation (χ^2 5.42, P 0.02). The two species exited similarly; however, the pattern of exits in laboratory and field tests differed significantly (χ^2 23.889, P 0.03). All lobsters exited within 56 days in a pattern generally approximating an exponential decline. Our evidence suggests that little direct mortality of lobsters is due to the inability to exit traps, and consequently ghost fishing by these traps is not considered a problem for spiny and slipper lobsters.

Parry, G.D., and D.R. Currie. 1992. The effect of scallop dredging on Port Phillip Bay. Newsletter of the Australian Society of Fish Biology. Vol. 22(2):46.

Abstract: A large study to examine the effects of scallop dredging on Port Phillip Bay will be described. Scallop fishermen respected areas closed to dredging and dredged experimental sites within the closed areas. The study has three components: 1) Studies to examine the environmental effects of current scallop dredging practices. 2) Studies to compare the environmental impacts of dredges of different design and to develop a better dredge. 3) Studies to determine the long-term impact of the least-damaging dredge. Preliminary results from the first of the above components will be discussed.

Parry, G.D., and D.R. Currie. 1992. Interim report on the effects of scallop dredging on Port Phillip Bay. Marine Science Laboratories. Queenscliff, Australia. Internal Report 193. 67 p.

Paul, L.M.B. 1984. Investigations into escape vent effectiveness and ghost fishing in captive populations of the spiny lobster *Panulirus marginatus*. Pages 283-295 *in* Proceedings of the Resource Investigations of the Northwest Hawaiian Islands. University of Hawaii Honolulu, Hawaii Sea Grant Report MR-84-01.

Abstract: The spiny lobster, *Panulirus marginatus*, comprises one of the major fishery resources of the Hawaiian Archipelago. It is usually captured with a double-chambered wire trap whose mesh size is unregulated. Sublegal lobsters fully recruited into the fishery and caught in traps are sorted on the dock. Dock sorting is time-consuming for the fisherman and frequently damaging to lobsters, and its value as a stock conservation method is now being

questioned. This study was designed to determine if spiny lobsters can be effectively 'sorted' on the bottom by fishing with traps equipped with escape vents. This study also investigated whether lobsters would enter traps 'baited' only with live lobster and thus be subject to ghost fishing. Three types of escape vents, single, bar, and mesh, were tested. The unbaited, vented traps were loaded with individually identified lobsters and left on the bottom of a large tank overnight. Results indicated that the overall escape rate of sublegal lobsters was approximately 60 percent with the escape rate decreasing linearly with increasing carapace length. There was no significant difference in escape rate between males and females. Differences in escape rates between vent types indicated that escape vent effectiveness may depend on total vent area. Since vented traps are able to sort out sublegal lobsters on the bottom, it is recommended either that traps be equipped with escape vents or that a minimum mesh size be required. In all the escape vent trials, ghost fishing did occur. Seven percent of the unloaded females and 9 percent of the unloaded males in the tank population were attracted to the vented traps baited only with live lobsters. It is recommended that lobster trap lids be fastened with biodegradable material. If not, lost traps should be included as part of total fishing effort until their estimated time of deterioration.

Pecci, K.J., R.A. Cooper, C.D. Newell, R.A. Clifford, and R.J. Smolowitz. 1978. Ghost fishing of vented and unvented lobster, *Homarus americanus*, traps. Marine Fisheries Review Paper 1307.

Abstract: Field experiments were conducted in waters near Boothbay Harbor, Maine, and Woods Hole, Mass., with 40 inshore-type lobster traps. Twenty of the traps were fished normally from the surface and 20 were left on the bottom and routinely surveyed by divers. Half of the traps in each group were fitted with sublegal escape vents. Catch-escape panels were also tested. Surface-hauled traps caught 3,425 lobsters in 53 sampling periods; 28 percent of the lobsters had one or more types of body damage. The "ghost" traps caught 456 lobsters during the same period; 25 percent of the lobsters died by the end of the experiment.

Pederson, J., and M. Hall-Arber. 1999. Fish habitat: a focus on New England fishermen's perspectives. Pages 188-211 *in* L. Beneka, editor. Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Abstract: This study sought input from fishermen on their knowledge of fish habitat and the effects of fishing gear to fill some gaps in the science. We looked for any documentation of habitats and effects to habitats from fishing gear or other causes that fishermen could or were willing to provide. This report summarizes documentation provided by fishermen of fish habitat, changes to habitat observed over time, and fishing gear effects. In addition, the report evaluates the effectiveness of different approaches to identify fishermen's knowledge and document their observations. To better represent fishermen and provide accurate information, we were interested in fishermen's responses to two questions: (1) How can we better solicit fishermen's knowledge of habitat, and (2) what would make it possible for fishermen to share that information? The results of this study were influenced by several factors, including the fact that methodologies for integrating fishermen's knowledge into fisheries scientific literature and fisheries management are at an embryonic stage. In addition, for this initial study, resources were limited, which gave the survey a strong New England bias. We also found that fishermen are reluctant to get involved in essential fish

habitat identification for several reasons, including the perceived proprietary nature of their habitat information. This review represents an important first step toward making the crucial linkage between fisheries management and fishermen's local knowledge. This study and future similar studies will provide opportunities to bring fishermen's knowledge to the forefront as essential fish habitat management plans are being developed. The contribution of fishermen's knowledge should help managers design a balanced regulatory system that will lead to sustainable fisheries and fisheries communities.

Pendleton, C. 1998. The edge of the bottom - heavily trawled and consistently productive. Page 138 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: A commercial fisherman describes his experiences fishing in the same productive areas year after year and his perception that fishing gear has no detrimental effect in these areas.

Perkins, E.J. 1988. The impact of suction dredging upon the population of cockles, *Cerastoderma edule*, in Auchencairn Bay. Report to the Nature Conservancy Council, Scotland Headquarters, from Solway Marine Investigations, Maryport, Cumbria.

Peterson, C.H., H.C. Summerson, and S.R. Fegley. 1987. Ecological consequences of mechanical harvesting of clams. Fishery Bulletin. Vol. 85(2):281-298.

Abstract: A field experiment was performed in 1,225 m^2 plots in each of two shallow estuarine habitats, a seagrass bed and a sand flat, in Back Sound, North Carolina (USA), to test the impact of clam raking and two different intensities of mechanical harvesting of clams ("clam kicking") for up to 4 years on 1) hard clam, *Mercenaria mercenaria*, recruitment, 2) seagrass biomass, 3) the density of benthic macroinvertebrates, and 4) the density of bay scallops, *Argopecten irradians*. The removal of adult hard clams with the contingent sediment disturbance had ambiguous effects on the recruitment of hard clams: in the sand flat recruitment tended to be lower (but not significantly) in intense-clam-kicking matrices than in controls, whereas in seagrass recruitment of hard clams did not show a clear response to treatment. In the raking and light-clam-kicking matrices, seagrass biomass fell immediately by ≅25% below controls but full recovery occurred within a year. In the intense-clam-kicking matrices, seagrass biomass fell by ≅65% below levels expected from controls; recovery did not begin until more than 2 years passed, and seagrass biomass was still ≅35% lower than predicted from controls 4 years later. Clam harvest did not affect either the density or species composition of small benthic macroinvertebrates from sediment cores, probably because of their rapid capacity for recolonization and generally short life spans. In all treatments, densities of benthic macroinvertebrates (mostly polychaetes) were substantially higher in the seagrass than in the sand flat during October samplings but equal during March samplings. Bay scallop density declined with declining seagrass biomass across harvest treatments, but the intense-clam-kicking matrices contained even fewer bay scallops than their seagrass biomass would predict, perhaps because of enhanced patchiness of the remaining seagrass. The relative inertia of the change in seagrass biomass following extensive destruction in the intensely kicked matrices suggests that seagrass replanting may be an extremely important means of returning disturbed, unvegetated areas to seagrass

systems. Emergence during summer of a between-habitat gradient in infaunal densities (higher in seagrass than in sand) supports the hypothesis that seagrass provides a partial prey refuge for infaunal invertebrates. The failure of the benthic macroinvertebrate density to respond to clam harvest treatments in both sand flats and seagrass beds implies that the polychaetes which dominate recover rapidly from disturbance and are probably not adversely affected by clam harvest. The negative and long-lasting impact of intense hard clam harvest on seagrass biomass with its effects on other fisheries, including bay scallops, implies that hard clam fisheries should be managed to minimize the intensity of harvest within seagrass beds.

Peterson, C.H., H.C. Summerson, and S.R. Fegley. 1983. Relative efficiency of two clam rakes and their contrasting impacts on seagrass biomass. Fishery Bulletin. Vol. 81(2):429-434.

Abstract: Fishing gear and techniques are continually being developed and modified as alternatives to traditional fishing methodologies. As new equipment becomes available, most individual fishermen carry out their own field trials and peer interviews to determine which gear best meets their needs. Nevertheless, both quantitative comparisons of the relative efficiencies of alternative methodologies (e.g., Medcof and MacPhail 1964; Caddy 1973) and controlled scientific tests of the environmental impacts of contrasting techniques (e.g., Glude and Landers 1953; Caddy 1973; Fonseca et al.) are necessary to provide the biological basis for resource managers to develop sound management policies. Quantitative data on the relative costs and benefits of alternative fishing methodologies are especially important in the estuaries, where fishing intensity often brings the demands of different fisheries into conflict. Here we provide relative cost and benefit data for two different clam rakes, both available to hard clam (*Mercenaria mercenaria*) fishermen along the east and gulf coasts of the United States. At a study site in coastal North Carolina, we estimated the efficiency of hard clam capture by each rake in two habitats -- a seagrass bed and a sand flat. We also employed replicate trials of both clam rakes within the seagrass bed to estimate relative impacts of raking on seagrass biomass. We chose damage to seagrass as a measure of important environmental impact because most coastal resource managers now recognize the direct and indirect contributions of seagrass beds to coastal zone fisheries production.

Pet-Soede, L., and M.V. Erdmann. 1998. Blast fishing in southwest Sulawesi, Indonesia. Naga. Vol. 21(2):4-9.

Abstract: Blast fishing has been a widespread and accepted fishing technique in Indonesia for over 50 years. The largest coral reef fishery in Indonesia is around the Spermonde archipelago in southwest Sulawesi. With the expanding population and the increasing demand for fish for export, fishing has intensified and fish catches per unit effort are stable or declining. The use of bombs made with a mixture of kerosene and fertilizer is widely prevalent. In the market of the city of Ujung Pendang, an estimated 10-40% of the fish from capture fisheries are caught through blast fishing. This is destroying the hard corals. Blast fishing is seen by the fishers as being much easier and results in higher catches than with other traditional methods. They believe that the only way to limit this practice is with stricter policing and higher fines. An effective management option could be to establish national marine reserves within the archipelago, supported by other income-generating activities.

Philippart, C.J.M. 1998. Long-term impact of bottom fisheries on several bycatch species of demersal fish and benthic invertebrates in the southeastern North Sea. ICES Journal of Marine Science. Vol. 55:342-352.

Abstract: Within the last few decades, the main bottom fishery in the south-eastern North Sea has changed from otter to beam trawling with beam trawling effort increasing from 1960 onwards. During this period, the Zoological Station in Den Helder (The Netherlands) has collected and registered by-catch species caught by commercial fisherman. The annual numbers of registered specimens were used to estimate the species-specific catch efficiencies of otter and beam trawlers between 1945 and 1983. This analysis was restricted to 7 fishes (sharks, rays, and skates) and 10 invertebrate species (whelks, urchins, squids, and crabs) all of which have a demersal lifestyle and were regularly delivered throughout the study period. For most species, the observed variations in annual numbers of fish and invertebrates delivered to the Zoological Station appeared to be related to the changes in type of gear and fishing effort. Results from the model suggest that otter trawlers caught relatively more fish than invertebrates, whilst beam trawlers caught proportionally more invertebrate species (i.e. velvet swimming crab, slender spindle shell) that were rarely delivered during periods of greatest otter trawling effort. On average, the catch efficiency of the beam trawl fleet appeared to be 10 times higher than that of the otter trawl fleet. Furthermore, the trends shown by the model in species delivered suggested that bottom fisheries had a considerable impact on several demersal fish and benthic invertebrates.

Pickett, G. 1973. The impact of mechanical harvesting on the Thames Estuary cockle fishery. MAFF Laboratory Leaflet. No. 29. 21 p.

Summary: This report describes the fishing techniques for the Thames Estuary cockle fishery. It also describes the effect of the dredges upon the sea bed. Dredge tracks are visible for up to 2 months. The author feels that continued dredging of an area could be detrimental only if dredging takes place in a confined, sheltered area where sediment is not rapidly replaced by natural processes.

Piet, G.J., J. Craeymeersch, J. Buijs, and A.D. Rijnsdorp. 1998. Changes in benthic invertebrate assemblage following the establishment of a protected area, the "plaice box". ICES CM 1998/V:2. 18 p.

Abstract: In 1989 a protected area in the south-eastern North Sea was established: the "plaice box." At first it was only effective during the 2nd and 3rd quarter, but in 1994 the box was extended to the 4th quarter and since 1995 the box was closed during the whole year. Data of the by-catch of benthic invertebrates of two beam trawl surveys were used to determine the effect of the closure of the box had on the benthic invertebrate assemblage. Multivariate analysis on the assemblage together with analysis of the eight most abundant species showed for both surveys a significant effect on the composition of the assemblage. Closing the box during the second and third quarter caused an increase in abundance of several species followed by a decline when the box was closed year-round. A possible explanation is that the most abundant species were scavengers and predators for which the deleterious effect of additional mortality is overruled by a decreased competition for food and risk of predation.

Pilskaln, C.H., J.H. Churchill, and L.M. Mayer. 1998. Resuspension of sediment by bottom trawling in the Gulf of Maine and potential geochemical consequences. Conservation Biology. Vol. 12(6):1223-1229.

Abstract: The benthic environment of the Gulf of Maine is characterized by a thick and basin-wide nepheloid layer, classically defined as a near-bottom region of permanent sediment resuspension. The high frequency of commercial bottom trawling in particular regions of the Gulf of Maine, documented by records compiled by the National Marine Fisheries Service, may strongly affect measured resuspension fluxes and contribute to the maintenance of the nepheloid layer. Indirect evidence of the effects of bottom trawling on sediment resuspension is observed in the seasonal collection of large, benthic infaunal worms, along with substantial amounts of resuspended bottom sediment, in a sediment trap deployed 25 m off the bottom in the western gulf region of Wilkinson Basin. These collections appear to be coincident with seasonal periods of intensive bottom trawling in this area. By comparison, the western gulf region of Jordan Basin is typified by significantly reduced annual bottom-trawling activity, and very few infaunal worms are found in the seasonal collections of a sediment trap located 25-30 m off the bottom. The extent to which trawling-induced bottom sediment excavation and resuspension occurs has important implications for regional nutrient budgets in terms of the input of sedimentary nitrogen and silica into the water column via this anthropogenic activity. Sediment mixing and frequent bottom disturbance from trawling activity may also produce changes in the successional organization of soft-sediment infaunal communities. The potential effects of trawling require serious examination and quantification to accurately determine the impact of such anthropogenic activity on the benthic ecosystems of continental margin environments.

Pitcher, C.R., C.Y. Burridge, T.J. Wassenberg, and I.R. Poiner. 1997. The effects of prawn trawl fisheries on GBR seabed habitats. Pages 107-123 *in* The Great Barrier Reef, Science, Use and Management, a National Conference Proceedings. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Pranovi, F., and O. Giovanardi. 1994. The impact of hydraulic dredging for short-necked clams, *Tapes* spp., on an infaunal community in the lagoon of Venice. Scientia Marina. Vol. 58(4):345-353.

Abstract: In order to assess the effects of hydraulic dredging on bottom sediments and on benthic populations, experimental fishing was carried out in the central part of the Venetian Lagoon. Analysis of bottom sediments showed long-term effects on sieve fractions, caused by loss of resuspended and dispersed fine particles. Infaunal samples were collected every three weeks in dredged and control areas. Immediately after dredging, significant differences in total abundance (number) and in biomass (wet weight) were observed, some persisting as long as two months. There were also long-term effects on biocenoses, related to changes in sediment particle size and the mechanical action of the dredge on marine Phanerogames (i.e. *Zostera* spp.). It is hypothesized that the recovery of the infaunal community, which was slow compared with recovery times recorded for this type of fishing at sea, is related to the medium/low energy conditions of the lagoon environment. It is concluded that hydraulic dredging produces considerable negative effects on the bottom environment of the Venetian Lagoon.

Pratt, V.R. 1996. The growing threat of cyanide fishing in the Asia Pacific Region and emerging strategies to combat it. Coastal Management of Tropical Asia. Vol. 6:9-11.

Prena, J., T. W. Rowell, P. Schwinghamer, K. Gilkinson, and D.C. Gordon, Jr. 1996. Grand Banks otter trawling impact experiment: I. Site selection process, with a description of macrofaunal communities. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 2094. 38 p.

Abstract: As part of a long-term study on the potential impacts of mobile fishing gear on benthic habitat and communities, it was necessary to identify suitable experimental sites on the continental shelf off Atlantic Canada. Selection criteria included: little or no recent bottom disturbance from fishing activity, likelihood of excluding bottom-disturbing fisheries during the experiment the uniformity of environmental properties, the efficiency of sampling equipment and ease of processing, and the characteristics of the benthic communities. A preliminary evaluation initially suggested the 4TVW haddock nursery area on Western Bank, which has been closed to mobile groundfish gear since 1987, and a specific site on the nose of the Grand Banks. After a trial research mission in 1991, sampling on Western Bank in 1992 was focused at two specific sites in the closed area about 30 km apart. Field observations at all sites consisted of sidescan sonar surveys and biological sampling using a video-equipped epibenthic sled and a newly developed video grab. The macrobenthos of each site was evaluated in terms of species occurrence, abundance, commonality, richness, and homogeneity. The two Western Bank areas, although species-rich, were found to be sparsely and heterogeneously populated and would require a high level of sampling effort to detect changes to species assemblages which might result from trawling activities. The Grand Banks site community was also species-rich but was much more homogeneously populated as well as having a greater number of epibenthic species, abundant species and individuals, and a greater biomass. Hence, this site would require less sampling effort to detect a given level of change. Assessing all available information against the selection criteria, it was concluded that of the three candidate sites the most suitable location for a single otter trawl impact experiment is the one on the Grand Banks. New faunistic information for each of the three sites is also presented.

Prena, J., P. Schwinghamer, T.W. Rowell, D.C. Gordon, Jr., K.D. Gilkinson, W.P. Vass, and D.L. McKeown. 1999. Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: analysis of trawl bycatch and effect on epifauna. Marine Ecology Progress Series. Vol. 181:107-124.

Abstract: An experimental study of the effects of otter trawling was conducted in a deep (120 to 146 m) sandy bottom ecosystem of the Grand Banks of Newfoundland from 1993 to 1995. Each year, three 13 km long corridors were trawled 12 times within 31 to 34 h with an Engel 145 otter trawl equipped with rockhopper foot gear. The width of the disturbance zones created was on the order of 120 to 250 m. The total biomass of invertebrate bycatch in the trawl decreased significantly over the 12 sets, even though only a very small proportion of the biomass present was removed and each set did not pass over exactly the same area of seabed. An influx of scavenging snow crabs *Chionoecetes opilio* into the trawled corridors was observed after the first 6 sets (approximately 10 to 12 h). Benthic organisms in trawled and nearby reference corridors were sampled with an epibenthic sled. Their biomass was on

average 24% lower in trawled corridors than in reference corridors. At the species level, this biomass difference was significant for snow crabs, *Chionoecetes opilio*, sand dollars *Echinarachnius parma*, brittle stars *Ophiura sarsi*, sea urchins *Strongylocentrotus pallidus* and soft corals *Gersemia* sp. The reduced biomass of epibenthic organisms in trawled corridors is thought to be due to several interacting factors including direct removal by the trawl, mortality, damage, predation, and migration. The homogeneity of the macro-invertebrate community collected by epibenthic sled was lower in trawled corridors. Sand dollars, brittle stars and sea urchins demonstrated significant levels of damage from trawling. The mean individual biomass of epibenthic organisms was lower in trawled corridors suggesting size specific impacts of trawling, especially for sand dollars. No significant effect of trawling was observed in the 4 dominant mollusc species captured by the sled (*Astarte borealis*, *Margarites sordidus*, *Clinocardium ciliatum* and *Cyclocardia novangliae*). This experiment indicates that otter trawling on a sandy bottom ecosystem can produce detectable changes on both benthic habitat and communities, in particular a significant reduction in the biomass of large epibenthic fauna.

Pringle, J.D., and R.E. Semple. 1976. A preliminary assessment of the ecological impact of an experimental *Chondrus* (Irish moss) harvester off coastal Prince Edward Island. The Branch, Invertebrate and Plants Division, Technical Report Series MAR/T. Halifax, Nova Scotia. 76 p.

Pringle, J.D., J. Murchison, and D.J. Jones. 1979. A study to develop a replacement for the basket-dragrake for *Chondrus* harvesters of the southern Gulf of St. Lawrence. Canadian Fisheries and Marine Service Manuscript Report. Vol. 1496. 48 p.

Abstract: The basket dragrake was banned as a *Chondrus* harvesting implement due to its adverse ecological impact. A joint industry/provincial-federal committee was created to design a replacement. It was decided the latter should be simple in design and used in conjunction with the dragrake. Two prototypes, both elevated on runners, were constructed. Sea trials were conducted on the Pleasant View bed, near Miminegash, P.E.I. The experimental design included the traditional dragrake and the basket dragrake.

Pringle, J.D., and D.J. Jones. 1980. The interaction of lobster, scallop and Irish moss fisheries off Borden, Prince Edward Island. Canadian Technical Reports of Fisheries and Aquatic Sciences. No. 973.

Abstract: Basket-dragrakes were towed across Irish moss (*Chondrus crispus*) beds off Borden, Prince Edward Island, from May through July, 1979, to determine seasonal distribution of lobsters (*Homarus americanus*) on the beds. Divers holding onto basket-dragrakes counted lobsters (0.04 min^{-1}) and noted their behaviour. No lobsters were captured but gunnels, flounders, sculpins, crabs, and starfish were. The techniques were tested in *Chondrus* beds off Miminegash, Prince Edward Island, where lobsters were more abundant. Here, basket-dragrakes captured 0.18 lobsters per minute; divers observed 1.9 lobsters per minute. Lobsters moved laterally or up to avoid basket-dragrakes. One lobster was captured in 120 tows of scallop rock drags over scallop beds off Borden. It was concluded that the decline in lobster landings off Borden was not due to *Chondrus* or scallop dragging.

Pringle, J.D., D.J. Jones, and P. Rowe. 1981. Fishing power and ecological impact on Gulf *Chondrus* (Irish moss) of modified *Chondrus* dragrakes. Canadian Manuscript Reports of Fisheries and Aquatic Sciences. No. 1601. 80 p.

Abstract: The harvest of the traditional dragrake employed in the southern Gulf of St. Lawrence to harvest *Chondrus crispus* Stackhouse (Irish moss), consists of between 24% and 35% (by number) fronds with holdfasts attached and between 50% and 66% prerecruits. It was hypothesized that minor modifications to rake characteristics such as tine extension, tine height off bottom, and tine spacing would have a significant (P less than 0.05) effect on ecological impact. Trials were carried out with 16 prototypes towed behind both haulers and winchers in Marine Plant Harvesting Dist. 1 and 2 (western P.E.I.). The grand mean (all trials) yield per prototype varied significantly, ranging from 8.3 + or - 6.2 kg/h to 20.4 + or - 10.3 kg/h. Prototypes with narrow tine spacings or narrow and elevated tines and significantly greater fishing success than those with broad tine spacings or broad and elevated. Dragrakes with longer tines employed in Dist. 1 removed significantly fewer fronds attached to holdfasts than traditional dragrakes but fishing success was significantly reduced. Vertically thicker tines increased ecological impact.

Probert, P.K., and D.G. McKnight, and S.L. Grove. 1997. Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 7(1):27-40.

Abstract: Benthic invertebrate bycatch was collected during trawling for orange roughy (*Hoplostethus atlanticus*) at water depths of 662-1524 m on the northern and eastern Chatham Rise, New Zealand, in July 1994. Seventy-three trawl tows were examined, 49 from 'flat' areas and 24 from two groups of 'hills' (small seamounts). Benthos was recorded from 82% of all tows. Some 96 benthic species were recorded including Ophiuroidea (12 spp.), Natantia (11 spp.), Asteroidea (11 spp.), Gorgonacea (11 spp.), Holothuroidea (7 spp.), and Porifera (6 spp.). Cluster analysis showed the bycatch from flats and hills to differ significantly. Dominant taxa from flats were Holothuroidea, Asteroidea and Natantia; whereas taxa most commonly recorded from hills were Gorgonacea and Scleractinia. Bycatch from the two geographically separate groups of hills also differed significantly. The largest bycatch volumes comprised corals from hills: Scleractinia (*Goniocorella dumosa*), Stylasteridae (*Errina chathamensis*) and Antipatharia (*Bathyplates platycaulus*). Such large sessile epifauna may significantly increase the complexity of benthic habitat and trawling damage may thereby depress local biodiversity. Coral patches may require more than 100 years to recover. Other environmental effects of deep-water trawling are briefly reviewed. There is an urgent need to assess more fully the impact of trawling on seamount biotas and, in consequence, possible conservation measures.

Quandt, A. 1999. Assessment of fish trap damage on coral reefs around St. Thomas, USVI. Independent Project Report, UVI, Spring 1999. 9 p.

Summary: The author examines the habitats that fishermen use when fishing with fish traps. The study also examines the damage done by the traps on different habitat types.

Rachor, E. 1989. Effects on the benthos of commercial fishing for sandeel. Annex to the Eighth Report of the Benthos Ecology Working Group. ICES CM 1989/L:19. p. 79.

Summary: This brief report concludes that the available information for the sandeel fishery indicates that there is little direct disturbance on the benthos from the sandeel fishery.

Raloff, J. 1996. Fishing for answers: deep trawls leave destruction in their wake - but for how long? Science News. Vol. 150:268-271.

Summary: This article discusses the state of the knowledge concerning fishing gear impacts to habitat. It briefly discusses several worldwide ongoing research projects that are looking at these impacts and their preliminary findings.

Ramas, G.C. 1964. Effects of blast fishing. Underwater Naturalist. Vol. 6(2):31-33.

Summary: This article describes the use of dynamite to catch fish in the Philippines. It gives a brief history on the origin of blast fishing. The author states the solution to the blast fishing problem is education.

Ramsay, K., M.J. Kaiser, and R.N. Hughes. 1996. Changes in hermit crab feeding patterns in response to trawling disturbance. Marine Ecology Progress Series. Vol. 144(1-3):63-72.

Abstract: Bottom trawling leads to the death, injury or exposure of benthic fauna, thus creating a potential source of food for predators and scavengers. We examined the behavior of 2 sympatric species of hermit crab, *Pagurus bernhardus* and *P. prideaux*, in response to beam trawl disturbance. Catch numbers, body size and stomach contents of the 2 species were analyzed from a treatment wayline before and after it was fished with a 4 m commercial beam trawl and from 2 adjacent unfished control waylines. Catch numbers of *P. bernhardus* were significantly higher on the treatment wayline 2 and 3 d after fishing, whilst on the fourth day they were no longer significantly different. Numbers of *P. prideaux* did not vary significantly between control or treatment waylines or with time. After fishing, the size distribution of *P. bernhardus* on the treatment wayline became skewed towards larger size-classes of crabs. For 3 d after fishing, *P. bernhardus* collected from the treatment wayline had significantly higher stomach content weights per unit body mass than those from the control area. No such difference occurred for *P. prideaux*. The diets of the 2 species were similar, including crustaceans, polychaetes and molluscs, although the ranked importance of each type of prey differed between the 2 hermit crab species. There was an increase in the proportion of crustaceans and polychaetes found in the stomachs of *P. bernhardus* from the treatment wayline 1 d after fishing. These results suggest that *P. bernhardus* migrate into recently trawled areas because they are able to benefit from feeding on the damaged or disturbed fauna generated by beam trawling. *P. prideaux* apparently neither move into the trawled area nor respond to the additional food source if already there, even though they have similar dietary characteristics to P. *bernhardus*

Ramsay, K., and M.J. Kaiser. 1998. Demersal fishing disturbance increases predation risk for whelks (*Buccinum undatum* L.). Journal of Sea Research. Vol. 39:299-304.

Abstract: Field observations by divers indicated that a high rate of predation of whelks (*Buccinum undatum*) by starfish (*Asterias rubens*) occurred in an area disturbed by scallop dredging, although these whelks mostly appeared to be alive and externally undamaged. The ability of whelks to escape from starfish was tested in the laboratory after they were dropped or rolled to simulate direct physical contact with bottom fishing gear. Dropping whelks did not significantly affect their escape behavior, but whelks which had been rolled took significantly longer to right themselves and were significantly less likely to perform an escape response than whelks that had not experienced this treatment. This study suggests that demersal fishing may indirectly increase whelk mortality by increasing their risk of predation.

Ramsay, K., M.J. Kaiser, and R.N. Hughes. 1998. Responses of benthic scavengers to fishing disturbance by towed gears in different habitats. Journal of Experimental Marine Biology and Ecology. Vol. 224:73-89.

Abstract: The aggregation and feeding behavior of invertebrate scavengers in areas disturbed by trawling was investigated at three different localities. At each site a fishing disturbance was created using a commercial 4 m beam trawl and scavenger density was quantified using a light beam trawl. At one site two diver surveys were also carried out; along a line fished with a scallop dredge or a beam trawl on two separate occasions. For all experiments the fished and adjacent unfished control areas were sampled before, and at intervals after, the initial fishing disturbance. Sampling with the light beam trawl revealed that hermit crabs *Pagurus bernhardus* moved into areas which had been fished with a 4 m beam trawl at an experimental site near Anglesey. The density of these hermit crabs increased significantly in the fished area after fishing had taken place, but no change in density occurred in the adjacent control (unfished) area. At two other sites (Red Wharf Bay, Anglesey and a site offshore from Walney Island) there were no detectable increases in scavenger numbers in the fished areas. Furthermore, at the site near Walney Island, numbers of hermit crabs *P. bernhardus*, swimming crabs *Liocarcinus depurator* and starfish *Asterias rubens* actually decreased after fishing. Thus the responses of scavengers to towed fishing gears varied considerably between different communities. At Red Wharf Bay, divers observed similar responses of scavengers to both beam trawl and scallop dredge disturbance. Four predatory species were observed feeding in the fished area; starfish *A. rubens*, hermit crabs *P. bernhardus*, brittlestars *Ophiura ophiura* and whelks *Buccinum undatum*. These predators fed on damaged bivalves, echinoderms, crustaceans, whelks and polychaetes. The proportion of starfish feeding in the fished area was significantly higher after fishing had taken place. Demersal fishing activities provide food for scavengers in the form of damaged animals which are left in the tracks of the trawl or dredge. The responses of scavengers to fishing disturbance are not always manifested as a large increase in their abundance. It is clear that the magnitude of response varies between species and between habitat types.

Rangeley, R.W. 1994. The effects of seaweed harvesting on fishes: a critique. Environmental Biology of Fishes. Vol. 39:319-323.

Abstract: Black & Miller (1991) concluded that there was no large impact of an experimental harvest of rockweed, *Ascophyllum nodosum*, on fishes. A critique of their study demonstrates that this conclusion cannot be substantiated by their data because of

sampling biases, errors in experimental design and low statistical power. Further, evidence is presented which supports the hypothesis that rockweed may provide an important nursery habitat for juvenile fishes.

Redant, F. 1987. A bibliography on the effects of bottom fishing gear and harvesting techniques on benthic biota. Benthos Ecology Working Group. ICES CM 1987/L:26. p. 20-27.

Abstract: The present bibliography covers the literature on the effects of seaweed, fish and shellfish harvesting techniques, ranging from digging and hand raking to dredging, hydraulic dredging and bottom trawling, on the sea bed, the zoobenthos and the phytobenthos.

Redant, F. 1991. An updated bibliography on the effects of bottom fishing gear and harvesting techniques on the sea bed and benthic biota. Working Document to the Study Group on Ecosystem Effects of Fishing Activities, ICES:1-12.

Summary: The present bibliography on the effects of bottom fishing gear and harvesting techniques is an update of an earlier bibliographic review, presented to the Benthos Ecology Working Group of the International Council for the Exploration of the Sea in 1987. It contains about 100 references both to the open literature and to contract reports, which are not always readily accessible. A special effort was made to also include working group and committee meeting reports, dealing with the subject.

Rees, E.I.S. 1996. Environmental effects of mechanized cockle fisheries: a review of research data. A report commissioned by the Marine Environment Protection Division, Ministry of Agriculture, Fisheries and Food, London. 42 p.

Rees, H.L., and P.T. Dare. 1993. Sources of mortality and associated life cycle traits of selected benthic species: A review. Fisheries Research Data Report. Directorate of Fisheries Research. Lowestoft, England. No. 33. 36 p.

Abstract: This review was prepared as a working document for an ICES Study Group on the Ecosystem Effects of Fishing Activities which met for the second time in April 1992. Its aim was to provide an assessment of the relative importance of a variety of sources of mortality of selected benthic species, amongst which the action of commercial trawling and dredging at the seabed were of particular interest. Because such an appraisal necessitated a consideration of the influence of a wide range of factors (natural and anthropogenic) in attempting to place fishing effects in context, the account was felt to have a wider interest, notably because it crossed traditional boundaries for applied assessments. While several of the species will be familiar to fisheries or environmental scientists, synopses of relevant information along the lines of the following account have not hitherto been readily available. There is clearly scope for widening the approach to other named species or species-groups for which integrated assessments of the implications of man-induced changes are likely to be helpful. It is hoped that this account will provide a stimulus for future activity.

Reise, K. 1982. Long term changes in the macrobenthic invertebrate fauna of the Wadden Sea: Are polychaetes about to take over? Netherlands Journal of Sea Research. Vol. 16:29-36.

Summary: Records from 1869 to 1981 on macrobenthic invertebrates of intertidal and subtidal soft-bottom habitats east of northern Sylt have been analyzed with respect to long-term phenomena. Out of the 101 common species studied 28 have decreased, chiefly because oyster beds, *Sabellaria* reefs and a subtidal seagrass bed disappeared. Almost all losses occurred in the subtidal region. Increases are recorded for 30 species with a disproportionately high share of polychaetes (18). The total amount of long-term change involves 59% of all common species. A net loss of species occurred subtidally while tidal flats showed a net gain. Probably half of all changes are ultimately caused by human interference. A high proportion of the polychaetes, which proportion increased over the years, is adapted to disturbed habitats.

Reise, K., and A. Schubert. 1987. Macrobenthic turnover in the subtidal Wadden Sea: the Norderaue revisited after 60 years. Helgoländer Meeresunters. Vol. 41:69-82.

Abstract: The benthic macrofauna of a tidal inlet in the northern Wadden Sea was sampled with grab and dredge in 1924-1926 (Hagmeier & Kändler, 1927), and again in 1985 and 1986. The comparison of surveys from consecutive years, as well as observations from an adjacent area, are employed to separate spurious from real long-term changes. Several epibenthic species of the 1920s became rare or absent in the 1980s. Oyster beds and reefs of the colonial polychaete *Sabellaria spinulosa* have disappeared completely. On the other hand, mussel beds have extended their range, and the abundance of mobile infauna has increased. The total number of species has remained approximately the same. Compared to surveys from consecutive years, the 60-year interval has doubled the species turnover rate, and has decreased the similarity in relative abundances by one third. The observed losses are best explained by the impact of dredging and trawling on the benthic fauna, while gains seem to indicate coastal eutrophication.

Richards, A.H. 1994. Problems of drift-net fisheries in the South Pacific. Marine Pollution Bulletin. Vol. 29(1-3):106-111.

Summary: The author describes the use of drift-nets in the South Pacific and discusses problems associated with the fisheries that employ drift-nets. He also discusses lost or discarded nets and their associated ghost fishing.

Richter, I.U. 1999. Model experiments for the analysis of the interaction between fishing gear elements and the over-dragged sediment. ICES/SCOR Symposium, Ecosystem Effects of Fishing, April 1999, St. John's, Newfoundland. 14 p.

Abstract: The task of the international research project TRAPESE exists in the modeling and simulation of the mutual influence of fishing gears towed along the bottom of the sea and the over-dragged sediment. The target is the creation of a methodology for estimating the consequences of technical fishery activities at the sea bottom. Apart from theoretical analyses using methods of the hydraulic and soil mechanics, model experiments for the quantitative evaluation of influence parameters full-scale experiments a further focus during work on the above mentioned task. The theoretical analyses and model experiments are executed primarily by the University of Rostock. In a test concept created on a long-term basis special test arrangements are conceived, built and used at the institute of maritime

systems and fluid engineering. For the time being the available results represent a further contribution to the present level of knowledge about the interaction between fishing gear elements and the bottom of the sea. Validating of the results from the model tests is in the responsibility mainly of the project partners from Belgium and the Netherlands.

Riegl, B., and K.E. Luke. 1998. Ecological parameters of dynamited reefs in the northern Red Sea and their relevance to reef rehabilitation. Marine Pollution Bulletin. Vol. 37(8-12):488-498.

Abstract: Dynamite damage was investigated on 60 reefs in the Egyptian Red Sea. 65% of the investigated reefs had signs of dynamite damage, mostly in leeward areas (58%). Significant changes in coral and fish community composition within dynamited sites were observed. Coral cover decreased, the amount of bare substratum and rubble increased, fish communities in dynamited areas suffered a decrease in species richness and abundance. Due to a stable pattern of coral community differentiation on northern Red Sea reefs (windward *Acropora*, leeward *Porites*) most damage is on near-climax *Porites* reef slopes or *Porites* carpets. Natural regeneration of such communities is likely to be very slow, possibly taking several hundred years. Rehabilitation would be difficult since coral transplants would have to mimic the previously existing community.

Riemann, B., and E. Hoffmann. 1991. Ecological consequences of dredging and bottom trawling in the Limfjord, Denmark. Marine Ecology Progress Series. Vol. 69:171-178.

Abstract: During August 1988, effects of mussel dredging and bottom trawling on particulate material, internal nutrient loads, and oxygen balance were examined at 3 shallow locations in Limfjorden, Denmark. Water samples were taken simultaneously from areas exposed to fishing activities and from unused control areas. Sampling was carried out before fishing and 0 (immediately after fishing), 30, and 60 min after fishing. Sampling and control areas, which were situated close to one another, each covered 160 000 m^2 and included 9 sampling stations and 3 depths. Immediately after mussel dredging, suspended particulate material increased significantly, but 30 min after dredging these differences had decreased and had returned to the start level after 60 min. The effect per dredged m^2 (1850 m^2) extrapolated to the total area (160 000 m^2) was 1470 g suspended particulate material per m^2 dredged, corresponding to an increase of 1361% on the average suspended particulate material in the water column before dredging. Similar values for eel trawling from 2 different stations gave 960 and 1000% , respectively. Oxygen decreased significantly after mussel dredging and average ammonia content increased, but large horizontal variations in the ammonia content prevented detailed interpretation of these increases. Changes in other nutrients were small. Changes in particulate matter and nutrients were also observed at 2 stations on a day with high (15 m s^{-1}) followed by a day with low wind velocity (3 m s^{-1}). Particulate matter and total phosphorus were markedly higher on the windy day. A significant proportion of dredging and trawling in the Limfjord takes place during summer, when wind speeds are mostly low, nutrients are low, and oxygen consumption and temperatures are high. During these periods, trawling and particularly dredging reduce the water quality by increasing internal nutrient loads, oxygen consumption, and possibly phytoplankton primary production. An extended evaluation of the ecological role of dredging and trawling requires an estimate of intensity of, and more information on the role of, natural wind-stress.

Riesen, W., and K. Reise. 1982. Macrobenthos of the subtidal Wadden Sea: revisited after 55 years. Helgoländer Meeresunters. Vol. 35:409-423.

Abstract: During the years 1923-1926 Hagmeier & Kändler (1927) sampled the macrofauna of subtidal shallows and channels of the Wadden Sea close to the Island of Sylt (German Bight, North Sea). Reinvestigating this study area in 1980, a substantially altered faunal composition was recorded. An approach is made to quantify the comparison in terms of abundance, species richness and diversity of invertebrate taxa. Human interference is assumed to be responsible for the major changes. Natural oyster beds have been overexploited and the local population of *Ostrea edulis* has been driven to extinction. Subsequently, mussels (*Mytilus edulis*) spread in the entire region, promoted by shell fishery. Particularly barnacles and many polychaetes took advantage of the expansion of mussel banks which is substantiated by correlation analysis. Reefs of the colonial polychaete *Sabellaria spinulosa* stood in the way of shrimp trawling and became destroyed together with the associated fauna. A subtidal *Zostera marina* bed was wiped out in 1934 by a natural epidemic disease but never succeeded in reestablishing itself. The associated fauna disappeared. Large epibenthic predators and scavengers (crabs, snails and starfish) survived all these changes. The total number of species remained approximately at the same level but molluscs experienced losses and polychaetes diversified. Overall abundance increased with a disproportionately large share of a few species *(Mytilus edulis, Balanus crenatus, Cerastoderma edule, Scoloplos armiger).* The subtidal fauna of the Wadden Sea proved to be vulnerable to human disturbance; thus, the present community can no longer be viewed as the outcome of entirely natural processes.

Rijnsdorp, A.D., A.M. Buys, F. Storbeck, and E.G. Visser. 1996. Micro-scale distribution of beam trawl effort in the southern North Sea between 1993 and 1996 in relation to the trawling frequency of the sea bed and the impact on benthic organisms. ICES CM 1996/Mini:11. 34 p.

Rijnsdorp, A.D., P. Groot, and F.A. van Beek. 1991. The micro distribution of beam trawl effort in the southern North Sea. ICES CM 1991/G:49.

Abstract: This paper describes the spatial distribution of fishing effort in a sample of 18 fishing trips of Dutch commercial beam trawlers fishing for sole and plaice in the southern North Sea. The micro distribution of effort was studied with a resolution of 1 x 1 mile in order to estimate the frequency with which the sea bed is trawled in the most heavily trawled areas in the southern North Sea. Analysis of individual fishing trips showed that vessels do not trawl at random but concentrate their effort on restricted fishing grounds. On average a 1 x 1 mile square was fished 1.5 times during a week. Comparison of the spatial distribution of beam trawl effort between fishing trips showed a higher overlap than could be expected when vessels choose their fishing grounds at random. Extrapolation of the micro distribution patterns was done using a Monte Carlo simulation, assuming the effort was distributed at random between fishing trips, but was patchy within each fishing trip. Comparison of the observed and simulated distribution statistics in the ICES rectangles that were fished during 4-8 fishing trips, suggested that in three out of five rectangles less than 60% of the available area was trawled. In the trawlable area the beam trawl effort was patchy, suggesting that the fishing trips were not randomly distributed over the trawlable area, but tend to concentrate

the effort in small areas. The relevance of this observation for the study of the impact of beam trawling on the benthic fauna is discussed.

Rijnsdorp, A.D., and P.I. Van Leeuwen. 1996. Changes in growth of North Sea plaice since 1950 in relation to density, eutrophication, beam trawl effort, and temperature. ICES Journal of Marine Science. Vol. 53:1199-1213.

Abstract: Annual length increments of female North Sea plaice were back-calculated from distances between rings in otoliths. Growth of the smaller size classes (<25 cm) increased from the mid-1950s and decreased in the 1980s. Length increments of intermediate size classes varied more or less randomly, and those of the larger size classes (>35 cm) increased from 1970. Growth changes of the smaller size classes were significantly correlated with indices of plaice density, eutrophication, and seabed disturbance by beam trawling. Moreover, they could be related to spatial and temporal patterns in variations in eutrophication and beam trawling. No correlation was observed with temperature. The analysis led to a consistent interpretation suggesting that eutrophication and beam trawling have both affected the growth rate of plaice. The contributions of these factors differed in space. Effects of eutrophication dominated in the shallow coastal waters, whereas beam trawling dominated in the waters further offshore.

Rijnsdorp, A.D., A.M. Buys, F. Storbeck, and E.G. Visser. 1998. Micro-scale distribution of beam trawl effort in the southern North Sea between 1993 and 1996 in relation to the trawling frequency of the sea bed and the impact on benthic organisms. ICES Journal of Marine Science. Vol. 55:403-419.

Abstract: This paper analyses the spatial distribution of fishing effort in a sample of 25 Dutch commercial beam trawlers fishing for sole and plaice in the period 1993-1996, based on an automated recording system with an accuracy of about 0.1 nautical mile. Intensive fishing occurred along the borders of the closed areas (12 mile zone and the "plaice-box", a protected area in the eastern part of the North Sea) and at certain off-shore grounds in the southern and central North Sea. Effort distribution was studied within 30 x 30 (ICES rectangles), 10 x 10, 3 x 3 and 1 x 1 nautical mile squares and showed a patchy distribution. The degree of patchiness decreased with resolution. Within 3 x 3 mile squares, beam trawling was randomly distributed in some parts of the most heavily fished ICES rectangles but patchily distributed in others. Within 1 x 1 mile squares, the distribution became random within more than 90% of the squares. The micro-distribution showed a remarkable similarity between the 4 years with a mean coefficient of overlap of 0.66, range 0.56 - 0.76. The microdistribution of the sampled vessels was raised to the total Dutch fleet in order to estimate the frequency at which the sea bed was trawled. It was estimated that during the four year study period in eight of the most heavily fished rectangles of the North Sea, 5% of the surface area was trawled less than once in 5 years and 29% less than once in a year. The surface area of the sea bed that was trawled between 1 and 2 times in a year was estimated at 30%. The surface area trawled more than five times in a year was estimated at 9%. The relevance of the findings for the study of the impact of beam trawling on the benthic fauna is discussed.

Robichaud, D.A., A.M. Williamson, and D.E. Graham. 1987. Characteristics of the St. Marys Bay lobster stock in relation to scallop gear impact. Canadian Manuscript Reports of Fisheries and Aquatic Sciences. No. 1955. 17 p.

Abstract: The purpose of the present study is to estimate the severity of the conflict in St. Marys Bay by: 1) determining the distribution of catch and effort of the lobster and scallop fishery in St. Marys Bay; 2) estimating scallop and lobster densities and distribution in local areas using SCUBA and 3) determining the movement of tagged lobsters in St. Marys Bay.

Robinson, R.F., and C.A. Richardson. 1998. The direct and indirect effects of suction dredging on a razor clam (*Ensis arcuatus*) population. ICES Journal of Marine Science. Vol. 55:970-977.

Abstract: Surveys were conducted in two shallow bays in the Orkney Islands, U.K.; Orphir Bay, an unexploited (control) site, and Bay of Ireland, a fished site, to investigate the effects of suction dredging on the resident razor clam, *Ensis arcuatus*, populations. A lower density and significantly smaller mean length of razor clams were present at the dredged site compared with the control site. The age of individual razor clams was estimated using internal shell microgrowth patterns, visible in acetate peels of polished and etched shell cross-sections. *Ensis arcuatus* are relatively slow growing animals with the two study populations characterized by old individuals and an obvious lack of juveniles, indicating populations with little resilience to disturbance. An analysis of the shell sections of razor clams from the Bay of Ireland revealed the presence of shell margin breaks, consisting of deep clefts in which sand grains were embedded in the shell matrix, whilst those from Orphir Bay had fewer disturbances to shell growth. It is suggested the disturbances to shell growth are the result of repeated suction dredging operations in the Bay of Ireland. *In situ* reburrowing experiments were conducted to determine the survival rate of *E. arcuatus* (<160 mm shell length), returned to the sea after capture and to estimate the indirect effect of dredging on the razor clam population. These individuals displayed a slow initiation of "escape-digging" which rendered them vulnerable to attack from predatory crabs and fish, indicating that there is likely to be a low survival rate of any returned undersized clams or ones that are disturbed and escape from the suction dredge.

Robinson, S. 1999. The battle over bottom trawling. National Fisherman. August 1999. p. 24-25.

Summary: This article discusses the recent debate over mobile fishing gear, and its effect on the bottom habitat. The article discusses both sides of the debate. It examines the proposed bill by U.S. Representative Joel Hefley that would ban mobile gear in fishing areas around the country and also discusses the reauthorization of the Magnuson-Stevens Act in 2000.

Roddick, D.L., and R.J. Miller. 1992. Spatial and temporal overlap of the American lobster (*Homarus americanus*) and sea scallop (*Placopecten magellanicus)* as related to the impact of inshore scallop dragging. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 49:1486-1492.

Abstract: Assessment of the damage of one fishery by another requires knowledge of the overlap, in time and space, of the damaging fishing effort and the abundance of the damaged species, as well as a measure of the rate of damage. This approach was used to measure the impact of inshore scallop dragging on lobsters in Nova Scotia. Areas of reported co-occurrence of lobster and scallop grounds were surveyed by divers to determine the extent of overlap. Only 2 of 52 sites surveyed had lobsters on scallop grounds that could be dragged. Divers surveyed one site six times during 1987 and 1988 and found lobsters most abundant during August and September. Only 2% of the lobsters in the path of scallop drags were either captured or injured. The estimated value of lobsters destroyed by dragging for scallops during periods of peak lobster abundance was minor: $757 at one site and $176 at the other. Restricting dragging to periods of low lobster abundance significantly reduces this cost.

Rogers, C.S., L. McLain, and E. Zullo. 1990. Damage to coral reefs in Virgin Island National Park and biosphere reserve from recreational activities. Pages 405-410 *in* Proceedings of the Sixth International Coral Reef Symposium, Townsville, Australia, 8-12 August 1988. Volume 2: Contributed Papers.

Rogers, S.I., M.J. Kaiser, and S. Jennings. 1998. Ecosystem effects of demersal fishing: A European perspective. Pages 68-78 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Abstract: This paper reviews the most recent developments in European research on the ecosystem effects of demersal trawling. We provide a summary of the most prevalent demersal gear types in the waters of northwestern Europe, and show how the perceived effects of these gears on the sea bed has stimulated interest in the potential for damage to benthic communities. There has been a rapid increase in experimental work on the short term effects of trawling on nontarget communities since the 1970s. Some of the more recent studies are described and related to the main focus of interest, the North Sea marine ecosystem. New techniques for describing the structure and diversity of marine assemblages focus on the impact of fishing on the size structure of populations, and identify fish species which may be most vulnerable through unfavorable life history characteristics. The utility of these measures is described.

Rogers, S.I., D. Maxwell, A.D. Rijnsdorp, U. Damm, and W. Vanhee. 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. IV. Can comparisons of species diversity be used to assess human impacts on demersal fish faunas? Fisheries Research. Vol. 40:135-152.

Abstract: Patterns in the abundance of commercially important and non-target demersal fish species collected by beam trawl survey from the coastal waters of the northeast Atlantic are described. Catches were dominated by a small number of species, which occurred in large numbers and at high biomass. The most abundant species (plaice and dab) were typical of shallow, uniform sandy and muddy seabed which occurred extensively throughout the southern North Sea, and to a limited extent in UK western waters. Renyi's diversity index family was used to rank the diversity of coastal sectors throughout the region. The less

species-rich North Sea fauna, partly a result of the uniform nature of the seabed, was largely responsible for lower diversity of North Sea coastal faunas compared to those in the Channel and west of the UK. West of the Dover Strait, the more heterogeneous substrate supported a more diverse fauna of smaller sized fish, with the occurrence of southern species such as red gurnard and thickback sole and an increasing abundance of elasmobranchs. In the Irish Sea, fish biomass was dominated by plaice and dab, but to a lesser extent than on the continental coast of the North Sea. Sole, lesser spotted dogfish and cod were also important in the assemblage. Patterns in community structure over such a wide spatial scale, and without historical perspective, can be explained by biogeographic factors, seabed structure, and the influence of regional hydrography. Inferring from these patterns an impact of anthropogenic factors (such as towed fishing gears) is unlikely to be achieved. Identifying vulnerable species, and use of fishing effort distribution data of high resolution, may be a more fruitful approach.

Rostron, D.M. 1993. The effects of tractor towed cockle dredging on the invertebrate fauna of Llanrhidian Sands, Burry Inlet. Report to Countryside Council for Wales, Bangor, Gwynedd. 71 p.

Rothschild, B.J., J.S. Ault, P. Goulletquer, and M. Héral. 1994. Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. Marine Ecology Progress Series. Vol. 111:29-39.

***Abstract*:** The oyster population in the Maryland portion of Chesapeake Bay, USA, has declined by more than 50-fold since the early part of this century. The paper presents evidence that the mechanical destruction of habitat and stock overfishing have been important factors in the decline, even though it is commonly thought that 'water quality' and, more recently, oyster diseases are critical. Quantitative analyses show that the long-term decline of oysters largely results from habitat loss associated with intense fishing pressure early in this century, and stock overfishing from early in the century through recent times. Furthermore, the major ecological effects on Chesapeake Bay occurred well before World War II, before industrialization and the reported prevalence of disease. To effect the recovery of the ailing Chesapeake Bay oyster stock, a 4-point management strategy is proposed.

Rowell, T.W., P. Schwinghamer, K. Gilkinson, D.C. Gordon, Jr, E. Hartgers, M. Hawryluk, D.L. McKeown, J. Prena, W.P. Vass, and P. Woo. 1994. Investigating the impact of otter trawling on benthic communities of the Grand Bank. Annex report to the ICES Working Group on the Ecosystem Effects of Fishing Activities and the Benthos Ecology Working Group. ICES CM 1994/L:4. p 49-74.

Summary: This report studies the impact of otter trawls in Canadian waters. The study was designed to determine trawl-track degradation rates in a number of energy and sediment regimes and to determine the immediate, short-term, intermediate-term, and long-term impacts of otter trawling on the seabed and benthos. This report is a report in progress since at the time it was written, the study was ongoing.

Rowell, T.W., P. Schwinghamer, M. Chin-Yee, K. Gilkinson, D.C. Gordon, Jr., E. Hartgers, M. Hawryluk, D.L. McKeown, J. Prena, D.P. Reimer, G. Sonnichsen, G. Steeves, W.P. Vass, R. Vine, and P. Woo. 1997. Grand Banks otter trawling impact experiment: III. Sampling equipment, experimental design, and methodology. Canadian Technical Reports of Fisheries and Aquatic Sciences. No. 2190. 36 p.

Abstract: In order to obtain quantitative information on the impacts of otter trawling on benthic communities, DFO initiated an experiment on the Grand Banks in July 1993. Further work was carried out in September 1993, July 1994 and June/July 1995. The experiment has two components: a major component, which we have termed the "corridor study" and a minor component termed the "long-trawl". The report describes both the equipment used, most of it new or highly adapted, and the design and methodology of the experiments.

Rubec, P.J. 1986. The effects of sodium cyanide on coral reefs and marine fish in the Phillipines. Pages 297-302 *in* J.L. Maclean, L.B. Dizon, and L.V. Hosillos, editors. The First Asian Fisheries Society Forum. Asian Fisheries Society, Manila, Philippines.

***Abstract*:** Sodium cyanide (NaCN) has been in use by tropical marine fish collectors in the Philippines since 1962. This paper reviews the many detrimental toxic effects of cyanide on fish which were published in the pet hobby and scientific literature. Interviews with scientists, fish collectors and aquarium industry personnel confirmed that NaCN is contributing to the destruction of Philippine coral reefs and the decline of aquarium and food fishes. About 71% of Philippine reefs are in poor to fair condition due to excessive siltation due to deforestation and the widespread use of NaCN and explosives by fishermen. There is a high mortality of fish squirted with NaCN on the reef and delayed mortalities throughout the chain of middlemen to the marine hobbyist. It is postulated that the "Sudden Death Syndrome" observed in aquaria is due to the conversion of thiocyanate in the blood back to hydrocyanic acid when the fish receives a mild stress. A program to train divers in the use of fine-mesh nets has been initiated to replace the use of NaCN. A pilot project in 1984 had demonstrated that nets can benefit the coral reefs, the collectors and the marine aquarium industry.

Rubec, P.J. 1988. Cyanide fishing and the international marine life alliance net-training program. Tropical Coastal Area Management. Vol. 3(1):11-13.

Summary: The author reviews the use of sodium cyanide on coral reefs in the Philippines. The paper then details the international marine life alliance net-training program which teaches fishermen how to use fine mesh nets that are not as destructive to coral reefs.

Ruffin, K.K. 1995. The effects of hydraulic clam dredging on nearshore turbidity and light attenuation in Chesapeake Bay, MD. Master's Thesis. University of Maryland. 79 p.

***Abstract*:** Soft-shell clam dredging occurs in the shallow waters (<3.5 m) of the Maryland portion of the Chesapeake Bay. The fisheries influences on the nearshore ecosystem, in particular submerged aquatic vegetation (SAV), are of concern. In this study, the effects of resuspended sediments due to clam dredging on turbidity and light attenuation (K_d) in nearshore waters were examined. Turbidity and K_d values were monitored along transects

in areas with and without dredge plumes. A drogue was used to track individual plumes as they returned to background levels of turbidity and light attenuation. Existing aerial photographs and a geographical information system (ARC/INFO) were used to examine plume sizes and dredge boat locations in relation to bathymetry. Hydraulic clam dredging produced plumes with significantly higher turbidity and light attenuation compared to background values. Plume characteristics were determined by sediment type and water depth. The greatest increase in turbidity and light attenuation was in shallow water (< 1.0 m) with fine grained bottom sediments. The plumes dissipated exponentially over time, rapidly at first as the coarse sediments settled out and at a slower rate for the fine sediment remaining in suspension. Plumes that moved into shallow water showed a slower rate of exponential decay than plumes remaining in water greater than 1.0 m. Examination of aerial photographs indicated that 71% of the dredge boats digitized were operating in less than 2 m water. The area of a plume per boat in the Chester River was highly variable with an average of 8 hectares/boat. Plume areas associated with single boats ranged from 1 to 64 hectares.

Rumohr, H. 1989. Information on impact of trawling on benthos in Kiel Bay. Annex to Eighth Report of the Benthos Ecology Working Group. ICES CM 1989/L:19. p. 80.

Summary: This short report states that considerable amounts of nutrients from the pore-water are remobilized by mechanical suspension by otter boards. After suspension, a proportion of the nutrients are precipitated or absorbed in a matter of hours or days. The author finds that after passage of the otter boards and ground rope, there are fewer fauna in the upper layers of the sediment. There is an increase in predatory and scavenging species. The author concludes that there is no evidence for long-term destruction of animal life by trawl action in Kiel Bay.

Rumohr, H., and P. Krost. 1991. Experimental evidence of damage to benthos by bottom trawling with special reference to *Artica islandica*. Meeresforschung. Vol. 33(4):340-345.

***Abstract*:** In Kiel Bay (Western Baltic), benthos samples were taken at 20 m water depth using rectangular botanical dredges fixed to the otter boards of an 80 ft Sønderborg standard trawl to document possible effects of trawl fishery on the benthic fauna. Thin-shelled bivalves like *Syndosmya (Abra) alba*, *Mya* spp. and *Macoma calcarea*, as well as the starfish *Asterias rubens* were damaged by otter boards to a high extent. Thick-shelled bivalves such as *Astarte borealis* and *Corbula gibba*, however, seem to be more resistant to mechanical stress of bottom-trawl fishery. *Musculus niger*, an epibenthic species, is probably only resuspended and dislocated. The rate of damage to *Arctica islandica*, *Macoma baltica* and *Macoma calcarea* is related to their body size. Large specimens are more affected than smaller specimens due to the unfavorable relationship between shell surface and shell thickness. The size distribution of *Arctica islandica* in heavily trawled areas of Kiel Bay shows reductions in the upper size class in these areas.

Rumohr, H., H. Schomann, and T. Kujawski. 1994. Environmental impact of bottom gears on benthic fauna in the German Bight. p.75-86. NIOZ Rapport 1994-11, Netherlands Institute for Fisheries Research, Texel.

Russell, D. 1997. Hitting bottom: As trawling goes into high gear, undersea coastal habitat is being razed to the ground. The Amicus Journal. Winter 1997:21-25.

Summary: The author describes the Georges Bank environment, the current use of fishing gear there, and its impact on the habitat. The author also discusses alternative fishing methods that lessen the impact on habitat.

Sadzinski, R., M. Naylor, D. Weinrich, J.H. Uphoff, Jr., H. Speir, and D. Goshorn. 1996. Effects of haul seining on submerged aquatic vegetation in upper Chesapeake Bay. Maryland Department of Natural Resources. Fisheries Technical Report No. 20. Annapolis, Maryland.

Summary: In 1996 Maryland's Department of Natural Resources investigated the haul seine fishery's effect on SAV. Commercial haul seining had no detectable impact on the quantity or composition of submerged aquatic vegetation on the Susquehanna Flats in 1996. Test seining at three experimental sites of varying plant densities and species composition had no detectable effects on plant height, plant density or species composition. Video tapes taken during actual commercial haul seining and during test seining revealed that both commercial and DNR test seines easily rode over stands of SAV of varying density with little or no effect. Inspection of aerial photographs taken before and after commercial haul seining also revealed no discernable effect.

Saeger, J. 1993. The Samar Sea, Philippines: a decade of devastation. Naga. Vol. 16(4):4-6.

Summary: This article discusses decreased catches in the Samar Sea. The reasons for the decreases are discussed and they include overfishing, dynamite fishing, and overpopulation in the surrounding areas.

Saila, S.B., V.L. Kocic, and J.W. McManus. 1993. Modelling the effects of destructive fishing practices on tropical coral reefs. Marine Ecology Progress Series. Vol. 94:51-60.

Abstract: A literature review of the use of underwater explosives indicated that the largest lethal zone for swimbladder fishes is located near the surface of the water. Mortality in this zone is due to rupture of the swimbladder from negative pressure induced by cavitation of the near-surface water volume from a subsurface explosion. Observational studies of blast fishing in the Philippines indicated that valuable pelagic species rather than typical coral reef species were the primary targets. Empirical data on the extent of various destructive fishing practices (blast fishing, anchor damage, and use of poisons), as well as coral regrowth estimates, provided inputs to a nomographic model of the reef ecosystem. The model provided time graphs of fish diversity and the amount of coral regrowth under various conditions. The results of the simulation model studies indicated that the sum of all current destructive practices was sufficient to continue loss of diversity and loss of live coral cover for about 25 yr before any recovery was expected. On the other hand a reduction in the rate of destructive fishing to about 30% of the current level would permit continuing slow recovery of both diversity and live coral cover. Available observational information suggests that this might best be accomplished by attempting to eliminate the use of poisons (such as cyanide) in reef areas and reducing anchor damage in addition to reducing blast fishing in coral areas. The probable effects of the latter may have been overemphasized in the past.

Sainsbury, K.J., and I. Poiner. 1988. A preliminary review of the effects of prawn trawling in the Great Barrier Reef Marine Park. Great Barrier Reef Marine Park Authority, Townsville, Queensland.

Sainsbury, K.J., R.A. Campbell, and A.W. Whitelaw. 1993. Effects of trawling on the marine habitat on the north west shelf of Australia and implications for sustainable fisheries management. Pages 137-145 *in* D.A. Hancock, editor. Sustainable fisheries through sustaining fish habitat. Canberra, Australia, Australian Government Publishing Service.

Summary: The authors discuss several fisheries that have taken place on Australia's north west shelf over time. These include several trawl fisheries. The authors conclude that the composition of the multispecies fish community on the north west shelf is at least partially habitat dependent and that historical changes in relative abundance and species composition in this region are at least in part a result of the damage inflicted on the epibenthic habitat by the demersal trawling gear.

Sainsbury, K.J., R.A. Campbell, R. Lindholm, and A.W. Whitelaw. 1997. Experimental management of an Australian multispecies fishery: examining the possibility of trawl-induced habitat modification. Pages 107-112 *in* E.K. Pikitch, D.D. Huppert, and M.P. Sissenwine, editors. Global trends: fisheries management. American Fisheries Society, Symposium 20, Bethesda, Maryland.

Abstract: The North West Shelf of Australia supports a diverse tropical fish fauna. Changes in species composition were observed following the introduction of fishing. Several different ecological hypotheses to explain the changed species composition were consistent with the available data. These hypotheses included combinations of interspecific interactions, intraspecific interactions, and trawl-induced modification of benthic habitat. Some hypotheses indicated that a considerable improvement in catch value was possible. It was shown that an experimental or actively adaptive management approach with spatial and temporal manipulation of the trawl fishery effort was scientifically and economically viable for resolving key management uncertainties. Experimental periods of less than approximately 5 years were not expected to provide sufficient hypothesis discrimination to allow significantly improved management decisions, and experimental periods longer than around 15 years cost more in research and forgone catches than the resulting hypothesis discrimination is worth. Three contrasting management zones were established on the North West Shelf; one area was closed to trawling in 1985, a second was closed to trawling in 1987, and the third remained open to trawling. Research surveys were used to monitor fish abundance and the benthic habitat. The North West Shelf management experiment provided close to the expected level of hypothesis discrimination. The results increased the probability placed on hypotheses involving habitat modification mechanisms. Consequently, the possibility of improved catch value is judged more likely than was the case before the experiment. However, the results also indicate that habitat recovery dynamics are slower than previously thought, so that resources recovery will be slow. Furthermore, direct observations of trawl-habitat interactions showed a high rate of damage to the habitat on encounter with the trawl gear. Consequently, a high-yield fishery is expected to be slow to attain and difficult to maintain if existing trawl fishing methods are used.

Salm, R.V. 1983. Coral Reefs on the Western Indian ocean: a threatened heritage. Ambio. Vol. 12(6):349-353.

Abstract: Reefs are both hardy and fragile environments. They protect the land against the ravages of the sea, and provide nursing grounds and shelter for a myriad of marine life. But the reefs of the Indian Ocean are in retreat. Wholesale mining for construction materials, sedimentation and pollution from a host of land-based activities, dynamite fishing and over-exploitation by spear-fishermen and shell collectors, are among the most serious causes of reef destruction. The author argues that conservation measures are urgently needed in some areas and gives specific proposals on what should be done to save the remainder of the Region's coral heritage.

Samoilys, M.A. 1988. Abundance and species richness of coral reef fish on the Kenyan coast: The effects of protective management and fishing. Pages 261-266 *in* Proceedings of the Sixth International Coral Reef Symposium, Townsville, Australia, 8-12 August 1988. Volume 2: Contributed Papers.

Abstract: Underwater censuses were used to measure species richness and abundance of coral reef fish at 19 study sites on the Kenyan coast. While species richness was highest in marine parks where no fishing or collecting is allowed, the same was not true for fish abundance, or for biomass of commercially important fish. Some of the highest densities and weights of fish were recorded from the marine reserves where traditional fishing methods are allowed. Areas with higher fishing intensity has smaller standing crops of fish, but not comparably smaller abundances. This suggests that average fish size is lowered by more intense fishing. Two factors, siltation from rivers and dynamite "fishing", have a major impact on the fish communities. Reefs badly damaged from dynamiting, including Mako Kokwe in Kisite marine park, are characterized by low species richness and a low biomass of commercially important species.

Sánchez-Jerez, P., and A.A. Ramos Esplá. 1996. Detection of environmental impacts by bottom trawling on *Posidonia oceanica* (L.) Delile meadows: sensitivity of fish and macroinvertebrate communities. Journal of Aquatic Ecosystem Health. Vol. 5(4):239-253.

Abstract: Along the Mediterranean coast, *Posidonia oceanica* (L.) Delile meadows have a great ecological and economical importance. However, there is a general regression of these meadows due to human activities such as illegal bottom trawling, may be affecting to overall ecosystem health. We examined changes in the community structure of mobile fauna associated with *P. oceanica* meadows at different spatial scales and taxonomic levels. The aim of this paper was to identify the most efficient taxonomic level to use in environmental impact studies of bottom trawling. At the macroscale level (10 to 100 m), there were significant differences between sites in the densities of some fish species and also the total fish assemblage structure, at both family and species taxonomical levels. At the microscale (0.1 to 1 m), some species of amphipods and isopods showed significant differences in their population densities. In the overall analysis of community structure, the coarse taxonomical levels, such as phyla and class, did not show significant differences, however amphipods and isopods showed significant differences at family and species levels. From these results, both study scales are required to detect changes on Posidonia meadows' fauna. Monitoring of

some fish species such as *Diplodus annularis* (Linnaeus, 1758) and the overall fish assemblage as well as the structure of the amphipod and isopod communities appears to be the most efficient tool in the assessment of environmental impacts by bottom trawling on *P. oceanica* meadows.

Sanchez-Lizaso, J.L., J.E. Guillén Nieto, and A.A. Ramos Esplá. 1990. The regression of *Posidonia oceanica* meadows in El Campello. Rapp. Comm. Int. Mer Medit. 32(1):7.

Abstract: The regression of *Posidonia oceanica* meadows has been studied along a 7 km coastal sector on the El Campello littoral. Changes of shallow *Posidonia* beds in the last 30 years are described. Deep *Posidonia* meadow is badly damaged due to illegal trawling. The first symptoms of trawling are detected at 13 m depth. But the deeper we go, the more degraded the meadow gets, reaching densities under 1 sh/m^2. Dead *Posidonia* is seen even suggest at 29 m depth. In order to protect the deep meadow, we suggest as a feasible solution the installation of artificial reefs.

Santbrink, J.W., and M.J.N. Bergman. 1994. Direct effects of beam trawling on macrofauna in a soft bottom area in the southern North Sea. p. 147-178. NIOZ Rapport 1994-11, Netherlands Institute for Fisheries Research, Texel.

Sargent, F.J., T.J. Leary, D.W. Crewz, and C.R. Kruer. 1995. Scarring of Florida's seagrasses: Assessment and management options. Florida Marine Research Institute Technical Reports. TR-1. Florida Marine Research Institute, St. Petersburg, Florida. 37 p. plus appendices.

Abstract: Seagrasses are submerged, grass-like plants that inhabit the shallow coastal waters of Florida. Seagrasses are a vital component of Florida's coastal ecology and economy; they provide nutrition and shelter to animals important to marine fisheries, provide critical habitat for many other animals (e.g., wading birds, manatees, and sea turtles), and improve water quality. Marine-habitat degradation in Florida is continuing at an alarming rate as the coastal residential population and the number of seasonal visitors increase. Habitat degradation has many sources (e.g., pollution, dredge and fill), but an increasingly common cause of habitat degradation is the scarring of seagrasses. In this report, scarring can refer to either the activity of scarring or to a group of scars in a seagrass bed. Seagrass beds can be scarred by many activities, but scars are most commonly made when a boat's propeller tears and cuts up roots, stems, and leaves of seagrasses, producing a long, narrow furrow devoid of seagrasses. Boats operating in shallow waters are severely scarring, and sometimes completely denuding, seagrass beds throughout the state. The Florida Department of Environmental Protection recognized the need to reduce scarring of seagrasses by boats and committed resources to address this issue. As one component of this effort, the Florida Marine Research Institute (FMRI) investigated the distribution of scarred seagrass beds in the shallow marine waters of Florida's coastal counties. Aerial photography was used to locate seagrass scarring. Aerial surveys were then conducted in 1992-1993 to confirm the location of scarred seagrasses. We did not attempt to distinguish among the different specific causes of seagrass scarring. During aerial surveys, observations of scarred seagrasses were recorded on National Oceanic and Atmospheric Administration nautical charts and U.S. Geological Survey quadrangle maps. Scarring intensity was categorized as *light*, *moderate*, or *severe*. Areas with substantial scarring recognizable on 1:24,000-scale photography were delineated on the maps with polygons, which were assigned a scarring intensity. Polygons

categorized as *light* contained less than 5 percent scarring, those categorized as *moderate* contained 5-20 percent scarring, and those categorized as *severe* contained more than 20 percent scarring. The information acquired in this survey was incorporated into the FMRI's Marine Resources Geographic Information System (MRGIS), which produces maps and tabular products so that geographically based data can be effectively disseminated to resource managers, appropriate regional and county governments, and other interests (e.g., conservation groups and private citizens). Scarred seagrasses were observed in all areas of the state, mostly in shallow coastal waters less than six feet deep. More than 173,000 acres of the state's 2.7 million acres of seagrasses were scarred-most of it lightly. This is a conservative estimate of scarring because we mapped groups of scars, not isolated, individual propeller scars. The total seagrass acreage in Florida (2.7 million acres) includes areas in the Florida Keys that have sparse seagrass and hardbottom with dense-seagrass patches. Excluding these areas, seagrasses totaled approximately 1.9 million acres. Also, these totals do not include sparse, deep *Halophila* beds that are offshore in the Big Bend region. The greatest acreage of *moderate* and *severe* (M/S) scarring occurred in areas having denser human populations and more registered boats. The Florida Keys (Monroe and Dade counties), Tampa Bay (Hillsborough, Manatee, and Pinellas counties), Charlotte Harbor (Lee County), and the north Indian River Lagoon (Brevard and Volusia counties) had the greatest M/S scarring. Monroe County, which includes most of the Florida Keys, had the greatest acreage of M/S scarring of all counties in the survey. The Panhandle and Big Bend regions had little M/S-scarred acreage, but in the western Panhandle embayments, M/S scarring was prevalent in the few acres of seagrasses there. If an area has little seagrass acreage, then any scarring may have a critical effect on habitat functions.

Scarratt, D.J. 1971. Investigation into the effects of Irish moss raking on lobsters. Fisheries Research Board of Canada. Vol. 1105. 36 p.

Abstract: Most of the lobsters killed are in the 3- to 4-inch total length size group and would not enter the fishery for 2-3 years. Their value is accordingly most difficult to assess. Other larger lobsters losing claws will reduce the value of the commercial fishery. It is clear that damage to lobsters is not constant but varies from place to place and from one time of the year to another. It is also clear that damage is probably greater than was hitherto believed and may, at times, render moss raking of marginal economic value. Observations also suggest that moss raking as currently practiced is of questionable efficiency and also crops significant quantities of other noncommercial seaweeds. The long-term ecological effects cannot yet be predicted.

Scarratt, D.J. 1972. The effects on lobsters (*Homarus americanus*) of raking Irish moss (*Chondrus crispus*). ICES Shellfish and Benthos Committee. ICES CM 1972/K:36. 8 p.

Abstract: The principal species of seaweed harvested from the Canadian Atlantic is Irish moss *Chondrus crispus*. All areas where Irish moss grows are also fished for lobster. The seaweed is harvested by towing rakes 3 m wide with power boats. This study investigated the damage to lobsters from commercial rakers on different grounds. Using diving techniques, the numbers of lobsters on Irish moss beds, their reactions to raking, and the numbers of lobsters killed or damaged were examined. A total of 469 tows were observed to retain a total of 73 lobsters, 29 in the rake and 44 in the rake basket. All lobsters were

sublegal size. Damage to lobsters by moss raking was related to the roughness of the beds and lobster abundance on them. On smooth beds, lobster populations are low and mortality negligible. On rough grounds, lobster populations are high and damage to them justifies some control of raking activities. Chain-bridled rake and higher tow speeds caused significantly more damage.

Scarratt, D.J. 1973. Claw loss and other wounds in commercially caught lobsters *Homarus americanus*. Journal of the Fisheries Research Board of Canada. Vol. 30:1370-1373.

Abstract: Incidence of claw loss in commercially caught lobsters (*Homarus americanus*) ranged between 5 and 19% but could not be attributed to any single cause, although factors such as rough handling by fishermen, moving fishing gear, and ice in shallow waters may contribute. The incidence of other wounds ranged between 1 and 11% and there was evidence that serious wounding was related to the local practice of harvesting Irish moss by rakes.

Scarratt, D.J. 1973. The effects of raking Irish moss (*Chondrus crispus*) on lobsters in Prince Edward Island. Helgoländer wiss. Meeresunters. Vol. 24:415-424.

Summary: This paper studies the effects of raking Irish moss on lobsters. Observations were made onboard commercial moss raking vessels to determine fishing rate and capture rate of lobsters. Lobster abundance estimates were made in the area that raking takes place. The reaction of lobsters to the moving rakes were recorded and the rake tracks were examined to determine whether more lobsters were killed or injured than were seen by observers. The authors concluded that damage to lobsters by moss raking is related to the roughness of the beds and lobster abundance on them, the type of rake used, and the speed of towing. On smooth beds, lobster populations are low and mortality negligible. On rough grounds, lobster populations are high and damage to them justifies some control of raking activities.

Schoellhamer, D.H. 1996. Anthropogenic sediment resuspension mechanisms in a shallow microtidal estuary. Estuarine, Coastal and Shelf Science. Vol. 43(5):533-548.

Abstract: The mechanisms that resuspend bottom sediments in Hillsborough Bay, a shallow, microtidal, subtropical estuary in West-central Florida, were determined by analyzing hydrodynamic and suspended-solids concentration data collected during several instrument deployments made in 1990 and 1991. Large vessels in a dredged ship channel can generate forced solitary long waves that cause large water velocities and sediment resuspension at the study sites. An experiment was conducted with a trawler that resuspended bottom sediments, and some of the resuspended sediments remained in suspension for at least 8 h. A secondary impact of vessel-generated long waves and trawling is that sediments that are resuspended and newly deposited are more susceptible to resuspension by tidal currents than undisturbed bottom sediments. Natural sediment resuspension by wind waves and tidal current is less frequent or of smaller magnitude than anthropogenic sediment resuspension. The annual mass of sediment resuspended by vessel-generated long waves is estimated to be one order of magnitude greater than the annual mass of sediment resuspended by wind waves generated by winter storms.

Schubel, J.R., H.H. Carter, and W.M. Wise. 1979. Shrimping as a source of suspended sediment in Corpus Christi Bay (Texas). Estuaries. Vol. 2(3):201-203.

Abstract: Our field study showed that the total amount of sediment disturbed in Corpus Christi Bay each year by shrimp trawling is 10-100 times greater than that dredged in an average year for maintenance of shipping channels. The maximum concentrations of suspended sediment measured in the trails of the shrimp boats were comparable to those observed in the turbid plume off the discharge of the dredge operating in the same area.

Schultz, L.P. 1948. The use of rotenone for collecting reef and lagoon fishes at Bikini. Copeia. No. 2:94-98.

Summary: This paper describes the effects of rotenone on reef fish and on coral when used to collect fish in a reef environment.

Schwinghamer, P., J.Y. Guigné, and W.C. Siu. 1996. Quantifying the impact of trawling on benthic habitat structure using high resolution acoustics and chaos theory. Canadian Journal of Fishery and Aquatic Sciences. Vol. 5:288-296.

Abstract: Very high resolution and broadband parametric array acoustics were used to estimate the small-scale structural properties of surficial sediments as part of a trawling impact experiment on the sandy sediment of the eastern Grand Banks. The seabed was ensonified by a 12 x 30 cm, 40-element acoustic array (DRUMS^{TM}) deployed on the frame of a 0.5-m^2 bottom grab. Acoustic images of the upper 4.5 cm of sediment were taken in 10 sampling blocks along each of two corridors that were 13 km long, before and after intensive otter trawling. The acoustic return signals were Hilbert transformed and divided into five depth strata of 50 μs, or approximately 1 cm from slightly above the average sediment surface to approximately 4.5 cm depth. The fractal of the transformed signal from each acoustic element was calculated for each depth stratum. The fractals of the acoustic returns from pretrawled sediments are consistently and significantly higher than those from trawled sediments in all five depth strata in both corridors. A chaos model, using fractals of the parametric array acoustic signals as metrics, provides an analytical framework in which the structural effects of physical disturbance of the benthic habitat can be quantified.

Schwinghamer, P., D.C. Gordon, Jr., T.W. Rowell, J. Prena, D.L. McKeown, G. Sonnichsen, and J.Y. Guigné. 1998. Effects of experimental otter trawling on surficial sediment properties of a sandy-bottom ecosystem on the Grand Banks of Newfoundland. Conservation Biology. Vol. 12(6):1215-1222.

Abstract: We conducted a 3-year experiment on the effects of otter trawling on benthic habitat and communities on a sandy-bottom ecosystem of the Grand Banks of Newfoundland that has supported commercial fisheries. Each year, three 13-km-long corridors were trawled 12 times with an Engel 145 otter trawl, creating a disturbance zone 120-250 m wide. Using a variety of oceanographic instruments, measurements were made before and after trawling to document effects. Trawling had no detectable effect on sediment grain size. Tracks made by trawl doors were readily visible on the sea floor immediately after trawling and 10 weeks later; in some cases they were still faintly visible after 1 year. Acoustic data indicated that

trawling increased the topographic relief or roughness of surficial sediments and changed small-scale biogenic sediment structures down to depths of 4.5 cm. Video observations in trawled corridors revealed that organisms and shells tended to be organized into linear features parallel to the corridor axis. They also demonstrated that trawling reduces both surficial biogenic sediment structure and the abundance of flocculated organic matter; untrawled sediments had a hummocky, mottled appearance, whereas trawled sediments were smoother and cleaner. These changes combined to give the trawled corridors a lighter appearance in color. It appears that the physical effects of otter trawling observed in this experiment are moderate and that recovery occurs in about a year. The biological effects of this experimental trawling have yet to be examined.

Sharp, G.J. 1981. An assessment of *Ascophyllum nodosum* harvesting methods in southwestern Nova Scotia. Canadian Technical Reports of Fisheries and Aquatic Sciences. No. 1012. 28 p.

Abstract: Since 1959 *Ascophyllum nodosum* resources in southwestern Nova Scotia estimated at 180 000 t have been exploited at 6 000 T/year for alginate production by Scotia Marine Products Ltd. The harvesting method has evolved over 18 years from entirely hand methods to 80% mechanical methods. In the summer of 1978, a study examined the effects of mechanical harvesting (the Aquamarine Harvester) and compared them with those of the hand cutter rake. Harvest sites with a known harvest history were examined for residual biomass and population structure and a controlled experiment was conducted in one location. It was recommended that the cutter rake be banned due to its adverse effect on recruitment. The mechanical cutter must be made more efficient and the harvests strategy be revised to reach a MSY for this resource.

Sharp, G.J., and D.L. Roddick. 1980. The impact of *Chondrus* dragraking on substrate stability in southwestern Nova Scotia. Canadian Manuscript Reports of Fisheries and Aquatic Sciences. No. 1593. 14 p.

Abstract: Dragrakes and handrakes are the *Chondrus crispus* harvesting tools in southwestern Nova Scotia. Reports of serious substrate damage by the dragrake prompted an extensive survey and experimental program by the Marine Plants Section of Resource Branch Dept. of Fisheries and Oceans in 1979. Dragrakes were found to overturn rocks up to 58 cm x 43 cm maximum dimensions. The total bottom disruption averaged 0.6% to 4.8% of the bottom area reaching a maximum of 6.8%. Substrate disruption was cumulative - up to 8 hr. of dragging the same area. The avg. size of displaced rocks was constant (0.05-0.07 sq m) after the peak of harvesting effort. Dragraking was restricted to 43% of the commercial *Chondrus* beds surveyed and to 11% of the harvest effort. Damage to the resource was sufficient to recommend the development of new harvest methods and phasing out of the dragrake.

Sheldon, W.W., and R.L. Dow. 1975. Trap contribution to losses in the American lobster fishery. Fishery Bulletin. Vol. 73:449-451.

Summary: This study examines the impact of unbuoyed traps on American lobster, *Homarus americanus*, survival. The study concluded that unbaited, unbuoyed traps continue

to catch lobsters for an indefinite time, and that one-third or more of all lobsters in or entering unbuoyed traps will be lost to the fishery from cannibalism or retention.

Shepard, A.N., and P.J. Auster. 1991. Incidental (non-capture) damage to scallops caused by dragging on rock and sand substrates. Pages 219-230 *in* S.E. Shumway and P.A. Sandifer, editors. An International Compendium of Scallop Biology and Culture. World Aquaculture Society, Baton Rouge, Louisiana.

Abstract: A rock rake or drag is used inshore off the coast of Maine to commercially harvest sea scallops, *Placopecten magellanicus* (Gmelin). The gear is designed for use in rocky habitat. In the Swans Island Conservation Area, recently closed to commercial dragging, scallop habitat is extremely variable with respect to substrate type. A study was done there to determine the extent and types of incidental (non-capture) damage to scallops on sand and rock substrates. Test tows showed the rock rake fished differently in response to catch weight, tow direction, and less than 25% changes in tow speed and scope of the warp. Incidental damage was significantly higher on rock than on sand substrate; 25.5% versus 7.7% in 1988 experiments. The dominant types of damage were chipped valve margins and separated hinges. The severity of damage may be related to catch weight and number of tows impacting an individual. No relationship was observed between scallop shell height and incidental damage rate.

Shepard, A.R.D., R.M. Warwick, K.R. Clarke, and B.E. Brown. 1992. An analysis of fish community responses to coral mining in the Maldives. Environmental Biology of Fish. Vol. 33:367-380.

Abstract: Coral mining takes place on shallow reef flats at a number of localities in the Maldives, but not on the adjacent deeper reef slopes. A semi-quantitative census method for fish species abundance and biomass is described. Fish community structure is compared on mined and non-mined reef flats and their adjacent slopes using a variety of univariate, graphical/distributional and multivariate statistical techniques. In general, univariate and graphical distributional methods do not indicate significant differences between mined and non-mined localities with respect to the relative abundances and biomasses of the species. Multivariate methods (both classification and ordination), however, indicate very clear-cut effects of mining on the reef flats, and also significant effects on reef slopes adjacent to mined flats. The effect was equally clear using non-quantitative (presence/absence) data. The fish species mainly responsible for the differences between mined and non-mined localities are identified, and the differences are explained in terms of the feeding biology of these species.

Short, F.T., and S. Wyllie-Echeverria. 1996. Natural and human-induced disturbance of seagrasses. Environmental Conservation. Vol. 23(1):17-27.

Abstract: Many natural and human-induced events create disturbances in seagrasses throughout the world, but quantifying losses of habitat is only beginning. Over the last decade, 90,000 ha of seagrass loss have been documented although the actual area lost is certainly greater. Seagrasses, an assemblage of marine flowering plant species, are valuable structural and functional components of coastal ecosystems and are currently experiencing

worldwide decline. This group of plants is known to support a complex trophic food web and a detritus-based food chain, as well as to provide sediment and nutrient filtration, sediment stabilization, and breeding and nursery areas for finfish and shellfish. We define disturbance, natural or human-induced, as any event that measurably alters resources available to seagrasses so that a plant response is induced that results in degradation or loss. Applying this definition, we find a common thread in many seemingly unrelated seagrass investigations. We review reports of seagrass loss from both published and 'grey' literature and evaluate the types of disturbances that have caused seagrass decline and disappearance. Almost certainly more seagrass has been lost globally than has been documented or even observed, but the lack of comprehensive monitoring and seagrass mapping makes an assessment of true loss of this resource impossible to determine. Natural disturbances that are most commonly responsible for seagrass loss include hurricanes, earthquakes, disease, and grazing by herbivores. Human activities most affecting seagrasses are those which alter water quality or clarity: nutrient and sediment loading from runoff and sewage disposal, dredging and filling, pollution, upland development, and certain fishing practices. Seagrasses depend on an adequate degree of water clarity to sustain productivity in their submerged environment. Although natural events have been responsible for both large-scale and local losses of seagrass habitat, our evaluation suggests that human population expansion is now the most serious cause of seagrass habitat loss, and specifically that increasing anthropogenic inputs to the coastal oceans are primarily responsible for the worldwide decline in seagrasses.

Short, K.S., and R. Walton. 1992. The transport and fate of suspended sediment plumes associated with commercial geoduck harvesting. Final Report. Prepared by Ebasco Environmental (Bellevue, Washington) for the Washington Department of Natural Resources. 92 p.

Simboura, N, A. Zenetos, M.A. Pancucci-Papadopoulou, M. Thessalou-Legaki, and S. Papaspyrou. 1998. A baseline study on benthic species distribution in two neighboring gulfs, with and without access to bottom trawling. Marine Ecology. Vol. 19(4):293-309.

Abstract: An extensive survey of the benthic fauna was carried out at two neighboring regions of the Aegean Sea, one normally trawled and the other closed to trawlers. Benthic samples were collected from seven areas located away from land-based sources. The faunistic analysis showed that species diversity and abundance was higher in the trawled area compared with the untrawled area, a fact which was attributed to the difference in sediment characteristics between the two areas. A degree of disturbance detected in the trawled area was evidenced by an increase in the number of polychaetes at the expense of other benthic groups and an abundance of some opportunistic species. This could possibly be related to trawling activities, as no other causes of disturbance were found in either area.

Simpson, D.G., and G.C. Maltezos. 1983. An assessment of trawl-related injury to lobsters in western Long Island Sound. Unpublished Report. Connecticut Department of Environmental Protection, Marine Fisheries Division. 4 p.

Summary: This study was conducted because of concerns that trawling for lobsters was damaging lobsters and destroying habitat. The researchers found that no habitat was being destroyed, and the gear used was not designed to dig into the bottom or endure heavy bottom

contact. The researcher also found that damage to sub-legal lobsters was not as great as feared.

Smeltzer, E. 1974. A study of the effects of the hydraulic clam dredge on *Mya* populations and on the pH of the interstitial water of the Harraseeket River mud flats. Unpublished report. Bates College, Lewiston, Maine.

Smith, C.J., K.N. Papadopoulou, A. Kallianiotis, B. Catalano, and S. Diliberto. 1997. The interaction between otter trawling and the marine environment. Pages 33-36 *in* Proceedings of the Hellenic Symposium on Oceanography and Fisheries, Vol. 2. 5th Hellenic Symposium on Oceanography and Fisheries, Kavala (Greece). NCMR Association of Employees, Athens, Greece.

Abstract: The impact on the environment of otter trawling is evident from direct observation: severe and persistent increase in turbidity, general smoothing of the surface under the area covered by the trawl and deep scrapes caused by the trawl doors. Trawl marks have been seen on the sediment surface of all the major trawl grounds in the Aegean. From unpublished work, marks seem to be much more persistent in deeper areas of soft sediment, the extent of their impact on the infauna is still not yet fully known. This could include reduction in numbers, change in community composition, exclusion of non-robust species. Effects measured on fish communities include removal. Nothing is known of indirect effect. Trawling is also an attraction and this could be seen in the changes in number of some species. Gadoids are quickly removed and numbers are not replaced. Scavengers are attracted by disturbed sediments, damaged and uncovered fauna.

Smith, E., M.A. Alexander, M.M. Blake, L. Gunn, P.T. Howell, M.W. Johnson, R.E. MacLeod, R.F. Sampson, D.G. Simpson, W.H. Webb, L.L. Stewart, P.J. Auster, N.K. Bender, K. Buchholz, J. Crawford, and T.J. Visel. 1985. A study of lobster fisheries in the Connecticut waters of Long Island Sound with special reference to the effects of trawling on lobsters. Unpublished Report. Connecticut Department of Environmental Protection, Marine Fisheries Program. Hartford, Connecticut.

Abstract: Within the sweep path of the net investigated, minor surface sediment disturbance (less than 1" in depth) occurred. The trawl made light contact by the extreme lower loops of the chain attached to the net mouth. Observations of trawl net behavior and studies of heavily rigged trawl gear in the United Kingdom confirm the observation that such nets have little effect on the seabed -- "digging" on the order of ½ - 1" deep. Much sediment disturbance is created by "wake turbulence" suspending epifauna and flocculent material (clouds of silt) as the net passes, rather than by direct physical contact. A "chumming" effect attracted motile predators due to the exposure of prey organisms. The possibility of increased sea floor productivity due to "cultivation" of the sea bed is mentioned. Greater than 80% of the predominant crustacea (e.g. lobsters, crabs) that have been observed in the path of such nets avoid capture. The most notable evidence of trawl passage was a 4-10" wide, 2-6" deep trawl door depression track for each of the two doors. These features were "naturalized" in a short time by tidal currents but attracted motile predator organisms and apparently offered temporary artificial habitat for certain species. No evidence of mortality to lobsters and crabs was observed in the net path or at the leading region of the trawl

rigging. A similar study in Rhode Island in 1980 also found no evidence of mortality to lobsters in the trawl net path. Minimal effects of trawl gear on larval or juvenile stages are believed to occur. Trawl door furrows created in soft mud substrate, typical of central and eastern Long Island Sound, did not cause habitat loss and may increase excavation sites for formation of mud lobster shelters or "burrows." Alteration of lobster mud burrows was minor and appeared easily reconstructable by resident lobsters. The success of trawl fishing for lobsters in Long Island Sound is attributed to benthic environmental parameters and features of lobster behavior rather than to any special gear modifications that result in a disruption or extraction of lobsters from the sea bed.

Smolowitz, R.J. 1978. Lobster, *Homarus americanus*, trap design and ghost fishing. Marine Fisheries Review. Vol. 40(5-6):2-8.

Abstract: The Northeast Fisheries Center of the National Marine Fisheries Service has conducted research on the American lobster, *Homarus americanus*, for many years. Recently, research efforts have been directed toward forming a data base upon which recommendations for management of the inshore and offshore stocks in waters off the New England and Mid-Atlantic coasts can be based. The Center is assembling information on population, size, stock separation and mixing, growth rates, mortality rates , and recruitment indices. To understand the effects of fishing on the resource, fisheries managers need not only catch/effort statistics and total weight and size composition of removals, but also data on the effects of non-selective and destructive fishing methods. Fisheries engineers and diver/biologists of the Center conducted a series of studies into these latter two factors; the results of this research are contained herein.

Smolowitz, R.J. 1978. Trap design and ghost fishing: discussion. Marine Fisheries Review. Vol. 40(5-6):59-67.

Abstract: This paper presents an assessment of ghost fishing in the New England lobster fishery by reviewing trends in trap design, loss rates, lost-trap catch rates, and related factors. Preventative solutions are discussed.

Smolowitz, R.J. 1998. Bottom tending gear used in New England. Pages 46-52 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: This paper is a brief review of five major gear types used in New England that contact the sea floor during their operation: bottom trawls, scallop dredges, gill nets, hooks, and lobster traps. Each gear type is outlined in terms of technical evolution, bycatch, selectivity, and management issues. The review emphasizes how the gear interacts with bottom habitat and the possible impacts of this interaction. The paper concludes that cumulative fishing impacts of each gear type need to be identified in order to define appropriate fishing levels/strategies.

Spencer, B.E., M.J. Kaiser, and D.B. Edwards. 1998. Intertidal clam harvesting: Benthic community change and recovery. Aquaculture Research. Vol. 29(6):429-437.

Abstract: Mechanical harvesting of intertidal bivalve molluscs inevitably leads to the physical disturbance of the substratum and its associated fauna. Hence, it is necessary to consider the consequences of such activities for the requirements of other species (e.g. fish and birds) which utilize these areas. The present study reports a long-term experiment that studied the effects of Manila clam, *Tapes philippinarum* (Adams & Reeve), cultivation on an estuarine benthic habitat and its fauna. The study began with the initial seeding of the clams, and continued through ongrowing, and finally, harvesting 30 months later. Earlier observations revealed that plots covered with netting elevated sedimentation rate, and hence, encouraged the proliferation of certain deposit-feeding worm species which persisted throughout the cultivation cycle until harvesting took place. The immediate effects of harvesting by suction dredging caused a reduction of infaunal species and their abundance by approximately ≈80%. Recovery of the sediment structure and the invertebrate infaunal communities, judged by similarity to the control plots on both the harvested and unharvested but originally netted plots, had occurred 12 months after harvesting. Comparisons with other similar studies demonstrate that, in general, suction harvesting causes large short-term changes to the intertidal habitat. The rate at which recolonization occurs and sediment structure is restored varies according to local hydrography, exposure to natural physical disturbance and sediment stability. The management of clam farming procedures and other forms of mechanical harvesting should incorporate a consideration of site selection, rotational seeding, cultivation and harvesting to create fallow areas, and seasonal harvesting to ameliorate the recovery of sites.

Spur, E.W. 1978. An assessment of the short term effects of otter trawling on large epibenthic invertebrates. Unpublished Report. New Hampshire Fish and Game Department. NHFGD-Proj-3-248-R. 12 p.

Abstract: The effect of otter trawling on lobsters in the near shore environment was examined. During the 2 years in which work on the project was conducted, lobsters were found on trawlable substrata only in the months of July, August, and September. Highest catch per unit of effort for lobsters occurred in August. The percent of lobsters sustaining injuries from trawling varied from 11-75% and averaged 23%. The most common site of injury was the chelae. Forty-five percent of these lobsters receiving injuries sustained injury to the chelae.

Stephan, C.D., R.L. Peuser, and M.S. Fonseca. 2000. Evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies. ASMFC Habitat Management Series #5. Atlantic States Marine Fisheries Commission. Washington, D.C.

Summary: This report classifies injuries to submerged aquatic vegetation (SAV) from fishing gear. Different fishing gears that are used in areas of SAV are identified and described. Their potential impacts are described as well as mitigation strategies. The report also describes guidelines for applying the mitigation strategies identified.

Stevens, B.G. 1996. Crab bycatch in pot fisheries: Causes and solutions. Pages 151-158 *in* Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Program Report No. 96-03, University of Alaska Fairbanks.

Abstract: This paper summarizes some recent research on crab bycatch in crab pot fisheries. The problem has three major aspects: (1) Reducing the catch of unwanted crabs. Bering Sea crab fishermen discarded almost 6 crabs for every legal king crab retained in 1992. Use of a circular excluder panel can significantly reduce capture of small snow crab. Escape rings will allow 80-95% of undersized crab to escape from pots. Careful design can improve the ability of pots to capture and retain only targeted species-sex-size groups. (2) Effects of handling and discarding unwanted crabs. On-board studies indicated that 2% of king crabs and 10% of Tanner crabs died within 48 hr as a result of handling. However, long-term studies in controlled environments were unable to demonstrate any significant mortality of king or Tanner crabs as a result of damage or repeated handling. Handling, therefore may not be a major source of mortality to healthy crabs except under unusual circumstances. (3) Unseen bycatch due to ghost fishing by derelict pots. A sonar survey of Chiniak Bay, Kodiak, Alaska, revealed 190 lost crab pots in an area of about 4.5 km^2, for an average density greater than 42 pots/km^2. Eight intact pots recovered from this area contained an average of 4 crab, and 0.5 octopus. Observations by remote camera and submersible showed that crabs and fish are common residents of crab pots, whether or not the pot mesh is intact. Crabs left in pots over long time periods will starve, weaken, and subsequently die. Mortality in ghost pots can be reduced by adding pot retrievers, more degradable mesh, and other changes.

Stevenson, J.C., and N.M. Confer. 1978. Summary of available information on Chesapeake Bay submerged vegetation. U.S. Fish and Wildlife Service Office of Biological Services. FWS/OBS-78/66. 335 p.

Summary: A thorough report on Chesapeake Bay seagrasses. Brief discussion on pages 245-246 on clam dredge impacts and boating impacts on seagrasses.

Stewart, P.A.M. 1999. Gear modification as a management tool to limit ecosystem effects of fishing. ICES/SCOR Symposium, Ecosystem Effects of Fishing, April 1999, St. John's, Newfoundland. 20 p.

Abstract: The known impacts of the commonly used active and passive methods of sea fishing are summarized and techniques for reducing these impacts are discussed, with examples from particular studies. Studies of the processes of capture by mobile and static fishing gears are needed to provide a firm basis for modifying fishing gears to lessen the effects of commercial fishing on the ecosystem. Proven techniques are now available to improve the size and species selectivity of fishing gears for both target and non-target organisms. Given the variation in morphology and behaviour of marine species, successful approaches tend to be species and fishery specific. Reference is made to the selective effects of net construction and to escape panels, separator trawls, selection grids, square mesh netting, ghost fishing, scaring devices for sea mammals and to direct physical impacts on the sea bed. More selective fishing gears tend to be relatively complex and reduce catches of marketable fish, rendering them unacceptable to the fishing industry unless part of a management system of perceived mutual benefit. Further work is needed on methods of separating species in fishing gears in mixed fisheries, on acoustic scaring devices and aspects of ghost fishing. Also to achieve wider use of improved fishing methods, more work is needed on the economic effects on fisheries of gear modified to reduce impacts.

Stokes, R.J., E.A. Joyce, Jr., and R.M. Ingle. 1968. Initial observations on a new fishery for the sunray venus clam, *Macrocallista nibosa* (Solander). Florida Department of Natural Resources Technical Series. Vol. 56:1-27.

Abstract: Florida with its thousands of square miles of shallow estuarine areas, would appear to have ideal habitats for many species of clams and, consequently, a potentially vigorous clam industry. Many areas throughout the State are already known to have several species of clams in relatively high abundance. Yet the total State production in 1966 was slightly over 5,000 pounds of meats valued at about $2,000. The present method of harvesting is one major reason for this apparent disregard for a natural resource and the subsequent loss to the State of a potentially rich industry. In major clam producing areas, such as Chesapeake Bay, the most efficient production is accomplished through the use of mechanical harvesters. In Florida, these harvesters are very unpopular in certain areas and are not used. Consequently, Florida clams have traditionally been harvested by hand, a method not conducive to mass production. The effects of a mechanical harvester on the extensive grass flats and rich bottom habitats of southern estuaries are virtually unknown. Approximately 75% of Florida's commercial species of fishes and invertebrates spend at least a portion of their life cycle in these shallow estuarine areas. Consequently, mechanical harvestering, especially on large scale commercial operation, should be restricted until sufficient research can be performed to determine whether such harvesters should be allowed in Florida and what restrictions, if any, should be applied. It would certainly not be in the interest of good management to jeopardize the established commercial efforts in an attempt to initiate production on an unproven resource, no matter how great its potential.

Sudara, S., and R.W. Buddemeier. 1981. Conditions of the coral reef in Thailand and the potential usage in the future. Pages 209-212 *in* The Reef and Man. Proceedings of the Fourth International Coral Reef Symposium. Volume 1.

Abstract: Major contributions to the deterioration of the coral reef in the Thai waters are: the mining activities both inland and offshore, illegal dynamite fishing, bottom trawling, coral collecting, industrial and domestic pollution. Each factor can cause intensive coral damage in its own way, therefore the problem in one area will not be the same as others. Preventive measures for each factor causing deteriorating conditions should be developed. Certain areas should be conserved for future use not only for the conservation of nature or for fisheries but for tourism as well.

Sutherland, D.L., G.L. Beardsley, and R.S. Jones. 1983. Results of a survey of the south Florida fish-trap fishing grounds using a manned submersible. Northeast Gulf Science. Vol. 6(2):179-183.

Summary: In this study, sixteen dives were made with a submersible to survey the sea floor and examine derelict fish traps. Twenty-three abandoned fish traps were found. Five of the traps were not damaged and continued to fish. The authors estimated that the traps had been lost for four to six months. Some of the traps were found on and near reef and live bottom habitat, but they did not notice any damage to the reef and live bottom habitat from the traps.

Sutherland, D.L., and D.E. Harper. 1983. The wire fish-trap fishery of Dade and Broward counties, Florida December 1979 - September 1980. Florida Marine Research Publications. No. 40. 21 p.

Summary: This paper describes the fishing gear and fishing grounds for the wire fish-trap fishery. It also examines the impact these traps have on reef fish stocks, tropical fish, and the coral habitat where the traps are deployed.

Tabb, D.C. 1958. Report on the bait shrimp fishery of Biscayne Bay, Miami, Florida. Florida State Board of Conservation, Marine Lab, University of Miami. 16 p.

Abstract: This study provides information on (1) the effect of trawling operations upon the algae and spermatophytes, and (2) the fishes in bait shrimp catches, their sizes and extent of mortality. At the time of the survey there were twelve bait shrimp boats fishing in Biscayne Bay. Three of these boats were fishing only with otter trawls. Seven boats were using roller frame trawls and two boats were using both frame and otter trawls. Six boats were berthed at the Dinner Key marina, four boats were at Key Biscayne; one boat was at Cutler Power Plant and one near MacArthur Causeway. Trawling takes place in two kinds of bottom, the mud bottom for otter trawls and grassy bottoms for roller frame trawls. Observations of roller frame trawl operations and trash hauls did not indicate that this gear is crushing or destroying the "grass flats." Plant material taken in the trash was almost exclusively dead and dying fragments of *Thalassia testudinum*. Examination of the fragments indicate that this material is made up of "grass" blades that are being naturally shed as a result of the normal growth of this plant. No whole plants or rhizomes were encountered during the study although bottom grab and grapnel samples indicate that the nets were fishing in grassy areas. Fish catches from the grassy areas were small, and few sport or forage fish were taken. Sorting techniques were well organized and the fish and invertebrates appear to be returned to the water without harm. Observations of otter trawls in the mud show no damage to the bottom. This gear is known, however, to uproot some plants when dragged over grassy bottoms. The otter trawl fish catches were somewhat larger than those of single roller frame trawls and included a higher percentage of sport, food and bait species, although in neither case was the proportion high. The sorting techniques were similar to those used with the frame trawl and appear not to harm the fish in significant quantity. A description of gear units involved has been presented and sources of possible gear modification suggested. Finally, a list of suggested recommendations has been added.

Tabb, D.C., and N. Kenny. 1967. A brief history of Florida's live bait shrimp fishery with description of fishing gear and methods. Institute of Marine Sciences, University of Miami, Miami, Florida. Contribution No. 1070. (Pages 1119-1134 *in* Proceedings of the World Scientific Conference on the Biology and Culture of Shrimp and Prawns, Mexico City, Mexico. FAO Fish Report 57(3).)

Abstract: A brief history of the live bait shrimp fishery of Florida is given as well as descriptions of the methods of capture of the three major bait species. The present fishery is growing in direct proportion to the growth of tourism and recreational fishing in Florida and it is expected that the bait shrimp fishery will capture more and more of the same shrimp that traditionally have been taken on the offshore grounds. The major portion of the shrimp

catch from Florida estuarine areas is now being caught by roller-frame trawls. The roller-frame trawl evolution is described and construction features of the most advanced design given. The roller-frame trawls are probably not destructive to the estuarine habitat. Methods of fishing, handling the catch, and kinds of organisms caught are described. The roller-frame trawls of modern design are relatively inexpensive and easy to construct. They should be adaptable to a wide variety of uses in estuarine areas of the world where shrimp stocks are not now being exploited.

Talge, H.K. 1991. Impact of recreational divers on Scleractinian corals of the Florida Keys. Master's Thesis. University of South Florida. 92 p.

Summary: This study examines the impact of recreational divers on coral reefs in the Florida Keys. Divers were observed, and their interactions with corals were recorded. While not dealing directly with fishing impacts on habitat, this paper describes the types of interactions that spear fishermen could have on coral reefs.

Tarr, M.A. 1977. Some effects of hydraulic clam harvesting on water quality in Kilisut Harbor, Port Susan, and Agate Pass, Washington. State of Washington, Department of Fisheries, Progress Report No. 22. 82 p.

Tasker, M.L., P.A. Knapman, and D. Laffoley. 2000. Effects of fishing on non-target species and habitats: identifying key nature conservation issues. Pages 281-289 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) This paper summarizes the key nature conservation issues arising from the effects that fishing may have on the marine environment in north-western European seas. 2) Nature conservation issues arise as a result of the localized effects caused by fishing as well as cumulative impacts that result at the ecosystem level. Such concerns have both given rise to a growing body of research and also contributed towards international and national agreements, conventions and directives aimed at conserving biodiversity and putting uses of the environment on a ecologically sustainable basis. Such initiatives have increased the pressure for change and helped to focus when nature conservation issues arise. 3) The paper concludes by making a number of suggestions about how fisheries and nature conservation could be brought closer together for the benefit of fishermen, the industry as a whole and nature conservation interests. This paper is accordingly very much a discussion paper and should not be taken as a position paper of any nature conservation organization.

Taylor, F.B. 1956. Is the shrimp trawl net destructive to marine life (a survey of the literature). Bears Bluff Laboratory, Wadmalaw Island, South Carolina. 52 p.

Summary: This report was an attempt to survey the literature to determine the impacts of the shrimp trawl on the sounds, rivers, and creeks of South Carolina. Several reports are reviewed and the relevant information from these reports is summarized and presented. The author concludes that little evidence is available to support either side of the impact debate, and that most of the literature surveyed analyzed the trawling impact on commercial finfish and not the bottom habitat. The author makes a very timely statement when he states "Calm discussion based on scientific research should discover the answers. The pure scientist

possibly could not reach a satisfactory conclusion under a lifetime of study. Then, he might not be satisfied that all knowledge of the subject had been gained. For day to day living, often it is necessary to proceed without all the facts. It may be required that certain assumptions be adopted as a guide. It should be sufficient that these assumptions are based upon clear knowledge of the basic facts. Let it be certain that these basics are facts, however - not assumptions." These words are still true today.

Taylor, R.G., and R.H. McMichael, Jr. 1983. The wire fish-trap fisheries in Monroe and Collier Counties, Florida. Florida Marine Research Publications. No. 39. 19 p.

Summary: This paper describes the fishing gear and fishing grounds for the wire fish-trap fishery. It also examines the impact these traps have on reef fish stocks, tropical fish, and the coral habitat where the traps are deployed.

Thompson, G. 1993. Impacts of trawling on the seabed and benthic community. Appendix F. Amendment 24, Bering Sea/Aleutian Islands Groundfish Fishery Management Plan. 5 p.

Summary: This paper reviews several studies on the impact of trawling to bottom habitat. It examines the physical impacts on the seabed, sediment resuspension, destruction of the benthos, changes to community structure, and changes to the availability of food by trawling. Although it is a short review, it provides a good overview of trawling impacts to the seabed.

Thrush, S.F., J.E. Hewitt, V.J. Cummings, and P.K. Dayton. 1995. The impact of habitat disturbance by scallop dredging on marine benthic communities: what can be predicted from the results of experiments? Marine Ecology Progress Series. Vol. 129(1-3):141-150.

Abstract: Field experiments were conducted on 2 subtidal sandflats to identify the short-term impacts of commercial scallop dredging on macrobenthic communities. The 2 sites (1400 m^2) were situated 14 km apart, both at about 24 m depth, with similar exposure aspects and were characterized by infaunal communities dominated by small and short-lived species. Prior to dredging, preliminary sampling failed to reveal significant differences in the density of common macrofauna within each site, although community composition was distinctly different between sites. The experiment was initiated by using a commercial scallop dredge to dredge half of each study site. Macrofauna samples were collected in both the dredged and adjacent reference plot at each site immediately after dredging and again 3 mo later. The density of common macrofaunal populations at each site decreased as a result of dredging, with some populations still significantly different from the adjacent reference plot after 3 mo. Significant compositional differences in the assemblage structure between dredged and reference plots were also recorded at each site over the course of the experiment. The findings of this experiment are considered a conservative assessment of bottom disturbance by fishing because of the area of seabed used, the types of community present and the intensity of disturbance used in the experiment. The findings of this and similar short-term experiments are discussed in light of the need to predict and assess possible large-scale changes to benthic communities as a result of habitat disturbance by fishing.

Thrush, S.F., J.E. Hewitt, V.J. Cummings, P.K. Dayton, M. Cryer, S.J. Turner, G.A. Funnell, R.G. Budd, C.J. Milburn, and M.R. Wilkinson. 1998. Disturbance of the marine benthic habitat

by commercial fishing: impacts at the scale of the fishery. Ecological Applications. Vol. 8(3):866-879.

Abstract: Commercial fishing is one of the most important human impacts on the marine benthic environment. One such impact is through disturbance to benthic habitats as fishing gear (trawls and dredges) are dragged across the seafloor. While the direct effects of such an impact on benthic communities appear obvious, the magnitude of the effects has been very difficult to evaluate. Experimental fishing-disturbance studies have demonstrated changes in small areas; however, the broader scale implications attributing these changes to fishing impacts are based on long-term data and have been considered equivocal. By testing a series of a priori predictions derived from the literature (mainly results of small-scale experiments), we attempted to identify changes in benthic communities at the regional scale that could be attributed to commercial fishing. Samples along a putative gradient of fishing pressure were collected from 18 sites in the Hauraki Gulf, New Zealand. These sites varied in water depth from ~17 to 35 m and in sediment characteristics from ~1 to 48% mud and from 3 to 8.5 µg chlorophyll *a*/cm^3. Video transects were used for counting large epifauna and grab/suction dredge and core sampling were used for collecting macrofauna. After accounting for the effects of location and sediment characteristics, 15-20% of the variability in the macrofauna community composition sampled in the cores and grab/suction dredge samples was attributed to fishing. With decreasing fishing pressure we observed increases in the density of echinoderms, longlived surface dwellers, total number of species and individuals, and the Shannon-Weiner diversity index. In addition, there were decreases in the density of deposit feeders, small opportunists, and the ratio of small to large individuals of the infaunal heart urchin, *Echinocardium australe*. The effects of fishing on the larger macrofauna collected form the grab/suction dredge samples were not as clear. However, changes in the predicted direction in epifaunal density and the total number of individuals were demonstrated. As predicted, decreased fishing pressure significantly increased the density of large epifauna observed in video transects. Our data provide evidence of broad-scale changes in benthic communities that can be directly related to fishing. As these changes were identifiable over broad spatial scales they are likely to have important ramifications for ecosystem management and the development of sustainable fisheries.

Tilmant, J.T. 1979. Observations on the impact of shrimp roller frame trawls operated over hard-bottom communities in Biscayne Bay, Florida. National Park Service Report Series No. P-553. 23 p.

Abstract: The impact to benthic organisms on hard bottom substrate by bait shrimp roller frame trawls was observed at a study site in south Biscayne Bay, Dade County, Florida. Pre-trawl and post-trawl observations were made of dominant benthic organisms including sponges, scleractinian and gorgonian corals, and algae. Highest incidence of damage was to the stony corals *Porites porites* and *Solenastrea hyades* where 80% of those corals encountered were turned over, or crushed. Over 50% of the sponges of the genera *Neopetrosia*, *Spheciospongia*, *Spongia* and *Hippiospongia* were damaged when in the trawl path. Thirty-eight percent of the gorgonians *Pseudopterogorgia* and *Pterogorgia* were uprooted. Most algae were not significantly affected by trawling with the exception of *Halimeda* and *Sargassum*. Results indicate disruption of commercially valuable sponges by trawling activities may be seriously affecting the sponge fishery in Biscayne Bay. Eleven

months after shrimp trawling ceased, the benthic community had not fully recovered. Repeated seasonal trawling at the study site could therefore lead to permanent alteration of naturally occurring organisms.

Tilmant, J.T. 1987. Impacts of recreational activities on coral reefs. Pages 195-214 *in* Human Impacts on Coral Reefs: Facts and Recommendations. Antenne Museum, French Polynesia.

Abstract: A review is made of current scientific knowledge of recreational impact on coral reefs. Reference is given to studies conducted in Florida, USA and in the Great Barrier Reef, regarding management of coral reefs with respect to boating, diving and fishing impacts on the environment.

Tuck, I.D., S.J. Hall, M.R. Robertson, E. Armstrong, and D.J. Basford. 1998. Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. Marine Ecology Progress Series. Vol. 162:227-242.

Abstract: The effects of trawling disturbance on a benthic community were investigated with a manipulative field experiment in a fine muddy habitat that has been closed to fishing for over 25 yr. We examined the effects of extensive and repeated experimental trawl disturbance over an 18 mo period on benthic community structure and also followed the subsequent patterns of recovery over a further 18 mo. During the period of trawl disturbance the number of species and individuals increased and measures of diversity (Shannon's exponential *H'* and Simpson's reciprocal *D*) and evenness decreased in the trawled area relative to the reference site. The cirratulid polychaetes *Chaetozone setosa* and *Caulleriella zetlandica* were found to be most resistant to disturbance, whilst the bivalve *Nucala nitidosa* and polychaetes *Scolopolos armiger* and *Nephtys cirrosa* were identified as sensitive species. Multivariate analysis and abundance biomass comparison plots confirmed that community changes occurred following disturbance, with some differences between treatment and reference sites still apparent after 18 mo of recover. Physical effects, examined with Side-scan and RoxAnn, were identifiable immediately after disturbance, but were almost indistinguishable after 18 mo of recovery. Such long recovery times suggest that even fishing during a restricted period of the year may be sufficient to maintain communities occupying fine muddy sediment habitats in an altered state.

Turner, S.J., S.F. Thrush, J.E. Hewitt, V.J. Cummings, and G. Funnell. 1999. Fishing impacts and the degradation or loss of habitat structure. Fisheries Management and Ecology. Vol. 6:401-420.

Abstract: The wider effects of fishing on marine ecosystems have become the focus of growing concern among scientists, fisheries managers and the fishing industry. The present review examines the role of habitat structure and habitat heterogeneity in marine ecosystems, and the effects of fishing (i.e. trawling and dredging) on these two components of habitat complexity. Three examples from New Zealand and Australia are considered, where available evidence suggests that fishing has been associated with the degradation or loss of habitat structure through the removal of large epibenthic organisms, with concomitant effects on fish species which occupy these habitats. With ever-increasing demands on fish-stocks and the need for sustainable use of fisheries resources, new approaches to fisheries

management are needed. Fisheries management needs to address the sustainability of fish-stocks while minimizing the direct and indirect impacts of fishing on other components of the ecosystem. Two long-term management tools for mitigating degradation or loss of habitat structure while maintaining healthy sustainable fisheries which are increasingly considered by fisheries scientists and managers are: (1) protective habitat management, which involves the designation of protected marine and coastal areas which are afforded some level of protection from fishing; and (2) habitat restoration, whereby important habitat and ecological functions are restored following the loss of habitat and/or resources. Nevertheless, the protection of marine and coastal areas, and habitat restoration should not be components of an integrated program of coastal zone and fisheries management. A number of recent international fisheries agreements have specifically identified the need to provide for habitat protection and restoration to ensure long-term sustainability of fisheries. The protection and restoration of habitat are also common components of fisheries management programs under national fisheries law and policy.

Vakily, J.M. 1993. Dynamite fishing in Sierra Leone. Naga. Vol. 16(4):7-9.

Summary: The dynamite fishing operations in Sierra Leone are enumerated and discussed.

Van Den Heiligenberg, T. 1987. Effects of Mechanical and Manual Harvesting of Lugworms *Arenicola marina* L. on the Benthic Fauna of Tidal Flats in the Dutch Wadden Sea. Biological Conservation. Vol. 39:165-177.

Abstract: Effects of bait digging by hand and mechanical harvesting of *Arenicola marina* (L.) on the macrobenthic fauna of the Dutch Wadden Sea were investigated. Samples were taken on two tidal flat areas: the Balgzand and the Vlakte van Kerken, from March to October 1981. Most of the major species were severely reduced immediately after digging. Some species, e.g. *Macoma baltica* and *Scoloplos armiger*, showed a fast return into the depopulated area. Further recovery varied per species, with in general a larger recruitment of juveniles in the dug-over areas compared to the non-disturbed areas. Mechanical harvesting appeared to be more efficient, catching more *Arenicola* per m^2. Hand diggers caused less mortality of other benthic animals per gram *Arenicola* harvested. Disturbance of feeding birds is discussed. People walking and hand diggers cause a serious problem. The most frequently used tidal flats, within walking distance from the shore, can be more or less permanently unsuitable for feeding birds.

Van der Knapp, M. 1993. Physical damage to corals caused by trap fishing on reefs of Bonaire, Netherlands Antilles. Environmental Conservation. Vol. 20(3):265-267.

Summary: The main objective of this study was to study the impact of trap fishing on coral reefs, and the physical damage caused to corals and other invertebrates. Data were restricted to opportunistic observations on damage caused during fishing trials. No quantitative measurements were preformed on coral regeneration, although qualitative results were reported.

Van der Valk, L. 1992. Estimated amount of physical disturbance of the seabed in the shallow southern North Sea due to natural causes. ICES CM 1992/E:39.

Abstract: In this paper the natural causes for the disturbance in the shallow (< 20 m) Southern North Sea are discussed as opposed to the disturbance by bottom fishery. Also, a semi-quantitative estimate is given of the depth to which these natural disturbances are active. From 0 to -12 m the physical disturbances reach a depth which is several times deeper than those due to bottom fishery and occur several times per year. From -12 to -20 m disturbances due to fishery equal those due to natural causes and occur frequently, but possibly not every. The transition is gradual.

Van Dolah, R.F., P. Hinde, and N. Nicholson. 1983. Effects of roller trawling on a hard bottom sponge and coral community. Final Report to Sanctuary Program Division, NOAA. 89 p.

Summary: Due to concern over the use of roller trawls in hardbottom areas, this study was initiated to determine the effects of trawling on large benthic invertebrates associated with an inshore hardbottom habitat, determine the rate at which these large sessile invertebrates recover, in terms of growth and recolonization, after trawling in the area, and examine the invertebrate communities associated with these large sessile invertebrates. Results of the study documented damage to all species counted, but only the density of barrel sponges was significantly decreased by trawling activities. Twelve months after trawling, no damaged sponges or corals were observed in the area and the abundance of specimens counted in the trawled quadrants had increased to pre-trawl densities or greater.

Van Dolah, R.F., P.H. Wendt, and N. Nicholson. 1987. Effects of a research trawl on a hard-bottom assemblage of sponges and corals. Fisheries Research. Vol. 5:39-54.

Abstract: The effects of a research trawl on several sponge and coral species was assessed in a shallow-water, hard-bottom area located southeast of Savannah, Georgia. The study entailed a census of the numerically dominant species in replicate 25-m^2 quadrats located along five transects established across a trawling alley. The density of undamaged sponges and corals was assessed in trawled and non-trawled (control) portions of each transect immediately before, immediately after, and 12 months after a 40/54 roller-rigged trawl was dragged through the alley once. Some damage to individuals of all target species was observed immediately after trawling, but only the density of barrel sponges (*Cliona* spp.) was significantly reduced. The extent of damage to the other sponges (*Ircinia campana*, *Haliclona oculata*), octocorals (*Leptogorgia virgulata*, *Lophogorgia hebes*, *Titanideum frauenfeldii*) and hard corals (*Oculina varicosa*) varied depending on the species, but changes in density were not statistically significant. Twelve months after trawling, the abundance of specimens counted in the trawled quadrats had increased to pre-trawl densities or greater, and damage to the sponges and corals could no longer be detected due to healing and growth. Trawl damage observed in this study was less severe than the damage reported for a similar habitat in a previous study. Differences between the two studies are attributed to (1) differences in the roller-rig design of the trawls used, and (2) differences in the number of times the same bottom was trawled.

Van Dolah, R.F., P.H. Wendt, and M.V. Levisen. 1991. A study of the effects of shrimp trawling on benthic communities in two South Carolina sounds. Fisheries Research. Vol. 12:139-156.

Abstract: Two estuarine sounds in South Carolina were studied to evaluate the effects of commercial shrimp trawling on the abundance, diversity and species composition of benthic infaunal assemblages. In each sound, two areas were sampled just prior to the opening of the shrimp trawling season and then again after 5 months of trawling activities. One area was located in a portion of the sound which was actively trawled and the other area was located in a nearby portion of the sound closed to trawling. Significant differences were observed between sampling periods in both sounds with respect to total faunal abundance, the relative abundance of dominant taxa, and the total number of species. Changes in species composition were also noted between sampling dates. Indices of species diversity and the relative proportion of species representing major taxonomic groups in each area were generally similar over time. The reduction in faunal abundance and number of species observed in all four areas during the second sampling period was more likely due to natural seasonal variability rather than trawling effects since there were no significant differences between trawled and non-trawled sites with respect to these parameters. There were also no obvious differences in species composition among the trawled vs. non-trawled areas based on cluster analysis. Although this study was not designed to address all of the potential impacts of trawling activities on benthic organisms, lack of any consistent differences among sites with respect to the community parameters assessed suggests that 5 months of trawling in the areas studied did not have a pronounced effect on the abundance, diversity or composition of the soft-bottom communities sampled.

Van Marlen, B., Van Duyn, J.B., and D.J.C. Blijker. 1985. An introduction of direct observation techniques using a remotely controlled television vehicle on bottom trawls with square mesh cod-ends. ICES CM 1985/B:34.

Abstract: Co-operative research using the Marine Laboratory direct observation equipment, a remotely controlled television vehicle, abbreviated RCTV, was done on the Dutch Fishery Research Vessel "Tridens" in March 1985. The RCTV towed from a vessel and can be positioned alongside a fishing gear to take video and still pictures. Two bottom trawls were investigated with several different cod-ends, made of diamond and square meshes to observe fish reactions in the Moray Firth and close to the Orkney Islands. The co-operation provided for the Dutch scientists a unique chance to learn all aspects of running a RCTV for direct observation purposes. A third party involved was the "Institute für Fangtechnik" of Germany, which sent an observer. A total of 14 hauls supplied valuable information on the geometry of and fish reactions to 10 different cod-ends including tapered square mesh ones and cod-end covers. Generally square mesh cod-ends open well, when designed properly and create a large escape area for small fish.

Van Marlen, B. 2000. Technical modifications to reduce the by-catches and impacts of bottom-fishing gears. Pages 198-216 *in* M.J. Kaiser and S.J. de Groot. The Effects of Fishing on Non-target Species and Habitats. Blackwell Science.

Summary: 1) Many techniques have been developed to improve the species and size selectivity of fishing gears and to reduce discards. 2) Given a proper and clear incentive, fishermen use techniques to improve gear selectivity (e.g. sorting grids, square mesh windows). 3) Application of these techniques contributes to stock conservation. 4) It is much more difficult to reduce mortality of benthic organisms due to demersal trawling, as

these gears need bottom contact to achieve their required catch efficiency. 5) Possibly alternative stimulation techniques (electrical fields, water injection) could be applied, but these still require further research and development. 6) Techniques to release benthic animals from nets at sea may have a smaller, but nevertheless worthy, contribution to the conservation of benthic fauna.

Vienneau, R., and M. Moriyasu. 1994. Study of the impact of ghost fishing on snow crab, *Chionoecetes opilio*, by conventional conical traps. Canadian Technical Reports of Fisheries and Aquatic Sciences. No. 1984. 9 p.

Abstract: In an attempt to quantify the impact of ghost fishing by lost, abandoned or illegally submerged conventional conical traps on the snow crab industry, it was revealed that ghost fishing activity was not constant throughout the trap immersion period. If baited, the trap would capture crabs to its saturation level, then, decline in the number of crab captured due to cannibalism and predation by sea fleas (amphipods). During a period after July, after the fishing season, when this decline occurred, the number of new crab entering the trap was negligible. However, from September to the following summer, the catch has increased again to its saturation level and, therefore, re-initiating the ghost fishing cycle. Traps that are non-baited will also catch crab. They probably have less impact on the crab stock in the short term, but they will however become as devastating as self- baited traps in the long term.

Vining, I.W., S. Byersdorfer, W. Donaldson, and B. Stevens. 1997. Lost crab and cod pot recovery and ghost fishing in Chiniakk Bay and other areas in the waters around Kodiak Island, Alaska. Alaska Department of Fish and Game. Regional Information Report. No. 4K97-42. Kodiak, Alaska.

Vining, R. 1978. Final environmental impact statement for the commercial harvesting of subtidal hardshell clams with a hydraulic escalator shellfish harvester. State of Washington, Department of Fisheries, Department of Natural Resources. 57 p.

Walker, D.I., R.J. Lukatelich, G. Bastyan, and A.J. McComb. 1989. Effect of boat moorings on seagrass beds near Perth, Western Australia. Aquatic Botany. Vol. 36:69-77.

Abstract: Boat moorings have been found to produce circular scours in seagrass meadows, ranging from 3 to 300 m^2. "Cyclone" moorings (which have three anchors and a swivel) are much less damaging to seagrass meadows than "swing" moorings (with a single anchor and chain). The total area of seagrass meadow lost due to moorings totals some 5.4 ha in the Rottnest Island, Warnbro Sound and Cockburn Sound regions of Western Australia, with most loss (3.14 ha) in the Rottnest region. While the relative area of seagrass meadow lost is small (<2%), there is considerable visual impact in some areas. The scours created by moorings in the seagrass canopy interfere with the physical integrity of the meadow. Though relatively small areas of seagrass are damaged by moorings, the effect is much greater than if an equivalent area was lost from the edge of a meadow.

Warwick, R.M., and K.R. Clarke. 1993. Comparing the severity of disturbance: a meta-analysis of marine macrobenthic data. Marine Ecology Progress Series. Vol. 92:221-231.

Abstract: A multivariate method of comparing the severity of disturbance to subtidal macrobenthic communities on a common scale is described. Data on species abundances and biomasses from a variety of stations on the NE Atlantic shelf at which the pollution/disturbance status is known have been aggregated to phylum level and the abundance and biomass data merged using an allometric equation to form a 'production' matrix. An ordination (non-metric Multi-Dimensional Scaling, MDS) of all these data, combined in a single meta-analysis, produces a configuration with disturbance as its major axis. These 50 samples can be used as a training data-set against which the status of communities from new studies can be assessed.

Watling, L., and E. A. Norse. 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. Conservation Biology. Vol. 12(6):1180-1197.

Abstract: Bottom trawling and use of other mobile fishing gear have effects on the seabed that resemble forest clearcutting, a terrestrial disturbance recognized as a major threat to biological diversity and economic sustainability. Structures in marine benthic communities are generally much smaller than those in forests, but structural complexity is no less important to their biodiversity. Use of mobile fishing gear crushes, buries, and exposes marine animals and structures on and in the substratum, sharply reducing structural diversity. Its severity is roughly comparable to other natural and anthropogenic marine disturbances. It also alters biogeochemical cycles, perhaps even globally. Recovery after disturbance is often slow because recruitment is patch and growth to maturity takes years, decades, or more for some structure-forming species. Trawling and dredging are especially problematic where the return interval–the time from one dredging or trawling event to the next-- is shorter than the time it takes for the ecosystem to recover; extensive areas can be trawled 100-700% per year or more. The effects of mobile fishing gear on biodiversity are most severe where natural disturbance is least prevalent, particularly on the outer continental shelf and slope, where storm-wave damage is negligible and biological processes, including growth, tend to be slow. Recent advances in fishing technology (e.g., rockhopper gear, global positioning systems, fish finders) have all but eliminated what were de facto refuges from trawling. The frequency of trawling (in percentage of the continental shelf trawled per year) is orders of magnitude higher than other severe seabed disturbances, annually covering an area equivalent to perhaps half of the world's continental shelf, or 150 times the land area that is clearcut yearly. Mobile fishing gear can have large and long-lasting effects on benthic communities, including young stages of commercially important fishes, although some species benefit when structural complexity is reduced. These findings are crucial for implementation of "Essential Fish Habitat" provisions of the U.S. Magnuson-Stevens Fishery Conservation and Management Act which aim to protect nursery and feeding habitat for commercial fishes. Using a precautionary approach to management, modifying fishing methods, and creating refuges free of mobile fishing gear are ways to reduce effects on biological diversity and commercial fish habitat.

Way, E.W. 1976. Lost gill-net retrieval experiment. Canadian Fisheries and Marine Service, Industrial Development Branch. 76 p.

Abstract: The Industrial Development Branch, Fisheries and Marine Service, Department of the Environment, carried out a project to locate and recover lost gill nets in an effort to

determine what effect 'ghost nets' were having on the groundfish and shellfish resource. It should be noticed that the purpose of the project was not only to retrieve as many lost nets as possible, but also to determine the effectiveness of the designed gear and to ascertain to what degree, if any, these ghost nets were fishing and what effects they were having on groundfish stocks.

Way, E.W. 1977. Lost gill net (ghost net) retrieval project, 1976. Canadian Fisheries and Marine Service (Newfoundland Region), Industrial Development Branch. 30 p.

Abstract: Over the past twelve years increasing numbers of gill nets, constructed from synthetic materials which do not deteriorate in water used by fishermen along the coast of eastern Newfoundland and Labrador, are reported lost due to ice, storms and other causes. Many fishermen feel the nets continue to fish in what is locally termed "ghost net" fishing, and are having a damaging effect on the crab stocks and an increasingly declining groundfish resource. Based on the results of work carried out on a lost gill net retrieval experiment in the Trinity/Bonavista Bay areas during the latter part of 1975, the Industrial Development Branch implemented a program in the Notre Dame Bay area where large numbers of gill nets are allegedly lost, with emphasis on "clean up."

Wells, R.S., S. Hofmann, and T.L. Moors. 1998. Entanglement and mortality of bottlenose dolphins, *Tursiops truncatus*, in recreational fishing gear in Florida. Fishery Bulletin. Vol. 96:647-650.

Summary: This paper describes the death of two bottlenose dolphins and the role that discarded or lost recreational fishing gear played in their deaths.

Wenner, C.A. 1983. Species associations and day-night variability of trawl-caught fishes from the inshore sponge-coral habitat, South Atlantic Bight. Fishery Bulletin. Vol. 81(3):537-552.

Abstract: Biomass, species composition, diversity, and community structure of demersal fishes were studied during the spring of 1978 in the sponge-coral habitat of the South Atlantic Bight. These results were compared with sampling at an open-shelf site. Otter trawl catch rates were an order of magnitude higher in the sponge-coral habitat than at the open-shelf site. Density and biomass estimates in the sponge-coral habitat averaged 384 individuals/ha and 31.0 kg/ha, respectively, whereas at the open-shelf site they averaged 57 individuals/ha and 3.2 kg/ha. In sponge-coral habitat samples, 101 species of demersal teleosts were taken. The Sparidae accounted for the greatest number of species (9), as well as 59% of the total number and 48% of the weight of demersal teleosts. Species diversity was highest in night-trawl tows in the sponge-coral habitat. Species associations, described by numerical classification, showed major differences in faunal assemblages between reef and open-shelf sites and between day and night samples.

Summary: The author briefly discusses (page 550) the use of otter trawl nets in the sponge-coral habitat and their effect on the bottom substrate.

West, B. 1987. 1986 Bering Sea trawling impact project. Pages 626-631 *in* Proceedings Ocean '87 The Ocean - An International Workplace. Halifax, Nova Scotia. September 28 - October 1, 1987.

Abstract: A fishing gear research project was carried out to assess the impact of commercial bottom trawling by the U.S. fishing fleet on the demersal fauna and habitat of the eastern Bering Sea. Impact was assessed by means of an underwater TV-equipped remotely operated vehicle maneuvered in and around trawl gear during fishing operations, observing and recording the physical performance of two types of gear typically used in this fishery, the reactions of various fish and invertebrate species to the gear, and the gear's impact on the bottom. The observations suggest that the impact of modern gear on benthic invertebrates and the substrate is less than that of older types of trawl gear, and that much of the trawl's rigging and ground gear makes little or no contact with the bottom at all.

Westley, R.E. 1976. A lawsuit (environmentally oriented) brought against mechanical clam harvest in Washington State with a Hanks-type harvester. Proceedings of the National Shellfish Association. Vol. 65:6.

Abstract: Harvest of Eastern soft-shell clams on the intertidal flats of Skagit Bay by a Hanks-type harvester was halted by an injunction issued against the clam harvester and the Washington State Department of Fisheries. Initial basis for the injunction was fear of damage to a high intertidal rush used for food by wild fowl located above the clam beds. Trial was held and the Court ruled that the clam harvest operator had failed to comply with the terms of the Washington State Shorelines Management Act, and that mechanical clam harvest was both a substantial development and dredging in terms of the Washington law. He further ruled that the Department of Fisheries had failed to consider terms of the Washington State Environmental Policy Act of 1971 and that the clam harvest permit was not valid. This trial and action have potential for major impact on the Washington shellfish industry and it currently appears that it may greatly complicate the management regulation and conduct of shellfish harvest in Washington State.

Whitaker, J.D. 1979. Abandoned crab trap study. South Carolina Wildlife and Marine Resources Department, Unpublished Report. 14 p.

Abstract: During the summer of 1977, the Office of Conservation, Management and Marketing, Crustacean Management Section initiated a study designed to estimate the impact of abandoned (derelict) commercial crab traps on the South Carolina blue crab fishery. An undetermined number of commercial crab traps (many crab fishermen indicate a significant number) are abandoned each year throughout the state. These losses may be attributed to uncontrollable factors including extreme tides, siltation, currents and sudden storms or they may simply reflect negligence on the part of the fishermen to properly construct and maintain their gear especially with regard to attachment lines, floatation markers and in the selection of favorable fishing locations. These abandoned traps remain intact and continue fishing for an undetermined length of time. It is the purpose of this study to document how long abandoned crab traps actually fish and how many crabs are lost per trap.

Whitelaw, W. 1997. Using videos to study the effects of trawling on the marine habitat. Unpublished Report. http://www.environment.gov.au/marine/coastal_atlas/documentation/standards/biology/whit2.html.

Abstract: This paper describes the use of video cameras on characterizing the effects of trawl nets on tropical shallow benthos. It will describe the techniques and equipment used as well as the subsequent analysis, advantages and limitations of this type of study.

Wickham, D.A., and J.W. Watson, Jr. 1976. Scuba diving methods for fishing systems evaluation. Marine Fisheries Review. Vol. 38(7):15-23.

Abstract: The scuba diving methods and operational procedures used by the Harvesting Technology Group, Pascagoula Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, during the development of new fish trawl technology are described. Procedures for using diving sleds for efficient transport of divers to and from the trawls to facilitate on-the-net observations of operational bottom and mid-water trawls are provided. Procedures are described for the static deployment of bottom and mid-water trawls in fishing configuration, as required during the development of electric trawling systems. Diving safety is discussed as it relates to the use of a diving sled and to both operational and static deployment of fish trawls.

Williamson, J. 1998. Gillnet fishing. Pages 87-89 *in* E.M. Dorsey and J. Pederson, editors. Effect of Fishing Gear on the Sea Floor of New England. Conservation Law Foundation. Boston, Massachusetts. 160 p.

Summary: A commercial fisherman describes his fishing gear and its perceived effects on habitat.

Witbaard, R., and R. Klein. 1993. A method to estimate the bottom trawl intensity independently from fisheries itself by using internal molluscan growth lines. ICES CM 1993/K:16. 8 p.

Abstract: Field observations and literature data showed that high numbers of the bivalve mollusc *Arctica islandica* are affected by beam trawl fisheries. The occurrence of damage mainly on the postventral shell side suggests that tickler chains are the responsible cause. Scars formed in shells which survived after being fished, were used to reconstruct fishing intensity for one site in the SE North Sea for the past 30 years. It was found that the location has been disturbed annually since 1974. The increasing trend in the relative occurrence of scars since that period coincides with the developments of the Dutch fishing fleet for the same period. It is suggested that the method presented might be valuable for estimating actual fishing intensities on very local scales.

Witbaard, R., and R. Klein. 1994. Long-term trends on the effects of the southern North Sea beamtrawl fishery on the bivalve mollusc *Arctica islandica* L. (Mollusca, bivalvia). ICES Journal of Marine Science. Vol. 51:99-105.

Abstract: *Arctica islandica* has been used as an indicator organism for the intensity of bottom trawling in the southern North Sea. That this species is affected by beamtrawl

fisheries is illustrated by the high incidence of damage found on shells from heavily fished areas. Between 80 and 90% of the damage was found at the posterior ventral side of the shell. This can be explained by the orientation of the living animal in the upper sediment layer and the horizontal movement of the tickler chains on the bottom. Scars on the external shell surface were dated by internal growth lines, revealing that the sampling site had been disturbed at least once a year since 1974. The observed trends in the occurrence of scars per year show a striking coincidence with the increase in capacity of the Dutch fishing fleet over the period 1972-1991.

Woodburn, K.D., B. Eldred, E. Clark, R.F. Hutton, and R.M. Ingle. 1957. The live bait shrimp industry of the west coast of Florida (Cedar Key to Naples). Florida State Board of Conservation Marine Laboratory Technical Series No. 21.

Summary: The live bait shrimp industry has grown into a multi-million dollar industry in the State of Florida. The Cedar Key to Naples area produces over 60% of the bait shrimp in the State. Pinellas County alone is responsible for 76% of this west coast production. The retail value of the shrimp from this area totals nearly $2,000,000. The production of live bait shrimp along the west coast is centered around 1 species, the brown-spotted or pink shrimp, *Penaeus duorarum*. Because this shrimp is nocturnal in habit, the bait shrimping operation is limited to the night time. The death of food, game and other fish due to the bait shrimping operation is negligible. Although our studies indicate that shrimp trawls do not destroy grass beds, they do show that the scouring action of boat propellers can be detrimental to very shallow areas of marine vegetation. In order to reduce the mortality rate which adversely affects profits and supply, especially during the summer, live bait shrimp should be handled and distributed with the utmost speed and care. The pinfish, *Lagodon rhomboides*, is by far the most common fish associated with the bait shrimp in the grassy areas. There is the possibility that this fish and other so-called trash fish captured with the bait shrimp could be used in stock or poultry feeds as by-products of the live bait industry.

Wright, D.G., and G.E. Hopky. 1998. Guidelines for the use of explosives in or near Canadian fisheries waters. Canadian Technical Reports of Fisheries and Aquatic Science. No. 2107. 68 p.

Abstract: The federal Fisheries Act includes provisions for the protection of fish, shellfish, crustaceans, marine mammals and their habitats. The detonation of explosives in or adjacent to fish habitat has been demonstrated to cause disturbance, injury and/or death to fish and marine mammals, and/or the harmful alteration, disruption or destruction of their habitats, sometimes at a considerable distance from the point of detonation. Within the context of the guidelines and procedures outlined in this report, an explosive is defined as a chemical compound which, when detonated, creates a compressional wave having an almost instantaneous rise time to a very high peak pressure followed by a decay to below ambient pressure by either rapid oxidation or the breaking of high-energy chemical bonds. The purpose of this report is to provide information to proponents who are proposing works or undertakings that involve the use of confined or unconfined explosives in or near Canadian fisheries waters, and to which the Fisheries Act, Sections 32 and 35 in particular, may apply. Guidelines are provided on methods and practices for the conservation and protection of fish, marine mammals, and fish habitat from impacts arising from the destructive forces of

explosives. The report describes the suggestive application and review procedures and processes for proponents whose use of explosives may result in the destruction of fish, or the harmful alteration, disruption or destruction of fish habitat.

Wynberg, R.P., and G.M. Branch. 1994. Disturbance associated with bait-collection for sandprawns (*Callianassa kraussi*) and mudprawns (*Upogebia africana*): Long-term effects on the biota of intertidal sandflats. Journal of Marine Research. Vol. 52:523-558.

Abstract: The sandprawn *Callianassa kraussi* and the mudprawn *Upogebia africana* are used extensively as fish bait in southern Africa. A holistic analysis of disturbance associated with experimental prawn-collecting was undertaken to determine its repercussions upon the sediment and associated macrofaunal, meiofaunal, microbial and microalgal communities. Patterns of recovery were examined for 18 months following the disturbance. The recovery of both *C. kraussi* and *U. africana* was far more protracted than predicted, taking 18 months for completion. Sedimentary compaction, associated with the removal of prawns, could account for these prolonged recoveries. Both *C. kraussi* and *U. africana* suffered greater depressions of population densities (ca. 70%) than would have been expected from the proportions removed (ca. 10% and 46% respectively). This suggests that disturbance and sedimentary compaction have greater effects than the removal of sand- and mudprawns *per se*. One month after the disturbance of *C. kraussi*, chlorophyll levels increased above control levels and remained elevated for a further 2-3 months. In contrast, the removal of *U. africana* resulted in nett decreases in chlorophyll levels for approximately one month following the disturbance. A short-lived decline in bacterial numbers was apparent following the removal of *C. kraussi* but not *U. africana*. Meiofaunal numbers declined immediately after disturbance of both *C. kraussi* and *U. africana*, but this depression was followed by explosive increases and then a return to control levels. The macrofauna was slower to recover and, after initial reductions of numbers, biomass and species richness, still showed signs of depression 18 months after the disturbance. Three response patterns were apparent: species which were immediately reduced by the treatments and were also slow to recover; species which appeared to have their recruitment suppressed relative to the control; and species which were unaffected by the treatment. Only a single macrofaunal species, the hermit crab *Diogenes brevirostris*, benefitted from the disturbance. Similar trends were observed following the harvesting of both *C. kraussi* and *U. africana*.

Zenetos, A. 1997. Trawling impact on benthic ecosystems. Unpublished Report. National Center for Marine Research. DG-XIV-Contract-Number-95/14. Athens, Greece. 120 p.

Abstract: In order to assess the trawling impact on benthic ecosystems the project initiated with an extensive study of the benthic fauna in two neighbouring gulfs of the Aegean Sea, one regularly trawled (Petalioi Gulf) and the other closed to trawlers (South Evvoikos proper Gulf). Results showed that the two areas host different benthic communities, which is related to differences in the type of sediment and water depth. Disturbance caused by fishing was detected in the trawled area as an increase of opportunistic species.

Zieman, J.C. 1976. The ecological effects of physical damage from motor boats on turtle grass beds in southern Florida. Aquatic Botany. Vol. 2:127-139.

Abstract: Observation has shown that beds of turtle grass, *Thalassia testudinum*, although highly productive, do not recover rapidly following physical disturbance of the rhizome system. In shallow waters the most common form of rhizome disturbance is from the propellers of motor boats. In turtle grass beds which are otherwise thriving, tracks resulting from propellers have been observed to persist from 2 to 5 years. The proportion of fine sediment components is reduced in the sediments from the boat tracks, and the pH and EH are reduced in comparison to the surrounding grass bed. Damage of this type is most likely to occur in the shallow passes between islands and keys. These areas are also the slowest to recover due to the rapid tidal currents present in the shallow passes.