NOAA Technical Memorandum NMFS-AFSC-116

Mobile Fishing Gear Effects on Benthic Habitats: A Bibliography

by
D. A. Wion and R. A. McConnaughey (editors)

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

August 2000

NOAA Technical Memorandum NMFS

The National Marine Fisheries Service's Alaska Fisheries Science Center uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series reflect sound professional work and may be referenced in the formal scientific and technical literature.

The NMFS-AFSC Technical Memorandum series of the Alaska Fisheries Science Center continues the NMFS-F/NWC series established in 1970 by the Northwest Fisheries Center. The new NMFS-NWFSC series will be used by the Northwest Fisheries Science Center.

This document should be cited as follows:

> Wion, D. A. and R. A. McConnaughey. 2000. Mobile fishing gear effects on benthic habitats: A bibliography. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-116, 163 p.

Reference in this document to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

NOAA Technical Memorandum NMFS-AFSC-116

Mobile Fishing Gear Effects on Benthic Habitats: A Bibliography

by
D. A. Wion and R. A. McConnaughey (editors)

Alaska Fisheries Science Center
7600 Sand Point Way N.E.
Seattle, WA 98115-0070

U.S. DEPARTMENT OF COMMERCE
Norman Y. Mineta, Secretary
National Oceanic and Atmospheric Administration
D. James Baker, Under Secretary and Administrator
National Marine Fisheries Service
Penelope D. Dalton, Assistant Administrator for Fisheries

August 2000

Introduction

In 1996, the U.S. Congress amended the Magnuson Fishery Conservation and Management Act of 1976 (renamed the Magnuson-Stevens Fishery Conservation and Management Act) with the Sustainable Fisheries Act (SFA), and set forth a number of new mandates including protection of essential fish habitat (EFH) and requirements to develop rebuilding plans for overfished stocks. The National Marine Fisheries Service (NMFS) subsequently defined EFH for a species as the combined area required to support a sustainable fishery and maintain the managed species' contribution to a healthy ecosystem. In response to the SFA, the NMFS and the eight regional fishery management councils were required to amend their fishery management plans to identify and describe EFH for all federally managed fishery stocks. Furthermore, activities with potential adverse effects on EFH, including fishing, must be investigated and conservation measures implemented to minimize or eliminate any impacts.

Viable marine habitats are needed to sustain healthy fish populations, and the disturbance, degradation or destruction of such habitats is a globally important issue. Scientific research has indicated that fishing, dredging and other anthropogenic activities may alter physical and biological characteristics of the benthos. Improved access to scientific research about fishing gear effects on fish habitat will facilitate a greater understanding of the issue, promote informed discussion amongst scientists, policymakers and interested stakeholders, and encourage more rapid progress toward management solutions. To this end, scientists at the Alaska Fisheries Science Center (AFSC) have assembled a bibliographic database of pertinent literature. It was initially developed in support of field research programs investigating effects of bottom trawls on eastern Bering Sea, Gulf of Alaska and Aleutian Islands benthos. Ultimately, this literature should aid the NMFS and the eight regional fishery management councils in assessing effects of fishing on EFH.

The original bibliography has been updated and is now a comprehensive listing of scientific and popular literature on demersal, mobile fishing gear and its effects in marine ecosystems. In addition to peer reviewed literature, the bibliography includes state and Federal reports, contract and industry reports, theses and dissertations, conference and meeting proceedings and popular articles. The primary focus of this bibliography is bottom trawling, dredging, and raking, and the resulting direct disturbance of marine habitats and the associated biological communities. To a lesser extent, papers addressing other potential effects, such as bycatch and discards, are also referenced. This bibliography does not reference papers that specifically investigate fishing impacts due to longline fishing, trapping, ghost fishing, use of poisons/chemicals, dynamite blasting, or impacts due to boat hulls, anchors, or propeller wash.

The bibliography is worldwide in scope since the principles of gear disturbance are globally significant. Referenced papers reflect studies conducted in diverse habitats ranging from nearshore tidal flats to the deeper regions of the continental shelf. Papers written in languages other than English are also cited in the bibliography, and English translations of the material are provided. When available, author abstracts are included with each reference. If no abstract was available for use, a brief summary was produced and added. If papers were not available to produce a summary, only a citation is given.

This bibliography can be found on the AFSC web site (www.afsc.noaa.gov) as an Adobe PDF document under Online Publications and as a searchable, dynamic database at http://www.afsc.noaa.gov/groundfish/HAPC/references.html.

Acknowledgments

The authors are grateful for significant assistance by a number of individuals. Susan Calderon, Gary Duker, Sonja Kromann and Maureen Woods provided technical guidance during early stages of this project. Additionally, Susan Calderon was responsible for publishing the finished document (and the searchable database version of the bibliography) online, and Gary Duker and James Lee contributed significantly with editing and document formatting. Maureen Woods at the NOAA Library Seattle, and Patricia Cook at the Northwest and Alaska Fisheries Science Centers Library, located many of the cited documents. Hanane Mtafi, Lorenzo Ciannelli and Susanne McDermott provided language translation assistance. Keith Smith typed many of the abstracts and Paul von Szalay assembled the initial list of citations. Finally, we thank the individual researchers who gave permission to use their abstracts and provided copies of their papers. Publishers granting permissions to use abstracts are duly noted, and acknowledgments are provided within.

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

Keywords: hydraulic clam harvester/ British Columbia

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

Keywords: dredging/ hydraulic cockle dredging/ dredging effects

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

Keywords: baitworm harvesting/benthic disturbance

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

Keywords: heavy tickler chain/ trawl effects

Summary: The majority of this article is a review by Dr. H. A. Cole (Director of the Lowestoft Fisheries Laboratory at the time this article was published). This article addresses the increasing concerns related to the use of heavy tickler chains on commercial trawlers in the Dutch and Belgian sole fisheries. The review discusses the North Sea and areas in the west coast grounds, including Morecambe Bay, Trevose, the Irish Sea and Bristol Channel. Additionally, adverse effects such as damage to young fish, obstruction and damage to gear by boulders, and disturbance and destruction of bottom animals are discussed.

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.

Keywords: fishing effects/ benthic habitat disturbance/ trawling/ dredging/ raking

Summary: This is a report prepared in 1984 by Dobrocky Seatech for the Environmental Protection Service in Nova Scotia, Canada. The report reviews various fishing activities that were occurring, or had occurred, in the Maritime Provinces prior to 1984. Environmental effects on marine benthic habitat due to drag- and handrakes, mechanical and hydraulic harvesters, scallop dredges, otter trawls and ghost fishing are discussed.

Anonymous. 1990. The impact of commercial trawling on the benthos of Strangford Lough. Interim Report No. TI/3160/90. Industrial Science Division, Lisburn, County Antrim.

Keywords: trawling/ commercial trawling/ trawling impacts/ Strangford Lough

Anonymous. 1996. Detection of trawl marks on the sea floor by using sidescan sonar. Marine Geological Assistance, Merelbeke, Belgium. 65 p.

Keywords: trawl mark detection/ seafloor/ sidescan sonar

Anonymous. 1999. 'Effects of trawling' report summarized. Queensland Fisherman. 17(1) : 20-28.

Keywords: trawling effects/ Great Barrier Reef

Anonymous. 1999. Gear Locker: Trawling [Never mind the naysayers. Today's trawls have lower bycatch and are habitat friendly.]. National Fisherman. 80(8) 52.

Keywords: trawling/bycatch/benthic habitat

Ardizzone, G. D. and Migliuolo, A. 1982. Modification of a *Posidonia oceanica* (L.) Delile prairie of the Mid-Tyrrhenian Sea after trawling activity [Modificazioni di una prateria di *Posidonia oceanica* (L.) Delile del medio tirreno sottoposta ad attivita di pesca a strascico]. Naturalista sicil. S. IV, VI (Suppl.), 3 : 509-515.

Keywords: *Posidonia oceanica*/ Mid-Tyrrhenian Sea/ trawling

Abstract: Effects of trawling on *Posidonia oceanica* beds. *Posidonia* beds between Capo Circeo and Terracina (Mid-Tyrrhenian Sea) were studied as part of a study of the effects of illegal trawling inside the three mile limit. More than a hundred stations, placed along transects orthogonal to the shore, were considered. The results obtained show great damage to the *Posidonia* beds: reduction in mean density (leaf shoot/m^2) to less than 50 in most of the area observed, regression of lower borders and wide areas of dead beds.

Ardizzone, G. D. and Pelusi, P. 1983. Fish populations exposed to coastal bottom trawling along the middle Tyrrhenian Sea. Rapports et Proces-Verbaux des Reunions. 28(5) : 107-110.

Keywords: trawling/ environmental impact/ demersal fisheries/ Tyrrhenian Sea

Ardizzone, G. D. and Pelusi, P. 1983. Regression of a Tyrrhenian *Posidonia oceanica* prairie exposed to nearshore trawling. Rapports et Proces-Verbaux des Reunions Conseil International pour l'Exploration Scientifique de la Mer Mediterranee [Rapp. Comm. Int. Mer Medit.]. 28(3) : 175-177.

Keywords: trawling effects/ *Posidonia oceanica*/ Tyrrhenian Sea

Abstract: During a series of observations led in the Tyrrhenian Sea, in order to evaluate the effects of the trawling practiced illegally within three miles from the coast, the state of a 'herier' of *Posidonia* subject to this activity has been studied. The results showed a serious situation of alteration, with a regression of the lower limit and a reduction of the density until less than 50 beams/m^2 for most of the observed zone.

Ardizzone, G. D. and Pelusi, P. 1984. Yield and damage evaluation of bottom trawling on *Posidonia* meadows. Pages 63-72 *in* C.F. Boudouresque, A. Jeudy de Grissac and J. Olivier (eds.). International Workshop on *Posidonia oceanica* Beds. GIS Posidonie, Marseille, France.

Keywords: trawling/ *Posidonia oceanica*/ Tyrrhenian Sea/ fishing impacts/ ROV

Abstract: Bottom trawling on *Posidonia oceanica* beds is a common fishing activity along the Mid-Tyrrhenian Sea coasts. Experimental trawl surveys have been carried out aiming at understanding the yield of this activity in three different areas: inside the *Posidonia* bed and both offshore and inshore. An economic index of output in these areas shows an higher yield for tows carried out inside and inshore the *Posidonia* bed than for the offshore ones. For the evaluation and fast control of the damage suffered by *Posidonia* beds a remotely controlled underwater vehicle which allows rapid and efficient observations has been tested. *Reprinted with author permission (Dr. G.D. Ardizzone).*

Ardizzone, G. D., Tucci, P., Somaschini, A., and Belluscio, A. 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 (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: environmental impact/ illegal trawling/ sediment/ sedimentation/ seagrass

Summary [author's 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* 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 areas, 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. Levels of silt and clay that exceed 10% of the sediment composition will cause a decline in seagrass bed. 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

Armstrong, D. A., Wainwright, T. C., Jensen, G. C., Dinnel, P. A., and Andersen, H. B. 1993. Taking refuge from bycatch issues: Red king crab (*Paralithodes camtschaticus*) and trawl fisheries in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences. 50(9) : 1993-2000.

Keywords: trawling impacts/ trawl fisheries/ bycatch/ crab fisheries/ red king crab/ Bering Sea

Abstract: Concerns about possibly heavy impacts of bottom trawl fisheries on red king crab (*Paralithodes camtschaticus*) pot fisheries in the eastern Bering Sea led in 1987 to an emergency closure of trawling in an area of adult and juvenile crab habitat. We examine the effectiveness of this bycatch refuge in protecting and possibly enhancing the crab resource using three approaches. First, bycatch of crab in trawl fisheries is a small proportion of total estimated abundance throughout the southeastern Bering Sea but may be high relative to stock abundance within the closed area and relative to annual crab landings; recent regulations have diminished this apparent effect. Effects of direct bycatch on the stock are obscured by lack of evidence on indirect effects of trawling, including crushing of crab and degradation of juvenile habitat. Second, surveys inside and outside the refuge before and after closure show no significant changes in abundance of female and prerecruit male crab. Third, important breeding and hatching grounds and juvenile habitat are not protected by the refuge, leaving long-term stock renewal subject to trawl impacts. We suggest that full consideration of the needs of all life history stages could lead to a more effective refuge design. *Reprinted with the permission of NRC Research Press and the Canadian Journal of Fisheries and Aquatic Sciences.*

Arntz, A. B., Moore, H. F., and Kendall, W. C. 1994. Mid- and long-term effects of bottom trawling on the benthic fauna of the German Bight. NIOZ Rapport 1994-11, Netherlands Institute for Fisheries Research, Texel, The Netherlands. 59-74.

Keywords: long-term effects/ bottom trawling/ benthic fauna/ German Bight

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

Keywords: dredging/ dredging impacts/ scallop fishery/ macrobenthos

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. *Reprinted with author permission (Dr. M.M. Aschan).*

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 8th Report of the Benthos Ecology Working Group. ICES CM 1989/L:19.

Keywords: scallop dredging/ benthos impact

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

Keywords: dredging/ scallop dredging/ benthic communities/ Northeast Atlantic

Abstract: In this paper the effects of dredging on the macrobenthos of *Chlamys islandica* fields will be presented. The study was conducted from the research vessel R/V *Johan Ruud* during the summers 1987-1990 in an area south of Jan Mayen at 60-120 m depth and at the northern side of Spitsbergen at 25-80 m depth. Data on the faunal composition was collected by dredging, photography and underwater video recording.

In addition to *Chlamys islandica* the dominating species are *Stongylocentrotus droebachiensis*, *Ophiopholis aculeata*, *Ophiura robusta* and *Astarte* sp. At Jan Mayen both the sea cucumber *Cucumaria frondosa* and the crustaceans *Sabinea septemcarinatus* and *Spirontocaris spinus* are common. In the Svalbard areas, the crustaceans *Hyas coarctatus*, *Sclerocrangon boreas*, *Lebbeus polaris* and *Balanus* which encrusts the scallops are characteristic.

As a result of the scallop dredging the number of species, the number of individuals/sample and the biomass in each sample, diminished from 1987 to 1990 in the Moffen areas (N Svalbard). *Strongylocentrotus droebachiensis* and *Pagurus pubescens* became more dominant during the four years of heavy dredging, because they probably stand the physical disturbance better than other species. In the Jan Mayen area no recovery could be observed two years after the fishery stopped. However, *Ophiura robusta* and polychaetes showed an increase.

Atlantic States Marine Fisheries Commission. 2000. ASMFC guidelines for evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies. Atlantic States Marine Fisheries Commission, Washington, D.C.

Keywords: fishing gear impacts/ aquatic vegetation

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

Keywords: fish harvesting/ trawl effects/ fishing effects/ Biscayne National Park

Abstract: Recreational and commercial harvesting of fishes and invertebrates is permitted in Biscayne National Park (BNP). While there are obvious economic and social benefits associated with fishing in BNP, there may also be insidious effects that reduce ecosystem productivity.

Specifically, these effects are in the form of habitat modification and degradation resulting from the use of certain fishing gears. The purpose of the present study was to determine the extent of the effects of commercial activities which predominate in terms of both human participation and areal coverage, namely, bait shrimp trawling and trapping of spiny lobster, stone crab, and blue crab. This project was composed of three principal components: (1) analysis of existing data; (2) field surveys and ground-truthing; and (3) field experiments. Techniques in scientific data visualization and advanced statistical analysis were used to facilitate assessment and modeling. The major activities and findings of our research program are summarized below.

• Existing data, reports and literature were compiled and analyzed to provide syntheses of the historical development, landings and effort, and current gear and practices for each fishery.

• Spatially-explicit databases pertaining to submerged natural habitats within BNP and adjacent areas of Biscayne Bay were obtained, integrated, and analyzed. The areal extent of each of BNP's five major benthic communities (i.e., seagrass, hardbottom, mixed seagrass/hardbottom, bare bottom, and offshore coral reef) were quantified and mapped.

• Questionnaires were designed and distributed to commercial trap and trawl fishermen to characterize temporal and spatial fishing effort patterns. About 25% of the bait shrimp trawlers responded. No questionnaires were returned from lobster, stone crab or blue crab fishermen. Bait shrimp trawlers operating within BNP fish areas measuring about 165 km^2 during the wet season (June-November) and 350 km^2 during the dry season (December-May). These areas represent about 24.6% and 52.2% of BNP's entire submerged substrate, respectively. Seagrass habitats are the primary habitats trawled, followed by mixed seagrass/hardbottom, and then hardbottoms.

• A series of aerial overflights were conducted to estimate the location and numbers of commercial traps from their surface buoys within BNP. Traps were then inspected using SCUBA and snorkeling techniques to characterize the immediate microhabitat upon which the respective traps were set. Trap "footprints" were also captured on video tape. Lobster and stone crab traps were found primarily over *Thalassia* beds, while blue crab traps were found primarily over *Halodule* beds.

• Controlled trawling experiments were conducted over seagrass and hardbottom communities. Pre-trawl underwater video recordings were compared with post-trawl recordings of five linear transects that had received from one to five rollerframe trawl passes. While we were unable to detect any damage along the seagrass bed transects, damage to sessile invertebrates along the hardbottom transects was conspicuous after one pass. The rate of damage appeared to decrease with subsequent trawling efforts. The sponge *Ircina felix* and the corals of the genus *Pseudoplexaura* appeared to be the taxa most vulnerable to breakage or dislodgement by trawling.

• Trap experiments revealed that damage to underlying seagrasses depended on soak time, trap type and plant species. For lobster traps, mean *Thalassia* loss was approximately 1% of initial plant cover after one day, 7% after one week, and 26% after one month. For stone crab traps mean loss of *Thalassia* cover was 4% after one day, 27% after one week, and 74% after one month. Blue crab traps reduced *Halodule* coverage by 4% after one day, by 24% after one week and by 70% after one month.

• The bait shrimp fishery regularly comes in contact with a largest contiguous areas of BNP's submerged habitat resources. Restriction of commercial bait shrimp fishing in BNP's seagrass habitats cannot be justified solely on the basis of physical habitat damage. However, the issue of juvenile fish and crab bycatch deserves further attention, if not directed research.

• While rollerframe trawling does not appear to damage seagrasses, damage to sessile invertebrates (i.e., sponges and soft corals) in hardbottom communities is conspicuous and is likely to be long-lasting. Hardbottom habitats would undoubtedly benefit from closure of commercial bait shrimping in areas that support high densities of sponges and corals. The feasibility of accurately marking the boundaries of BNP's hardbottom areas and preventing nocturnal trawling within them should be investigated.

• It is essential to conduct a limited number of additional trawl effects experiments in conjunction with areal closures to obtain precise estimates of habitat recovery rates for sponge and soft-coral habitats damaged by commercial trawling activities.

• The primary benthic resource that the three major trap fisheries affect is seagrass habitat. The extent of damage to the habitat is a function of gear soak time, trap type, and the particular seagrass species which constitute the habitat. We strongly recommend that additional field experiments be conducted which focus on the rate at which *Thalassia* and *Halodule* recolonize after being impacted by trap-damage.

• We further recommend that additional measurements of size and spatio-temporal extent of each of the trap fisheries be conducted. These studies are required before definitive estimates of cumulative Park-wide resource damage resulting from commercial trap fishing can be made.

Auster, P. J. 1997. ROV technologies and utilization by the science community. Marine Technology Society Journal. 31(3) : 72-76.

Keywords: ROV/scientific studies/ fishery research technology

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

Keywords: Impacts of fishing gear/ effects of fishing gear/ fish habitats

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 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 Langton, R. W. 1999. The effects of fishing on fish habitat. Pages 150-187 *in* L. R. Benaka (ed.). Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22. Bethesda, Maryland. 22.

Keywords: fishing effects/ fishing impacts/ fish habitat

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 . 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. *Reprinted with the permission of the American Fisheries Society*.

Auster, P. J. and Malatesta, R. J. 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 (eds.). *Marine Protected Areas and Sustainable Fisheries*. Science and Management of Protected Areas Association, Wolfville, Nova Scotia.

Keywords: benthic habitat/ habitat complexity/ non-extractive reserves/ mobile fishing gear/ gear impacts/ biogenic structure

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

Keywords: fishing gear impacts/ mobile fishing gear/ benthic community change/ trawl effects/ sediment disturbance

Summary: This document follows the proceedings of the Northwest Atlantic Fisheries Organization's Scientific Council Meeting in June 1995. The paper addresses the relationship between habitat composition and species type, and discusses the implications of fishing gear impacts on the sustainability of harvested species. Three case studies at different locations in the Gulf of Maine (Swans Island, Jeffreys Bank and Stellwagen Bank) are presented.

Auster, P. J., Malatesta, R. J., Langton, R. W., Watling, L., Valentine, P. C., Donaldson, C. L. S., Langton, E. W., Shepard, A. N., and Babb, I. G. 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. 4(2) : 185-202.

Keywords: ROV/occupied submersible/sidescan sonar/habitat distribution

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 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 to 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. *Reprinted with permission from Reviews in Fisheries Science. Copyright CRC Press, Boca Raton, Florida, USA.*

Auster, P. J., Malatesta, R. J., LaRosa, S. C., Cooper, R. A., and Stewart, L. L. 1991. Microhabitat utilization by the megafaunal assemblage at a low relief outer continental shelf site - Middle Atlantic Bight, USA. Journal of Northwest Atlantic Fisheries Science. 11 : 59-69.

Keywords: microhabitat utilization/ megafaunal assemblage/ continental shelf/ Middle Atlantic Bight/ fishing gear effects

Abstract: Direct underwater observations, using a manned submersible (May 1987) and remote operated vehicle (July and November 1988), were made of the small-scale distribution and microhabitat relationships of the megafaunal assemblage at a 55 m low relief outer continental shelf site (40° 50' N, 70° 55' W). Four microhabitat types were defined: flat sand with amphipod tubes, sand wave crests, shell (single valves and valve aggregates) and biogenic depressions. Microhabitat heterogeneity occurred on the scale of meters. Significant species-specific microhabitat relationships were found. Temperature mediated mesoscale shifts in megafaunal-microhabitat associations were found for several species. *Reprinted with the permission of the Northwest Atlantic Fisheries Organization and the Journal of Northwest Atlantic Fisheries Science.*

Auster, P. J., Michalopoulos, C., Valentine, P. C., and Malatesta, R. J. 1998. Delineating and monitoring habitat management units in a temperate deep-water marine protected area. Pages 169-185 *in* N.W. Munro and J.H.M Willison (eds.). *Linking protected areas with working landscapes, conserving biodiversity* , Proceedings of the Third International Conference on Science and Management of Protected Areas, 12 -16 May 1997. Science and Management of Protected Areas Association, Wolfville, Nova Scotia.

Keywords: marine habitat management/ deep-water

Auster, P. J., Watling, L., and Rieser, A. 1997. Comment: The interface between fisheries research and habitat management. North American Journal of Fisheries Management. 17 : 591-595.

Keywords: habitat management/ fisheries research/ bottom fishing/ mobile fishing gear

Summary: The authors argue against the premise of another paper, concerning management of essential habitats for specific species, that fisheries scientists will learn enough over time to estimate what fish habitats will be worthy of being classified as 'essential.' The authors suggest that this train of thought too closely parallels the inadequacies of recent management strategies in single-species management; that managers, once obtaining relevant life-history information about any or all species, will be able to identify essential habitat needs for each. Furthermore, the authors suggest these assumptions imply that adequate life-history data be obtained before any habitat management action can be taken for a particular species. Instead, the authors propose that known life history data could be utilized immediately in a more broad management stratagem to conserve a variety of "sensitive" habitats (habitats related to the unpredictable settling of juveniles), which are not exclusive from essential habitats. It is further suggested that this would allow for the unpredictable nature of juvenile settlement, and for the current limited knowledge of essential habitat and how it is impacted by current fishing practices.

Bailey, C. 1997. Lessons from Indonesia's 1980 trawler ban. Marine Policy. 21(3) : 225-235.

Keywords: trawlers/ fishery management/ Indonesia

Abstract: In 1980 the Indonesian government imposed a ban on trawling along the Malacca Straits and off the north coast of Java, the nation's two most important fishing grounds. The ban on trawling was extended nation-wide in 1981, effectively eliminating a highly productive type of fishing gear and the most important source of shrimp for the lucrative international market. The political nature of this decision and factors contributing to what has proven to be effective enforcement are discussed. Data on the Malacca Straits and the north coast of Java are used to assess the consequences of the trawler ban on the demersal fisheries. Prior to the trawler ban, little or no growth occurred in numbers of fishers, numbers of small-scale demersal gear, or landings by small-scale demersal gear. After 1980, however, small-scale demersal fisheries experienced dramatic growth, generating significant new employment opportunities but raising anew serious resource management problems. *Reprinted from Marine Policy, Vol. 21; Bailey, C.; Lessons from Indonesia's 1980 trawler ban; pages 225-235; Copyright (1997); with permission from Elsevier Science.*

Ball, B., Fox, G., and Munday, B. 2000. Long and short term consequences of otter trawling on the *Nephrops* fishing grounds of the NW Irish Sea. ICES Journal of Marine Science.

Keywords: trawling impacts/ lobster fishery/ Nephrops/ Irish Sea

Ball, B., Munday, B., and Tuck, I. 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 (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: muddy sediments/ trawling/ community change/ habitat alteration/ alternative stable state

Summary [author's 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 bycatch 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. These 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

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

Keywords: fishing gear impacts/ essential fish habitat/ Gulf of Mexico

Baulch, H. 1999. Clear-cutting the ocean floor: trawling gear devastates the world's continental shelves. Alternatives Journal. 25(3) : 7.

Keywords: trawling effects/ fishing gear impacts

Summary: A brief article arguing the various negative effects commercial trawling has on benthic habitats. The viewpoints of many professionals involved with research in this subject are cited.

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

Keywords: trawling/ southeast Alaska

Belliveau, D. J., Milligan, T. G., Cranford, P., Chin-Yee, M., Steeves, G., McKeown, D. L., Vass, P., and Muschenheim, D. K. 1997. New equipment for benthic habitat studies. Proceedings of Oceans '97. 1 : 374-379.

Keywords: instruments/ sensors/ samplers/ video/ otter trawling/ benthic habitat

Abstract: This paper presents an overview of new systems used in benthic habitat studies at the Bedford Institute of Oceanography. These new systems include towed, profiling and moored instruments. A partial list of sensors used in these systems includes high resolution video, silhouette cameras, hydraulic bottom grab, surficial floc sampler, water bottles and a near bottom multi-level water sampler. These systems have been used to study the effects of otter trawling on benthic habitat and biological communities and/or the fate of particulate drilling wastes around offshore rigs. *Belliveau, D.J., Milligan, T.G., Cranford, P., Chin-Yee, M., Steeves, G., McKeown, D.L., Vass, P. and Muschenheim, D.K. 1997, IEEE. Reprinted, with permission, from Oceans '97; Halifax, Nova Scotia, Canada, 6-9 October, 1997; pp. 374-379.*

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

Keywords: fishing gear/ beamtrawl gear/ beamtrawl

Summary: This reports constitutes a collection of three studies conducted in the late summer/early fall of 1989 in the North Sea. The primary issues addressed in these studies were beamtrawl gear penetration depths in differing sediment types, and the resulting impacts on the benthic communities.

BEON (Beleidsgericht Ecologisch Onderzoek Noordzee). 1991. Effects of beamtrawl 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.

Keywords: beamtrawl fishery/ beamtrawl effects/ bottom fauna/ gear penetration/ benthic disturbance/ bycatch/ benthos/ North Sea

Summary: A collection of three papers based on beamtrawl studies conducted from 20-31 of August, 1990 near the Borkum Riff in the North Sea. The reports focus on three primary categories of investigation: 1) how gear penetrates into the sediments, 2) benthos, fish and bycatch survival in the trawl codends during trawling, and 3) the long-term effects to benthic habitats. Results in each study are reported, respectively.

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.

Keywords: trawling/ trawl impacts/ demersal fishery

Bergman, M. J. N. 1991. Long term effects of beamtrawl fishing on the benthic ecosystem in the North Sea. Pages 69-89 *in* Effects of Beamtrawl Fishery on the Bottom Fauna in the North Sea, II: the 1990 studies. BEON-RAPPORT 13.

Keywords: beamtrawl fishing/ beamtrawl effects/ benthic ecosystem/ North Sea

Summary: The is one of the studies conducted and presented in *BEON report effects of beamtrawl fishery on the bottom fauna in the North Sea II - The 1990 studies*. To study the long-term effects of trawling on benthic habitats in the North Sea, two areas in and around Borkum Riff were trawled; a region of relatively low trawled habitat in the Riff, and an area somewhat heavily trawled around the Riff. Due to the results of the statistical analyses, it was suggested that long-term effects of beamtrawling on species composition of fish and epifauna could not be demonstrated in this study. One problem suggested that the type of gear (boxcorer and 2.8 m beamtrawl) used prevented fauna from being sampled effectively. Another problem was the uncertainty about the historical trawling intensity in both areas surveyed. In regards to future research, suggestions were made for the use of different survey gear (benthos dredge), and for the designation of no-trawl zones where future studies could be conducted.

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

Keywords: bottom trawling/ environmental impact/ benthic environment/ North Sea

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-I (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. *Reprinted with the permission of the Netherlands Institute for Sea Research (NIOZ). 1999.*

Bergman, M. J. N., Fonds, M., Hup, M., and Stam, A. 1990. Direct effects of beamtrawl fishing on benthic fauna in the North Sea. ICES CM 1990/MINI:11. Copenhagen, Denmark. 19 p.

Keywords: bottom trawling/ benthic disturbance/ North Sea/ zoobenthos/benthic community structure

Abstract: Direct effects of beamtrawling on benthic species in the North Sea were determined by comparing faunal abundances before and after commercial beamtrawling on hard-sandy sediments. Three-fold trawling resulted in a decrease in density (10-65%) of a number of species (echinoderms, polychaete worms and molluscs). Mortality of a number of species which were caught in the nets and treated on board 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 in 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 beamtrawling 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 beamtrawling 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 beamtrawl 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 Hup, M. 1992. Direct effects of beamtrawling on macrofauna in a sandy sediment in the southern North Sea. ICES Journal of Marine Science. 49(1) : 5-11.

Keywords: trawling/ benthic fauna/ beam trawling/ fishing effects/ sandy sediments/ North Sea

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 van Santbrink J. W. 1994. A new benthos dredge ('triple-D') for quantitative sampling of infauna species of low abundance. Netherlands Journal of Sea Research. 33 : 129-133.

Keywords: dredging/ benthos/ quantitative sampling/ infauna abundance

Bergman, M. J. N. and van Santbrink J. W. 1994. Direct effects of beam trawling on macrofauna in a soft bottom area in the southern North Sea. Environmental impact of bottom gears on the benthic fauna in relation to natural resource management and protection of the North Sea. NIOZ Rapport 1994-11. RIVO-DLO Report CO 26/94. Netherlands Institute for Fisheries Research, Texel, The Netherlands. 179-208.

Keywords: beam trawling/ macrofauna/ North Sea/ soft bottom

Bergman, M. J. N. and van Santbrink, J. W. 2000. Fishing mortality of populations of megafauna in sandy sediments. Pages 49-68 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: bottom-trawling impacts/ fishing mortality/ megafaunal populations/ sustainable fisheries

Summary [author's 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 mortality of animals that died in the trawl track, either as a direct result of 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 th 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

Berkely, S. A., Pybas, D. W., and Campos, W. L. 1985. Bait shrimp fishery of Biscayne Bay. Florida Sea Grant College Program Technical Paper No. 40. 16 p.

Keywords: bait shrimp fishery/ habitat disturbance/ roller trawls

Summary [author's summary]: The value of the Biscayne Bay bait shrimp fishery is considerable. In 1983 the estimated total commercial bait shrimp harvest from the Bay was 36.4 million shrimp worth $1.1 million at dock side (assuming an average ex-vessel price of $30 per 1,000) or approximately $3.0 million at retail (assuming an average retail price of $1.00 per dozen). The availability of live bait for sale makes the existence of retail bait and tackle stores possible and provides a valuable support service for the local tourist industry. However, while the economic and social value of the fishery is undeniable, the possible detrimental effects of the fishery on the biota or the environment are potentially of greater consequence and must be considered in evaluating the future of the fishery. Annual mean CPUE's from 1971-1983 have remained relatively stable, suggesting that the fishery has not significantly affected the habitat's ability to function as a shrimp nursery. Species composition and community structure of juvenile fish in Biscayne Bay appears to have remained unchanged since the mid 1960's. However, it does not follow that effects of the bait shrimp fishing operations are non-existent. While natural mortality is undoubtedly quite high among these small juvenile fishes, and the estimated total catch of these species by the bait shrimp fleet is relatively small, the effect of the fishery on subsequent gamefish recruitment cannot be evaluated without knowing the magnitude of fishing mortality relative to all other sources of natural mortality. In addition to estimates of natural and fishing mortality, ecological information, such as habitat and trophic interactions between juvenile fishes and shrimp, would be necessary to evaluate and quantify the impact of the fishery on the fish populations in the Bay.

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. 33(2) : 219-227.

Keywords: *Arenicola*/ *Mya*/ tidal flats/ fishery effects/ long-term changes

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. *Reprinted from Netherlands Journal of Sea Research, Vol. 33; Beukema, J.J.; Long-term effects of mechanical harvesting of lugworms*

Arenicola Marina on the zoobenthic community of a tidal flat in the Wadden Sea; pages 219-227; Copyright (1995); with permission from Elsevier Science.

Blaber, S. J. M., Brewer, D. T., Burridge, C., Caeser, D., Connell, M., Dennis, D., Dews, G. D., Glaister, J., Gribble, N., Hill, B. J., Milton, D. A., Pitcher, R., Poiner, I. R., Salini, J. P., Thomas, M., Veronise, S., and Wassenberg, T. J. 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.

Keywords: trawling/ fishing effects/ Great Barrier Reef

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

Keywords: sediment disturbance/ dredging/ scallop fisheries/ Port Phillip Bay/ Australia

Abstract: The first direct measurements of turbidity caused by scallop dredging are presented. The physical effects of scallop dredging on the sediments 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, suspended concentrations above natural levels were confined to a region within c.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. *Reprinted with the permission of the Queensland Museum and Memoirs of the Queensland Museum.*

Blackburn, J. and Schmidt, D. 1988. Injury and apparent mortality rates from incidental trawl catches of halibut, king crab, and Tanner crab in the Kodiak area, 1977-81. Regional Information Report 4K88-21. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Keywords: incidental trawl catch/ bycatch/ Kodiak/ Alaska/ mortality

Bradshaw, C., Veale, L. O., Hill, A. S., and Brand, A. R. 2000. The effects of scallop dredging on gravelly seabed communities. Pages 83-104 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: scallop dredging/ benthic community disturbance/ long-term effects/ community change

Summary [author's 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

Bradstock, M. and Gordon, D. P. 1983. Coral-like bryozoan growths in Tasman Bay, and their protection to conserve commercial fish stocks. New Zealand Joumal of Marine and Freshwater Research. 17(2) : 159-163.

Keywords: *Celleporaria agglutinans*/ *Hippomenella vellicata*/ fisheries/ marine ecology/ resource conservation/ Tasman Bay/ Australia

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*, *Hippomenella 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. *Reprinted with the permission of the Royal Society of New Zealand and the New Zealand Journal of Marine and Freshwater Research.*

Brailovskaya, T. 1998. Obstacles to protecting marine biodiversity through marine wilderness preservation: examples from the New England region. Conservation Biology. 12(6) : 1236-1240.

Keywords: marine biodiversity/ commercial fishing/ New England

Abstract: The amount of terrestrial protection achieved for biodiversity through designation of no-take public wilderness areas in the United States is much greater than no-take protection in the nation's National Marine Sanctuary System. With the exception of a small area in the Florida Keys, no permanent reserve in the United States protects marine biodiversity from commercial fishing with gear that has strong effects on marine habitats and which has been identified as one of the major threats to marine biodiversity. A recent national poll has shown that public support does exist for conservation of the marine environment and protection of marine biodiversity. The New England region provides examples of the obstacles that such support may face in regions with a long history of commercial exploitation of marine species. I discuss the overall Influence that the commercial fishing industry in New England has had on marine conservation efforts in the region, contrast the public's perception of marine versus terrestrial wildlife species, and describe the nature of the media's coverage of the commercial fishing industry and fisheries management issues in the region. I propose the creation of a national no-take marine wilderness preservation system as a way to achieve protection of marine biodiversity as a separate goal from sustainable fisheries management in New England and other; similar regions in the United States.

Brambati, A. and Fontolan, G. 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. 8(2) : 113-121.

Keywords: dredging/ environmental impact/ sediment disturbance/ hydraulic dredge/ Gulf of Venice/Adriatic Sea

Brand, A. R., Allison, E. H., and Murphy, E. J. 1991. North Irish Sea scallop fisheries: a review of changes. Pages 204-218 in S.E. Shumway and P.A. Sandifer (eds.). An International Compendium of Scallop Biology and Culture. World Aquaculture Society, Baton Rouge, LA.

Keywords: North Irish Sea/ scallop fisheries/ dredging

Brand, A. R. and Hawkins, S. J. 1996. Assessment of the effects of scallop dredging on benthic communities. Interim Report to Ministry of Agriculture, Fisheries and Food. February, 1996.

Keywords: dredging/ scallop dredging/ fishing effects/ benthos

Brewer, D. T., Eayrs, S. J., Rawlinson, N. J. F., Salini, J. P., Farmer, M., Blaber, S. J. M., Ramm, D. C., Cartwright, I., and Poiner, I. R. 1997. Recent advancements in environmentally friendly trawl gear research in Australia. Pages 537-543 *in* Developing and sustaining world fisheries resources. The state of science and management. CSIRO, Collingwood, Australia.

Keywords: demersal fisheries/ trawl nets/ gear research/ gear selectivity/ environmental impact/ Australia coasts

Abstract: The effects of demersal trawling on marine communities in Australia are a major concern for the industry, managers, conservation agencies and the Australian public. Australian researchers have recently developed and tested fish trawls that decrease the impact on benthic communities and unwanted bycatch populations in tropical waters, and developed and tested a range of bycatch reduction devices (BRD) for prawn trawls in New South Wales and North Eastern Australia. Scientific trials of several devices demonstrated significant reduction in the amount of unwanted bycatch, exclusion of turtles and other large animals, and one -- the Super Shooter – maintained commercial catches of prawns. Planned commercial trials will improve the performance of these devices and facilitate their implementation into Australia's fisheries. When BRD's are widely adopted the decreased impact of trawling on bycatch populations will address key issues relating to their impact on marine communities. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia (Books Section).*

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

Keywords: trawling/ trawl effects/ seabed disturbance

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

Keywords: sediment disturbance/ trawl effects/ tickler chains

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

Keywords: commercial digging/ disturbance/ baitworms/ clams/ soft-sediment community/ *Heteromastus filiformis*/ *Streblospio benedicti*/ *Tharyx acutus*

Abstract: This study assessed the influence of commercial digging for worms and clams of a mudflat on the associated benthic infaunal community in Lowes Cove, Walpole, Maine, USA. Four replicate experimental sites were established within each of which were two 1 m^2 digging plots and one 1 m^2 undug, control plot. Digging was done with a four-tined hoe by thrusting the tines into the sediment surface and pulling the sediment towards the digger. Such digging was repeated until an entire plot was dug. Two digging intensities were analyzed: low frequency digging (plot was dug twice a month) and high frequency digging (plot was dug twice a week). By the end of the 2.5 month experiment, the density of polychaetes *Heteromastus filiformis* (Claparede), *Streblospio benedicti* (Webster and Benedict), and *Tharyx acutus* (Webster and Benedict) as well as the total number of taxa were significantly reduced in the plots that had been dug (regardless of frequency) relative to those of the control. Other densities (total number of individuals, *Scoloplos fragilis* (Verrill), *Exogone hebes* (Webster and Benedict), *Hydrobia totteni* (Morrison), total oligochaetes) were not affected by the digging. The lack of undug mudflats in Maine makes comparison of these results to benthic communities in undisturbed areas virtually impossible. *Reprinted from Journal of Experimental Marine Biology and Ecology, Vol. 218; Brown, B. and Wilson Jr., W.H.; The role of commercial digging of mudflats as an agent for change of infaunal intertidal populations; pages* 49-61*; Copyright (1997); with permission from Elsevier Science.*

Brown, R. A. 1989. Bottom trawling in Strangford Lough: problems and policies. Proceedings reprints. Distress signals: signals from the environment in policy and decision-making, May 31 - June 2, 1989. Rotterdam, Netherlands. 117-127.

Keywords: bottom trawling/ Strangford Lough

Brylinsky, M., Gibson, J., and Gordon, D. C. 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. 51(3) : 650-661.

Keywords: flounder trawls/ physical disturbance/ biological effects/ recovery/ intertidal/ Minas Basin/ Bay of Fundy

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 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. *Reprinted with the permission of NRC Research Press and the Canadian Journal of Fisheries and Aquatic Sciences.*

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

Keywords: dredging/ scallop dredging/ fishing effects/ Skomer Marine Reserve

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

Keywords: dredging/ scallop dredges/ fishing effects/ Jervis Bay/ Australia

Summary: Responding to reports made by area divers that dredging activities were significantly harming scallop populations in Jervis Bay, Australia, a study was conducted to investigate scallop dredging impacts and to compare scallop densities with data from ten years prior. Sediments consisted mostly of large-grained sand, and the macrobenthic species composition was relatively low. After passage of a trawl, sediments settled quickly. Old trawl tracks not made in the study were discerned. Aside from the sediment disturbance, no other impacts to habitat were readily observed. Scallop population structure was found to be unchanged from results 10 years earlier. Scallop damage due to dredging was evident, but the ratio of scallops damaged to undamaged was relatively small.

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

Keywords: scallop dragging/ dredging

Caddy, J. F. 1970. Records of associated fauna in scallop dredge hauls from the Bay of Fundy. Fisheries Research Board of Canada Technical Rep. 225. 11 p.

Keywords: scallop dredge/ Bay of Fundy

Caddy, J. F. 1971. Efficiency and selectivity of the Canadian offshore scallop dredge. ICES Shellfish and Benthos Committee Document. 1971/K25:7.

Keywords: scallop dredge

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

Keywords: dredge tracks/ trawl tracks/ dredging effects/ gear impacts

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 interval 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. *Reproduced with the permission of Her Majesty the Queen in Right of Canada, 1999, and Fisheries and Oceans Canada*.

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

Keywords: fishing effects/ *Buccinum undatum*/ Dutch Wadden Sea

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.

Keywords: scallop dragging/ underwater television equipment

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

Keywords: seabed disturbance/ trawling/ fishing effects

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.

Keywords: fishing gear disturbance/ trawling/ mobile fishing gear/ Bras d'Or Lakes

Cardador, F., Sanchez, F., Pereiro, F., Borges, M. F., Caramelo, A., Azevedo, M., and Fernandez, A. 1997. Groundfish surveys in the Atlantic Iberian waters (ICES division VIIIc and IXa): history and perspectives. ICES CM 1997/Y:08, 25 p.

Keywords: groundfish/ trawling/ Atlantic Iberian

Carr, H. A. and Milliken, H. 1998. Conservation engineering: options to minimize fishing's impacts to the sea floor. Pages 100-103 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea Floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: trawling gear/ gear technology/ gear designs/ fishing impacts/ habitat disturbance

Summary: A paper discussing the technological advances in demersal fishing over the last 20 years, with emphasis on the improvements in trawl gear designs. Different gear designs are discussed, as well as the impacts to the respective habitat types where they are used. Methods to further reduce impacts to habitat by improving gear design, limiting trawling terrain, and changing to fixed gears are suggested.

Chapman, C. J., Mason, J., and Kinnear, J. A. M. 1977. Diving observations on the efficiency of dredges used in the Scottish fishery for the scallop, *Pecten maximus* (L). Scottish Fisheries Research Report No 10. Department of Agriculture and Fisheries for Scotland, Aberdeen, Scotland. 16 p.

Keywords: dredge/ dredging/ dredge efficiency/ scallop dredging/ *Pecten maximus* L.

Abstract: The efficiency of standard and spring-loaded scallop dredges is low. Standard dredges with a fixed tooth bar caught about 20% of all scallops in their path. Dredges with a spring-loaded toothed bar caught 13%. Both gears were highly selective and, at most, only 4% of scallops below 80 mm in size were caught. For commercial sized scallops (80 mm) the average efficiencies were 25% for standard and 15% for spring-loaded dredges. Most of the scallops were pushed aside by the build-up in sediments in front of the toothed bar of the standard dredge. A small mortality (about 3%) occurred in severely damaged scallops missed by the dredges. The overall efficiency of the dredge can be divided into two components: the selectivity of the teeth and meshes (S) and the catching efficiency (E). The results for different gears are discussed in relation to these components and it is suggested that both are strongly influenced by the nature of the sea bed.

Chin-Yee, M. B., McKeown, D. L., and Steeves, G. D. 1997. Proven equipment for selectively sampling the seafloor. Proceedings of Oceans '97. 1(MTS/IEEE) 766 p.

Keywords: benthos collecting devices/ seafloor sampling equipment/ samplers/ BRUTIV / Benthic Video Grab/ Campod

Summary: This paper compares and discusses various seafloor sampling equipment that provides high resolution visual information as well as sizable quality controlled benthic samples. Equipment discussed is the Bottom Referencing Underwater Towed Instrumentation Vehicle (BRUTIV), the Benthic Video Grab and the Campod.

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

Keywords: fishing gear/ fish escape

Christian, P. A. and Harrington, D. L. 1985. Alternative fisheries development: a summary of Georgia's cooperative alternative fishery development and fishing demonstration project for 1984. Technical Report Series No. 85-5. Georgia Marine Science Center, University System of Georgia, Skidaway Island, Georgia. 76 p.

Keywords: alternative fisheries development/ trawling gear/ southeaster coast/ Georgia/ USA

Abstract: In the spring of 1984, six vessel operators participated in a cooperative effort to investigate the feasibility of using traditional shrimp boats for harvesting fin fishes. Concurrently, another shrimp boat operator was interested in the harvesting of royal red shrimp (*Hymenopenaeus robustus*) and deep-water crabs, such as red crabs (*Geryon* sp.) and rock crabs (*Cancer* sp.).

Most of the craft engaged in this project were shrimp trawlers. They converted to bottom longlining, fish trawling, or deep-water shrimp trawling. In addition, a snapper boat, which was built to fish with snapper reels (or "bandit rigs") was converted to bottom longlining. Results

presented include the following: (1) Descriptions of boat conversions and cost data. (2) Diagrams and descriptions of gear modifications. (3) Descriptions of fishing methods. (4) Trip summaries, including market outlets, prices, expenses, problems, and solutions. *Reprinted with author permission (P.A. Christian).*

Christian, P. A., Rivers, J. B., Rawson, M. V., Harrington, D. L., and Parker, L. G. 1985. Trawling off the Southeastern U.S. Coast. Georgia Sea Grant Marine Extension Bulletin No. 8. 28 p.

Keywords: trawling/ trawl gear/ effects /southeastern coast/ USA

Summary: This bulletin was produced by the Georgia Sea Grant Marine College Program in response to the "financially precarious" shrimping industry in the South Atlantic Bight. Weather-induced mortality to shrimp stocks, fuel costs, and increasing numbers of shrimping vessels caused many fishermen to trawl for finfish as a means of supplementing their income. This bulletin provides information on how to modify a shrimping vessel for fish trawling, by discussing gears used, fishing tips and regions to fish.

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

Keywords: trawling/ trawling impacts/ sediment resuspension/ Middle Atlantic Bight/ continental shelf/ Nantucket Shoals

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 outer shelf sediments. *Reprinted from Continental Shelf Research, Vol. 9; Churchill, J.H.; The effect of commercial trawling on sediment resuspension and transport over the Middle Atlantic Bight Continental-shelf; pages 841-864; Copyright (1989); with permission from Elsevier Science.*

Churchill, J. H. 1998. Sediment resuspension by bottom fishing gear. Pages 134-137 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: sediment disturbance/ trawl effects/ sediment resuspension

Summary: This is an article in which the author uses his knowledge to discuss the broad-reaching effects of sediment resuspension from trawling. At the end of the paper, the author makes suggestions as to what studies are needed to better understand the impact of resuspending marine sediments by bottom fishing gear.

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.

Keywords: mechanical harvesting/ shellfish fishery

Coffen Smout, S. S. and Rees, E. I. S. 1999. Burrowing behavior and dispersion of cockles *Cerastoderma edule* L. following simulated fishing disturbance. Fisheries Research. 40(1): 65-72.

Keywords: displacement/ fishing impacts/ reburrowing/ recolonization/ *Cerastoderma edule*

Abstract: Field experiments were conducted on the cockle *Cerastoderma edule* L. to study effects of simulated harvesting on reburrowing behavior, displacement by tides, and recolonization of cleared patches. The study was prompted by needs to interpret results when experimental mechanized harvesting is conducted in relatively small plots from which discards that should survive are lost or which are recolonized by immigrant adults. Simulation of machine-induced physical shocks caused delays to the normal cockle reburrowing response. Small (<20 mm) cockles were less affected than those of a size to be retained in the landed catch (>20 mm) and more of all sizes reburrowed if deposited in pools rather than on wet sand. None reburrowed into drained sand. Tagged and marked cockles failing to reburrow were transported up the shore with the flow of the flood tide, some being found again 200 m away. Many of these reburrowed at new positions. On a gently sloping macro-tidal shore the tidally mediated displacement varied with the predicted tide range. Theoretical estimates based on tide curves and extrapolations from formulae for tidal bores suggested that in the front of the flooding tide across the intertidal flat, current speeds reach 0.62 m/s on an 8.28 m spring tide. Very slight displacement took place on a neap tide, the critical speed of tide advance to displace exposed cockles being about 0.3 m/s. The majority of tagged cockles that reburrowed before the first flood tide came in subsequently remained where they had re-established themselves. Those moved to new positions stayed where they had been carried to. Extrapolation, from the slight decline in numbers still present, suggested that from a population of 80 per m^2 roughly 12 would have moved to new positions in 14 days. This compares with unmarked individuals recolonizing plots, cleared at 14-day intervals, at <3/m^2/14 days. *Reprinted from Fisheries Research, Vol. 40; Coffen Smout, S.S. and Rees, E.I.S.; Burrowing behaviour and dispersion of cockles Cerastoderma edule L. following simulated fishing disturbance; pages 65-72; Copyright (1999); with permission from Elsevier Science.*

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 (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: fishing effects/ fishing gear impacts/ New England

Summary: This paper discusses the effects of fishing gear at three locations of the Gulf of Maine; Swans Island, Jeffreys Bank and Georges Bank. Bottom sediments and levels of disturbance are described for each location, with emphasis on George's Bank.

Collie, J. S., Escanero, G. A., Hunke, L., and Valentine, P. C. 1996. Scallop dredging on Georges Bank: photographic evaluation of effects on benthic epifauna. ICES C.M. 1996/Mini:9. 14 p.

Keywords: habitat disturbance/ benthic communities/ Georges Bank/ *in situ* photography

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

Keywords: benthic communities/ fishing impacts/ habitat disturbance/ scallop dredging

Abstract: This study addresses ongoing concerns over the effects of mobile fishing gear on benthic communities. Using sidescan 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 busby 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. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Collie, J. S., Hall, S. J., Kaiser, M. J., and Poiner, I. R. (In press). Shelf sea fishing disturbance of benthos trends and predictions. Journal of Animal Ecology.

Keywords: fishing disturbance/ shelf/ benthos

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

Keywords: dredging/ oyster shell dredging/ benthic disturbance/ species composition

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 (Czechanowski'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. North Western and North Wales Sea Fisheries Committee. 30 p.

Keywords: hydraulic dredging/ dredging impacts/ cockle/ macrobenthos

Cote, I. M., Vinyoles, D., Reynolds, J. D., Doadrio, I., and Perdices, A. 1999. Potential impacts of gravel extraction on Spanish populations of river blennies *Salaria fluviatilis* (Pisces, Blenniidae). Biological Conservation. 87(3) : 359-367.

Keywords: gravel extraction/ *Lipophrys fluviatilis*/ *Blennius fluviatilis*/ environmental disturbance/ conservation/ Mediterranean freshwater fish

Abstract: River blennies *Salaria fluviatilis* have a wide circum-Mediterranean distribution, but they are mostly confined to small, very localized populations. In the Iberian Peninsula, they are endangered due to a variety of causes, including gravel extraction. This study identified the breeding requirements of river blennies at a site where gravel extraction takes place and at three other sites in different drainage basins in Spain. Breeding males chose nest stones that were significantly larger than other stones available in the immediate vicinity. Although clutch area was significantly related to stone size in two of three populations, male size was not. Stone size appeared to be the main correlate of clutch size, and stone sizes were significantly smaller at sites where gravel had been extracted. The potential effects of stone and gravel removal on nesting density and egg productivity were simulated, and it was found that a 75% reduction in stone size, as observed in this study, could result in a 47% decrease in nesting density. Because of the relationship between clutch size and nest stone size, egg production would be reduced even further, to 25% of its initial level. Removal of stones and gravel from the river bed also causes structural alterations which may render the habitat unsuitable for breeding blennies despite the presence of apparently suitable nest stones. Our results may be applicable to the conservation of other substrate-spawning fish. *Reprinted from Biological Conservation, Vol. 87; Cote, I.M., Vinyoles, D., Reynolds, J.D., Doadrio, I. and Perdices, A.; Potential impacts of gravel extraction on Spanish populations of river blennies Salaria fluviatilis (Pisces, Blenniidae); pages 359-367; Copyright (1999); with permission from Elsevier Science.*

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

Keywords: tractor dredger/ cockles/ Burry Inlet/ South Wales

Craeymeersch, J. A. 1994. Environmental impact of bottom gears on benthic fauna in relation to natural resource management and protection of the North Sea. NIOZ -Rapport 1994-11/RIVO-DLO Report CO 26/94. 209-236.

Keywords: gear impact/ benthic fauna/ bottom gear/ environmental impact/ North Sea

Craeymeersch, J. A., Piet, G. J., Rijnsdorp, A. D., and Buijs, J. 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 (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: benthic community/ fishing effort/ spionid worms/ trawling/ macrofauna

Summary [author's 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

Cranfield, H. J., Michael, K. P., and Doonan, I. J. 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. 9(5) : 461-484.

Keywords: oyster dredging/ Foveaux Strait/ New Zealand

Creutzberg, F., Duineveld, G. C. A., and van Noort, G. J. 1987. The effect of different numbers of tickler chains on beam-trawl catches. Journal du Conseil International pour L'exploration de la Mer. 43(2) : 159-168.

Keywords: trawling/ catch efficiency/ tickler chains

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

Keywords: scallop fisheries/ bottom trawling/ zoobenthos/ environmental impact/ Australia/ Victoria/ Port Phillip Bay

Abstract: Changes to benthic infauna caused by scallop dredging in Port Phillip Bay, Victoria, Australia, were examined experimentally using a BACI (Before, After, Control, Impact) design. Analysis of 150 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 structure between the control and dredge plots through time enabled a test of the statistical significance of change following dredging. Multi-dimensional scaling was used to describe patterns of change. Statistically significant ($0.05 < p < 0.10$) changes to community structure were detected; ecological significance of the changes requires further analysis. *Reprinted with the permission of the Queensland Museum and Memoirs of the Queensland Museum.*

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

Keywords: BACI/ benthic community/ environmental impact/ scallop dredging/ fishing impact

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. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Currie, D. R. and Parry, G. D. 1999. Impacts and efficiency of scallop dredging on different soft substrates. Canadian Journal of Fisheries and Aquatic Sciences. 56(4) : 539-550.

Keywords: bottom trawling/ scallop dredging/ environmental impact/ *Pecten fumatus*/ Australia/ Port Phillip Bay

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 × 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 licenses offers a unique opportunity to determine the contribution of scallop dredging to ecological changes in the bay over the past 30 years. *Reprinted with the permission of NRC Research Press and the Canadian Journal of Fisheries and Aquatic Sciences.*

Daan, N. 1991. Theoretical approach to the evaluation of ecosystem effects of fishing in respect of North Sea benthos. ICES CM 1991/L:27, 9 p.

Keywords: bottom trawling/ environmental impact/ North Sea/ benthos

Daan, N. and Richardson, K. (eds.). 1996. Changes in the North Sea ecosystem and their causes: Århus 1975 revisited. ICES Journal of Marine Science. 53 : 1-1225.

Keywords: North Sea/ changes/ fishing/ trawling effects

Dahm, E. 1993. Effects of set nets and trawl nets on marine organisms and their environment. Arbeiten des Deutschen Fischerei-Verbandes. (57) : 23-41.

Keywords: trawling impacts/ ecosystem disturbance/ benthic communities

Dare, P. J. 1974. Damage caused to mussels (*Mytilus edulis* L.) by dredging and mechanized sorting. Journal du Conseil International pour L'exploration de la Mer. 35(3) : 296-299.

Keywords: dredging/ mechanized sorting/ shell damage

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/ 10 p.

Keywords: dredging/ molluscan fisheries/ benthos/ substrates

Dare, P. J., Key, D., and Connor, P. M. 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.

Keywords: dredging/ gear selectivity/ commercial fishing/ *Pecten maximus*/ English Channel

Dayton, P. K. 1996. Environmental impacts of fishing on marine communities: working group report. Proceedings of the Solving Bycatch Workshop, September 25-27, 1995, Seattle, WA. Alaska Sea Grant College Program, Fairbanks, AK. 321-325.

Keywords: fishing impacts/ trawling

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

Keywords: environmental impact/ trawling/ ecosystem disturbance/ zoobenthos/ fishery management

Summary: This article addresses the effects of demersal fishing on benthic marine communities, and warns that such activities may potentially alter these habitats to such a degree as to result in "cascading ecological changes," or the inability to return to natural, intact conditions. Furthermore, it is indicated that successive generations of scientists may have different notions of what is natural because they study increasingly altered systems that become less and less similar to the original pristine conditions. The author suggests that firmer restrictions be applied in current fishing practices, and that more emphasis be placed on the importance of preserving marine systems as opposed to exploiting them for profit.

Dayton, P. K., Thrush, S. F., Agardy, M. T., and Hofman, R. J. 1995. Viewpoint: Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater Ecosystems. 5(3) : 205-232.

Keywords: habitat damage/ benthic communities/ bottom fishing gear/ environmental impacts

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 1' and 'Type II' errors is advocated.

De Alteris, J., Skrobe, L., and Lipsky, C. 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. R. Benaka (ed.). Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22. Bethesda, Maryland.

Keywords: seabed disturbance/ mobile fishing gear/ fishing effects/ dredging/ trawling/ trawling effects

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. Sidescan 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. *Reprinted with the permission of the American Fisheries Society*.

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

Keywords: tickler chains/ heavy tickler chains/ gear impacts

De Clerck, R. and Vanden Broucke, G. 1980. Preliminary results of selectivity experiments with beam trawls. ICES Council Meeting Papers. Copenhagen, Denmark. 6 p.

Keywords: gear selectivity/ beam trawls

De Graaf, U. H. and De Veen, J. F. 1973. *Asterias rubens* and the influence of the beam trawl on the bottom fauna. ICES Shellfish and Benthos Committee. ICES CM 1973/K:37. 8 p.

Keywords: beam trawl/ gear impacts/ fishing effects/ *Asterias rubens*

Summary: In this study, difference in percentage abundances of sea stars, *Asterias rubens*, in the process of regenerating missing arms were used to try and indicate the magnitude of trawling activity, and the resulting effects on the benthos, in localized waters of the North Sea, the Dutch Wadden Sea, the Zeeland estuary, the Irish Sea and the Bristol Channel. At the end of the study, results agreed with previous literature that beamtrawl fisheries were mainly responsible with the injury to starfishes resulting in regenerating arms. It was also found that significant differences existed between shrimp beamtrawls using no tickler chains and sole beamtrawls that do use chains. However, using the regenerating arm phenomenon of *Asterias rubens* as an index to local fishing intensity was not reliable due to factors such as temperature, substrate condition and forage food availability, which clouded the relationship.

de Groot, S. J. 1972. Some further experiments on the influence of the beam trawl on the bottom fauna. ICES Gear and Behaviour Committee. CM 1972/B:6. 7 p.

Keywords: trawl effects/ sediment disturbance/ North Sea

Summary: This is a short report discussing the effects of beamtrawls on the sediments in areas of the North Sea. The survey was conducted in 1972, and trawl tracks were analyzed using a "transit-sonar." Disturbance of the sediments due to the trawl was determined to be dependant on the sediment type and the velocity of the bottom currents. The most distinct disturbance was in bottom sediments that were soft and sandy (disturbance still visible after 150 minutes). Disturbance on hard, sandy bottoms was only slight, as the track was nearly gone after about 75 minutes.

de Groot, S. J. 1981. Bibliography of literature dealing with the effects of marine sand and gravel extraction on fisheries. ICES Marine Environmental Quality Committee. CM 1981/E:5. 39 p.

Keywords: selected bibliographies/ dredging/ ecosystem disturbance/ fishery biology

Abstract: At the third meeting of the ICES Working Group on Effects on Fisheries of Marine Sand and Gravel Extraction - Rijswijk (Z.H.), The Netherlands, 21-23 March 1979, it was recommended: (4) that a summarizing bibliography should be prepared by members on all relevant topics related to dredging (including documents by the Working Group) and be sent to the Working Group Chairman for submission as a draft to the MEQ committee at the 68th Statutory Meeting and that additional information should be submitted annually to the MEQ Committee under a separate heading. A preliminary bibliography, ICES CM 1980/E:13, was presented by the present author at the MEQ Committee at the 68th Statutory Meeting. This bibliography is now updated with 81 references including those of 1980, on request of the MEQ Committee. From now onwards the administrative report of the MEQ Committee will include a section of relevant literature dealing with the effects of marine sand and gravel extraction. Data for this bibliography were derived from the previous Working Group reports, as well as supplied by members from France, Ireland, The Netherlands and USA and the authors reference system. In total 488 references are given. *Reprinted with author permission (Dr. S.J. de Groot).*

de Groot, S. J. 1984. The impact of bottom trawling on benthic fauna of the North Sea. Ocean Management. 9(3-4) : 177-190.

Keywords: bottom trawling impacts/ benthic fauna/ North Sea

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.

Keywords: beamtrawl/ gear penetration/ sediment

de Groot, S. J. and Apeldoorn, J. M. 1971. Some experiments on the influence of the beam trawl on the bottom fauna. ICES Gear and Behaviour Committee. CM 1971/B:2. 5 p.

Keywords: beam trawl/ tickler chains/ gear impacts/ fishing effects

Summary: At the time of this paper, some of the most important commercial Dutch fishery species were sole, plaice and shrimp, all caught with beam trawls using tickler chains. In response to the increasing use of more and heavier tickler chains being used on trawl gear by the fishing fleets, this study was conducted to investigate the impacts of tickler chains to the benthos. Preliminary results of catch efficiency and benthos damage in relation to tickler chain number are presented.

de Groot, S. J. and Lindeboom, H. J. 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, Texel, The Netherlands. 257 p.

Keywords: gear impact/ benthic fauna/ bottom gear/ environmental impact/ North Sea

de Groot, S. J., Lindeboom, H. J., Rumohr, H., Arntz, W., Polet, H., Zevenboom, W., Lambeck, R. H. D., Hall, S., Spencer, B., Hughes, R., Damm, U., and Keegan, B. F. 1998. Impact 2: The effects of different types of fisheries on the North Sea and Irish Sea ecosystem. Pages 207-212 *in* K.G. Barthel, H. Barth, M. Bohle-Carbonell, C. Fragakis, E. Lipiatou, P. Martin, G. Ollier and M. Weydert (eds.). Third European Marine Science and Technology Conference (MAST Conference), Lisbon, 23-27 May 1998. Project synopses Vol. 5: Fisheries and Aquaculture (AIR: 1990-94) -- Selected projects from the research programme for Agriculture and Agro-Industry including Fisheries, European Commission DG 12 Science, Research and Development, Luxembourg.

Keywords: fishing effects/ North Sea/ Irish Sea/ trawling

de Moor, G., Lanckneus, J., and van de Linde. 1992. Detection of trawl marks on the seafloor of the southern North Sea: analysis of a time series of sidescan sonar recordings . Report Research Unit Marine Geomorphology, University of Ghent. Parts I and II. 11 pp.; 38 pp.

Keywords: trawl marks/ trawl disturbance/ North Sea/ sidescan sonar

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.

Keywords: bait shrimp fishery/ roller trawling/ Florida

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. 31 : 215-228.

Keywords: fishing effects/ cockles/ macrobenthos disturbance/ Wadden Sea

Demestre, M., Sanchez, P., Ramon, M., and Kaiser, M. J. (In press). The impact of otter trawling on mud communities in the NW Mediterranean. ICES Journal of Marine Science.

Keywords: otter trawling/ Mediterranean

Demestre, M. Sanchez P. and Kaiser M. J. 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 (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: fishing disturbance/ muddy sediment/ otter trawling/ scavenging behaviour

Summary [author's 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

Department of Fisheries and Oceans. 1993. Seabed disturbance from mobile fishing gear in the Bras d'or Lakes. Project Report No 44. Industry Services and Native Fisheries, Scotia-Fundy Region, Halifax, NS. 4 p.

Keywords: seabed disturbance/ mobile fishing gear/ Bras D'OR Lakes

Department of Fisheries and Oceans. 1993. Seabed disturbances from fishing activities. Project Report No 41. Industry Services and Native Fisheries, Scotia-Fundy Region, Halifax, NS. 4 p.

Keywords: seabed disturbance/ trawling effects

Dolmer, P., Kristensen, P. S., and Hoffmann, E. 1999. Dredging of blue mussels (*Mytilus edulis* L.) in a Danish sound: stock sizes and fishery-effects on mussel population dynamic. Fisheries Research. 40 : 73-80.

Keywords: blue mussel/ *Mytilus edulis*/ biomass/ effects of fishery/ effects of oxygen depletion/ stock size/ dredge efficiency

Abstract: In April 1993, 1994 and 1995 the abundance of blue mussels, *Mytilus edulis* L., was estimated in Limfjorden, Denmark. The stocks were assessed by using a down-scaled model of a commercial mussel dredge which efficiency was analyzed by comparing its samples with others collected by diver. The mean dredge efficiency was 17%. The fishing area in Limfjorden (700 km^2) is divided into 22 fishery zones and mussel stock size was calculated for each zone. From April 1993 to April 1994 the total stock size declined from 771 000 to 616 000 t. In the same period, the exploitation rate in the fishery was 14% of the 1993 stock, and the size of mussel landings from each zone significantly correlated with their change in stock. In April 1995, the total mussel stock was reduced to 494 000 t. The mean exploitation rate in 1994-1995 was 15%. No correlation was observed between the size of mussel landings and the change in the

mussel stock. In summer 1994, there was a long period of oxygen depletion in parts of Limfjorden. This caused mortality of 33% of the mussels in the affected areas. In fishery zones without oxygen depletion a 46% increase in the mussel stocks was estimated. The massive loss of blue mussels caused by oxygen depletion exceeds the annual landings of mussels from the fishery. *Reprinted from Fisheries Research, Vol. 40; Dolmer, P., Kristensen, P.S. and Hoffmann, E.; Dredging of blue mussels (Mytilus edulis L.) in a Danish soundstock sizes and fishery-effects on mussel population dynamic; pages 73-80; Copyright (1999); with permission from Elsevier Science.*

Dorsey, E. M. and Pederson, J. (eds.). 1998. Effects of Fishing Gear on the Sea Floor of New England. MIT Sea Grant Publication 98-4. Conservation Law Foundation, Boston, Massachusetts. 160 p.

Keywords: fishing gear/ fishing effects/ New England

Summary: A publication of collected works by both scientists and fishermen on a wide range of relevant issues concerning demersal fishing impacts in the waters of New England.

Drew, S. C. and Larsen, R. E. 1994. Worldwide trawl and dredge study. Marine Data Systems Trawl & Dredge Summary. 8 p.

Keywords: trawl/ dredge/ mobile fishing gear/ fishing gear penetration depth

Summary: This report was prepared using knowledge and information contributed from a variety of sources, including researchers, technicians, agencies and organizations, to analyze the penetration depth of demersal fishing gear in bottom sediments in order to establish cable burial depth requirements. Two general questions were addressed during this three month study: (1) "how deeply into the seabed do different types of mobile fishing gear penetrate, and (2) what bottom trawl and dredge fisheries are conducted in which areas of the world." Bottom trawls and dredges were found to be most likely to penetrate seabed deepest. Penetration depth depends on a number of variables, such as characteristics of the gear, hardness of the substrate, speed of the ship, and other factors. Various gear types and designs are described, and max "cutting" depths for normal fishing conditions (conditions where gear and ship operate without failure, breakdown, snagging, etc.) are given in millimeters. Geographic distribution of fisheries is also addressed.

Drinkwater, J. 1974. Scallop dredge selectivity experiments. ICES CM 1974:K25. 4 p.

Keywords: dredging/ scallop dredging/ scallop fisheries

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

Keywords: hydraulic escalator dredging/ oyster dredging/ dredging

Dupouy, H. 1982. Comparative study of scallop drags used in France. Canadian Translations of Fisheries and Aquatic Sciences. 11 p. 4901.

Keywords: scallop fisheries/ scallop dragging gear/ *Pecten maximus*/France

Dupouy, H. 1988. The harvesting and cultivation of mollusks of the family Pectinidae (scallops) in various parts of the world: Current situation and future prospects. Canadian Translations of Fisheries and Aquatic Sciences. 5417 29 Pp.

Keywords: mollusk harvesting/ cultivation/ scallops

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

Keywords: mussel dredging/ sediment disturbance/ ecosystem effects

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 absorbed 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. *Reprinted with author permission (Dr. S. M. Dyekjaer).*

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

Keywords: trawling effects/ beamtrawl/ benthic disturbance

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

Keywords: scallop dredging impacts/ benthic disturbance/ sandy community

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. *Reprinted from Netherlands Journal of Sea Research, Vol. 30; Eleftheriou, A. and Robertson, M.R.; The effects of experimental scallop dredging on the fauna and physical environment of a shallow sandy community; pages 289-299; Copyright (1992); with permission from Elsevier Science.*

Engel, J. D. 1998. Potential impacts of commercial trawling on a benthic community in Monterey Bay National Marine Sanctuary. Thesis.

Keywords: commercial trawling/ trawling effects

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

Keywords: trawling/ otter trawling/ trawling impacts/ benthic community/ Monterey Bay National Marine Sanctuary

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.

ESGEMAR (Estudios Geológicos Marinos). 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. Estudios Geológicos Marinos. 110 p.

Keywords: trawling/ *Posidonia oceanica*/ benthic community

Evans, P. L., Kaiser, M. J., and Hughes, R. N. 1996. Behaviour and energetics of whelks, *Buccinum undatum* (L.), feeding on animals killed by beam trawling. Journal of Experimental Marine Biology and Ecology. 197(1) : 51-62.

Keywords: whelks/ beam trawl/ bycatch/ energy flow

Abstract: Whelks, *Buccinum undatum*, are potentially important scavengers of animals damaged or killed as a result of beam trawling. In order to assess the ability of whelks to scavenge these moribund animals, and the consequences of this to energy flow, we presented them with four different species that were either damaged on the seabed or died as a result of capture by beam trawling. Whelks ate swimming crabs, *Liocarcinus depurator*, purple heart urchins, *Spatangus purpureus*, and a gadoid fish, the pouting, *Trisopterus minutus*, but not plaice, *Pleuronectes platessa*. Whelks moved most rapidly towards swimming crabs, suggesting that these were the most preferred prey type. Although the rate of energy intake was highest when whelks fed on sea urchins, when fed to satiation they acquired most energy from swimming crabs. When presented with whole animals, whelks fed preferentially on different body tissues, e.g. they consumed the eyes of pouting first, and never ate the gills or carapace of swimming crabs. Absorption efficiency was highest when fed a diet of swimming crabs (93%) and lowest when fed pouting (83%). Whelks are able to efficiently utilize animals killed by beam trawling, and our results indicate that they prefer the most energetically rich species. In areas of intense beam trawling, such as the southern North Sea, dead or moribund animals which result from these activities could constitute a considerable proportion of whelk diets. *Reprinted from Journal of Experimental Marine Biology and Ecology, Vol. 197; Evans, P.L., Kaiser, M.J. and Hughes, R.N.; Behaviour and energetics of whelks, Buccinum undatum (L.), feeding on animals killed by beam trawling; pages 291-312; Copyright (1996); with permission from Elsevier Science.*

FAO (Fisheries and Oceans). 1993. Review of the state of world marine fishery resources. Fisheries Technical Paper No. 335. FAO Marine Resources Service, Rome, Italy. 133 p.

Keywords: fishery resources

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

Keywords: community structure/ community changes/ disturbance/ ecosystem management/ exploitation/ Georges Bank/ habitat destruction and degradation/ indirect effects of harvesting/ marine fisheries/ marine management/ spatial structure/ species-selective harvesting/ sustainability

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 gadid 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 been 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. *Reprinted with the permission of the Ecological Society of America and Ecological Applications, 1999.*

Fonds, M. 1991. Measurements of catch composition and survival of benthic animals in beam trawl fishery for sole in the southern North Sea. Pages 53-68 *in* Effects of Beamtrawl Fishery on the Bottom Fauna in the North Sea, II: the 1990 studies. BEON-RAPPORT 13.

Keywords: beamtrawl effects/ bottom fauna/ North Sea

Summary: In this study, the authors investigated catch composition and survival of benthos caught on a commercial trawler using 12 meter beam trawls with 8 cm mesh nets and 10 tickler chains. In relation to the effect of tickler chains, the investigations were particularly concerned with the following: 1) Composition of the catch in marketable fish, discard fish and invertebrates. 2) Invertebrate mortalities in catch sorting. 3) Invertebrate survival chances after throwing back from catch sorting. 4) Survival chances of small fish passing through the 8 cm mesh of commercial sole nets. Hence, one net was trawled with tickler chains (starboard) and one without (port). Catch composition and survival were compared between the two nets. In general, benthic invertebrates were the most abundant in the catches (~70% of total catch), but fish were more important in weight (~64% of total catch). Most of the fish were undersized discards (80-90% in numbers, 60-80% in weight) and most of the invertebrates were echinoderms (80-90% in number). The net with tickler chains resulted in nearly twice as much total fish catch, compared to the net without chains, but it also caught nearly double the amount of discards. According to the author's estimates from this study, the amount of dead discard fish produced in the summer

sole fishery was about 4-5 times the total sole landings, and the amount of dead benthos was nearly equal to the total sole landings.

Fonds, M. 1994. Mortality of fish and invertebrates in beam trawl catches and the survival chances of discards. NIOZ Rapport 1994-11, Netherlands Institute for Fisheries Research, Texel. 131-146.

Keywords: beam trawl effects/ beam trawl/ discards

Fonds, M. and Groenewold, S. 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 (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: demersal fishery/ beam trawl/ benthos/ discards/ scavengers

Summary [author's summary]: 1. The intensive beam-trawl fishery for sole and plaice in the southern North Sea produces large amounts of discard material 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 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

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

Keywords: scallop harvesting/ eelgrass meadows/ environmental impacts/ larval settlement/ *Zostera marina*

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. *Reprinted with the permission of the American Fisheries Society and the North American Journal of Fisheries Management.*

Fonteyne, R. 2000. Physical impact of beam trawls on seabed sediments. Pages 15-36 in M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: beam trawl/ physical impact/ pressure/ seabed/ sediment/ track/ penetration depth/ sediment suspension

Summary [author's summary]: 1. The first data on the physical impact of beam trawling on the seabed were obtained during the 1970's, 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 the 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 head 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 sidescan 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 head 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 sidescan 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

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.

Keywords: trawling/ fishing effects/ seabed disturbance

Franklin, A. and Pickett, G. D. 1978. Studies on the indirect effects of fishing on stocks of cockles, *Cardium edule*, in the Thames Estuary and wash. Ministry of Agriculture Fisheries and Food, Fishery Research Technical Report No 42, 9 p.

Keywords: fishing effects/ cockles/ Thames Estuary

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

Keywords: trawling effects/ occupied submersible/ seafloor habitat/ mobile fishing gear/ invertebrate bycatch/ Gulf of Alaska

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. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Frid, C. L. J. and Clark, R. A. 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 (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: benthos/ long term/ indirect effects/ fishing/ direct mortality/ fish predation

Summary [author's 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 bycatch 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

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

Keywords: fishing impacts/ macrofauna/ time series/ benthos/ fishing disturbance/ species/ composition NE coast/ England

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., Hansson, S., Ragnarsson, S. A., Rijnsdorp, A., and Steingrimsson, S. A. 1999. Changing levels of predation on benthos as a result of exploitation of fish populations. Ambio. 28(7) : 578-582.

Keywords: fishing effects/ benthos

Frid, C. L. J., Harwood, K. G., Hall, S. J., and Dove, R. A. C. (In press). Long term trends in benthic communities on North Sea fishing grounds. ICES Journal of Marine Science.

Keywords: long-term effects/ benthos/ North Sea

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

Keywords: trawl/ sidescan sonar/ shelf slope/ Eureka, California

Abstract: The abundance and orientation of trawl marks was quantified over an extensive portion (>2700 m^2) of the Eureka, California, outer shelf and slope, an important commercial bottomtrawling 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 507-524 *in* J.F. Caddy (ed.). Marine Invertebrate Fisheries: Their Assessment and Management. John Wiley & Sons, New York, NY.

Keywords: clam dredging/ dredge/ Adriatic Sea

Froglia, C. and Bolognini, S. 1987. Clam fishery with hydraulic dredges in the Adriatic Sea. Evolution of Technology in Italian Fisheries: Studies and Reviews. General Fisheries Council for the Mediterranean. Rome, Italy. 62 : 37-40.

Keywords: clam fisheries/ dredging/ fishing gear/ Adriatic Sea

Fuller, S. 1998. The fauna of the scallop grounds in the lower Bay of Fundy. Marine Issues Committee Special Publication. Ecology Action Centre, Halifax, Nova Scotia. 90 p.

Keywords: scallop fishing/ benthos/ Bay of Fundy

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

Keywords: benthic habitat/ substrates

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

Keywords: baitshrimp fishery/ roller trawling/ Florida

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

Keywords: otter trawling/ lobster damage/ trawling effects

Gaspar, M. B., Castro, M., and Monteiro, C. C. 1998. Influence of tow duration and tooth length on the number of damaged razor clams *Ensis siliqua*. Marine Ecology Progress Series. 169 : 303-305.

Keywords: dredge/ *Ensis siliqua*/ indirect mortality/ bivalve

Abstract: The incidence of shell damage due to dredging was studied in the bivalve *Ensis siliqua* off Lagos, on the south coast of Portugal. Three tow durations (1, 3 and 5 min) and 2 tooth lengths (30 and 40 cm) were investigated. Both factors affected the proportion of damaged individuals. The increase of tooth length results in lower proportions of damaged razor clams. An increase in tow duration increased total numbers caught but also increased the proportion of damaged clams. It is suggested that dredges with 40 cm teeth and tows of 1 min duration should be used in this fishery, although experiments should be undertaken in order to evaluate the environmental and ecological impact of dredges. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Gaspar, M. B., Richardson, C. A., and Monteiro, C. C. 1994. The effects of dredging on shell formation in the razor clam *Ensis siliqua* from Barrinha, southern Portugal. Journal of the Marine Biological Association of the United Kingdom. 74(4) : 927-938.

Keywords: dredging/ dredging effects/ shell formation/ *Ensis siliqua*/ Portugal/ Barrinha/ disturbance

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 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. *Reprinted with the permission of Cambridge University Press and Journal of the Marine Biological Association of the United Kingdom.*

Gell, B. 1998. Bottom trawling on hard substrates. Pages 85-86 *in* E.M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. Conservation Law Foundation. Boston, Massachusetts.

Keywords: trawling/ rockhopper gear

Summary: Fisherman and skipper of the F/V *Xiphias* presents a case on rockhopper gear having limited effects on hard-bottom habitats.

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

Keywords: dredging/ zoobenthos/ dredging impacts/ Azov Sea

Giannini, S. and Froglia, C. 1985. Notes on beam-trawling in a coastal area of the Middle Adriatic Sea (Ancona). Oebalia. 11(N.s, 2) : 521-533.

Keywords: trawling/ Mediterranean/ Adriatic/ coastal fisheries

Abstract: A one year cycle of monthly nocturnal beam-trawlings in a coastal zone of the Central Adriatic sea evidenced a strong seasonal pattern in the abundance of main species. Adult spawners of *Sepia officinalis* and *Gobius niger* dominate in spring. Juveniles of *S. officinalis* and *Solea vulgaris* dominate in summer early autumn and in autumn-winter respectively. *Reprinted with the permission of Instituto Sperimentale Talassografico and Oebalia. 1999.*

Gibbs, P. J., Collins, A. J., and Collett, L. C. 1980. Effect of otter prawn trawling on the macrobenthos of a sandy substratum in a New-South-Wales Estuary . Australian Journal of Marine and Freshwater Research. 31(4) : 509-516.

Keywords: otter trawl/ otter prawn trawling/ trawling/ macrobenthos

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. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia, and the Australian Journal of Marine and Freshwater Research.*

Gilkinson, K., Paulin, M., Hurley, S., and Schwinghamer, P. 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. 224(2) : 291-312.

Keywords: damage/ infaunal bivalves/ otter trawl/ scouring/ trawl door

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. *Reprinted from Journal of Experimental Marine Biology and Ecology, Vol. 224; Gilkinson, K., Paulin, M., Hurley, S. and Schwinghamer, P.; Impacts of trawl door scouring on infaunal bivalvesresults of a physical trawl door model/dense sand interaction; pages 291-312; Copyright (1998); with permission from Elsevier Science.*

Giovanardi, O., Pravoni, F., and Franceschini, G. 1998. "Rapido" trawl fishing in the Northern Adriatic: preliminary observations of the effects on macrobenthic communities. Acta Adriatica. 39(1) : 37-52.

Keywords: trawl fishing/ benthic communities/ Northern Adriatic

Abstract: The "rapido", a kind of beam trawl, is used only in the Adriatic Sea. Preliminary results of a study on the impact of the "rapido" gear on macrobenthic communities in the Adriatic Sea (Chioggia-Venice) are presented. Experimental hauls were carried out at two sites (one prohibited to all trawl-fishing activity and one used for commercial fishing) at a distance of 2-3 nautical miles from the coast. With the aim of simulating the action of commercial fishing, either one or several consecutive passages were carried out. Results indicated that trawling produces a furrow about 7 cm deep in the bottom sediment, which disturbs macrobenthic communities. After experimental hauls, the mean abundance values at all stations showed statistically significant differences with respect to controls; no significant statistical differences were found in the commercial fishing area for biomass. Although fished and control areas did not exhibit significant differences two weeks after the experiments, analysis of the diversity indexes revealed that complete recovery had not occurred, since the control areas always had higher values than the fished areas. This study shows that gear such as the "rapido" has a very severe impact on benthic biocoenoses and that its use should, therefore, be better regulated.

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

Keywords: fishing effects/ towed fishing gear/ physical disturbance/ North Sea

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. *Reprinted from Marine Pollution Bulletin, Vol. 29; Gislason, H.; Ecosystem effects of fishing activities in the North Sea ; pages 520-527; Copyright (1994); with permission from Elsevier Science.*

Gislason, H. and Sinclair, M. (eds.). 2000. ICES Symposium on ecosystem effects of fishing. ICES Journal of Marine Science. (In press).

Keywords: fishing effects/ trawling

Glemarec, M., le Faou, Y., and Cuq, F. 1997. Long-term changes of seagrass beds in the Glenan Archipelago (South Brittany). Oceanologica Acta. 20(1) : 217-228.

Keywords: seagrass/ *Zostera marina*/ France/ Brittany/ Glenan Archipelago/ dredging disturbance

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 60 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. *Zostera 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.

Keywords: dredging/ clam dredging/ fishing effects

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

Keywords: clam fishery/ dredging/ power dredging/ clam raking

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.

Keywords: clam fishery/ hydraulic dredging/ dredging

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

Keywords: commercial fishing/ ecosystem disturbance/ environmental impact/ mortality causes/ bycatch/ overfishing

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). *Reprinted from Ocean & Coastal Management, Vol. 40; Goni, R.; Ecosystem effects of marine fisheriesan overview; pages 37-64; Copyright (1998); with permission from Elsevier Science.*

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

Keywords: mechanical harvester/ escalator harvester/ clam fishery/ Puget Sound/ Washington

Abstract: The hydraulic harvest of clams in the small experimental plot produced some changes which were evident to divers shortly after harvest was completed. The abundance of attached kelp was reduced in the treatment plot compared to the control plot. The harvest left large amounts of old clamshell and sand at the substrate surface. The harvest greatly reduced the standing crops of commercial size clams within the treatment plot. Butter and littleneck seed clam abundance was as high within the treatment plot as the control plot, and a new crop of these clams was expected to develop from these small clams. The harvest had little, if any, effect on

the number of benthic animal species, but did reduce the number of individuals and the weight per unit area of some organisms. These reductions are probably a short-term situation. Most species had recovered to the control plot levels in 1978. No effects on the percentage of fines in the substrate of the treatment plot were observed. Some vertical changes in substrate distribution were evident since clam shell and sand was more abundant in the substrate surface after harvest in the treatment plot compared to the control plot. Chemical parameters of the substrate were slightly reduced or unchanged in the treatment plot compared to the control plot. These changes were probably a direct result of lowered biomass of clams and other organisms in the treatment plot due to the harvest.

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

Keywords: mechanical harvester/ escalator harvester/ clam fishery/ Port Townsend/ Washington

Abstract: This study has shown that the hydraulic harvester can produce some major changes to an intertidal clam beach such as: an increase in the amount of dead clam shell at the substrate surface, an increase in the movement of surface substrate material producing transient sand bars which can smother clams and other benthic organisms, a decrease in substrate compactness and general beach substrate stability. It has also shown that a harvested beach will recover from the effects of harvest rapidly and clams will repopulate and thrive in harvested beaches. An important point is the lack of harvest and disturbance in the eelgrass bed. Commercial quantities of clams were present in the eelgrass bed on the beach and no legal restrictions prevented the harvest of clam from that portion of the beach, yet the harvesters chose not to work in the eelgrass bed.

The study also demonstrates the complexity and the large effort required to adequately sample clam beds. It is difficult to accurately sample clams because of the great depth in the substrate that large clams live and the tendency for the substrate to slough from the walls of the sample holes. Clams are extremely variable and patchy in their distribution which greatly increases the number of samples to adequately describe population levels.

Gordon Jr., D. C., Rowell, T., Schwinghamer, P., Vass, P., Keizer, P., Woo, P., and Ducharme, A. 1995. Trawling impact study. A summary prepared by the Habitat Working Group for the 1995 Spring Meeting of the Scotia-Fundy Regional Advisory Process (RAP). 12 p.

Keywords: trawling impacts/ benthic habitat/ trawling

Gordon, Jr D. C., Schwinghamer, P., Rowell, T. W., Prena, J., Gilkinson, K., Vass, W. P., and McKeown, D. L. 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 (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: gear impacts/ mobile fishing gear/ benthic habitat/ New England

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 rockhopper footgear, which created a disturbance zone on the order of 120 to 250 m wide. Sidescan 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. *Reprinted with the permission of the Conservation Law Foundation.*

Goudey, C. A. and Bellingham, J. G. 1994. Autonomous underwater vehicle applications in fisheries. MIT Sea Grant 94-20J. MIT Sea Grant College Program. 6 p.

Keywords: underwater vehicles/ unmanned vehicles/ fishery management/ data acquisition

Abstract: Autonomous underwater vehicles (AUVs) are a class of underwater vehicle offering tremendous potential for ocean applications. This paper will explain the potential of AUVs in fisheries research and describe progress towards their actual use as a tool for the fisheries scientist and fisherman. The performance characteristics and operational experience of AUV Odyssey will be described. Its application in missions such as the direct counting animals in-situ will be discussed. Such an approach is an attractive method of stock assessment, one which eliminates the vagaries of present trawl and dredge sampling methods. In addition to video data, other sensor data could be included, such as temperature and conductivity. Data from these sensors could be correlated with observed local abundance, providing new and possibly useful insight into a specie's response to the environment. Critical information about species interaction and overlap would also be available; information that cannot be determined by conventional

methods. Other applications of AUVs in fish harvesting and in ocean aquaculture will also be discussed. *Reprinted with the permission of MIT Sea Grant College Program. 1999.*

Goudey, C. A. and Bellingham, J. G. 1994. Autonomous underwater vehicle applications in fisheries. MITSG 94-205. 6 p.

Keywords: autonomous underwater vehicle/ AUV applications/ fishery management/ data acquisition

Goudey, C. A. and Loverich, G. 1987. Reducing the bottom impact of Alaskan groundfish trawls. Proceedings of Oceans '87. The Ocean -- An International Workplace. Halifax, Nova Scotia, Canada. Volume 2. Marine Engineering; Policy, Education and Technology Transfer : 632-637.

Keywords: trawling/ demersal fisheries/ gear designs/ gear modeling

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 bycatch 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. *Goudey, C.A. and Loverich, G. 1987. IEEE. Reprinted, with permission, from Oceans '87 [The Ocean - An International Workplace]; Halifax, Nova Scotia, Canada, 28 September - 1 October, 1987; pp. 632-637.*

Goudey, C. A., Nicholson, C., and Allen, B. 1987. A towed underwater vehicle for fisheries research. Proceedings of Oceans '87. The Ocean -- An International Workplace. Halifax, Nova Scotia, Canada. Volume 2. Marine Engineering; Policy, Education and Technology Transfer : 455-460.

Keywords: fishing gear/ towed vehicles/ fishery technology/ Towed Underwater Gear Observation System

Abstract: Fishing gear research and the development of a better understanding of the fish behavior during capture has been hindered by the difficulty in observing the gear during the fishing operation. This paper will explain the operational requirements of a system suitable for observing harvesting gear in-situ, and describe a new underwater vehicle system designed to meet those requirements. Called the Towed Underwater Gear Observation System, or TUGOS, it is the first low-cost system available to meet the needs of gear researchers and fisheries biologists. The development of the prototype TUGOS vehicle will be described. Tank tests, sea trials, and trawler applications of the TUGOS will be reported. Other non-fishery applications of the system will also be included. *Goudey, C.A., Nicholson, C. and Allen, B. 1987. IEEE. Reprinted, with permission, from Oceans '87 [The Ocean - An International Workplace]; Halifax, Nova Scotia, Canada, 28 September - 1 October, 1987; pp. 455-460.*

Graham, M. 1955. Effect of trawling on animals of the sea bed. Deep Sea Research Supplement. 3 : 1-6.

Keywords: trawling effects/ bottom trawling

Greenstreet, S. P. R. and Hall, S. J. 1996. Fishing and the ground-fish assemblage structure in the north-western North Sea: an analysis of long-term and spatial trends. Journal of Animal Ecology. 65 : 577-598.

Keywords: trawling/ groundfish assemblage/ North Sea/ long-term trends

Greenstreet, S. P. R. and Rogers, S. I. 2000. Effects of fishing on non-target fish species. Pages 217-234 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: non-target species/ species diversity/ elasmobranchs/ fishing disturbance/ life history

Summary [author's summary]: 1. Although some of the studies reviewed examine data sets extending back over seven decades or more, none of the time series is sufficiently long to allow us to compare the current fished situation with the original unfished ecosystem. 2. Attempts to correlate time-series trends in the abundance of non-target species with fishing-disturbance trends have to date proved inconclusive. 3. A better approach towards determining fishing effects on non-target species lies through the development of underlying theory, which would enable the establishment of specific testable hypotheses. In particular, the development of hypotheses to predict changes to be more strongly related to changes in fisheries exploitation patterns, allowing changes in the abundance of different non-target species in time and space to be linked more directly to fishing. 4. Current applied theory has identified specific life-history characteristics likely to make a species vulnerable to fishing disturbance. These life-history characteristics include large ultimate size, slow growth rate, and large size and higher age at maturity. 5. The elasmobranchs have been identified as a group of species that have such life-history characteristics likely to render them susceptible to fishing disturbance. In general, trends in the abundance of the different shark, skate and ray species in the North Sea can be attributed to fishing mortality, since they follow predictions based on the life-history characteristics of each species. On the Georges Bank, skate and dogfish abundance actually increased, probably because they were always discarded, and likely to have a high survival rate following discarding. 6. An increased ability to predict the likely consequences of continued high levels of fishing disturbance would be a likely further benefit to be gained through the development of underlying theory. 7. Whilst fishing undoubtedly causes increased mortality for many non-target species, in some cases, it may also allow increased scope for population growth through scavenging and reduced predation and competition. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

Greenstreet, S. P. R., Spence, F. E., and McMillan, J. A. 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. Changes in the structure of the North Sea groundfish species assemblage between 1925 and 1996. Fisheries Research. 40(2) : 153-183.

Keywords: community structure/ whole fish assemblage/ non-target fish assemblage/ species diversity/ dominance/ fishing impact/ North Sea

Abstract: We examine long-term changes in the structure and composition of the groundfish species assemblage in four regions of the northwestern North Sea during the period 1925-96. Species diversity in the whole groundfish assemblage has declined in the three areas where fishing pressure has been greatest. In the area where fishing pressure was least, no trend in species diversity was detected. Only in the most intensively fished area was there a negative trend in species diversity in the non-target species assemblage. Marked spatial variation in species diversity was observed. For the whole groundfish assemblage, diversity was greatest in the inshore and southern regions and least in the offshore northern area. For the non-target species assemblage, the spatial diversity gradient was reversed. Multi-variate analyses indicated

long-term changes and between-area differences in the species composition of both the whole groundfish assemblage and the non-target species subset. However, these changes consisted mostly of subtle variations in the relative and absolute abundance of a few key species, rather than major species replacement events. Only one species showed any marked increase in abundance: a dominant species which became more abundant. Examination of species aggregated length-frequency distributions indicated a shift towards an assemblage dominated by smaller fish in the whole assemblage, but not in the non-targeted assemblage. *Reprinted from Fisheries Research, Vol. 40; Greenstreet, S.P.R., Spence, F.E. and McMillan, J.A.; Fishing effects in northeast Atlantic shelf seaspatterns in fishing effort, diversity and community structure. Changes in the structure of the North Sea groundfish species assemblage between 1925 and 1996; pages 153-183; Copyright (1999); with permission from Elsevier Science.*

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

Keywords: scallop fishing/ fishing effects/ fishing impacts/ Manx scallop

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. *Reprinted with the permission of Cambridge University Press and Journal of the Marine Biological Association of the United Kingdom.*

Guillén, J. E., Ramos, A. A., Martinez, L., and Sanchez Lizaso, J. L. 1994. Antitrawling reefs and the protection of *Posidonia oceanica* (L.) Delile meadows in the western Mediterranean Sea: demand and aims. Bulletin of Marine Science. 55(2-3) : 645-650.

Keywords: *Posidonia oceanica*/ sea grass/ ecosystem disturbance/ trawling impacts

Abstract: In the western 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.

Haig-Brown, A. Chambers S. Drouin M. and Warren B. 1999. The future of trawling. Pacific Fishing. 20(12) : 30-46.

Keywords: trawling/ gear design/ reduced bycatch/ Individual Vessel Quota/ rockhopper gear/Sea Bed Protection Act

Summary: A collection of articles pertaining to various aspects of trawl fisheries. Article topics include improvements in trawl gear design, Canada's Individual Vessel Quota and Groundfish Development Authority plan (IVQ/GDA), pay issues of Canada's observer program, restrictions to rockhopper and roller gear and a short article about the introduced Sea Bed Protection Act.

Hall-Arber, M. and Pederson, J. 1999. Habitat observed from the decks of fishing vessels. Fisheries. 24(6) : 6-13.

Keywords: fish habitat/ fishing gear effects/ essential fish habitat/ EFH

Abstract: From the decks of their boats, commercial fishers observe target species, habitat, prey, and changes through time to the environment. Their observations, perceptions, and impressions are colored by their values, culture, and interactions with other fishers. Fishers who are at sea every day hold a vast amount of knowledge; however, their information is considered anecdotal. Motivated by the need to describe essential fish habitat using all available data and information, we surveyed fishers to identify records and other documentation of their observations. Through surveys and focus group meetings, we collected information on fishing gear, seasons and years of fishing experience, types of fish caught, and general observations. We also asked fishers if they kept records of their findings and if they would share that information with fisher managers. Most fishers indicated they kept some type of record, and 68% were willing to share that information with managers. Another 30% indicated they might do so, while 5% said they would not, and 8% did not respond. At focus group meetings fishers used National Oceanic and Atmospheric Administration maps to delineate areas fished for target species, characterized bottom habitat when known, and often indicated seasons fished in the various areas. Fishers' perceptions of changes varied, but most identified changes in habitat as affecting fish abundance. Several fishers indicated that changes in their gear types and target species were related to fish availability. Nearly all fishers argued that habitat is important to fish productivity. *Reprinted with the permission of the American Fisheries Society and Fisheries magazine.*

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

Keywords: physical disturbance/ marine benthic communities/ trawling

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, Ltd. Oxford, U.K. 274 p.

Keywords: fishing effects/ gear impacts/ benthic disturbance

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

Keywords: dredging/ clam dredging/ fishing impacts/ habitat disturbance/ razor clams

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 hypothesized 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. *Reprinted from Netherlands Journal of Sea Research, Vol. 27; Hall, S.J., Basford, D.J. and Robertson, M.R.; The impact of hydraulic dredging for razor clams Ensis sp. on an infaunal community; pages 119-125; Copyright (1990); with permission from Elsevier Science.*

Hall, S. J. and Harding, M. J. C. 1997. Physical disturbance and marine benthic communities: The effects of mechanical harvesting of cockles on non-target benthic infauna. Journal of Applied Ecology. 34(2) : 497-517.

Keywords: benthic disturbance/ fishing disturbance/ dredge harvesting/ effects of mechanical harvesting

Abstract: 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 this study. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK and the Journal of Applied Ecology.*

Hall, S. J., Poiner, I. R., Kaiser, M. J., Collie, J. S., and Pantus, F. 2000. Global distribution and ecological significance of bottom-fishing disturbance. ICES Journal of Marine Science. (In press).

Keywords: fishing effects/ trawling/ bottom-fishing disturbance/ global distribution

Hall, S. J., Robertson, M. R., Basford, D. J., and Heaney, S. D. 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. 31(2) : 201-208.

Keywords: fishing effects/ benthic disturbance/ community structure/ North Sea

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. *Reprinted from Netherlands Journal of Sea Research, Vol. 31; Hall, S.J., Robertson, M.R., Basford, D.J. and Heaney, S.D.; The possible effects of fishing disturbance in the northern North SeaAn analysis of spatial patterns in community structure around a wreck; pages 201-208; Copyright (1993); with permission from Elsevier Science.*

Hall-Spencer, J. M. 1995. Evaluation of the direct and indirect impact of fishing gears on the substratum and on the benthos. Final Project Report to Directorate General XIV. European Commission, Brussels, Belgium.

Keywords: fishing gear impacts/ gear impacts/ trawling effects

Hall-Spencer, J. M., Froglia, C., Atkinson, R. J. A., and Moore, P. G. 1999. The impact of Rapido trawling for scallops, *Pecten jacobaeus* (L.), on the benthos of the Gulf of Venice. ICES Journal of Marine Science. 56(1) : 111-124.

Keywords: fishing/ trawling impact/ scallops/ *Pecten jacobaeus*/ *Atrina fragilis*/ Adriatic Sea/ Mediterranean Sea

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% mere >7 cm in shell height. Most organisms in the path of the trawl passed under or through the net; on average bycatch 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 Moore, P. G. 2000. Impact of scallop dredging on maerl grounds. Pages 105-117 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: maerl/ benthos/ scallop dredging/ long-term impacts/ Scotland

Summary [author's 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). *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK*.

Hamon, D., Berthou, P., and Fifas, S. 1991. Study of effects of fishing towed gears in coastal zone. Case trawling in the Bay of Saint-Brieuc (Western Channel). ICES CM1991/B:27. 15 p.

Keywords: bottom trawling/ ecosystem disturbance/ zoobenthos/ Saint-Brieuc Bay

Harden Jones, F. R. and Scholes, P. 1974. The effect of the door-to-door tickler chain on the catch-rate of plaice (*Pleuronectes platessa L.*) taken by an otter trawl. Journal du Conseil International pour L'exploration de la Mer. 35(2) : 210-212.

Keywords: otter trawl/ tickler chain/ *Pleuronectes platessa* L./ plaice

Summary: A short paper addressing the effectiveness of tickler chains on catch rates of plaice. At the time of this study, fishermen had claimed that door-to-door tickler chains used on otter trawls with short bridles would double the catch rate of plaice, but the authors found no published data to confirm this. Detailed trawling logs from two Lowestoft trawlers provided the authors with 5 years of haul-by-haul data, including notes on tickler chain fouling. This information was used in statistical analyses, and it was found that where gear fouling had occurred, a mean catch reduction of 56% resulted. The authors approximated that door-to-door tickler chains improved catch rates of plaice by a factor of 2-3 (127-194%).

Harper, D. E. Jr and Hopkins, S. H. 1976. The effects of oyster shell dredging on macrobenthic and nectonic organisms in San Antonio Bay. Pages 232-279 *in* A.H. Bouma (ed.). Shell dredging and its influence on Gulf coast environments. Gulf Publishing Company, Houston, Texas.

Keywords: oyster shell dredging/ dredging/ San Antonio Bay

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

Keywords: fishing effects/ long-term changes/ demersal fauna/ Gulf of Carpentaria/Australia

Harrison, P. H., Strong, K. W., and Jenner, K. A. 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. 32 p + figures and appendices.

Keywords: seabed disturbance/ fishing effects/ fishing disturbance

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

Keywords: dredging/ clam fishing/ mortalities

Heessen, H. J. L. and Daan, N. 1996. Long-term trends in ten non-target North Sea fish species. ICES Journal of Marine Science. 53 : 1063-1078.

Keywords: abundance/ distribution/ long-term changes/ non-target species/ North Sea

Abstract: Catch data on 10 non-target fish species from the International Bottom Trawl Survey during the years 1970-1993 are analyzed for changes in distribution and abundance by size class. Trends in catch rates of spurdog, starry ray, bib, poor cod, four-bearded, rockling, grey gurnard, bullrout, long rough dab, dab, and lemon sole have been compared using correlation and cluster analysis with indices describing different aspects of the North Sea ecosystem, including biomass of pelagic, demersal and industrial species, temperature, eutrophication, and beam trawl effort. Most species appear to have increased over the period. However, the statistical analysis does not provide a plausible explanation of the factors responsible for the observed changes.

Heifetz, J. (ed.). 1997. Workshop on the potential effects of fishing gear on benthic habitat. Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115-0070. Processed Report 97-04. 17 p.

Keywords: trawling effects/ fishing gear impacts/ benthic habitat disturbance/ Bering Sea/ Gulf of Alaska

Abstract: This report contains abstracts from a workshop on the potential effects of fishing gear on benthic habitat held in September 1996, at the National Marine Fisheries Service (NMFS) Auke Bay Laboratory (ABL) in Juneau, Alaska. The purpose of the workshop was to review the progress and preliminary results of studies begun in 1996 and to discuss approaches and priorities for proposed research in 1997. Attendance was by invitation, and about 30 people participated in the workshop, including scientists from the Resource Assessment and Conservation Engineering (RACE), Resource Ecology and Fishery Management (REFM), and ABL divisions of the NMFS Alaska Fisheries Science Center (AFSC); NMFS Alaska Regional Office (ARO); U.S. Geological Survey (USGS); Alaska Department of Fish and Game (ADF&G); University of Alaska Fairbanks (UAF); University of Washington; and the National Undersea Research Center. The workshop agenda and a list of workshop attendees are in appendices to this report. Presentations included preliminary observations from a manned submersible of trawled versus untrawled hard-bottom areas in the eastern Gulf of Alaska, an overview of field studies to examine bottom trawl impacts in the Bering Sea, a description of methods for examining benthic community structure and possible effects of trawling based on historical data in the Gulf of Alaska and Aleutian Islands, and video tape showing how different types of trawl gear can impact seafloor habitats. Additional presentations included a review of fishing gear impact studies off the northeastern United States and preliminary evaluations of the feasibility of using laser-line scan systems, sidescan sonar, and hydroacoustic habitat mapping systems as research tools to examine fishing gear impacts. Proposed research for 1997 included continuation of trawling impact studies begun in 1996, an examination of the effects of trawling on gorgonian corals in heavily fished areas in the Aleutian Islands near Seguam Pass, and examination of the effects of scallop dredges on benthic habitat.

Herrington, W. C. 1947. The role of intraspecific competition and other factors in determining the population level of a major marine species. Ecological Monographs. 17(3) : 317-323.

Keywords: intraspecific competition/ haddock/ gear effects/ otter trawl/ fishing effects/ food availability

Summary: In this paper the author takes a close look at the Georges Bank haddock fishery in New England between 1914 and 1946. The study largely addresses recruitment and catch landings in the haddock fishery in relation to spawning stock (number of eggs) and intraspecific competition. In the early 1940s, haddock landings tended to be low. With respect to observations made from low landings in earlier years, the author found that although food limitation was the most prominent factor to examine as a cause to the observed trends, low landings were not necessarily explained by food limitation due to food competition between other commercially important fish species. The author proposes an alternate explanation that the lower haddock catches were related to a lower total amount of haddock food supply and production in the Georges Bank region. It is noted in this paper that improvements in fishing gear technology made in the early to mid-1930s (such as the inclusion of rollers, which allowed trawlers to fish previously unfishable rough substrates, extending their geographic range) may have been the impetus to a reduction in haddock food availability. The geographic expansion of fishing range and the weight and efficiency increases of trawl gear may have had a profound impact to the benthic habitat, and as a result, to the haddock food supply. It is pointed out that at the time this study was conducted, little evidence existed either way concerning the effects of trawling in relation to haddock food availability, and that considerable research was needed.

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

Keywords: dredging/ benthic disturbance/ Irish Sea

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.

Hill, B. J. and Wassenberg, T. J. 1990. Fate of discards from prawn trawlers in Torres Strait. Australian Journal of Marine and Freshwater Research. 41 : 53-64.

Keywords: trawling discards/ prawn trawlers/ discards/ scavenging/ Torres Strait

Abstract: A study was made of the fate of teleosts, non-commercial crustaceans and cephalopods discarded from trawlers in Torres Strait. These groups make up about 80% of the discards by weight, have a high mortality rate and are therefore the most likely animals to be eaten by

scavengers. The remaining 20% of discards consists of animals such as turtles, sharks, bivalves and sponges, which are caught in low numbers and appear to have to low mortality from trawling. Fish made up 78%, non-commercial crustaceans 18% and cephalopods 3% by weight of the material studied. Nearly all fish were dead when discarded, and about half sank. About half of the non-commercial crustaceans were alive when discarded and all sank when discarded. Few cephalopods (2%) were alive when discarded, and around 75% sank. Sharks and dolphins were the most common scavengers of floating discards at night. Birds scavenged only during the day. Discards that sank did so rapidly, taking less than 5 min to reach 25 m depth. A high rate of loss of baits set for 10 min in the water column (24% in trawled area at night) indicated significant scavenging in midwater - probably by sharks. Observations of baits set on the bottom showed that teleosts (nemipterids) and sharks ate most of the material that reached the bottom; scavenging by invertebrates was negligible. In an adjacent area that had not been trawled for 8 years, no dolphins and fewer birds were seen attracted to a bait on the bottom at night compared with the trawled area. The cause of the difference in scavenging observed between the two areas is not known; while it may reflect learned behaviour by some scavengers such as birds and dolphins, there may also be intrinsic differences between the two areas unrelated to trawling. Discarding from trawlers has the effect of transferring large quantities of biological material from the bottom to the surface. This makes available to surface scavengers food that would otherwise be inaccessible. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia, and the Australian Journal of Marine and Freshwater Research.*

Holmes, B. 1997. Destruction follows in trawler's wake. New Scientist.

Keywords: trawl effects

Summary: A short article discussing trawling impacts. The article cites many researchers who are prominent in gear impact research. Many negative effects are pointed out, but the main message is that information on the long-term effects of trawling is lacking; more areas need to be made off limits to trawling in order for recovery and comparison studies to take place.

Horwood, J. W. 2000. No-take zones: a management context. Pages 302-311 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: no-take zones/ fisheries management/ closed areas

Summary [author's summary]: 1. Examples of the theoretical and empirical evaluation of closed areas for fisheries management are described. The potential benefits of the closure of the North Sea Plaice Box, and the actual benefits of the closure of the Mackerel Box off the south-west of England are demonstrated. 2. Closed areas to protect juveniles fish, especially those areas with high discards, will be of benefit to the stocks and fisheries. 3. Other closed areas require a case-specific evaluation, and the results will be sensitive to the biology of the fish, the behaviour of the fishermen and the other fishery regulations in operation. Closed areas, which divert fishing elsewhere, taking the same weight of fish, are unlikely to have any significant benefits to the fish or fishery. 4. It is shown that closed areas may require monitoring over a considerable time to demonstrate empirically any benefits on naturally highly variable populations of fish. 5. No-take zones are recognized as a special case of closed areas, and are amenable to *a priori* evaluation provided the objectives for management are specified. 6. Examples where no-take zones may

have a utility are described, but in many cases areas with fishery restrictions may give similar results with less local disruption. 7. The single most important measure for the management of our commercial fisheries is to restore the balance between the size of the resource and the size of the fishing fleets. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK*.

Houghton, R. G., Williams, T., and Blacker, R. W. 1971. Some effects of double beam trawling. ICES Gear and Behaviour Committee CM 1971/B:5.

Keywords: beam trawling/ gear impacts/ fishing effects

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

Keywords: shellfish harvesting/ harvesting effects/ raking/ dredging

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 *Aequipecten irradiens* fishery in North Carolina. The results suggested that clam kicking and claim raking have had significant negative effects on the bay scallop recruitment process. *Reprinted with the permission of the American Fisheries Society and the North American Journal of Fisheries Management*.

Hughes, S. 1996. An industry perspective -- the good, bad, ugly, and politically influenced. Proceedings of the Solving Bycatch Workshop, September 25-27, 1995, Seattle, WA, Alaska Sea Grant College Program, Fairbanks, AK. 89-90.

Keywords: bycatch/ gear selectivity/ demersal fisheries/ fishery management/ fishery protection/ trawling

Hutchings, P. 1990. Review of the effects of trawling on macrobenthic epifaunal communities . Australian Journal of Marine and Freshwater Research. 41(1) : 111-120.

Keywords: trawling effects/ macrobenthic epifauna communities/ community change

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. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia, and the Australian Journal of Marine and Freshwater Research.*

ICES. 1973. The effects of trawls and dredges on the seabed. ICES Gear and Behaviour Committee CM 1973/B:2. 4 p.

Keywords: trawling effects/ dredging/ trawling

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

Keywords: trawling effects/ benthic disturbance

ICES. 1991. Effects of extraction of marine sediments on fisheries. Report of the ICES Working Group on the Effects of Extraction of Marine Sediments on Fisheries. ICES Cooperative Research Report No 182. Copenhagen. 78 p.

Keywords: dredging/ sediment extraction/ benthic disturbance/ benthos/ resuspended sediments/ coastal engineering

Summary: An in-depth report on the effects of sand and gravel extraction by various means, and the resulting physical and biological impacts to benthic environments. The report is the result of cooperative research undertaken from 1986 to 1990, and includes data from each of the ICES countries for which data was available.

ICES. 1991. Report of the study group on ecosystem effects of fishing activities. ICES CM 1991/G:7. 66 p.

Keywords: fishing effects/ gear impacts/ ecosystem effects

ICES. 1992. Report of the study group on ecosystem effects of fishing activities. ICES CM 1992/G:11 Ref: Session T. 144 p.

Keywords: fishing effects/ecosystem disturbance/trawling

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

Keywords: fishing effects/ trawling/ ecosystem disturbance

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

Keywords: fishing effects/ trawling/ ecosystem disturbance

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

Keywords: benthic disturbance

ICES. 1995. Report of the Study Group on Ecosystem Effects of Fishing Activities. ICES Cooperative Research Report No 200. 120 p.

Keywords: fishing impacts/ long-term changes/ anthropogenic factors/ ecosystem management

ICES. 1996. Manual of methods of measuring the selectivity of towed fishing gears. ICES Cooperative Research Report No 215. Copenhagen. 126 p.

Keywords: gear selectivity/ towed fishing gear

ICES. 1996. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 1996/Assess/Env:1 Ref.: Session G.

Keywords: fishing effects/ trawling/ ecosystem disturbance

ICES. 2000. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2000/ACME:02, Ref.: ACFM + E. 93 p.

Keywords: fishing effects/ bottom trawling effects/ North Sea/ Irish Sea/ Baltic Sea

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.

Keywords: trawling/ trawling impacts/ benthos/ Strangford Lough

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. 70(3) : 379-395.

Keywords: dredging/ environmental impact/ predator control/ Delaware Bay

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. *Reprinted with the permission of Wiley-VCH (Berlin) and the Internationale Revue der Gesamten Hydrobiologie.*

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

Keywords: scallop fishing impacts/ Gulf of St. Lawrence

Abstract: Damage to American lobsters, *Homarus americanus* in Egmont Bay and off Miminegash, Price 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. A., Strong, K. W., and Pocklington, P. 1991. A review of fishery related seabed disturbance in the Scotia-Fundy Region. Project Report No. 166, Industry Services and Native Fisheries Branch, Department of Fisheries and Oceans. Fisheries and Habitat Management, Scotia-Fundy Region, Halifax, NS. 54 p.

Keywords: seabed disturbance/ fishery impacts/ Scotia-Fundy Region

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. All of the data bases examined were originally obtained for other purposes. 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 an temporal basis. Such information is required before potential impacts of seabed disturbance by fishing activity can be addressed fully. *Reprinted with the permission of Dr. Valerie Bradshaw - Project Officer.*

Jennings, S., Alvsvag, J., Cotter, A. J. R., Ehrich, S., Greenstreet, S. P. R., Jarre-Teichmann, A., Mergardt, N., Rijnsdorp, A. D., and Smedstad, O. 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. 40(2) : 125-134.

Keywords: beam trawl/ fishing effects/ fishing effort/ North Sea/ otter trawling/ trawling

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 degrees latitude x 1 degrees 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 2 000 h in 29% of rectangles and less than 10 000 h in 66% of rectangles. Total effort exceeded 40 000 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. *Reprinted from Fisheries Research, Vol. 40; Jennings, S., Alvsvag, J., Cotter, A.J.R., Ehrich, S., Greenstreet, S.P.R., Jarre-Teichmann, A., Mergardt, N., Rijnsdorp, A.D. and Smedstad, O.; Fishing effects in northeast Atlantic shelf seaspatterns in fishing effort, diversity and community structure. III. International trawling effort in the North Seaan analysis of spatial and temporal trends; pages 125-134; Copyright (1999); with permission from Elsevier Science.*

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

Keywords: effects of fishing/ marine ecosystems/ trawling/ dredging/ tropical/ temperate/ polar/ benthic communities

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 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. Bycatch 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 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. and Reynolds, J. D. 2000. Impacts of fishing on diversity: from pattern to process. Pages 235-250 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: fishing/ diversity/ fish/ scale/ multivariate analysis

Summary [author's summary]: 1. Fishing has led to reductions in the diversity of fish and invertebrate communities in the north-east Atlantic. 2. Diversity can be measured in many ways. Some approaches emphasize species richness, while others emphasize the distribution of individuals among species and the evolutionary relatedness among species. 3. Reductions in fish diversity result from the direct mortality of target species rather than the indirect effects of fishing on trophic relationships. 4. Reductions in invertebrate diversity result from the effects of towed gears on the seabed. This effect is particularly apparent on stable substrates, but may not be detectable where mobile sediments are continually resuspended by waves and tides. 5. It is difficult to separate biogeographical patterns in diversity from patterns induced by fishing. Large-scale studies of fishing effects on invertebrate diversity can only proceed if the spatial resolution of fishing effort data is reduced to meters rather than tens of kilometers. 6. Links between fish or invertebrate diversity and the stability or productivity of marine communities are not known. We should aim to start describing both pattern and process in order that we can describe the effects of fishing on ecosystem function. 7. Considerable resources are required for diversity studies and diversity is not a particularly sensitive measure of fishing effects. An alternative is to use multivariate methods to identify indicator species that are vulnerable to fishing. Studies of the abundance and distribution of these species would provide a cost-effective approach for identifying areas impacted by fishing. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK*.

Johnson, S. A. 1981. Estuarine dredge and fill activities: a review of impacts. Environmental Management. 5 : 427-440.

Keywords: dredging/ dredging impacts/ sediment disturbance

Jones, G. 1981. Effects of dredging and reclamation on the sediments of Botany Bay. Australian Journal of Marine and Freshwater Research. 32(3) : 369-377.

Keywords: dredging/ dredging impact/ sediment disturbance/ Australia/ Botany Bay

Abstract: Bottom sediments in Botany Bay were surveyed and analyzed for particle size using a wet-sieving volumetric determination. Sediments are predominantly clean sands, although substantial changes in sediment type have occurred in the northern region of the bay since 1968. Large areas which were formerly clean sand, now contain significant amounts of mud. This increase in fine sediments is particularly marked in the dredged areas protected by the Port Botany revetment and the Kingsford-Smith Airport runway extension. These changes have not been the result of exposure by dredging of silt and clay lenses within the underlying sediments, but have probably been caused by the combined effects of deposition of fine material discharged during dredging and reclamation, and increased deposition of fluvial suspended matter due to changes in tidal circulation following the development of port and airport facilities. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia, and the Australian Journal of Marine and Freshwater Research.*

Jones, G. and Candy, S. 1981. Effects of dredging on the macrobenthic infauna of Botany Bay. Australian Journal of Marine and Freshwater Research. 32(3) : 379-398.

Keywords: dredging/ benthic community disturbance/ species diversity/ Australia/ Botany Bay

Abstract: The macrobenthic, infauna of dredged and undredged areas in Botany Bay were sampled. Data were analyzed using tests of significance and computer classification. While dredging has not significantly affected average species density per sample, the benthic fauna of dredged areas differs from that of nearby undredged areas with respect to species composition and richness, both of which appear to be strongly associated with sediment type. Species richness, in particular, is generally higher in areas characterized by sand than in those characterized by mud. Thus, while dredging has brought about a change in sediment type from sand to mud, species richness has decreased. This has occurred in the dredged areas near the Kingsford-Smith Airport extension and Port Botany revetment. However, in the region of the entrance to the bay, where harsh conditions of high swell and current exposure apparently normally limit benthos, the deeply dredged entrance channel supports a particularly diverse and abundant fauna. It is concluded that the major influence of dredging on the macro benthos in Botany Bay seems to have been indirect, through permanent modification of its physical environment. Extension of the present facilities at Port Botany are expected to lead to a significant decrease in the benthic species diversity of this area. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia, and the Australian Journal of Marine and Freshwater Research.*

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

Keywords: New Zealand/ trawling/ environment/ damage/ impact/ effects/ benthos/ sediment/ mortality

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. *Reprinted with the permission of the Royal Society of New Zealand and the New Zealand Journal of Marine and Freshwater Research.*

Kaiser, M. J. 1996. Starfish damage as an indicator of trawling intensity. Marine Ecology Progress Series. 134(1-3) : 303-307.

Keywords: starfish/ beam trawl/ fishing intensity/ indicator species/ beam trawl

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 sidescan 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 indicator of physical disturbance by demersal fishing gears. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

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

Keywords: bottom-fishing disturbance/ ecological change/ community change

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 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 versus 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. 1999. [Dr. Michel Kaiser shoots holes in America's trawl ban plan] Biased scientific reporting is tainting the Hefley Bill. Fishing News International. 8-9.

Keywords: trawling/ habitat impacts

Summary: This article was written primarily in response to the Hefley Bill that was put before the House of Representatives. In this article, the author suggests that phrases in the Bill grossly misrepresented scientific information in favor of a rather bleak perspective of the state of ocean benthos. The author points out that as the general populace becomes increasingly more aware of the impacts trawling has on bottom habitats, researchers, managers and the fishing industry will all need to have a better understanding of the ecological relationships that exist between trawling and benthic communities to ensure informed habitat management decisions will occur. Indeed, the author suggests that managers should not be too quick to impose restrictions on trawling activities in areas that have historically been heavily trawled. It is suggested that attention should be paid to studies, despite their geographic locality, which indicate that trawling has proven to be an acceptable and environmentally sustainable activity in certain seabed habitats.

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 (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: fishing effects/ non-target species/ marine habitats

Summary: This paper represents the final chapter of the book in which it is published. The paper summarizes sciences current understanding of mobile gear impacts, specifically as it relates with trawling activities in European waters. The author highlights the following topics: 1) Distribution of fishing effort and physical interactions with the seabed, 2) effects of fishing on benthic fauna and habitats, 3) fishing as a source of energy subsidies, 4) long-term changes associated with fishing, 5) conservation methods, issues and implications for biodiversity, and 6), socio-economic implications and mechanisms for reducing fisheries impacts. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK .*

Kaiser, M. J., Armstrong, P. J., Dare, P. J., and Flatt, R. P. 1998. Benthic communities associated with a heavily fished scallop ground in the English Channel. Journal of the Marine Biological Association of the United Kingdom. 78(4) : 1045-1059.

Keywords: scallop fishery/ dredging/ scallop dredging/ RoxAnn acoustic profiling

Abstract: A survey of benthic communities found in a heavily fished scallop ground was undertaken in July 1993. Two main faunal assemblages were identified from samples obtained with fine-meshed scallop dredges, which were grouped either in gravelly sand sediments or sandy sediment, which was generally furthest offshore in deeper water. A third assemblage was found in either sandy or gravelly muddy sand sediments. The highest abundance of small and large size-classes of scallops were associated with the assemblage containing the greatest number of species and individuals in sandy sediments. This assemblage had the greatest biomass of emergent fauna such as hydroids and *Alcyonium digitatum*. Data acquired from a RoxAnn™ acoustic signal processor were able to differentiate between the substratum or biotopes

associated with the greatest abundance of scallops. This may provide a useful tool for refining surveys of commercial stocks or mapping suitable habitats. *Reprinted with the permission of Cambridge University Press and Journal of the Marine Biological Association of the United Kingdom.*

Kaiser, M. J., Cheney, K., Spence, F. E., Edwards, D. B., and Radford, K. 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. 40(2) : 195-205.

Keywords: biogenic structure/ physical disturbance/ biodiversity/ bottom trawling/ Serpulid tubeheads

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 recolonize 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. *Reprinted from Fisheries Research, Vol. 40; Kaiser, M.J., Cheney, K., Spence, F.E., Edwards, D.B. and Radford, K.; Fishing effects in northeast Atlantic shelf seaspatterns in fishing effort, diversity and community structure VII. The effects of trawling disturbance on the fauna associated with the tubeheads of serpulid worms; pages 195-205; Copyright (1999); with permission from Elsevier Science.*

Kaiser, M. J. and de Groot, S. J. eds. 2000. Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd., Oxford, UK. 399 p.

Keywords: fishing effects/ trawling/ North Sea

Kaiser, M. J., Edwards, D. B., Armstrong, P. J., Radford, K., Lough, N. E. L., Flatt, R. P., and Jones, H. D. 1998. Changes in megafaunal benthic communities in different habitats after trawling disturbance. ICES Journal of Marine Science. 55(3) : 353-361.

Keywords: beam-trawl disturbance/ megafauna/ recovery/ quantitative dredge

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

Keywords: clam cultivation/ benthic community/ harvesting/ environmental impact

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

Keywords: Irish Sea/ benthic disturbance/ trawling/ dredging/ demersal fisheries

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 bycatch 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. and Horwood, J. 1997. Damage limitation in the deep. New Scientist. 156, p. 55.

Keywords: trawling impacts/ benthic disturbance

Summary: This article addresses the effects of trawling impacts to benthic habitats, and suggests that trawling activities may not necessarily be as destructive as they are so considered, particularly in regions that are historically common trawling grounds.

Kaiser, M. J., Laing, I., Utting, S. D., and Burnell, G. M. 1998. Environmental impacts of bivalve mariculture. Journal of Shellfish Research. 17(1) : 59-66.

Keywords: bivalve/ mariculture/ environmental impact/ dredging

Abstract: There is a pressing need to protect the ecology of nearshore marine habitats that are used for an ever increasing range of activities. In particular, fisheries managers need to consider both environmental and socioeconomic issues in coastal areas owing to the environmental changes that can occur as a result of cultivation and harvesting processes associated with mariculture. Bivalve cultivation can be broadly split into three main processes: (1) seed collection, (2) seed nursery and on-growing, (3) harvesting.

The environmental impacts of each cultivation stage will vary depending on the species in question and the techniques used. In many instances, commercial species are reared as seed in hatcheries prior to seeding, with few effects on the environment. However, while some species are collected from the wild using benign techniques such as spat collectors, others are extracted using intrusive devices such as dredges. A growing number of studies of the ecological effects of mechanical collecting devices have demonstrated direct mortality of non-target species and the destruction of suitable settlement substrata or habitats. In addition, other species, such as birds, crabs and starfish, may be deprived of valuable food resources and habitat as a result of the mechanical harvesting of bivalve seed.

The nursery and ongrowing of bivalve involves either suspended culture subtidally, trestle culture intertidally or cultivation directly on/in the ground. Many of the environmental changes that occur result from their filter feeding activities that produce faeces and pseudofaeces. This can lead to depletion of phytoplankton in densely cultivated systems and accumulation of silt/pseudofaeces beneath suspended cultures that then often results in a locally anoxic environment and faunal impoverishment. In addition, the structures used during the cultivation process can cause environmental change. For example, the use of netting to protect clams from crab predators leads to siltation and accumulations of sediment. Parks of trestles can drastically alter the water flow regime leading to changes in sedimentation rate and oxygen exchange within the system. Extensive intertidal cultivation plots could deprive birds of feeding habitats, and the

associated husbandry practices may disturb roosting birds.

The final stage of cultivation involves harvesting. In many cases this involves little more than emptying the bivalves from poches or lifting ropes. However, in the case of species cultivated within sediment, or relayed on the seabed, the use of intrusive techniques is required. Both dredgers and suction devices cause disruption of the sediment and kill or directly remove non-target species. The time taken for communities affected by these processes to recover will vary depending on a number of factors, such as the cohesive qualities of the sediment and the aspect of the site and the longevity of the non-target fauna.

As is the case with all anthropogenic activities that impinge on the marine environment, the magnitude of the environmental changes that occur is linked to the scale of the cultivation processes. There are also positive aspects to coastal shellfish cultivation such as the provision of hard substrata and shelter in otherwise barren sites and the possibilities of using the cultured organisms as environmental sentinels.

Here, we review the potential environmental effects that occur throughout the cultivation cycle, from collection of the seed to harvesting. We suggest that careful consideration of the techniques used can effectively minimize environmental changes that might occur, and possibly ameliorate subsequent restoration of cultivated sites. *Reprinted with the permission of the National Shellfisheries Association and the Journal of Shellfish Research.*

Kaiser, M. J. and Ramsay, K. 1997. Opportunistic feeding by dabs within areas of trawl disturbance: Possible implications for increased survival. Marine Ecology Progress Series. 152(1-3) : 307-310.

Keywords: dab/ fishing disturbance/ diet/ feeding behaviour/ population changes

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 bycatch 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. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Kaiser, M. J., Ramsay, K., and Hughes, R. N. 1998. Can fisheries influence interspecific competition in sympatric populations of hermit crabs? Journal of Natural History. 32(4) : 521-531.

Keywords: fishing effects/ interspecific competition/ hermit crabs

Kaiser, M. J., Ramsay, K., Richardson, C. A., Spence, F. E., and Brand, A. R. (Submitted). Chronic historical fishing disturbance has changed shelf sea benthic community structure. Journal of Animal Ecology.

Keywords: fishing disturbance/ trawling impacts/ long-term effects/ benthic community structure

Kaiser, M. J., Ramsay, K., and Spencer, B. E. Short-term ecological effects of beam trawl disturbance in the Irish Sea: a review. 7 p. (Unpublished).

Keywords: beam trawl disturbance/ Irish Sea

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 studied 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. *Reprinted with author permission (Dr. M.J. Kaiser).*

Kaiser, M. J., Rogers, S. I., and Ellis, J. R. 1999. Importance of benthic habitat complexity for demersal fish assemblages. Pages 212-223 *in* L. R. Benaka (ed.). Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22. Bethesda, Maryland.
Keywords: benthic habitat/ essential fish habitat/ fishing effects/ demersal fish

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 dichotomized 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. *Reprinted with the permission of the American Fisheries Society.*

Kaiser, M. J., Rogers, S. I., and McCandless, D. T. 1994. Improving quantitative surveys of epibenthic communities using a modified 2 m beam trawl. Marine Ecology Progress Series. 106(1-2) : 131-138.

Keywords: epibenthic communities/ quantitative surveys/ beam trawl

Abstract: The addition of heavy, spiked, linked tickler chains (chain mat) to a 2-m beamtrawl without chain mat increased the catch rates of some epibenthic species, but not others. Catch rates of the invertebrates *Asterias rubens*, *Ophiura ophiura*, *Liocarcinus holsatus* and all combined flatfish species increased. In contrast, the catch rates of the epibenthic teleosts *Callionymus* decreased, but those of *Echiichthys vipera* were not affected. Comparisons with data in other studies suggested that this modification increased the catch rates of epifauna to give an improved estimate of population density. Although total biomass of the catch increased with tow durations between 2.5 and 7.5 min, there was no significant effect on estimates of either standardized species abundance or biomass ha^{-1}. Although short tows reduce catch sorting time, the variation between samples was greater than for longer tows (7.5 min). Hence, it is suggested that the latter are preferable for estimating population density and community structure, although this may depend on the spatial dimension and objectives of the study. The results are discussed in the context of the use of the gear as a sampling tool in ecological surveys of epibenthic communities in sublittoral and coastal shelf areas. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Kaiser, M. J., Spence, F. E., and Hart, P. J. B. (In press). Harvesting with due care and attention: fishing gear restrictions conserve habitat complexity. Conservation Biology.

Keywords: fishing effects/ fishing gear restrictions/ habitat complexity

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

Keywords: bottom trawls/ scavengers/ ecosystem disturbance/ stomach content analysis/ sidescan sonar

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 before and 3 h after fishing the same track three times with a 4-m beam trawl. Stomach contents of the fish 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 capitalize on animals killed or disturbed from their burrows, or other smaller predators that move into a recently trawled area. Furthermore, a sidescan 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. *Reprinted with author permission (Dr. M.J. Kaiser).*

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

Keywords: beam trawls/ bycatch survival/ fishing impacts/ North Sea

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. *Reprinted with author permission (Dr. M.J. Kaiser).*

Kaiser, M. J. and Spencer, B. E. 1994. Fish scavenging behavior in recently trawled areas. Marine Ecology Progress Series. 112(1-2) : 41-49.

Keywords: beam trawling/ scavengers/ disturbance/ community structure/ diet change

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 sidescan 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. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Kaiser, M. J. and Spencer, B. E. 1995. Survival of bycatch from a beam trawl. Marine Ecology Progress Series. 126 : 31-38.

Keywords: survival/ bycatch/ beam trawl

Abstract: The passage of a beam trawl across the seabed leads to the direct mortality, or indirect mortality through subsequent predation, of some benthic species. In addition, animals retained in, or those that pass through, the cod end may also die as a result of the fishing process. The extent of this additional mortality needs to be quantified to calculate total mortality of non-target species associated with this type of fishery. Hence, we investigated the survival of animals caught by a 4 m beam trawl, in order to identify those species most sensitive to capture. Starfishes, hermit crabs and molluscs were highly resistant to the effects of capture (> 60% survived in all cases). Fishes (except dogfish), sea urchins and swimming crabs suffered higher mortality after capture. Generally, the majority of the animals that passed through the meshes of the cod end survived. Experimental investigation of the cause of damage to certain species concluded that the chain matrix fitted to the gear was largely responsible for the injuries sustained. The types of injuries and their extent were species-specific, and were related to the fragility and physical characteristics of each species. Our experiments revealed that while some species are highly sensitive to capture, others are capable of surviving the effects of capture. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

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

Keywords: beam trawl/ disturbance/ predation/ scavengers

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 behaviour 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

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

Keywords: beam-trawling/ benthic community/ disturbance/ infauna/ habitat

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 sidescan 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK and the Journal of Animal Ecology.*

Kauwling, T. J. and Bakus, G. J. 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.

Keywords: dredging/ clam dredging/ Bering Sea/ fishing effects

Keegan, B. F., Van Marlen, B., Bergman, M. J. N., Zevenboom, W., Fonteyne R., Lange, K., and Browne, J. 1998. Reduction of adverse environmental impact of demersal trawls. Pages 313-314 *in* Third European Marine Science and Technology Conference, Lisbon, 23-27 May 1998. Fisheries and Aquaculture (FAIR: 1994-98) Vol. 6. European Commission DG 12 Science, Research and Development, Luxembourg (Luxembourg).

Keywords: fishing effects/ demersal fisheries/ trawl nets/ trawling/ benthos

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. South West Nova Fixed Gear Association. Shelburne, Nova Scotia, Canada.

Keywords: dragging/ fish dragging/ gear impacts/ fishing effects

Kendall, J. 1998. The effect of dredge harvesting on eastern oysters and the associated benthic community. Pages 90-93 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: dredging/ scallop dredging/ fishing effects/ benthos

Summary: The author, a scallop fisherman for 32 years, gives his account of scallop fishing in New England, and some food for thought (anecdotally) about what may and may not be important when considering benthic disturbance due to fishing activities.

Kennelly, S. J. 1995. The issue of bycatch in Australia's demersal trawl fisheries. Reviews in Fish Biology and Fisheries. 5(2) : 213-234.

Keywords: demersal fisheries/ bycatch/ environmental impact/ population density/ fishery protection/ shared stocks/ Australian fisheries

Abstract: A common definition of the term 'bycatch' is that part of the gross catch which is captured incidentally to the species towards which there is directed effort. Under such a definition, there are few fisheries in Australia (nor the world) which do not have bycatch, making the scope, diversity and history of the issue enormous. In recent years, the majority of interest in bycatch has focused on demersal trawl fisheries because conventional otter trawls are comparatively non-selective fishing gears and so catch large quantities of a wide range of untargeted species.

In general, the chief problems associated with bycatch from demersal trawling concern conflicts with other fisheries that target species which are discarded by trawlers. Research into this issue in Australia has concentrated on attempts to describe and quantify the highly variable but very large quantities and diversities of bycatches from prawn trawling. These descriptive aspects of the issue are prerequisite to identifying, understanding and eventually managing any problems. There has been some research on estimating actual impacts of demersal trawl bycatch on interacting fisheries via fishery-independent surveys of trawled and untrawled areas. Significant inroads also have been made in understanding the fate of discards as food for other organisms and effects that demersal trawling may have on habitats and consequences for macrobenthic assemblages.

Unfortunately the situation in Australia has been slow to progress to the next stage of solving the perceived problems of demersal trawl bycatch. It is clearly necessary to describe and quantify bycatches in specific fisheries (in order to assess whether any problems exist), but such work in itself is insufficient in solving the problems that arise when these bycatches are described. Once this preliminary descriptive work is done, it is necessary to test the effectiveness of alternative management strategies (such as closures and/or more selective trawl gears) which may alleviate any problems that have been detected. Several current research projects in Australia are showing the great potential that more selective trawl gears have for alleviating the

chief problems concerning demersal trawl bycatch. *Reprinted with kind permission from Kluwer Academic Publishers.*

Kenny, A. J. and Rees, H. L. 1994. The effects of marine gravel extraction on the macrobenthos: early post-dredging recolonization. Marine Pollution Bulletin. 28(7) : 442-447.

Keywords: dredging/ ecosystem impacts/ sediment disturbance/ environmental impact/ gravel extraction/ North Sea

Abstract: A small area of sea bed off the English east coast was experimentally dredged by a commercial suction-trailer dredger. Some 50 000 t of mixed aggregate were removed, representing about 70% of the sea bed area down to an average depth of 0.3 m. Results from benthic surveys undertaken at the experimental site and at a nearly reference site, indicate that significant reductions had occurred in the variety, abundance and biomass of benthic organisms as a consequence of dredging. Subsequent recolonization of denuded substrates by the dominant taxa proceeded relatively rapidly although the dredged site had clearly not fully recovered some 7 months later. Differences in the recruitment success of the dominant taxa, notably *Dendrodoa grossularia* and *Balanus creates*, between the reference and treatment sites pre- and post-dredging were observed. Possible explanations for these differences in relation to the observed physical alterations to the sea bed are discussed. *Reprinted from Marine Pollution Bulletin, Vol. 32; Kenny, A.J., Rees, H.L.; The effects of marine gravel extraction on the macrobenthosEarly post-dredging recolonization; pages 442-447; Copyright (1994); with permission from Elsevier Science.*

Kenny, A. J. and Rees, H. L. 1996. The effects of marine gravel extraction on the macrobenthos: Results 2 years post-dredging. Marine Pollution Bulletin. 32(8-9) : 615-622.

Keywords: dredging/ ecosystem impacts/ sediment disturbance/ environmental impact/ gravel extraction/ North Sea

Abstract: An offshore experimental dredging study was initiated off North Norfolk (UK) in 1992 to investigate the impacts of marine gravel extraction on the macrofauna. A dredged "treatment" and a non-dredged "reference" site were selected to evaluate the initial impacts and subsequent processes of recolonization. A survey of the benthos was conducted prior to the removal of 50,000 t of marine aggregate from the treatment site. Thereafter annual monitoring surveys were conducted commencing immediately after the dredging episode. Results indicated that whilst the dominant species recolonized quickly following dredging many rarer species did not. Evidence from sidescan sonar records and underwater cameras indicated a considerable amount of sediment transport during the first two winters following dredging and the once well-defined dredge tracks have now become infilled with sand and gravel. The substantially reduced biomass at the treatment site some 24 months after dredging is thought to be due to a local increase in sediment disturbance caused by tide and wave action over the winter period. Finally, the biological findings of this study are discussed in relation to their wider environmental significance. *Reprinted from Marine Pollution Bulletin, Vol. 32; Kenny, A.J., Rees, H.L.; The effects of marine gravel extraction on the macrobenthosResults 2 years post-dredging; pages 615-622; Copyright (1996); with permission from Elsevier Science.*

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

Keywords: trawling/ gear effects/ benthic disturbance

Klemanowicz, K. J. and Steele, G. H. 1983. Effects of a mechanical oyster harvester on macrobenthic community structure. Journal of Shellfish Research. 4(1), p. 92.

Keywords: mechanical harvester/ benthic disturbance/ macrobenthic community structure

Abstract: The ecological effects of mechanical harvesting on the intertidal benthic invertebrate community associated with oyster beds in Beaufort County, SC, has been studied. At a harvest site macrobenthos that inhabit oyster beds in the high and low intertidal zones were 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 was to be sampled on the same schedule as the harvested site.

For each sampling period, a 16-m^2 circular quadrat was 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 was made, whereas only the species composition of colonial and encrusting organisms is noted. Biomass was 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 were 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. *Reprinted with the permission of the National Shellfisheries Association and the Journal of Shellfish Research.*

Koslow, J. A. and Gowlett-Holmes, K. 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.

Keywords: trawling/ trawling impacts

Krost, P. 1990. The impact of otter-trawl fishery on nutrient release from the sediment and macrofauna of Kieler Bucht (western Baltic). Ph.D. dissertation. Berichte aus dem Institut fur Meereskunde an der Christian-Albrechts-Universitat Kiel. Kiel. 200, 160 pp.

Keywords: trawl impacts/ sediment disturbance/ zoobenthos/ Kiel Bight/ nutrient cycles

Abstract: The effects of otter-trawl fishery on nutrient release from the sediment and macrofauna of Kieler Bucht (Western Baltic) was investigated. The dimension of the impact by otter-board fishery on the sediment was estimated by sidescan sonar and underwater video. Only the otter boards imprint distinctive and long-lasting marks at the sea bottom. By the use of underwater video the depth of these tracks was estimated as about 5 cm on muddy sand, about 10 cm on sandy mud and about 15 cm on mud. The width of the tracks is usually around 0.8 m. A mapping of the otter-board tracks in the study area using sidescan sonar showed, that the areas of highest trawl-track frequency coincide with muddy sediments.

An approximation of fishery effort resulted in an area of 333 km^2 annually disturbed by

otter boards. The total area trawled per year (including all parts of the otter-trawl gear) is about 10 times larger.

Resuspension experiments in bell jars showed, that the spontaneous nutrient release from the sediment by resuspension equals the total amount of nutrients in the pore water of the resuspended sediment. Additionally, nutrients will be released by subsequent readjustion of the pore water gradients in the sediment to the previous profile.

Undisturbed porewater profiles were measured for the sediment types relevant for otter-board fishery, i.e. muddy sand, sandy mud and mud. By these profiles diffusional fluxes of nutrients from the sediment into the water column were calculated: on sandy mud they are 378 micromol $m^{-2}d^{-1}$ ammonia and 89 micromol $m^{-2}d^{-1}$ phosphate. For the area of 333 km^2 annually disturbed by otter boards an additional mobilization of 200-822 t silicon, 98-435 t nitrogen and 34-167 t phosphorus was calculated, as well as an annual oxygen demand of 491-2656 t O_2 due to the release of hydrogen-sulphide by sediment resuspension.

Effects of otter-trawl fishery on benthic macrofauna was studied by comparison of samples from new trawl tracks with undisturbed samples. Samples of extensively fished areas were compared with samples from control areas of similar sediments and water depth. An experiment was performed to study the damage of benthic animals suffered by an otter-board passage.

In the channel system in Kieler Bucht the fishery effort is strong enough to induce considerable changes of the benthic community. Endofauna is more affected than epifauna, abundance more than biomass. The most abundant animals are predominately reduced, resulting in often even higher evenness and diversity than in undisturbed areas. By prerunning water pressure and resuspension of sediment and animals living within, only a smaller portion of animals collide directly with the otter board. Especially spherical and compact molluscs have a good chance to survive an otter-board passage. *Reprinted with author permission (Dr. P. Krost).*

Krost, P. 1993. The significance of the bottomtrawl fishery for the sediment, its exchange processes, and the benthic communities in the bay of Kiel. Arbeiten des Deutschen Fischerei-Verbandes. (57) : 43-60.

Keywords: bottomtrawl/ sediment disturbance/ sediment redistribution/ sediment exchange

Abstract: The influence of the bottom trawl fishery on the release of nutrients and on the macrofauna was examined in the bay of Kiel. Of all the parts of the bottom trawl that are in contact with the bottom, the doors manifest the most significant disturbance to the sea floor. Depending on sediment type, the doors penetrate the sea floor up to 20 cm deep. The area fished per year can only be estimated roughly from the data available and should be around 3000 m^2. Trawl doors are used in 10% of that area. Door tracks can be preserved on soft bottom for long periods of time (4-5, maybe more years).

The main fishing grounds are situated in the silt areas. Those areas have a high concentration of nutrients and hydrogen sulfites in the pore water. A passage of the trawl doors results in a complete release of the dissolved nutrients in the pore water of the affected area. A quantitative estimate of the nutrient release is difficult because of the unpredictable and undocumented behavior of the fishery.

The release of nutrients by the fishery is estimated to be around 200-820 t silicates, 100-435 t nitrogen, and 35-170 t phosphate. This represents only a small percentage of the total amount of nutrients in the bay of Kiel.

However, release of hydrogen sulfite out of the porewater can lead to oxygen

consumptions of 500-2500 t of O_2 per year and therefore to localized anoxic conditions. It is therefore recommended not to use bottom trawls at times of low oxygen concentrations in the bottom waters. Low oxygen concentrations are found under low current situations in bottom depressions.

Only in the dredged channels of the bay of Kiel is the fishing intensity strong enough to cause documentable changes in the settling processes of the benthos. Small animals are less affected than bigger ones, animals with an epibenthic lifestyle are less affected than animals that live in the sediment. Especially small bivalves with thick shells can withstand the impact of trawl doors well. *Reprinted with author permission (Dr. P. Krost).*

Krost, P., Bernhard, M., Werner, F., and Hukriede W. 1990. Otter trawl tracks in Kiel Bay (Western Baltic) mapped by sidescan sonar . Meeresforschung Reports on Marine Research. 32(4) : 344-353.

Keywords: trawling impacts/ sidescan sonar/ Kiel Bay/ Western Baltic

Abstract: Tracks of bottom trawling gear, in particular of otter boards, have been mapped from sidescan 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. *Reprinted with author permission (Dr. P. Krost).*

Kurland, J. M. 1998. Implications of the essential fish habitat provisions of the Magnuson-Stevens Act. Pages 104-106 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: fishing effects/ essential fish habitat/Magnuson-Stevens Act/ EFH/ New England

Summary: Under the Sustainable Fisheries Act of 1996, amendments were made to the Magnuson-Stevens Fishery Conservation and Management Act to characterize and protect 'essential fish habitat' (EFH). The author explains what these amendments were, what they mean, and how they are being implemented in New England in context to the effects of fishing gear on habitat.

Kurland, J. M., Colligan, M. A., and Nelson, E. P. 1995. Improving the environmental management of dredging projects in shallow water habitats. Second Annual Marine and Estuarine Shallow Water Science and Management Conference. U.S. EPA, Philadelphia, PA. 25 p.

Keywords: dredging/ dredging impacts/ ecosystem disturbance/ environmental impact/ sediment disturbance

Kyte, M., Averill, P., and Hendershott, T. 1975. The impact of the hydraulic escalator shellfish harvester on an intertidal soft-shell clam flat in the Hanaseeket River, Maine. National Marine Fisheries Service Rep. 3-170-R, Department of National Resources, Augusta, Maine. 54 p.

Keywords: hydraulic escalator harvester/ clam fishery

Kyte, M. A. and Chew, K. K. 1975. A review of the hydraulic elevator shellfish harvester and its know 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.

Keywords: hydraulic elevator harvester/ clam fishery

Laban, C. and Lindeboom, H. 1991. Penetration depth of beamtrawl gear. Pages 37-52 *in* Effects of Beamtrawl Fishery on the Bottom Fauna in the North Sea, II: the 1990 studies. BEON-RAPPORT 13. Netherlands Institute for Sea Research, Texel, The Netherlands.

Keywords: sediment disturbance/ reciprocal formation factor/ pore water content/beam trawl effects/ bottom fauna/ North Sea

Summary: In this paper, sediment characteristics are measured to try and determine the penetration depth of demersal trawl gear in an area southwest of the Borkum Riff, North Sea. Boxcore samples were collected before and after the passage of a bottom trawl, and within and outside of the trawl track. The sediment characteristics analyzed were the reciprocal formation factor and the pore water content. Other techniques such as lacker peels, X-ray photographs and mud content were also used to provide insight to gear penetration depth. Additionally, meiofauna distribution was analyzed for distinctive patterns in sediment change. A number of factors made it difficult to make certain determinations about the depth of penetration. Most significant of these factors was not having a fixed reference depth in the sediments, or not being able to compare an original sediment profile in the same spot as that of the profile collected after the passage of the trawl. Passage of the beam trawl disturbed sediments at depths between at least 4 and 8 cm.

Lambert, J. and Goudreau, P. 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.

Keywords: dredging/ clam dredging/ *Mactromeris polynyma*

Langan, R. 1998. The effect of dredge harvesting on eastern oysters and the associated benthic community. Pages 108-110 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: dredging/ fishing effects/ benthos

Summary: An oyster bed at the mouth of the Piscataqua River, divided nearly equally on either side of the New Hampshire and Maine jurisdictional lines, was studied to evaluate the oyster populations and benthic community. Differences in state regulations provided the researcher with an opportunity to compare the benthos where the differing regulations on commercial harvesting were employed. Suspended sediments due to dredging activity was also studied. In Maine's jurisdiction (harvested), oysters showed a normal size distribution and good recent recruitment. In New Hampshire's jurisdiction (non-harvested) oysters were large and recruitment was poor. No significant differences (ANOVA) were found between the two areas in the number, species richness or diversity of epifaunal and infaunal invertebrates. Additionally, suspended sediments results indicated that the impact of the dredging activities in Maine were localized and not very large.

Lange, K. 1990. Application of an underwater television system for the development and improvement of travel equipment. Advances of Shipbuilding Technology in Theory, Experiment and Practice. Sect. E. Fischerei-Forschung. 28(4) : 29-30.

Keywords: underwater television/ gear construction/ fishing gear/ catching methods/ fishery technology

Lange, K. and Gabriel, O. 1997. Investigations with a modified roller gear for beamtrawls. Informationen fur die Fischwirtschaft. 44(4) : 168-170.

Keywords: roller gear/ beam trawling/ sediment disturbance/ gear modifications

Abstract: With a traditional roller gear, only the rollers in the center are working correctly. The rollers on both sides are more or less gliding on the sea bottom because their axis are not in a position perpendicular to the towing direction. Sediment is stirred up by these gliding rollers coupled with a negative bottom impact of this gear. With a modified roller gear for shrimp beam trawls the axis of all rollers are oriented 90º to the towing direction enabling all rollers to roll correctly on the sea bottom. The modified roller gear was tested with underwater cameras and it was found that the rollers on the sides of the beam were not touching bottom and therefore not as effective. (This is a traditional design to avoid stirring up the sediment and silt which dirties the catch.) When the modified rollers where lowered, fishing efficiency went up without sediment being stirred up. The increase in catch with the new gear was described as 10%. *Reprinted with the permission of Bundesforschungsanstalt für Fischerei [Federal Research Centre for Fisheries], 1999, and Informationen fur die Fischwirtschaft [Informations for the Fishing Industry]*

Lange, K. and Mentjes, T. 1998. Reduction of the adverse environmental impact of demersal trawls. Informationen fur die Fischwirtschaft. 45(3) : 121-122.

Keywords: bottom trawls/ environmental impact/ international cooperation/ research programs/ jetbeam trawl/ tickler chains

Abstract: An EU funded research project was started in 1998 by institutes from Ireland, Belgium, the Netherlands and Germany to reduce the adverse environmental impact of demersal trawls. In the frame of this project the Institute for Fishery Technique of the Federal Research Centre for Fisheries, Hamburg, is developing a jet beamtrawl replacing the heavy tickler chains of a traditional flatfish beam trawl by water jet nozzles placed at the lower side of the beam with the jets directed towards the sea bottom. First trials on the Dutch research vessel *Tridens* were performed in March 1998. Catch and bycatch of a jet beamtrawl and a traditional beamtrawl were compared. The efficiency of the jet beamtrawl was not satisfactory and will have to be improved. *Reprinted with the permission of Bundesforschungsanstalt für Fischerei [Federal Research Centre for Fisheries], 1999, and Informationen fur die Fischwirtschaft [Informations for the Fishing Industry]*.

Lange, K. and Steinberg, R. 1989. Influence of size and form of otterboards on the opening area of a bottom trawl. Informationen fur die Fischwirtschaft. 36(4) : 170-172.

Keywords: otter boards/ bottom trawls/ fishing gear design

Abstract: Four types of trawl doors were tested in August/September 1989 on the vessel *Solea*. The performance of the net with different door types as well as door behavior on different substrate types was examined. The net used was a (highrise) bottom trawl with 450 mesh circumference and a mesh size of 200 mm. As a measure of net performance scientists used the distance between upper wingtips in combination with the net opening measured at the center of the headrope. An underwater camera was used with a third-wire connection to the vessel which made it necessary to use a net sounder unit without cable. Using two different cables might risk entanglement.

Four different door types were used: 1) 4.5 m^2 flatdoors with a relationship of height to length of 1:2, wood construction with steel frames. 2) 3.8 m^2 louvered doors with curved single planes that overlap each other. 3) 2.6 m^2, like type #2. 4) V-doors with 10% bend in direction of tow, area and height to width relationship like in type #1.

The spreading power of the doors are a function of the area F and a shape factor C_a. The higher C_a the smaller the door area needs to be. The authors calculated C_a for the profile door with area 2.6 m^2 as 1.9 compared to the known value of C_a for the flat doors as 1.1. The C_a for the V-doors was described as 1.7.

It is not only important to know spreading power of doors but also their behavior when used. Even though experiments were not completed, it was obvious that all four door types were able to withstand rough fishing conditions. However, the profile doors were described as more sensitive to different settings than the rest of the door types. *Reprinted with the permission of Bundesforschungsanstalt für Fischerei [Federal Research Centre for Fisheries], 1999, and Informationen fur die Fischwirtschaft [Informations for the Fishing Industry].*

Lange, K. and Steinberg, R. 1989. The low-light-level underwater television camera – an important device for fisheries research. Animal Research and Development. 30 : 36-76.

Keywords: underwater vehicles/ underwater television cameras/ light intensity/ fishery surveys/ fishery research

Abstract: In the late 1970s, manufacturers began offering low-light-level television cameras described more closely in this work for underwater observation. Recent developments are represented with particular attention being paid to the use of underwater television for research work oriented toward fishing technology: description of basic equipment, remote controlled vehicles, flaps and rudders, side thrusters, magnus rotors and on board control systems. *Reprinted with author permission (Dr. K. Lange).*

Langton, R. W. 1994. Fishing effects on demersal fish habitats. Pages 7-8 *in* R.W. Langton, J. B. Pearce and J. A. Gibson (eds.). Selected Living Resources Habitat Conditions, and Human Perturbations of the Gulf of Maine: Environmental and Ecological Considerations for Fishery Management. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NE-106. Woods Hole, Massachusetts.

Keywords: fishing effects/ demersal fish habitat

Langton, R. W. and Auster, P. J. 1999. Fisheries management essay - managing essential fish habitat: what are the next steps? Fisheries. 24(6) : 30-31.

Keywords: essential fish habitat/ adaptive ecosystem management/ habitat recovery

Summary: This is a two-page essay that addresses essential fish habitat (EFH), and indicates a need to delineate EFH on a more localized scale. It is suggested that establishing marine protected areas, and utilizing these areas in habitat research is perhaps the best scenario for establishing adaptive ecosystem management.

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

Keywords: fishing impacts/ ecosystem effects/ food web effects/ feedback mechanisms/ benthic commmunities

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 scientists alike to apply the precautionary approach to all management decisions by using current ecological theory to guide this process. *Reprinted with the permission of the American Fisheries Society and Fisheries magazine.*

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

Keywords: scale/ fish assemblages/ fishing grounds/ microhabitat

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. *Reprinted with permission from Reviews in Fisheries Science. Copyright CRC Press, Boca Raton, Florida, USA*.

Laurenson, L. J. B., Unsworth, P., Penn, J. W., and Lenanton, R. C. J. 1993. The impact of trawling for saucer scallops and western king prawns on the benthic communities in coastal waters off south Western Australia. Fisheries Research Report No. 100. Fisheries Department of Western Australia. 93 p.

Keywords: bottom trawling/ scallop fisheries/ prawn fisheries/ benthic environment/bycatch/ discards/ south western Australia

Abstract: A 2-year study was undertaken to collect data for the assessment of the impact of the saucer scallop and western king prawn trawl fisheries on the benthic communities in coastal waters off south western Australia, between 31°20'S and 34°23'S latitude.

Monitoring of reported commercial landings, on-board sampling of commercial catches, research vessel trawl surveys, experimental and exploratory trawling, and underwater television observations have enabled the development of an extensive database on the fishery and benthic communities of the region.

These data indicate that the existing fishery operates on a number of relatively small, discrete grounds where saucer scallops or prawns are abundant, and affects approximately 2% of the waters shallower than 50 meters, within the fishery management zone. Recorded fishing effort and catches vary significantly from year to year, primarily in response to the abundance and price of saucer scallops and prawns which are the major target species in the southern sector of the fishery. During a year of intensive commercial catch sampling (1990/91), an estimated 354 tonnes of marine fauna were taken by the trawlers, comprising 109 tonnes of the target species, 21 tonnes of retained bycatch and 224 tonnes of discards of which approximately 67% were unlikely to survive.

Research vessel surveys recorded 150 species of teleost (bony) fish, elasmobranchs (sharks and rays) and invertebrates from commercial trawl grounds. Of these species, 39 were recorded at some time in commercial landings, however only 5 species, in addition to the target species of saucer scallops and prawns, were taken in any quantity. Of the top 10 species taken as bycatch, only two species, the blue manna crab and southern school whiting were both abundant and of significant interest to recreational fishers. Other species in the trawl bycatch which were found to be reasonably abundant and also of recreational interest were sand trevally, red mullets, long spined and blue spotted flathead, squid and cuttlefish.

A detailed assessment of the stock of southern school whiting, the most recreationally important bycatch species, indicates that the adults are predominantly in offshore waters and more abundant in the northern half of the fishery. Surveys revealed that an extensive stock, in excess of 2000 tonnes, exists in the management areas, and that trawl catches together with present recreational boat angling catches are not likely to exceed the estimated sustainable yield from the stock.

Underwater television observations indicated that productive scallop trawl grounds are

predominantly sand substrates, and that such substrates dominate the fishery north of Geographe Bay. In contrast, the Geographe Bay sea-floor was found to be largely untrawlable with very limited areas of sand habitat suitable for saucer scallops. Comparisons of fish communities present in surveys of commercially trawled and untrawled grounds indicated that commercial trawling had no significant impact on the benthic communities of existing commercial trawl grounds. Visual observations on these trawled sand substrates suggested that the physical impact of trawling was short lived.

The ground in the Zone D management sector (Comet Bay) was found to be atypical of the remainder of the fishery due to both the target species (western king prawns) and the size composition of the bycatch. The data show that Comet Bay, like other near-shore areas is a nursery area for a number of recreationally and commercially important species. However, only blue manna crabs, southern school whiting, goat fish and sand trevally were in significant numbers in the Zone D bycatch. The impact of trawling on the overall stocks of prawns, blue manna crabs and southern school whiting has been considered in detail. *Reprinted with the permission of Fisheries Western Australia, 1999.*

Lees, R. G., Rees, H. L., Lambert, M. A., Rowlatt, S. M., and Limpenny, D. S. 1990. Benthic studies in relation to dredging activity off the Isle of Wight, Southern England. ICES CM 1990/E:15. Copenhagen, Denmark. 19 p.

Keywords: dredging/ Isle of Wight/ community composition/ sediment disturbance/ baseline studies/ zoobenthos

Abstract: Benthic communities inhabiting gravel substrata to the southeast of the Isle of Wight, southern England, are subject to the effects of both intensive aggregate extraction and the dumping of large quantities of dredged material. In December 1989, a grid of twenty-two stations was sampled, by Anchor dredge, to establish the nature of the fauna inhabiting these substrates and to determine whether variations could be linked to either activity. Additionally, the sediments and benthos at two newly licensed extraction sites were characterized to provide a baseline for assessing the impact of future operations. The faunal assemblages existing at these sites are described and are related to sediment composition and intensity of dredging and dumping activities, as determined from sonographs of the sea floor and observations made *in situ* by divers. *Reprinted with author permission (Dr. R. G. Lees).*

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

Keywords: shellfish harvesting/ biological effects/ oyster reefs

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

Keywords: biogenic reef habitat/ *Crassostrea virginica*/ decline of/ ecosystem management/ estuarine ecosystems/ field experiment/ habitat degradation through fishery disturbance/ habitat structure/ hypoxia effects/ Neuse River estuary, North Carolina, USA / oyster reefs/ reduced reef height of/ water depth

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 similar to 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 hypoxic/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. *Reprinted with the permission of the Ecological Society of America and Ecological Applications, 1999.*

Levy, S. 1998. Watery Wastelands. New Scientist. 158(2134) : 40-44.

Keywords: demersal fishing impacts/ trawling

Summary: A popular article that addresses the significance of fishing impacts to benthic habitats. The insights of many researchers are represented in this paper. Adaptive-management strategies and the designation of marine reserves are highlighted as being important methods of conserving marine biodiversity.

Lindeboom, H. J. 2000. The need for closed areas as conservation. Pages 290-301 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: closed areas/ conservation/ management objectives/ North Sea

Summary [author's summary]: 1. A large body of evidence indicates that the long-term changes in benthic communities observed in the North Sea have been caused to a large extent by the direct and indirect effects of fishing activities and not solely by eutrophication, climatic fluctuations and /or pollution. 2. In order to minimize the effects of fisheries, and to move towards the sustainable use and protection of the marine ecosystem, it is necessary to reduce fishing effort, modify gear design and create areas closed to fisheries. 3. The rationale for the creation of closed areas includes: protection of specific species, habitats or juvenile fish, creation of a more natural population age-structure, and the prevention of continuous heavy impacts of certain fishing techniques slowly changing the entire ecosystem. An example for the North Sea is

worked out in the text. 4. Closed areas are also for scientific and monitoring purposes. Without them it will be very difficult to study the natural trends in the marine ecosystem or to ascertain which human activity has influenced the ecosystem the most. Furthermore, there may be no value in data that have been collected from areas with an unknown level of fishing disturbance. 5. The size of protected areas should be determined by the objectives of the closure and by the behaviour of species that are characteristic to that area. In such areas, where fisheries and inputs of pollutants will be prohibited or restricted, scientific research into the species composition, abundance and age distribution of different populations should be carried out and trends established. 6. The successful implementation of protected or closed areas requires the definition of clear objectives for the closure. In addition, stakeholders should be included from the beginning of the planning process to design proper, manageable and legally controllable boundaries. Regular monitoring and evaluation programs should be executed to see if the objectives are met, and to redesign the areas if necessary. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK*.

Lindeboom, H. J. and de Groot, S. J. ed. 1998. Impact II: The Effects of Different Types of Fisheries on the North Sea and Irish Sea Benthic Ecosystems. NIOZ-RAPPORT 1998-1/RIVO-DLO REPORT C003/98. Netherlands Institute for Sea Research. Texel, The Netherlands.

Keywords: fishing impacts/ fishing effects/ North Sea/ Irish Sea/ benthic ecosystems

Abstract: The EU funded research project AIR 94 1664 "The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystem" was set up to investigate the short-term and long-term effects of bottom trawl gear on benthic invertebrates and fish. As a follow-up to the IMPACT I (FARMA 2-549) project an extensive study of the relative physical and biological effects of different trawl types on the benthic ecosystem was executed at different sites in the southern North Sea and Irish Sea. The effects of fisheries upon scavengers was assessed, while the long-term impacts were studied by comparing fished and unfished areas and by collating nine different long-term data sets which might indicate possible changes in the marine ecosystem during the last decades and the last century.

An historical review of fishing fleets and gears used in the study area was made, being a clear indication of the rapid development from a large sailing fleet at the end of the previous century towards a smaller but much more efficient engine powered beam and otter trawl fleet nowadays. An inventory was made of the present numbers of Belgian, Dutch, German, Irish and UK fishing vessels active in the North Sea and Irish Sea. The gears in use per vessel size class in the different fleets is described, indicating that beam trawling is the most important fishery in Belgium and the Netherlands, while for England and Wales otter trawling is the most significant fishing method. The distribution of the fishing effort of the different fleets and gears is given for the North Sea.

The physical impact of the fleets on the seafloor was determined by direct pressure measurements, sidescan sonar observations, RoxAnn surveys, sediment profile imaging (REMOTS/SPI) and video and stills photography.

Trawling programs to further study the effects on benthic communities and to compare the impact of the different gear types were carried out in the southern North Sea and the Irish Sea. The catch efficiency of the different gears, and the mortality of the discards and of organisms in the trawl path was assessed. A comparison was made between the impact of the 4m beam trawl rigged with chain matrices or with tickler chains, the 12m beam trawl and the otter trawl. Before, and after, experimental trawling both in- and epifauna were sampled using various

pieces of equipment including; box corers, Van Veen grabs, Day grabs, 3m beam trawls, and the specially developed Triple-D dredge.

The responses to trawling of sub-surface scavengers was investigated both in the field and the laboratory. Repeated trawling over the same fishing strip, the use of baited traps, video and stills camera observations, and stomach content analyses all hinted at a very active response of possible scavengers to fishing activities. Using the results of the field surveys, and the outcome of feeding experiments under controlled conditions in the laboratory, the importance of fisheries as food source for selected scavenging species was assessed. A comparison was made between the effects in the southern North Sea and the Irish Sea.

To assess the longer term impact of fisheries at three study sites (Loch Gareloch, Firth of Clyde, Scotland; Iron Man/41 Fathom Fast in the Irish Sea, and West Gamma in the North Sea), areas disturbed by fishing were compared with undisturbed areas. In Loch Gareloch, the effect of experimental fishing was measurable. At the other two sites a difference in the benthic fauna was detected between these areas.

The long term trends on demersal fish and benthic invertebrates was assessed by analyzing seven different data sets. On average, the relative species composition appeared to have changed in the research area. Almost all benthic communities show a significant increase in biomass and a change in community structure with a shift towards dominance by opportunistic short-lived species and a decrease in long-living sessile organisms such as bivalves. A model describing fishing types and efforts implied that between 1947 and 1981, bottom fisheries has a considerable impact on the marine ecosystem by reducing several demersal fish and benthic invertebrate species to very low levels of abundance. Especially during the last decades not all data series show expected trends. This and possible other causes for the observed changes, e.g. climate change and eutrophication are discussed.

The actual impact of the different gear used in the southern North Sea was estimated by combining the fishing efforts, the estimated mortalities and the actual distribution of a number of selected species. *Reprinted with the permission of the Netherlands Institute for Fisheries Research (RIVO-DLO). 1999.*

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

Keywords: BACI/ benthic assemblages/ confounding/ large-scale experiment/ pseudoreplication/ trawling

Abstract: Disturbance due to trawling and dredging is a serious threat to assemblages of benthic marine animals. We tested hypotheses about effects of trawling on benthic assemblages in a manipulative field experiment, using gear and intensities relevant to future management of trawling in a Swedish fjord. Three trawled and three control sites were sampled at several times before and after trawling was initiated. This paper describes how conclusions about effects of trawling might differ between experiments involving replicate sites and experiments using only one trawled and one control site, as in several recent studies. Analyses of selected taxa showed that abundances of many species changed differently among control sites. Differences in temporal change between pairs of single trawled and control sites were also frequent. Neither the quantitative nor the qualitative nature of differences between treatments could, however, be coherently interpreted among the different combinations of trawled and control sites. This is consistent with results obtained from analyses using all sites, which showed no consistent effects

of trawling on many of these taxa. These results provide empirical evidence that spatial confounding may cause serious problems to formal interpretation of experiments, which use only one control and one trawled area. Such potential problems can best be solved by ensuring that the study incorporates more than one control site. *Reprinted from Journal of Experimental Marine Biology and Ecology, Vol. 245; Lindegarth, M., Valentinsson, D., Hansson, M. and Ulmestrand, M.; Interpreting large-scale experiments on effects of trawling on benthic faunaan empirical test of the potential effects of spatial confounding in experiments without replicated control and trawled areas; pages 155-169; Copyright (2000); with permission from Elsevier Science.*

Lindergarth, M., Hansson, M., Valentinsson, D., and Ulmestrand, M. (In press). Disturbance by trawling changes temporal and spatial structure of benthic soft-sediment assemblages in Gullmarsfjorden, Sweden. ICES Journal of Marine Science.

Keywords: trawling disturbance/ benthic assemblages/ Gullmarsfjorden/ Sweden

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, UK.

Keywords: dredging/ fishing effects/ North Irish Sea/ benthos

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

Keywords: marine environment/ benthos disturbance/ fishing impacts/ fishing gear disturbance/demersal fisheries

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. 1982. Compatibility of invertebrate populations and commercial fishing for ocean quahogs. North American Journal of Fisheries Management. 2(3) : 270-275.

Keywords: dredging/ hydraulic dredging/ clam fisheries/ commercial fishing/ quahogs

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. *Reprinted with the permission of the American Fisheries Society and the North American Journal of Fisheries Management.*

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

Keywords: hydraulic clam rake/ clam fishery

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

Keywords: dredging effects/ dredging/ megafauna/ Georges Bank

Magorrian, B. H. 1995. The impact of commercial trawling on the benthos of Strangford Lough. Dissertation. i-v + 218 p.

Keywords: trawling/ RoxAnn/ sidescan sonar/ video/ *Modiolus modiolus*

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. Sidescan 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 sidescan 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. *Reprinted with author permission (Dr. B. H. Magorrian).*

Magorrian, B. H. and Service, M. 1998. Analysis of underwater visual data to identify the impact of physical disturbance on horse mussel (*Modiolus modiolus*) beds. Marine Pollution Bulletin. 36(5) : 354-359.

Keywords: Modiolus/ Strangford Lough/ trawling/ video/ epifauna/ analysis

Abstract: Underwater visual data from video or still photography can provide immediate qualitative descriptions of in situ epibenthic communities. However, few studies have attempted statistical analysis of such data in order to quantitatively assess the sensitivity of epifauna to anthropogenic influences. This paper discusses the use of species-time techniques, which substitute time for area and produce estimates of relative abundance of species based on time. This paper adapts such a technique, the 'Visual Fast Count', to quantitatively assess the impact of trawling on horse mussel, *Modiolus modiolus*, communities. Direct counts of individuals at various taxonomic levels were made from the still photographic images. The potential role of such techniques in the management of epifaunal communities in wider marine pollution studies is discussed. *Reprinted from Marine Pollution Bulletin, Vol. 36; Magorrian, B.H., Service, M.; Analysis of underwater visual data to identify the impact of physical disturbance on horse mussel (Modiolus modiolus) beds; pages 354-359; Copyright (1998); with permission from Elsevier Science.*

Magorrian, B. H., Service, M., and Clarke, W. 1995. An acoustic bottom classification survey of Strangford Lough, Northern Ireland. Journal of the Marine Biological Association of the United Kingdom. 75(4) : 987-992.

Keywords: acoustic classification/ benthos/ Strangford Lough/ environmental impact/ trawling

Abstract: As part of an investigation into the impact of commercial trawling on the benthos of Strangford Lough a map of the distribution of the benthic communities in the Lough was required. To provide this an acoustic bottom classification survey of the Lough was carried out using a commercially available system, RoxAnn. RoxAnn process the information from a conventional echo-sounder to determine the nature of different substrata. Underwater cameras were used to obtain ground truth data to compare with the RoxAnn data. Used in conjunction, the two surveys provided valuable information on the different bottom substrata and associated epibenthic communities present in the Lough. *Reprinted with the permission of Cambridge University Press and Journal of the Marine Biological Association of the United Kingdom.*

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

Keywords: mechanical harvesting/ clam fishery

Summary: The report reflects a study that was prepared by the South Carolina Department of Natural Resources, Marine Resources Division (SCDNR-MRD) in cooperation with the U.S. Army Corps of Engineers (USACOE). The study was to investigate the potential impacts of the proposed use of mechanical hydraulic shellfish harvesters in coastal waters of South Carolina. Of particular concern was the impacts to tidal creeks and shallow open-water habitats. The three main objectives of the study were 1) to measure turbidity levels and the extent of turbidity plumes, 2) measure impacts to the abundance, diversity and species composition of the shallow-water invertebrates, and 3) measure impacts to the abundance, diversity and species composition of fish species associated with these habitats. The results for each objective are presented and discussed.

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

Keywords: bottom gear/ bottom trawling/ gear impacts

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

Keywords: gear impacts/ trawling/ trawl boards

Main, J. and Sangster, G. I. 1981. A study of the fish capture process in a bottom trawl by direct observations from a towed underwater vehicle. Scottish Fisheries Research Report No. 23. Department of Agriculture and Fisheries for Scotland, Aberdeen, Scotland. 23 p.

Keywords: trawl/ bottom trawl/ towed underwater vehicle

Abstract: Observations were made of the reactions of various species of fish to a "Lossie Q" 4-panel bottom trawl, which had a headline height of 4 m, wing end height of 2.1 m and wing end spread of 8.5 m. This net, when towing in both directions over the edge of a 10° slope, lifted off the sea bed at 1.5 m s^{-1}. A number of commercially important roundfish species (haddock, whiting and cod) formed a narrow column or ribbon formation equidistant between the bridles and wings before crossing the bobbin ground gear. The swimming endurance of most species is dependent on their length. Smaller fish dropped back into the net before the larger ones at a towing speed of 1.5 m s^{-1}. Cod showed a very pronounced, agitated, zig-zag swimming behaviour before turning low horizontally above the bobbins and back along the belly of the net. Haddock rose consistently from the sea bed when tiring and turned into the mouth of the net. Some rose and escaped over a 4 m headline at a towing speed of 1.5 m s^{-1}. Whiting, like cod, turned through 180° horizontally back over the bobbins. These fish entered the net just higher than cod. Saithe can swim in the mouth of a bottom trawl for more than 16 minutes at a towing speed of 1.5 m s^{-1}.

During this time, many dived to the sea bed and fed on sandeels. A number avoided fast swimming by sheltering in the eddies behind the bobbins. At a towing speed of 1.5 m s^{-1} mackerel swam head first into the trawl, turned and swam out again. Small fish (haddock, whiting, sandeels) escaped through the meshes in the batings and cod-end.

Main, J. and Sangster, G. I. 1982. A study of a multi-level bottom trawl for species separation using direct observation techniques. Scottish Fisheries Research Report No. 26. Department of Agriculture and Fisheries for Scotland, Aberdeen, Scotland. 17 p.

Keywords: trawl/ multi-level/ bottom trawl/ separation

Abstract: A series of three-level bottom trawls rigged with horizontal separating panels terminating in independent cod-ends was used in fishing trials in an attempt to separate commercially important fish at the mouth of the net according to their specific behavior. In shallow water (25-30 m), divers using an underwater towed vehicle measured, observed, and where necessary recorded, how adjustments to the nets should be made to allow the most favorable separation of each species prior to fishing in deep water. A remotely controlled television system enabled further direct observations of the working of each type of net to be made on commercial fishing grounds (70-90 m). Trawling was conducted by both day and night. Results showed that the majority of haddock consistently rose up from the seabed into the top level but many escaped over the 5 m headline. Whiting catches varied in the three cod-ends and may depend on the height setting and position of the first separator panel. Cod, flatfish, skates, angler, gurnards and spotted dogfish were caught almost solely in the bottom codend. Catches of haddock in the top cod-end of the net were similar during both day and night fishing, whereas whiting catches varied and definite conclusions were not drawn from these day/night results. The quality and condition of the fish caught in the top and middle codends were far superior to those of fish caught in the bottom codend. The use of this type of fishing net will (a) reduce the time spent on deck sorting out the catch; and (b) allow fishing to continue in the tip and middle levels if the belly in damaged or torn during a tow.

Main, J. and Sangster, G. I. 1983. A study comparing light and heavy ground gear. Scottish Fisheries Research Report No 27. Department of Agriculture and Fisheries for Scotland, Aberdeen, Scotland. 17 p.

Keywords: trawl/ gear/ fishing gear

Abstract: Direct observations were made in daylight of the reactions of haddock, saithe and mackerel to two contrasting types of bottom trawl, one with a lightly rigged grass footrope, the other rigged with a heavy bobbin groundline. Both nets appeared visually similar underwater (depth 20-30 m) but the heavy black rubber bobbin groundline was easily seen from as far forward as the wing ends, whilst the light footrope was relatively insignificant. The light net was virtually silent when fishing whereas the noise from the bobbin trawl could be heard approximately 10 m ahead of the wing ends. Ship noise was heard by the divers both at the otterboards and the net of both trawls. All fish swam towards both nets in the warp, otterboard, sweep and bridle areas. No fish swam in the towing direction in these areas. The majority of haddock and saithe tended to swim straight into the lightly rigged net, whereas they turned ahead of the noisy and more visually contrasted bobbin groundline. Haddock swam for no more than 2 ½ minutes at 1.5 m s^{-1} (3 knots) but saithe endured for about 15 minutes at that speed. Mackerel

in the mouth of the net increased their swimming speed and avoided capture by swimming straight out of it. Many haddock escaped over the headline of the bobbin trawl but none escaped from the lightly rigged net. There was physical damage to all sizes of fish in the flapper areas of the bobbin trawl. Direct observation during the side trawling "knock out" procedure showed that a large proportion of saithe escaped during this manoeuver. Haddock swam towards the nets at speeds between 0.2 and 0.4 m s^{-1} whilst saithe did so at between 0.7 and 0.85 m s^{-1}.

Main, J. and Sangster, G. I. 1983. TUV II a towed wet submersible for use in fishing gear research. Scottish Fisheries Research Report No 29. Department of Agriculture and Fisheries for Scotland, Aberdeen, Scotland. 19 p.

Keywords: submersible/ fishing gear research

Main, J. and Sangster, G. I. 1985. The behaviour of the Norway lobster, *Nephrops norvegicus* (L.), during trawling. Scottish Fisheries Research Report No 34. Department of Agriculture and Fisheries for Scotland, Aberdeen, Scotland. 23 p.

Keywords: trawling/ lobster behaviour/ Norway lobster/ *Nephrops norvegicus* (L).

Main, J. and Sangster, G. I. 1990. An assessment of the scale damage to and survival rates of young gadoid fish escaping from the cod-end of a demersal trawl. Scottish Fisheries Research Report No. 46. Department of Agriculture and Fisheries for Scotland, Aberdeen, Scotland. 28 p.

Keywords: trawling/ trawl escapement/ survival rates

Manzi, J. J., Bureell, B. G., Lemanowicz, Jr. K. J., Hadley, N. H., and Collier, J. A. 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.

Keywords: impacts/ mechanical harvester/ intertidal/ oyster communities/ South Carolina

Margetts, A. R. and Bridger, J. P. 1971. The effect of a beam trawl on the seabed. ICES CM 1971/B:8. 9 p.

Keywords: beam trawl effects/ beam trawling/ seabed disturbance

Mason, J. 1970. A comparison of various gears used in catching queens and scallops in Scottish waters. ICES CM 1970/K:19. 6 p.

Keywords: scallop fishing/ fishing effects/ dredges

Mason, J. 1978. The Scottish scallop fishery. Scottish Fisheries Bulletin. (44) : 38-44.

Keywords: shellfish fisheries/ *Pecten maximus*/ Clyde Sea/ British Isles/ Scotland/ marine fisheries

Mason, J., Chapman, C. J., Kinnear, J. A. M., and Thomas, H. J. 1979. Population abundance and dredge efficiency studies on the scallop, *Pecten maximus* (L.). Rapports et Proces-Verbaux des Reunions. 175 : 91-96.

Keywords: dredging/ abundance/ *Pecten maximus*/ British Isles/ Scotland

Mayer, L. M., Schick, D. F., Findlay, R. H., and Rice, D. L. 1991. Effects of commercial dragging on sedimentary organic matter. Marine Environmental Research. 31(4) : 249-261.

Keywords: trawling/ fishing gear disturbance/ sediment mixing/ anaerobic

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 Be-7 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. *Reprinted from Marine Environmental Research, Vol. 31; Mayer, L.M., Schick, D.F., Findlay, R.H. and Rice, D.L.; Effects of commercial dragging on sedimentary organic matter; pages 249-261; Copyright (1991); with permission from Elsevier Science.*

Mayo, R. K., Lange, A. M., Murawski, S. A., Sissenwine, M. P., and Brown, B. E. 1981. A procedure for estimating rates of escapement and discard, based on research vessel bottom trawl survey catches. ICES CM 1981 (Collected Papers). Copenhagen, Denmark. 18 p.

Keywords: bottom trawls/ escapement/ mesh selectivity/ fishery surveys

McAllister, D. E. 1991. Questions about the impact of trawling. Sea Wind. 5(2) : 28-33.

Keywords: trawling impacts

McAllister, D. E. and Spiller, G. 1994. Trawling and dredging impacts on fish habitat and bycatch. Pages 1709-1718. Coastal Zone Canada '94, Cooperation in the Coastal Zone: Conference Proceedings, Volume 4. Coastal Zone Canada Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada.

Keywords: trawling/ dredging/ fish/ fish habitat/ impact assessment

Abstract: Trawling and dredging for fishes, shrimp and shellfish have major impacts on habitat and, through bycatches, 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 harbor 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. Bycatches of trawling gear commonly average 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 bycatches 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 bycatches; (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. *Reproduced with the permission of Her Majesty the Queen in Right of Canada, 1999, and Fisheries and Oceans Canada.*

McCandless, D. T. 1992. Impact of bottom fishing on the benthos. M.S. Thesis. University of Wales, Bangor, UK.

Keywords: trawling/ benthos/ demersal fishery

McConnaughey, R. A., Mier, K. L. and Braxton, C. B. 2000. An examination of chronic trawling effects on soft bottom benthos in the eastern Bering Sea. ICES Journal of Marine Science. (In press)

Keywords: bottom trawls/ trawl impacts/ anthropogenic disturbance/ soft-bottom benthos/ Bering Sea/ macrofauna

Abstract: The eastern Bering Sea has experienced rapid and intensive development of commercial trawl fisheries. Because of good record keeping and the relatively brief history of fishing in the area, it is possible to reconstruct the spatial and temporal patterns of exploitation. Previously unfished (UF) areas can be identified and directly compared with heavily fished (HF) areas to investigate long-term consequences to the benthos. Using this approach, macrofauna populations in a shallow (48 m average) soft-bottom area were experimentally studied during 1996. Samples of 92 taxa (reduced for analysis) were collected at 84 1nm^2 sites straddling a closed-area boundary. Multi- and univariate statistical tests and raw patterns in the data support the following generalizations: (1) sedentary macrofauna (e.g. anemones, soft corals, sponges, whelk eggs, bryozoans, ascidians), neptunid whelks and empty shells were more abundant in the UF area; (2) mixed responses were observed within motile groups (e.g. crabs, sea stars, whelks)

and infaunal bivalves, suggesting the importance of life history considerations, such as habitat requirements and feeding mode; and (3) overall diversity and niche breadth of sedentary taxa were greater in the UF area. A systematic approach is required to address the complex issue of bottom trawl disturbances. This begins with the identification of chronic and acute impacts, followed by focused investigations of ecological implications and, ultimately, cost-benefit analyses to evaluate specific resource management options.

McKenzie, C. L. Jr. 1982. Compatibility of invertebrate populations and commercial fishing for ocean quahogs. North American Journal for Fishery Management. 2(3) : 270-275.

Keywords: commercial fishing/ quahogs

McKeown, D. L. and Gordon, D. C. Jr. 1997. Grand Banks otter trawling impact experiment: II. Navigation procedures and results. Canadian Technical Report of Fisheries and Aquatic Sciences 2159, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Canada. xi + 79 p.

Keywords: navigation systems/ environmental impact/ trawling/ fishing gear/ bottom trawls/ benthos/ otter trawls/ Grand Banks

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 2, 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 2, 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. *Reproduced with the permission of Her Majesty the Queen in Right of Canada, 1999, and Fisheries and Oceans Canada.*

McKeown, D. L. and Heffler, D. E. 1997. Precision navigation for benthic surveying and sampling. Proceedings of Oceans '97. 386-390.

Keywords: navigation systems/ benthic surveying/ sampling/ ship positioning

Summary: In 1990 cooperative research was conducted on the Grand Banks of Newfoundland to study trawling impacts on benthic habitats. The specific area was chosen because of its relative protection from trawling activities. Fully controlled trawling experiments were conducted to examine habitat before and after trawling. Due to the nature of the experiments, real-time presentation of navigation information was essential. Two methods of collecting differential corrections for the ships differential Global Positioning System (dGPS) were employed during the study and comparisons in precision, efficiency and reliability were made on ships positioning. The first method of collecting differential corrections was with a StarFix system, which provided corrections from real-time land-based monitoring stations by way of geostationary telecommunications satellites. When combined with the dGPS, the StarFix system produced ship positions to an accuracy of 3-4 m, and worked very reliably once a clear line-of-sight location for the shipboard satellite tracking antenna was found. The second method of collecting differential corrections was via the Canadian Coast Guards' Cape Race medium frequency beacon station using a CSI model MBX-1 receiver. The MBX-1 was a no-cost alternative to the StarFix system. The medium frequency transmissions from the Cape Race station were disrupted by electrical interference during storms, but otherwise no noticeable differences in reliability were made between the two systems. The course-over-ground (COG) and speed-over-ground (SOG) information from the Cape Race/MBX-1 corrections was two times more accurate than that from the StarFix system. The better COG and SOG information was especially helpful in the mobile gear studies.

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

Keywords: scallop dredge/ catching efficiency/ indirect fishing mortality

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. *Reprinted from Fisheries Research, Vol. 11; McLoughlin, R.J., Young,*

P.C., Martin, R.B. and Parslow, J.; The Australian scallop dredgeestimates of catching efficiency and associated indirect fishing mortality; pages 1-24; Copyright (1991); with permission from Elsevier Science.

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

Keywords: dredging/ scallop dredging/ macrobenthos/ Port Phillip Bay

MDMF (Massachusetts Division of Marine Fisheries). 1989. The impact of bottom trawling on American lobsters off Duxbury Beach, MA. October 1, 1989. Massachusetts Division of Marine Fisheries. Boston, Massachusetts.

Keywords: bottom trawling/ trawling impact/ American lobster/ Massachusetts

MDNR (Massachusetts Department of Natural Resources). 1964. Restricting the use of the beam trawl 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.

Keywords: trawling/ restrictions

Medcof, J. and Bourne, N. 1964. Causes of mortality of the sea scallop *Placopecten magellanicus.* Proceedings of the National Shellfisheries Association. 53 : 33-50.

Keywords: scallop fisheries/ gear impacts/ fishing effects

Medcof, J. C. 1961. Effects of a hydraulic escalator harvester on under-sized soft-shell clams. Proceedings of the National Shellfisheries Association. 50 : 151-161.

Keywords: hydraulic escalator harvester/ clam fishery

Medcof, J. C. 1964. Fishing efficiency of clam hacks and mortalities incidental to fishing. Proceedings of the National Shellfisheries Association. 55 : 151-161.

Keywords: clam fishery/ clam hacks

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

Keywords: clam fishery/ clam dredging/ dredging

Meillat, M., Dupouy, H., Bavouzet, G., Kergoat, B., Morandeau, F., Gaudou, O., and Vacherot, J. P. 1994. Preliminary results of a trawl fitted with a selective grid for the fishery of benthic species from Celtic Sea and Bay of Biscay. ICES Council Meeting Papers, Copenhagen, Denmark. 15 p.

Keywords: gear selectivity/ Celtic Sea/ Biscay Bay/ demersal fisheries/ sorting grid

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

Keywords: *Buccinum undatum*/ fishing impact/ mortality/ shell damage/ imposex/ beam trawl

Abstract: Common whelks *Buccinum undatum* collected from the southern North Sea were investigated to study the amount of shell damage and mortality caused by beam trawl fishery. The ability of whelks to repair their damaged shells was studied in the laboratory. Whelks (n = 876) were caught with a fine-meshed 3-m beam trawl or with commercial 4- and 12-m beam trawls, while in some areas whelks were also caught with baited traps (used as a reference). Shell damage varied considerably for the different groups. In whelks collected by beam trawling, minor shell damage was observed in 17-75%, and severe damage (when protection against predators and scavengers is lost) in 10-83%. Whelks caught with baited traps sustained only minor shell damage (0-27% of the individuals). Their damage was statistically significantly less than in beam-trawled specimens. Most whelks in all groups exhibited signs of former shell damage, which had since been repaired. Whelk survival was studied in the laboratory over a six-week period. Only 40% of the whelks caught with the 12-m beam trawl survived, irrespective of the damage suffered. Whelks that survived and recovered had repaired their shell after six weeks. More than 95% of the whelks caught with baited traps survived the six-week experimental period; this is statistically significantly higher than the survival of animals caught with the 12-m beam trawl. At five locations females were screened for the presence and stage of imposex. Mild imposex development (mostly stages 1 and 2) was observed at all locations with incidences of 32-80%. It is concluded that beam trawl fishery may be a much greater source of mortality in common whelks than previously thought. *Reprinted from Journal of Sea Research, Vol. 43; Mensink, B.P., Fischer, C.V., Cadee, G.C., Fonds, M., Ten Hallers-Tjabbes, C.C. and Boon, J.P.; Shell damage and mortality in the common whelk Buccinum undatum caused by beam trawl fishery; pages 53-64; Copyright (2000); with permission from Elsevier Science.*

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

Keywords: trawling/ dredging/ ocean dumping/ fishing gear impacts/ eastern Canadian continental shelf/ benthos/ benthic disturbance

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. *Reprinted from Continental Shelf Research, Vol. 11; Messieh, S.N., Rowell, T.W., Peer, D L. and Cranford, P.J.; The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed; pages 1237-1263; Copyright (1991); with permission from Elsevier Science.*

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

Keywords: shrimp trawling/ bait-shrimp/ seagrass/ bycatch/ Tampa Bay/ Florida

Summary: The bait-shrimp fishery in Florida utilizes roller beam trawls to primarily collect pink shrimp, *Penaeus duorarum*, which is commonly found in seagrass beds. The shrimp are culled from the catch on sorting tables and kept in live holds. The trawls are designed to roll over the surface of the seagrass, to reduce gear penetration and collection of debris. The trawling and culling time for this fishery is typically short (5-20 minutes, and 2-15 minutes, respectively) to reduce debris collection and injury to shrimp, and many trawl passes over the same grounds can be made in a short time. In addressing observations that roller trawls can break off the older seagrass leaves, and may be destructive to juvenile fishes, the authors investigated 1) the effects of roller beam trawls on seagrass biomass and morphometrics during intensive, short-term trawling, and 2) the bycatch mortality of finfish. Seagrass beds were not found to be significantly impacted by roller trawls, particularly in short-term operations. Survival of finfish bycatch was variable and depended on a number of factors, including species type, age, frequency of trawling activity, duration of culling time, and air and water temperature.

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

Keywords: clam dredge/ dredge track/ environmental effects

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% of the available clams; when below optimum, efficiency was 80%. When dredge performance was low; larger clams, which burrowed deeper into the sediment, suffered mortalities as high as 92%;

when high, mortalities decreased to 30%. In high clam density areas, 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 pre-dredging levels except for the moon snail, *Lunatia hero*, which was the only predator to increase in abundance after the 2-hour estimate.

Mirarchi, F. 1998. Bottom trawling on soft substrates. Pages 80-84 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: trawling/ fishing gear impacts/ habitat disturbance

Summary: The author, a fisherman of 35 + years, discusses his perspectives and insights on fishing practices and return yields over time in New England waters, particularly around Stellwagen Bank. Fishing gears are discussed and arguments made for the need to improve gear selectivity and impact, and for more stringent restrictions to fishing in sensitive areas.

Morgan, M. J., Deblois, E. M., and Rose, G. A. 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. 54(Supplement 1) : 217-223.

Keywords: spawning shoal/ fishing gear effects/ bottom trawling/ avoidance reactions/ Grand Banks

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 tract 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 cm (plus /minus 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 disturbance within the shoal over relatively large distances. *Reprinted with the permission of NRC Research Press and the Canadian Journal of Fisheries and Aquatic Sciences.*

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. 32(10) : 701-710.

Keywords: Mollusca/ Gastropoda/ Bivalvia/ suction dredging/ trawling impacts/ subtidal benthos

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 pre-dredging 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. *Reprinted from Marine Pollution Bulletin, Vol. 32; Morton, B.; The subsidiary impacts of dredging (and trawling) on a subtidal benthic molluscan community in the southern waters of Hong Kong; pages 701-710; Copyright (1996); with permission from Elsevier Science.*

Morton, J. W. 1977. Ecological effects of dredging and dredge spoil disposal: a literature review. Technical Papers of the U.S. Fish and Wildlife Service, Vol. 94. 33 p.

Keywords: dredging/ ecological effects

Murawski, S. A. 1996. Factors influencing bycatch and discard rates: analyses from multispecies multifishery sea sampling. Gear Selectivity Technical Interactions in Mixed Species Fisheries Symposium. Journal of Northwest Atlantic Fishery Science. 19 : 31-39.

Keywords: bycatch/ discards/ gear selectivity/ species composition

Abstract: Factors influencing the species composition and magnitude of landings and discards were evaluated based on data from at-sea observations of 4 533 otter trawl tows. Data were collected from the USA mixed species otter trawl fisheries of the Georges Bank-Southern New England region, sampled during 1989-92. General linear models for main effects have related discard rates, total catch, and indices of species richness, diversity and evenness to temporal, spatial and operational variables associated with the fishing process (year, month, statistical reporting areas, primary species sought, cod-end mesh size, vessel size, tow duration, total catch, total discards and depth). Discarding rates (proportion of the catch discarded) varied significantly both for individual species and for aggregated species by year, area, month, and target species.

The effects of cod-end mesh size were variable, and confounded with year-class strength, particularly in the case of yellowtail flounder. Fisheries regulated by minimum fish and mesh sizes generally exhibited higher average discard rates and more variation than fisheries directed to species without such restrictions (e.g. for small pelagics, skates and others). The species composition and diversity of catches were significant functions of area, year, target species and month, as well as mesh size and tow duration. Year effects were more important for explaining variation in discard rates than total (multispecies) catches. This result is probably because large, partially-recruited year-classes differentially attract effort from other species targets, but most of the fleet landings are composed of mixed catches of species at moderate abundance levels. Multivariate approaches to analysis of sea sampling data offer important insights into the potential effectiveness of technological and area/time management measures for reducing fishery discards. *Reprinted with the permission of the Northwest Atlantic Fisheries Organization and the Journal of Northwest Atlantic Fisheries Science.*

Murawski, S. A., Brown, R., Lai, H.-L., Rago, P. J., and Hendrickson, L. 2000. Large-scale closed areas as a fishery management tool in temperate marine ecosystems: The Georges Bank experience. Bulletin of Marine Science [1998 Mote International Symposium on Essential Fish Habitat and Marine Reserves, Sarasota, FL].

Keywords: trawling/ closed areas/ restrictive trawling/ management/ Georges Bank

Murawski, S. A. and Finn, J. T. 1986. Optimal effort allocation among competing mixed-species fisheries, subject to fishing mortality constraints. Canadian Journal of Fisheries and Aquatic Sciences. 43(1) : 90-100.

Keywords: fishing effects/ mixed-species fishery/ fishing mortality

Murawski, S. A. and Idoine, J. S. 1992. Multispecies size composition: a conservative property of exploited fishery systems? Journal of Northwest Atlantic Fisheries Science. 14 : 79-85.

Keywords: multispecies fisheries/ trawl surveys/ abundance/ trophic relationships/ fishery management/ Georges Bank

Abstract: During the past 30 years the species composition and abundance of finfishes on Georges Bank has changed dramatically, as measured by standardized trawl surveys and fishery performance data. Notwithstanding the dramatic shifts in species composition, the aggregate size composition (normalized numbers-at-length) has remained relatively stable. The descending limb of the aggregate species numbers-at-length curve estimates the weighted average rates of survival and growth (cumulative energy transfer) from one length category to the next. Observed changes in the slope of the aggregate size composition on Georges Bank can be correlated with various stanzas in the exploitation regime. Similar studies from other temperate fishery ecosystems indicate much different characteristic slopes to the aggregate catch-at-length curves. The conservation of aggregate size composition within fishery ecosystems may be indicative of size-based trophic interrelationships that tend to buffer fish production at length against perturbations to particular species and/or length components in highly-networked food webs. If such feedback mechanisms exist, they have important implications for the development of long-term multispecies management policy. A modeling approach to multispecies length composition is outlined, along with data requirements for such analyses. *Reprinted with the permission of the*

Northwest Atlantic Fisheries Organization and the Journal of Northwest Atlantic Fisheries Science.

Murawski, S. A., Lange, A. M., Sissenwine, M. P., and Mayo, R. K. 1983. Definition and analysis of multispecies otter-trawl fisheries off the Northeast coast of the United States. Journal du Conseil International pour l'Exploration de la Mer. 41(1) : 13-27.

Keywords: otter trawl fisheries/ Northeast coast/ United States

Murawski, S. A., Maguire, J.-J., Mayo, R. K., and Serchuk, F. M. 1997. Groundfish stocks and the fishing industry. American Fisheries Society. 27-70.

Keywords: demersal fisheries/ groundfish stocks

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

Keywords: dredging/ bivalve fisheries/ dredging effects

Murawski, S. A. and Serchuk, F. M. 1989. Mechanized shellfish harvesting and its management: The offshore clam fishery of the eastern United States. Pages 479-506 *in* J. F. Caddy (ed.). Marine Invertebrate Fisheries: Their Assessment and Management. John Wiley & Sons, New York, NY.

Keywords: mechanized harvesting/ clam fishery/ *Spisula solidissima*/ *Arctica islandica*

Newell, R. C., Seiderer, L. J., and Hitchcock, D. R. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology: An Annual Review. 36 : 127-178.

Keywords: dredging/ environmental impact/ benthos/ ecosystem disturbance

NHFGD (New Hampshire Fish and Game Department). An assessment of the short term effects of otter trawling on large epibenthic invertebrates. Completed Report of the New Hampshire Fish and Game Department.

Keywords: trawling/ environmental effects/ *Homarus americanus*/ *Limanda ferruginea*

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.

Nickerson, R. B. and Brown, T. J. 1979. The effects of an experimental hydraulic harvester on marginal an submarginal razor clam (*Siliqua patula*) habitat on the Cooper River Delta, Cordova, Alaska. Alaska Department of Fish and Game. Informational Leaflet 179. 19 p.

Keywords: hydraulic harvester/ fishing effects/ clam fishery/ Cooper River Delta/ Alaska

Nilsson, H. and Rosenberg, R. (In press). The impact of trawling on marine soft bottoms analyzed with sediment-profile-imaging. ICES Journal of Marine Science.

Keywords: trawling impacts/ soft bottom sediments

NMFS (National Marine Fisheries Service). 1987. Cruise results: Assessment of the impact of bottom trawling on crab, other target species and the benthic habitat. Cruise Report 86-01, NWAFC.

Keywords: bottom trawling/benthic habitat

Norse, E. A. 1997. Bottom trawling: the unseen worldwide plowing of the seabed. New England Biolabs, The NEB Transcript. 8(2) : 8-9.

Keywords: bottom trawling/ trawling effects/ demersal fishing impacts

Summary: A two-page article highlighting the negative effects of demersal fishing practices.

Norse, E. A. and Watling, L. 1999. Impacts of mobile fishing gear: the biodiversity perspective. Pages 31-40 *in* L. R. Benaka (ed.). Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22. Bethesda, Maryland.

Keywords: mobile fishing gear/ fishing impacts/ bottom trawling/ commercial fishing/ habitat impacts

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 predations 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. *Reprinted with the permission of the American Fisheries Society.*

Nugues, M. M., Kaiser, M. J., Spencer, B. E., and Edwards, D. B. 1996. Benthic community changes associated with intertidal oyster cultivation. Aquaculture Research. 27(12) : 913-924.

Keywords: benthic community changes/ oyster cultivation/ intertidal

Orsi Relini, G., Peirano, A., Tunesi, L., and Orsi Relini, L. 1985. Otter trawling in Ligurian coastal waters: 1. Qualitative and quantitative catch composition during one year observations. Oebalia. 11(2) : 489-508.

Keywords: trawling/ inshore otter trawl/ monthly catches/ Mediterranean Sea

Abstract: Otter trawling in ligurian waters: I - Qualitative and quantitative catch composition during one year observations. Diurnal catches obtained monthly in the Gulf of Genoa by otter trawl, between 20 and 90 m depth, are detailed in their composition of fish, cephalopods and crustaceans: species lists and seasonal catches per hour on 4 levels are given. Some observations on nocturnal trawling are also referred. *Reprinted with the permission of Instituto Sperimentale Talassografico and Oebalia. 1999.*

Orsi Relini, L., Tunesi, L., Peirano, A., and Relini, G. 1985. Otter trawling in Ligurian coastal waters: 2. Distribution and incidence in the catches of young specimens. Oebalia. 11(2) : 509-519.

Keywords: trawling/ inshore otter trawl/ fish juveniles distribution/ Ligurian Sea

Abstract: Fish juveniles caught monthly by otter trawl in coastal waters of the Gulf of Genoa are listed: the legal limit to trawlers, -50 m depth, separates the infralittoral nurseries of *Mullus barbatus*, *Sparidae*, *Conger conger*, *Loligo vulgaris* et al. by the circalittoral nurseries of *Merluccius merluccius*, *Eledone cirrhosa*, *Illex coindetii*. The incidence of young fish in the catches is outlined. *Reprinted with the permission of Instituto Sperimentale Talassografico and Oebalia. 1999.*

Orth, R. J., Moore, K. A., Wilcox, D. J., and Fishman, J. R. 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.

Keywords: fishing effects/ dredging/ habitat disturbance

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.

Keywords: harvester/ gear development/ Irish moss

Papatheodorou, G. 1997. Seafloor remote sensing techniques and their applications on fisheries research. Proceedings of the 5th Hellenic Symposium on Oceanography and Fisheries, Kavala, Greece. April 15-18, 1997. Fisheries, Aquaculture, Inland Waters. 2 : 37-40.

Keywords: fisheries/ bottom trawls/ remote sensing/ seafloor mapping/ environmental impact/ stock assessment

Parry, G. D. and Currie, D. R. 1992. The effect of scallop dredging on Port Phillip Bay. Newsletter of the Australian Society for Fish Biology. 22(2) 46 p.

Keywords: scallop dredging/ environmental impact/ Australia/ Port Phillip Bay

Parry, G. D. and Currie, D. R. 1992. Interim report on the effects of scallop dredging on Port Phillip Bay. Internal Report 193. Marine Science Laboratories. Queenscliff, Australia. 67 p.

Keywords: scallop dredging/ dredging/ Port Phillip Bay

Pederson, J. and Hall-Arber, M. 1999. Fish habitat: a focus on New England fishermen's perspectives. Pages 188-211 *in* L. R. Benaka (ed.). Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22. Bethesda, Maryland.

Keywords: fishing effects/ fishing gear effects/ fish habitat/ New England

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. *Reprinted with the permission of the American Fisheries Society.*

Peterson, C. H., Summerson, H. C., and Fegley, S. R. 1983. Relative efficiency of two clam rakes and their contrasting impacts on seagrass biomass. Fishery Bulletin. 81 : 429-434.

Keywords: clam rakes/ clam fishery/ seagrass

Summary: This paper reflects a study in which the impacts to seagrass beds from two clam rakes are compared; the pea digger (also called the potato rake) and the bull rake (also known as the shinnecock rake). Several other hand rakes are commonly used along the east and gulf coasts of the United States, but the pea digger and the bull rake were compared because they represent the opposite ends of the clam rake size range. The pea digger is smaller and lighter and generally has 3-6 prongs about 14 cm long. The bull rake is larger and heavier and has prongs that are extensions of a steel basket in which clams are collected. Both rakes dig through the sediments at depths between 3 and 14 cm, depending on substrate type, compaction, and habitat. Each rake was used in controlled experimental plots in sand-flat habitat and in seagrass beds. The pea digger proved to be more effective at collecting legal-size clams in the sand-flat habitat per unit of time. In contrast, the bull rake was more efficient in collecting legal-sized clams in the seagrass habitat. Additionally, the bull rake caused more than double the estimated loss of seagrass biomass (above- and below-ground components) compared to the pea digger, as well as a greater amount of seagrass biomass loss (particularly the below ground rhizome component) per unit area raked. Implications for environmental planners are discussed.

Peterson, C. H., Summerson, H. C., and Fegley, S. R. 1987. Ecological consequences of mechanical harvesting of clams. Fishery Bulletin. 85(2) : 281-298.

Keywords: raking/ mechanical harvesting/ clam fishery/ benthic disturbance

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 colonization 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. Emergence during summer of a between-habit 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.

Philippart, C. J. M. 1998. Long-term impact of bottom fisheries on several bycatch species of demersal fish and benthic invertebrates in the south-eastern North Sea. ICES Journal of Marine Science. 55(3) : 342-352.

Keywords: otter trawl catch efficiency/ beam trawl catch efficiency/ bycatch species/ North Sea

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 Dm Helder (The Netherlands) has collected and registered bycatch species caught by commercial fishermen. 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 fishes (sharks, rays, skates) and 10 invertebrate species (whelks, urchins, squids, crabs) all of which have a demersal life style 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 (New Series), No 29. Lowestoft Suffolk. 27 p.

Keywords: mechanical harvesting/ cockle fishery/ Thames Estuary

Piet, G. J. (In press). Fishing mortality in invertebrate populations: the effects of spatial resolution. ICES Journal of Marine Science.

Keywords: fishing effects/ mortality/ invertebrates/ benthos

Piet, G. J. and Rijnsdorp, A. D. 1998. Changes in the demersal fish assemblage in the south-eastern North Sea following the establishment of a protected area ("plaice box"). ICES Journal of Marine Science. 55 : 420-429.

Keywords: species composition/ size structure/ reduction trawling effort

Abstract: This paper studies the effect of the reduction in the trawling effort of large beam trawlers (> 300 hpi) in the coastal waters of the south-eastern North Sea following the establishment in 1989 of a protected area, the "plaice box", using data from annual beam trawl surveys carried out since 1985. Two different aspects of the demersal fish assemblage were analyzed: (1) the size distribution using multiple analysis of variance; and (2) the species composition using multivariate techniques such as principal component analysis, multidimensional scaling and multiple analysis of variance.

It is shown that the overall size structure of the commercially exploited fish species was affected by the change in trawling effort whereas that of the non-target species was not. In particular, the abundance of commercial fish within the marketable size-range of 25-40 cm increased when fishing effort was reduced.

Multiple analysis of variance showed that, in contrast to the size structure of the fish assemblage, the species composition was not significantly affected by the change in fishing effort, However principal component analysis does indicate that after the closure of the "plaice box" a considerable proportion of the variation in the abundance of the large fish (≥ to 25 cm) over the years can be explained by a higher abundance in the "box" area than in the reference area of most fish species, including the two main commercial species plaice and sole. Other trends that were observed during the study period both within and outside the closed area were: (1) a decrease of the relative abundance of plaice and (2) a general increase of species richness due to the influx of southerly species.

Pilskaln, C. H., Churchill, J. H., and Mayer, L. M. 1998. Resuspension of sediment by bottom trawling in the Gulf of Maine and potential geochemical consequences. Conservation Biology. 12(6) : 1223-1229.

Keywords: fishing gear effects/ bottom trawling/ Gulf of Maine/ sediment resuspension

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

Keywords: seabed habitat/ recovery/ prawn trawling/ Great Barrier Reef

Pitcher, C. R., Burridge, C. Y., Wassenberg, T. J., and Poiner, I. R. 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. The Great Barrier Reef Marine Park Authority, Townsville, Australia.

Keywords: trawling/ fishing effects/ Great Barrier Reef/ Australia

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

Keywords: prawn trawling/ fishing effects/ Great Barrier Reef/ Far Northern Section/ Australia

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

rates of the seabed fauna (Chapter 7). Finally, implications of the findings of the study for management of the GBR and for management of the East Coast prawn trawl fishery are discussed (Chapter 7).

Poiner, I. R. and Kennedy, R. 1984. Complex patterns of change in the macrobenthos of a large sandbank following dredging I. Community analysis. Marine Biology. 78 : 335-352.

Keywords: dredging/ sediment disturbance/ macrobenthos

Abstract: The impact of dredging operations on the marine benthos of a large, subtropical, sublittoral sandbank (Middle Banks, Moreton Bay, Queensland, Australia) was investigated during July and August 1982. Statistical comparisons (ANOVA) of species richness, total abundance, Shannon diversity and Shannon equatability were made with extensive pre-dredging data base. Both the dredged and adjacent areas were investigated. Changes in sediments and the distribution and deposition rates of the dredge plumes were also examined. There were significant decreases (P less than or equal to 0.025) in the species richness (from 33.0 to 16.6 mean number of species per site), total abundance (from 117.9 to 47.6 mean number of individuals per site) and Shannon diversity (from 4.03 to 3.22 mean diversity per site) within the dredged area. There were significant increases (P less than or equal to 0.01) in species richness (from 31.2 to 67.9 mean number of species per site) and total abundance (from 177.7 to 752 mean number of individuals per site) in adjacent benthic areas. The distribution and the predicted deposition rates of the sediment plume correlated precisely with the area of enhancement (P less than 0.05). The potential causal relationship between deposition and faunal enhancement is discussed. We suggest that the enhanced effect is probably a response of the benthic biota to an increase in available resources.

Pranovi, F. and Giovanardi, O. 1994. The impact of hydraulic dredging for short-necked clams, *Tapes* spp., on an infaunal community in the lagoon of Venice. Scientia Marina. 58(4) : 345-353.

Keywords: clam fishery/ dredging/ benthos/ Venice Lagoon

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.

Pranovi, F. and Giovanardi, O. 1995. The bivalve fishery in Venice Lagoon: effects and consequences. Biol. Mar. Mediterr. 2(2) : 121-122.

Keywords: Venice Lagoon/ bivalve fishery/ dredging

Abstract: To assess the effects of hydraulic and manual dredging on benthic biocenosis, experimental fishing was carried out in the Venetian Lagoon. The manual gear produces lighter effects.

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

Keywords: macrobenthos/ recolonization dynamics/ anthropic impact/ Adriatic Sea/ Lagoon of Venice/ rapido beamtrawl/ hydraulic dredge

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

Pranovi, F., Giovanardi, O., and Strada, R. 1996. Preliminary observations on the trawl fishery within the three miles of the coast along the marine district of Chioggia [Osservazioni preliminari sulla pesca a strascico entro le tre miglia dalla costa nel compartimento marittimo di Chioggia]. Biol. Mar. Mediterr. 3(1) : 214-221.

Keywords: trawl-fishery/ coastal area/ Adriatic Sea

Abstract: Results of some trawl-surveys carried out in 1984 and 1994 in a coastal area of the North Adriatic Sea are reported. Data collected make it feasible to evaluate the effects of a one month fishery ban, mainly on catches of red mullet (*Mullus* sp.) and cuttlefish (*Sepia officinalis*). Some considerations about the abundance and distribution of juveniles of the most important species are reported.

Prena, J., Rowell, T. W., Schwinghamer, P., Gilkinson, K., and Gordon, D. C. 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 2094, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. viii + 38 p.

Keywords: fishing gear/ otter trawls/ trawling/ man-induced effects/ community composition/ Grand Banks

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 one on the Grand Banks. New faunistic information for each of the three sites is also presented. *Reproduced with the permission of Her Majesty the Queen in Right of Canada, 1999, and Fisheries and Oceans Canada.*

Prena, J., Schwinghamer, P., Rowell, T. W., Gordon, D. C., Gilkinson, K. D., Vass, W. P., and McKeown, D. L. 1999. Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: analysis of trawl bycatch and effects on epifauna. Marine Ecology Progress Series. 181 : 107-124.

Keywords: mobile fishing gear impacts/ otter trawling/ bycatch/ epibenthic organisms/ marine biodiversity/ Grand Banks

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 *C. 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. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Pringle, J. D. and Jones, D. J. 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.

Keywords: dredging/ raking/ harvesting/ Prince Edward Island/ Canada

Pringle, J. D., Jones, D. J., and Rowe, P. 1981. Fishing power and ecological impact of Gulf *Chondrus* (Irish moss) of modified *Chondrus* dragrakes. Canadian Manuscript Reports of Fisheries and Aquatic Sciences. No. 1601. 80 p.

Keywords: fishing effects/ Irish moss/ dragrakes

Pringle, J. D., Murchison, J., and Jones, D. J. 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.

Keywords: basket dragrake/ Irish moss harvester/ Gulf of St. Lawrence

Pringle, J. D. and Semple, R. E. 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.

Keywords: benthic disturbance/ Irish moss harvester/ Prince Edward Island

Probert, P. K., McKnight, D. G., and Grove, S. L. 1997. Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. Aquatic Conservation: Marine and Freshwater Ecosystems. 7(1) : 27-40.

Keywords: invertebrate bycatch/ trawl fishery/ Chatham Rise/ New Zealand

Queirolo, L. E., Fritz, L. W., Livingston, P. A., Loefflad, M. R., Colpo, D. A., and deReynier, Y. L. 1995. Bycatch, utilization, and discards in the commercial groundfish fisheries of the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-58, 148 p.

Keywords: bycatch/ discards/ commercial fisheries/ groundfish

Abstract: Total harvest, bycatch, catch utilization, and discards are currently the subjects of considerable attention and debate worldwide. This report documents reported catch, bycatch, utilization, and discard data and attempts to identify patterns and trends in the commercial groundfish fisheries of the Gulf of Alaska (GOA), eastern Bering Sea, and Aleutian Islands (BSAI) (areas which currently make up the United States' Exclusive Economic Zone off Alaska). The report identifies existing data sources and examines the historical catch record, as well as current domestic groundfish fisheries in these areas.

Many factors have contributed to the increased interest in this issue. Among these are: 1) improvements in understanding of basic ecological relationships and fish stock dynamics; 2) changes in fishing effort, capacity, and technology; 3) the increasing economic and market importance of these fisheries; and 4) changes in management capability and authority (e.g., extension by the United States of exclusive management authority under the Magnuson Fishery Conservation and Management Act of 1976).

There are many reasons why groundfish fisheries discard groundfish. Among these are: 1) the directed fishery for a given species, say species A, may be closed (due to quota or other restrictions) forcing all other fisheries which catch species A as bycatch to discard it; 2) individual fish in the catch are too small or large for mechanical processors, or are the wrong sex (e.g., males in the rock sole roe fishery); 3) to change the species composition of their total catch for the reporting week, preventing the vessel from being considered a "participant" in a particular fishery for that week, and as such, subject to different, possibly more stringent, prohibited species bycatch rate standards set by the North Pacific Fishery Management Council; 4) a lack of handling or processing capacity aboard the vessel; or 5) market limitations on the utilization of retention of certain species. Particularly for various groundfish fisheries (e.g., walleye pollock, Pacific cod, Atka mackerel and rockfish), the size composition of the target species population can greatly affect the rate of discard by the fishery. If a prerecruited year class is very strong, large catches of fish too small for market may be unavoidable, increasing the rate of discard. Discards are subtracted from catch tonnage prior to calculation of product recovery rates, but discarded fish are included as part of the total harvest.

An analysis, based upon Weekly Product Reports for 1994, suggest that for all GOA and BSAI groundfish fisheries combined, approximately 15% of the total catch was discarded in-the-round. Significantly, the weight of offal returned to the sea was nearly four times as great as the weight of discards. About 70%, by weight, of "target" catch is returned to the sea as offal; offal discharges make up almost 60% of "total" catch. Thus, when considering energy transfer in the ecosystem, offal production vastly overshadows discard amounts.

Groundfish discards may have unanticipated and/or undesirable economic implications. Bycatch discards may, for example, impose direct economic costs on competing groundfish fisheries in the form of forgone catches. Through a series of simplifying assumptions, it was possible to estimate the "opportunity cost" (as measured at the first wholesale level) to target fisheries of the foregone catch, attributable to groundfish bycatch discards in individual BSAI and GOA fisheries.

In 1994, all BSAI groundfish fisheries discarded an aggregate total of 162,161 metric

tons (t) of allocated groundfish species for which the total allowable catch was binding. The opportunity cost of these discards exceeded $91,848,000. The total retained catch of all groundfish species in these fisheries was just over 1,699,500 t and had a value which exceeded $925,229,800. Thus, the ratio of the value of retained catch to discards (Retained/Discard Value Ratio), weighted by fishery, across all BSAI groundfish fisheries, was 10.1. That is, for each dollar of bycatch "opportunity cost" imposed, $10.10 of output was produced from retained catch. Individual rates varied from a high of $29.2 in the pollock target fishery, to a low of $2.4 in the "other" groundfish target fishery. In the GOA groundfish fisheries, equivalent discards totaled 15,685 t. The opportunity cost of these discards exceeded 196,588 t and had a value which exceeded $235,825,000. Thus, the Retained/Discard Value Ratio, weighted by fishery across all GOA groundfish fisheries, was 16.1. That is, for each catch. Individual rates varied from a high of 45.4 in the sablefish target fishery, to a low of 3.4 in the arrowtooth flounder target fishery. Groundfish discards may also impact markets by affecting product form, supply, and price which, in turn, influence international seafood trade and U.S. market share.

Raloff, J. 1996. Fishing for answers: deep trawls leave destruction in their wake - but for low long? Science News. 150 : 268-271.

Keywords: trawling/ fishing effects/ trawling impacts

Ramsay, K. and Kaiser, M. J. 1998. Demersal fishing disturbance increases predation risk for whelks (*Buccinum undatum* L.). Journal of Sea Research. 39(3-4) : 299-304.

Keywords: *Buccinum undatum*/predation/escape response/fishing impact

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 behaviour, 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. *Reprinted from Journal of Sea Research, Vol. 39; Ramsay, K.//Kaiser, M.J.; Demersal fishing disturbance increases predation risk for whelks (Buccinum undatum L.); pages 299-304; Copyright (1998); with permission from Elsevier Science.*

Ramsay, K., Kaiser, M. J., and Hughes, R. N. 1996. Changes in hermit crab feeding patterns in response to trawling disturbance. Marine Ecology Progress Series. 144(1-3) : 63-72.

Keywords: beam trawling/ hermit crabs/ feeding/ fishing impact

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 behaviour 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*. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Ramsay, K., Kaiser, M. J., and Hughes, R. N. 1997. A field study of intraspecific competition for food in hermit crabs (*Pagurus bernhardus*). Estuarine, Coastal and Shelf Science. 44(2) : 213-220.

Keywords: aggressive behaviour/ feeding/ intraspecific competition/ fisheries/ crabs/ Irish Sea

Abstract: A tethered, frame-mounted video camera deployed on the sea-bed was used to observe the competitive interactions that occurred between hermit crabs, *Pagurus bernhardus*, that were attracted to food patches (dead dragonets, *Callionymus lyra*) of differing size. Hermit crab numbers on the small food patch ceased increasing c. 20 min after the camera arrived on the sea-bed, whilst numbers on the large patch increased throughout the experiment. The number of observed aggressive interactions increased with increasing hermit crab density, but was generally highest on the small patch. The probability of a hermit crab being able to feed increased with size for each of three size-groups on the small patch, whereas on the large patch, both large and medium-sized hermit crabs were equally likely to feed. Small and medium-sized hermit crabs had a higher probability of being able to feed on the large patch than the small patch. As the density of hermit crabs around a patch increased, the proportion of small individuals actively feeding decreased. The size-frequency distribution of hermit crabs on the large patch was significantly different from that on the small patch, with the latter being skewed towards larger individuals. These results suggest that the intensity of competition increases both with increasing numbers of hermit crabs and decreasing size of food resource. Large hermit crabs were more successful at feeding than smaller crabs when competition was more intense.

Ramsay, K., Kaiser, M. J., and Hughes, R. N. 1998. Responses of benthic scavengers to fishing disturbance by towed gears in different habitats. Journal of Experimental Marine Biology and Ecology. 224(1) : 73-89.

Keywords: scavengers/ feeding behaviour/ fishing disturbance/ habitat differences

Abstract: The aggregation and feeding behaviour 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. *Reprinted from Journal of Experimental Marine Biology and Ecology, Vol. 224; Ramsay, K., Kaiser, M.J. and Hughes, R.N.; Responses of benthic scavengers to fishing disturbance by towed gears in different habitats; pages* 73-89*; Copyright (1998); with permission from Elsevier Science.*

Ramsay, K., Kaiser, M. J., Richardson, C. A., Veale, L. O., and Brand, A. R. (In Press). Shell scars on dog cockles (*Glycymeris glycymeris* L.): an in situ record of historic fishing disturbance. Marine Ecology Progress Series.

Keywords: fishing disturbance/ shell scars/ cockle fishery

Ramsay, K., Kaiser, M. J., Rijnsdorp, A. D., Craeymeersch, J. A., and Ellis, J. 2000. Impact of trawling on populations of the invertebrate scavenger *Asterias rubens*. Pages 151-162 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: starfish populations/ fishing effort/ NAO/ trawling impact

Summary [author's summary]: 1. The relationship between starfish numbers and fishing effort is a quadratic, meaning that, as fishing effort increases, starfish numbers also increase until they reach a turning point, after which starfish numbers decline as fishing effort further increases. 2. This relationship, although significant, is fairly weak, suggesting that other factors must strongly influence starfish numbers. 3. Until we know more about the ecology and population dynamics of starfish populations, it will be difficult to determine the exact extent of the impact of beam trawling on starfish populations. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK*.

Redant, F. 1987. A bibliography on the effects of bottom fishing gear and harvesting techniques on benthic biota. ICES Working Document Benthos Ecology Working Group, Edinburgh. 8 p.

Keywords: bottom fishing gear/ bottom fishing/ fishing gear/ harvesting/ benthic biota

Redant, F. 1991. An updated bibliography on the effects of bottom fishing gear and harvesting techniques on the sea bed and benthic biota. ICES Working Document to the Study Group on Ecosystem Effects of Fishing Activities. 12 p.

Keywords: bibliography/ fishing effects/ harvesting/ benthic biota

Rees, H. L. and Dare, P. T. 1993. Sources of mortality and associated life cycle traits of selected benthic species: A review. Fisheries Research Data Report No 33. Directorate of Fisheries Research, Lowestoft, Great Britain. 36 p.

Keywords: mortality/ life cycle/ benthos/ literature reviews/ commercial trawling/ dredging

Summary: This report summarizes the responses of selected benthic species in the North Sea to natural and anthropogenic influences (effects of fishing being of particular interest) in relation to habitat status. Nine species from four major invertebrate groups (Polychaeata, Mollusca, Crustacea and Echinodermata) were selected for the study to represent a reasonable spread across the "r/K" continuum, and to cover a wide range of habits, geographical areas and varying degrees of sensitivity to natural and anthropogenic disturbance. The same variables were examined similarly for each species, and fell under two categories; 1) species characteristics and 2) sources of mortality. The authors found that insufficient data were available to make full quantitative assessments of certain variables, such as life-history traits and mortality sources on a North Sea-wide scale. Instead, implications are drawn on local and/or regional scales because of the expectation of marked habitat-related differences.

Reeves, J. C. and DiDonato, G. S. 1972. Effects of trawling in Discovery Bay, Washington. Washington Department of Fisheries Technical Report No. 8. 45 p.

Keywords: trawling/ trawling effects/ Discovery Bay/ Washington

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. 16 : 29-36.

Keywords: macrobenthic changes/ Wadden Sea

Reise, K. and Schubert, A. 1987. Macrobenthic turnover in the subtidal Wadden Sea: The Norderaue revisited after 60 years. Helgolander Meeresuntersuchungen. 41(1) : 69-82.

Keywords: community composition/ trawling/ dredging/ Wadden Sea/ macrobenthic changes

Abstract: The benthic macrofauna of tidal inlet in the northern Wadden Sea was sampled with grab and dredge in 1924-1926, 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. *Reprinted with the permission of Biologische Anstalt Helgoland and Helgoland Marine Research (formerly Helgolander Meeresuntersuchungen).*

Rice, M. A., Hickox, C., and Zehra, I. 1989. Effects of intensive fishing effort on the population structure of quahogs, *Mercenaria mercenaria* (Linnaeus 1758), in Narragansett Bay. Journal of Shellfish Research. 8(2) : 345-354.

Keywords: fishing effort/ population structure/ *Mercenaria*/ Narragansett Bay/ shellfishery

Abstract: *Mercenaria mercenaria* and sediment samples were collected from 3 locations in Narragansett Bay: Greenwich Cove, Greenwich Bay, and the West Passage. Greenwich Cove has been closed to shellfishing for several decades. Average density of quahogs in the cove was 190/m^2, ranging from 32 m^2 -500/m^2 in 30 quadrats. Average valve length of quahogs in Greenwich Cove was 62 mm. Adjacent to Greenwhich Cove in Greenwhich Bay which has been heavily fished since the 1930s. The average density in Greenwich Bay was 78/m^2, ranging from 8/m^2-184/m^2. The average valve length was 31 mm. There were no significant differences in salinity, Secci disk turbidity or total organic content of sediments between these two sites. There was a slightly higher content of very fine-grained sands, silts, and clays in the Greenwich Cove sediments. The average *Mercenaria* density at another closed site on the West Passage was 46/m^2 with an average valve length of 61 mm. The lower density may be due to higher silt and clay content of the sediments. There were significantly more juvenile (< 40 mm) quahogs in the heavily fished area ($p < 0.01$, ANOVA). Determination of age by shell growth rings showed that quahogs in the bay were 12 yr of age or less. Ages were greater in the closed areas and exceeded 25 years in the largest individuals. Growth data from quahogs in the closed areas was fit to the von Bertalanffy growth equation. This yielded asymptotic valve length maxima (L_{max}) of 110 mm plus or minus 9.6 (SE) in the West Passage and 86 mm plus or minus 4.7 (SE) in the cove, suggesting density-dependent stunting in the latter site. Active fishing tends to remove adults from the population and enhance either the set or survival of juvenile quahogs. The mechanism for increasing the juvenile density is not understood; possible explanations include removal of competing adults and sediment disturbance/turnover as a result of the fishing methods. Reburrowing of quahogs placed on the sediment surface was studied. Results indicate that the largest adults (> 86 mm valve length) have the least ability to reburrow. *Reprinted with the permission of the National Shellfisheries Association and the Journal of Shellfish Research.*

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.

Keywords: fishing gear effects/ sediment disturbance/ model experiments

Riemann, B. and Hoffmann, E. 1991. Ecological consequences of dredging and bottom trawling in the Limfjord, Denmark. Marine Ecology Progress Series. 69(1-2) : 171-178.

Keywords: dredging/ bottom trawling/ ecological impacts/ sediment disturbance/ Limfjord/ Denmark

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. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Riesen, W. and Reise, K. 1982. Macrobenthos of the subtidal Wadden Sea: revisited after 55 years. Helgolander Meeresuntersuchungen. 35(4) : 409-423.

Keywords: macrobenthos/ macrofauna changes/ Wadden Sea/ trawling effects/ fishing effects

Abstract: During the years 1923-1926, Hagmeier and Kaendler (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 creates*, *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. *Reprinted with the permission of Biologische Anstalt Helgoland and Helgoland Marine Research (formerly Helgolander Meeresuntersuchungen).*

Rijnsdorp, A. D., Buys, A. M., Storbeck, F., and Visser, E. G. 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. 55(3) : 403-419.

Keywords: beam trawling/ effort distribution/ ecosystem effects/ benthos

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 micro-distribution 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.

Rijnsdorp, A. D., Groot, P., and van Beek, F. A. 1991. The microdistribution of beam trawl effort in the southern North Sea. ICES CM 1991/G:49. 20 p.

Keywords: gear impact/ beam trawl/ North Sea/ trawling impacts

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 microdistribution of effort was studied with a resolution of 1×1 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 1×1 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 microdistribution patterns was done using a Monte Carlo simulation, assuming that 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 areas was trawled. In the trawlable areas 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. *Reprinted with author permission (Dr. A.D. Rijnsdorp).*

Rijnsdorp, A. D., van Leeuwen, P. I., Daan, N., and Heessen, H. J. L. 1996. Changes in abundance of demersal fish species in the North Sea between 1906-1909 and 1990-1995. ICES Journal of Marine Science. 53(6) : 1054-1062.

Keywords: demersal fish species/ long-term changes/ North Sea

Robichaud, D., Williamson, A., and Graham, D. 1987. Characteristics of the St. Mary's Bay lobster stock in relation to scallop gear impact. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1955: iv + 17 p.

Keywords: lobsters/ scallop fishing gear/ gear impact/ St. Mary's Bay

Abstract: An assessment of the impact of scallop fishing on the lobster fishery in St. Marys Bay, N.S. was undertaken to help alleviate a conflict that recently arose between the two fisheries. A diving survey undertaken during July 1986 showed that relatively high lobster densities (111 lobsters/1000 m^2) occurred on rough, rocky bottom where no scallops were found. Lobsters at lower densities (2.5-15 lobsters/1000 m^2) co-occurred with scallops on mud bottom interspersed with a few rocks. Although scallop density in the whole areas surveyed was low (57.8 scallops/1000 m^2), the animals were large (78% $\geq$ 120 mm shell height). Tagging results showed that the majority (91%) of recaptured (82) lobsters remained in St. Marys Bay and that the average straight-line distance traveled by mature females was significantly ($p < 0.01$) greater (35 km) than for both mature males (16 km) and immature lobsters (12 km). Sales slip analysis showed that annual lobster landings and catch rates increased markedly between 1978 and 1986. Size-sex frequency distributions were obtained from 5152 lobsters caught at different locations inside St. Marys Bay with commercial traps and an experimental Rockhopper trawl. Although lobster fishing occurred in most of the Bay, dragging for scallops took place in < 7% of the Bay in areas of low lobster density. The data suggest little adverse impact on lobsters by scallop dragging in St. Marys Bay. *Reprinted with author permission (Dr. D. Robichaud).*

Robinson, R. F. and Richardson, C. A. 1998. The direct and indirect effects of suction dredging on a razor clam (*Ensis arcuatus*) population. ICES Journal of Marine Science. 55(5) : 970-977.

Keywords: bivalve/ razor shell/ *Ensis arcuatus*/ age determination/ dredging/ dredge disturbance

Abstract: Surveys were conducted in two shallow bays in the Orkney Islands, UK; 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). 24-25.

Keywords: trawling

Roddick, D. L. and Miller, R. J. 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. 49(7) : 1486-1492.

Keywords: scallop dragging/ fishing effects/ spatial and temporal overlap

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. *Reprinted with the permission of NRC Research Press and the Canadian Journal of Fisheries and Aquatic Sciences.*

Rogers, S. I. 1997. A review of closed areas in the United Kingdom Exclusive Economic Zone. Scientific Services Technical Report, No. 106. Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, UK. 20 pp.

Keywords: closed fishing areas/ EEZ/ United Kingdom

Rogers, S. I. and Millner, R. S. 1996. Factors affecting the annual abundance and regional distribution of English inshore demersal fish populations: 1973 to 1995. ICES Journal of Marine Science. 53(6) : 1094-1112.

Keywords: demersal fish distribution

Rogers, S. I., Kaiser, M. J., and Jennings, S. 1998. Ecosystem effects of demersal fishing: a European perspective. Pages 68-79 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: fishing gear impacts/ benthic community disturbance/ trawling/ demersal fisheries

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. *Reprinted with the permission of the Conservation Law Foundation*.

Rogers, S. I., Rijnsdorp, A. D., Damm, U., and Vanhee, W. 1998. Demersal fish populations in the coastal waters of the UK and continental NW Europe from beam trawl survey data collected from 1990 to 1995. Journal of Sea Research. 39(1-2) : 79-102.

Keywords: demersal fish population/ North Sea/ NW Europe/ trawl survey

Abstract: Samples of the demersal fish fauna have been collected by beam trawl from the coastal waters of northwest Europe (49-57 degree N, 8 degree W-9 degree E) by the UK, Netherlands, Germany and Belgium, since 1990, during the third quarter of the year. Changes in community structure within small spatial scales were subtle as species compositions formed part of a continuum over the entire continental shelf. Populations of low diversity were particularly evident in the German Bight and on the North Sea continental coast, where dab *Limanda limanda* were abundant. In the Channel and to the west of the UK the demersal assemblages were more species-rich than in the North Sea and, although dab was still an important member of the underlying fish assemblage, the abundance of other species, especially poor cod *Trisopterus minutus*, solenette *Buglossidium luteum*, plaice *Pleuronectes platessa*, and the lesser weever, *Echiichthys vipera*, allowed a range of different groups to be identified. Despite the greater species diversity in this westerly region only eight out of a total nineteen flatfish species were found in abundance. The dominance of different species in different size classes was a key feature of the community structure. Flatfish were the largest group by weight in the smaller-length classes (< 30 cm), and in western areas the elasmobranchs dominated the larger-size classes. Observed patterns in community structure were partly explained by the zoogeography of the region and the presence of the British Isles at the boundary between two faunal types. The

additional influence on demersal populations of depth and substrate type, which may regulate the abundance of flatfish at key stages in their life history, was also discussed. In addition to these natural processes, recent increases in fishing effort are thought to have affected the structure of the demersal assemblage, and an examination of aggregated length-frequency distributions from these surveys tends to support this conclusion. Without further information on the distribution of fishing effort, it is not possible to separate the influence of natural faunal changes between regions from that of artificial changes caused by fishing activity. *Reprinted from Journal of Sea Research, Vol. 39; Rogers, S. I., Rijnsdorp, A. D., Damm, U. and Vanhee, W.; Demersal fish populations in the coastal waters of the UK and continental NW Europe from beam trawl survey data collected from 1990 to 1995; pages 79-102; Copyright (1998); with permission from Elsevier Science.*

Rogers, S. I., Maxwell, D., Rijnsdorp, A. D., Damm, U., and Vanhee, W. 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. 40(2) : 135-152.

Keywords: diversity/ fishing impact/ assemblage/ demersal/ beam trawl

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 this 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. *Reprinted from Fisheries Research, Vol. 40; Rogers, S.I., Maxwell, D., Rijnsdorp, A.D., Damm, U., Vanhee, W.; 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?; pages 135-152; Copyright (1999); with permission from Elsevier Science.*

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

Keywords: fishing gear technology/ design modification/ fishing effects/ benthos disturbance/ trawl/ dredge/ rake

Summary: This paper addresses the components of various demersal fishing gears that have the greatest impact on benthic habitat, and discusses under what conditions the gear components effects are most pronounced. Several gear types are categorized and their effects summarized. Additionally, methods to study such effects are listed. Implications are made for cooperative research between fishing gear technologists and researchers of benthic effects, to improve gear component designs that could reduce effects on habitat.

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.

Keywords: dredging/ cockle dredging/ invertebrate fauna/ dredging effects/ Burry Inlet

Rothschild, B. J., Ault, J. S., Goulletquer, P., and Héral, M. 1994. Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. Marine Ecology Progress Series. 111 : 29-39.
Keywords: oyster habitat destruction/ fishing effects/ Chesapeake Bay

Rowell, T. W., Schwinghamer, P., Chin-Yee, M., Gilkinson, K., Gordon, Jr D. C., Hartgers, E., Hawryluk, M., Mckeown, D. L., Prena, J., Reimer, D. P., Sonnichsen, G., Steeves, G., Vass, W. P., Vine, R., and Woo, P. 1997. Grand Banks otter trawling impact experiment: III, sampling equipment, experimental design, and methodology. Canadian Technical Report of Fisheries and Aquatic Sciences 2190. Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. viii + 36 p.

Keywords: otter trawling/ Grand Banks/ sampling equipment

Abstract: In order to obtain quantitative information on the impacts of otter trawling on benthic communities, the Canadian Department of Fisheries and Oceans 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 had two components; a major component, which we have termed the "corridor study" and a minor component termed the "long-trawl". The study site for the primary experiment, the "corridor study", centered at 47^0 09' N, 48^0 17' W, has an average water depth of about 137 m, a well-sorted sandy sediment, and an extensive benthic fauna. The area was closed to trawling for the duration of the experiment. In 1993, after pre-trawl sampling by the C.S.S. *Parizeau*, three replicate experimental corridors, each 13 km long and approximately 200 m wide, were trawled twelve times by the C.S.S. *Wilfred Templeman* using a commercial Engel 145 otter trawl equipped with rockhopper foot gear. The trawl catch, including captured benthic organisms, was immediately processed and sampled. Immediately after trawling, the area was again sampled by the *Parizeau* to evaluate immediate impacts. The

extent and duration of physical disturbance was visually assessed using video imaging by BRUTIV and acoustically assessed using sidescan sonar, DRUMS, and RoxAnn. Biological samples, in both trawled and reference corridors, were collected with a newly-developed hydraulically-powered grab (0.5 m^2) and an existing epibenthic sled which was modified to provide more quantitative samples. Both the grab and sled are video-equipped. The high resolution acoustic imaging system, DRUMS, was also newly developed for the study. Variables measured included epifauna, macrofauna, meiofauna, bacteria, grain size, organic carbon/nitrogen, and sediment structure. A second sampling was carried out in September 1993, ten weeks after trawling, to evaluate short-term impacts. A third sampling was carried out, in July of 1994, to evaluate intermediate-term impacts one year after the initial trawling; the corridors were then re-trawled and immediately thereafter a fourth sampling, the second for immediate impacts, was carried out. A fifth sampling, in June/July 1995, evaluated intermediate-term and cumulative impacts from the 1993 and 1994 trawlings. The corridors were then retrawled and immediately afterward sixth sampling, the third for immediate impacts, was carried out. The secondary experiment, the "long-trawl", was designed by the Geological Survey of Canada to traverse a range of water depths and sediment types in order to determine decay rates of a trawl-created bottom disturbance, as an analog for an iceberg scour, in these substrates and energy regimes. During the establishment of the "long-trawl" in July 1993, the C.S.S. *Parizeau* accompanied the C.S.S. *Wilfred Templeman* from 47° 04.00′N, 48° 11.00′W to 46° 45.46′ N, 48° 46.27′ W as the *Templeman* laid down a trawl track over a distance of 60 km and covering a depth range of 75-135 m. The "long-trawl" was resurveyed using sidescan sonar in September 1993, July 1994 and July 1995 by the C.S.S. *Parizeau* and in August 1994 by the C.S.S. *Hudson*. This report describes both the equipment used, most of it new or highly adapted, and the design and methodology of the experiments. *Reproduced with the permission of Her Majesty the Queen in Right of Canada, 1999, and Fisheries and Oceans Canada.*

Ruffin, K. K. 1995. The effects of hydraulic clam dredging on nearshore turbidity and light attenuation in Chesapeake Bay, MD. M.S. Thesis. University of Maryland. 79 p.

Keywords: dredging/ clam dredging/ dredging effects/ sediment disturbance/ Chesapeake Bay/ Maryland

Rumohr, H. 1989. Information on impact of trawling on benthos in Kiel Bay. Annex to 8th Report of the Benthos Ecology Working Group. ICES CM 1989/L:19.

Keywords: trawling impacts/ Kiel Bay/benthos

Rumohr, H. and Krost, P. 1991. Experimental evidence of damage to benthos by bottom trawling with special reference to *Arctica islandica*. Meeresforschung Reports on Marine Research. 33(4) : 340-345.

Keywords: bottom trawling/ benthic environment/ environmental impact/ Germany/ Kiel Bight/ benthos

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 Sonderborg 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. *Reprinted with author permission (Dr. P. Krost).*

Rumohr, H., Schomann, H., and Kujawski, T. 1994. Environmental impact of bottom gears on benthic fauna in the German Bight. NIOZ Rapport 1994-11, Netherlands Institute for Fisheries Research, Texel. 75-86.

Keywords: gear impact/ benthic fauna/ bottom gear/ environmental impact/ North Sea

Russell, D. 1997. [Hitting Bottom] As trawling goes into high hear, undersea coastal habitat is being razed to the ground. Amicus Journal. 18(4) : 21-25.

Keywords: trawling impacts/ habitat disturbance

Summary: This article is a quick look at the recent trends of bottom trawling and its effects to benthic sediments and their faunal communities. The paper argues the destructive impacts of trawling on benthic communities and compares the effects to that of forest clearcutting and other terrestrial activities that impact habitat.

Saila, S. B. 1992. Application of fuzzy graph theory to successional analysis of a multispecies trawl fishery. Transactions of the American Fisheries Society. 121(2) : 211-233.

Keywords: trawl fishery/ fuzzy graph theory

Saila, S. B. 1995. New England groundfisheries -- what next? Maritimes. 38(2) : 1-3.

Keywords: demersal fisheries/ fishery management/ New England

Sainsbury, K. J. 1982. The biological management of Australia's multispecies tropical demersal fisheries: A review of problems and some approaches. CSIRO Marine Laboratories Report, No. 147. CSIRO, Cronulla, NSW, Australia. 18 p.

Keywords: fishery management/ demersal fisheries/ multispecies fisheries/ Australia Coasts

Abstract: Declaration of a 200 n. mile fisheries management zone gave Australia the responsibility to mange the exploitation of demersal fish stocks inhabiting the broad continental shelf of tropical Australia. Tropical demersal fisheries have three pronounced attributes which lead to difficulty in their biological management; (1) a large number of species are exploited, (2) there are biological interactions between species and (3) the additional mortality imposed by the fishery is not equal for all species and is influenced by fishermen behaviour. The implications of each attribute to biological management of the tropical fisheries are examined.

It is concluded that currently available methods are inadequate to resolve many of the questions arising from management of Australia's tropical demersal fish resources; particularly

questions requiring prediction of the species mix under widely differing fishing regimes. Research directions are indicated which would overcome some of these difficulties. In particular an experimental management approach is suggested, utilizing part of the area occupied by the existing fishery, to both empirically test some fishery development options and provide the opportunity of evaluating some assumptions of available multispecies fishery models. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia (Books Section).*

Sainsbury, K. J. 1987. Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. Pages 465-503 *in* J. J. Polovina and S. Ralston, (eds.). Tropical snappers and groupers: biology and fisheries management. Westview Press, Boulder, Colorado.

Keywords: demersal fisheries/ fishery management/ stock assessment/ Australia

Abstract: The diverse fish community on the continental shelf of northwestern Australia has been exploited since 1959. The history of exploitation is summarized, and concurrent changes in fish community are inferred from data collected during research surveys. Some possible reasons for the observed changes in fish community structure are provided, including the direct modification of the demersal habitat by trawling. Assessments of the North West Shelf fishery have utilized surplus production models and multiple "dynamic pool" models of the Beverton and Holt type. These assessments are described, and their limitations discussed. Present management questions concern the extent of management control over the fish community and determination of the yield available from alternative configurations of the fish community. An approach to examination of these questions is described. *Reprinted with the author's permission (Dr. K. J. Sainsbury).*

Sainsbury, K. J. 1991. Application of an experimental approach to management of a tropical multispecies fishery with highly uncertain dynamics. Multispecies models relevant to management of living resources. ICES marine science symposia. 193 : 301-320.

Keywords: multispecies fishery/ sociological aspects/ experimental fishery management regime/ fishery economics/ mathematical models/ Australia/ multispecies fisheries

Abstract: In most multispecies fisheries there is considerable uncertainty in selection of an appropriate model to represent the dynamics of the resource. Many model structures and/or parameterizations may be consistent with ecological principles and the available data. These models may have very different management implications, but may be impossible to distinguish by process-oriented research at reasonable cost and on a time frame of relevance to management. In some circumstances an adaptive experimental management regime can be economically beneficial by allowing empirical learning about resource dynamics and discrimination between alternative models. However, in any particular situation it must be determined whether an experimental regime is economically viable, and which management actions and research observations should be included in the regime. The development and application of an experimental management regime for the fisheries operating on a tropical fish community in northwestern Australia are described. The history of exploitation is summarized and a number of simple models are suggested which can mimic past changes observed in fish community composition. These models include interspecific, intraspecific, and habitat modification mechanisms. Possible socio-economic responses of the fishing industry to changes in the resource state are important to evaluation of a prospective fishing regime, and these are also

modeled. The models are used to evaluate options for management of competing trap and trawl fisheries on the Northwest Shelf. It was found that if an experimental management regime were adopted for about 5-15 years (during which time key uncertainties in the resource dynamics and socio-economic responses could be resolved) a larger expected value could be obtained from the resource than if the existing management regime were continued. Some experimental management regimes also provided a greater expected value than would be obtained form immediate application of the management regime that is optimal for any of the individual resource models. Experimental management periods of less than about 5 y did not allow sufficient resolution of uncertainties to be worthwhile, and periods of longer than about 15 y often resulted in the cost of obtaining the additional resolution exceeding the value fo the expected improvement in returns from the resource. *Reprinted with author permission (Dr. K. J. Sainsbury).*

Sainsbury, K. J., Campbell, R. A., Lindholm, R., and Whitelaw, A. W. 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 (eds.). Global trends: fisheries management. American Fisheries Society, Symposium 20, Bethesda, Maryland.

Keywords: fishery management/ trawling/ trawl fishery impacts/ multispecies fisheries/ Australia

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. *Reprinted with the permission of the American Fisheries Society.*

Sainsbury, K. J., Campbell, R. A., and Whitelaw, A. W. 1993. Effects of trawling on the marine habitat on the north west shelf of Australia and implications for sustainable fisheries management. Pages 137-145. Sustainable Fisheries through Sustainable Fish Habitat. Bureau of Resource Sciences Publication. Australian Government Publishing Service. Canberra, Australia.

Keywords: trawling impacts/ fishing gear effects/ species composition/ ecosystem disturbance/ North West Shelf/ Australia

Summary: The focus of this paper is on the effects of trawling on the marine habitat and the relationship of this habitat and the fish composition on the North West Shelf (NWS) of Australia. This paper is discussed in three parts. First, it addresses some of the problems facing managers of Australia's tropical marine fish resources. Second, the NWS fishery is reviewed and the ecological communities in that region are described. Finally, it describes both the research and management approaches taken in this region. From the results of this study, it was found that the relative composition of the multispecies fish community on the NWS is habitat dependant, and the historical changes in animal composition are partly a result of long-term habitat disturbance due to demersal trawling gear. It is anticipated that continued habitat alteration will further alter species composition. Areas that had been closed to trawling showed that large epibenthic species were slow to recover. The authors also suggest that "adaptive" management strategies have considerable scope in providing information which will guide the decision of long-term management actions.

Sainsbury, K. J. and Poiner, I. 1988. A preliminary review of the effects of prawn trawling in the Great Barrier Reef Marine Park. Report to the Great Barrier Reef Marine Park Authority, Townsville, Queensland. 49 p.

Keywords: prawn trawling/ Great Barrier Reef/ trawling effects

Summary: This review details prawn trawling in the Great Barrier Reef Marine Park. The review discusses the considerable controversy between the Great Barrier Reef Marine Park Authority (GBRMPA), the Queensland Commercial Fishermen Organization (QCFO), the Queensland Fish Management Authority and the Queensland Department of Primary Industries over the no trawl zoning that the GBRMPA imposed in about 20% of the Great Barrier Reef region. The closures were made due to increasing concern about the impacts of trawling on habitat and fish bycatch. However, the Australian fishing industry feels that closures are unfounded, and that trawlers have been singled out unfairly. The author points out that the effects that trawlers have on the reef communities are not trivial, and several issues (such as habitat degradation and bycatch) are discussed in this review. However, at the time of this report, there had been very few studies on the effects of trawling and little understanding of the long-term effects was known. Hence, the studies at the time of this paper did not provide an adequate information base for management of the effects of trawling in the Marine Park. Several management strategies are discussed in this review, and preliminary implications about what steps should be taken are given.

Sanchez-Jerez, P. 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. 5(4) : 239-253.

Keywords: benthos/ community structure/ seagrass/ habitat degradation/ Mediterranean Sea

Abstract: Along the Mediterranean coast, *Posidonia oceanica* (L.) Delile meadows have a grate 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. *Reprinted with kind permission from Kluwer Academic Publishers.*

Sanchez-Lizaso, J. L., Guillen Nieto, J. E., and Ramos Esplà, A. A. 1990. The regression of *Posidonia oceanica* meadows in El Campello. Rapp. Comm. Int. Mer Medit. 32(1) p. 7.

Keywords: *Posidonia oceanica* regression/ seagrass

Sargent, F. J., Leary, T. J., Crewz, D. W., and Kruer, C. R. 1995. Scarring of Florida's seagrasses: Assessment and management options. Florida Marine Research Institute Technical Reports. 0(1): I-V : 1-46.

Keywords: benthic disturbance/ seagrass/ Florida

Scarratt, D. J. 1971. Investigation into the effects of Irish moss raking on lobsters. Fisheries Research Board of Canada. Vol. 1105. 36 p.

Keywords: raking/ Irish moss/ environmental effects

Scarratt, D. J. 1972. The effects on lobsters (*Homarus americanus*) of raking Irish moss (*Chondrus crispus*). ICES CM 1972/K:36. 8 p.

Keywords: raking/ Irish moss/ fishing effects

Scarratt, D. J. 1973. Claw loss and other wounds in commercially caught lobsters *Homarus americanus.* Journal of the Fisheries Research Board of Canada. 30 : 1370-1373.

Keywords: fishing effects/ trawling impacts/ lobster fishery/ *Homarus americanus*

Scarratt, D. J. 1973. The effects of raking Irish moss (*Chondrus crispus*) on lobsters in Prince Edward Island. Helgolander Meeresuntersuchungen. 24 : 415-424.

Keywords: benthic raking/ raking impacts/ Prince Edward Island

Abstract: Effects of harvest of « foam of Ireland » (*Chondrus crispus*) on lobsters, in Prince-Edouard Island. Four principal methods were used to evaluate the damage caused to lobster stocks by the harvest of *Chondrus crispus*: observation with boats arranged and equipped for the occasion, examination of the sectors prospected by the plungers and the density of the lobster settlements, underwater observations of the moving rakes and the reactions caused on the lobsters (*Homarus americanus*), and examination of the tracks dug by the rakes and the lobsters that were there. On the smooth foam funds, the lobster settlements were not very dense and the damage caused by foam harvest was not important. On the moderately rough funds, the abundance of lobsters is estimated at 600 per hectare; roughly 2% of lobsters collected on the rakes tracks were killed with each passage. On the very rough funds, the abundance of lobsters exceeded 1000 per hectare; 5.2% of lobsters collected on the rakes tracks were killed. An intensive foam harvest is estimated to be involved in the loss of 280 lobsters per boat and day; other damages may be added to this, such as claw loss and wounds which lower the growth rate and the commercial value. The average size of killed lobsters was 35 mm for the length of the carapace (approximately 1000 mm total length); these lobsters would have been commercially exploitable within two years, and their value would have then been of approximately 8 « cents » canadians per lobster. The total loss caused to these rough funds was evaluated to $36,000, corresponding to 16-20% of the value of the foam harvest, or to 7% of the yearly value of the lobster harvest in this sector. These figures are sufficiently high to justify a critical examination of the efforts devoted to the foam harvest. *Reprinted with the permission of Biologische Anstalt Helgoland and Helgoland Marine Research (formerly Helgolander Meeresuntersuchungen).*

Schroeder, A. and Knust, R. (In press). Long term changes in the benthos of the German Bight (North Sea) - possible influence of fisheries? ICES Journal of Marine Science.

Keywords: trawling effects/ long-term changes/ benthos/ German Bight/North Sea

Schubel, J. R., Carter, H. H., and Wise, W. M. 1979. Shrimping as a source of suspended sediment in Corpus Christi Bay (Texas) . Estuaries. 2(3) : 201-203.

Keywords: shrimp trawling/ fishing effects/ sediment disturbance

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. *Permission to reprint titles and abstracts of articles in Estuaries and Chesapeake Science is granted by the Estuarine Research Federation.*

Schwinghamer, P., Gordon, Jr. D. C., Rowell, T. W., Prena, J. P., McKeown, D. L., Sonnichsen, G., and Guignes, J. Y. 1998. Effects of experimental otter trawling on surficial sediment properties of a sandy-bottom ecosystem on the Grand Banks of Newfoundland. Conservation Biology. 12(6) : 1215-1222.

Keywords: otter trawling/ benthic habitat/ sandy-bottom ecosystem/ Grand Banks

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.

Schwinghamer, P., Guigne, J. Y., and Siu, W. C. 1996. Quantifying the impact of trawling on benthic habitat structure using high-resolution acoustics and chaos theory. Canadian Journal of Fisheries and Aquatic Sciences. 53(2) : 288-296.

Keywords: impact of trawling/ benthic habitat/ high resolution acoustics/ chaos theory

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 microns, 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. *Reprinted with the permission of NRC Research Press and the Canadian Journal of Fisheries and Aquatic Sciences.*

Seiderer, L. J. and Newell, R. C. 1999. Analysis of the relationship between sediment composition and benthic community structure in coastal deposits: Implications for marine aggregate dredging. ICES Journal of Marine Science. 56(5) : 757-765.

Keywords: marine aggregate dredging/ sediment composition/ community structure

Serchuk, F. M. and Smolowitz, R. J. 1980. Size selection of sea scallops by an offshore scallop survey dredge. ICES Council Meeting 1980 (Collected Papers). ICES, Copenhagen, Denmark. 38 p.

Keywords: scallop dredging/ gear selectivity/ bottom trawling/ *Placopecten magellanicus*

Service, M. 1998. Monitoring benthic habitats in a marine nature reserve. Journal of Shellfish Research. 17(5) : 1487-1489.

Keywords: Marine Nature Reserve/ RoxAnn/ sidescan sonar/ fisheries impact/ Strangford Lough

Abstract: Acoustic and underwater photographic techniques have been used to assess the impact of commercial trawling on the benthic habitats of a Marine Nature Reserve. The results have been used as part of the management of the area. The further application of these techniques as tools for fisheries research and environmental monitoring is discussed. *Reprinted with the permission of the National Shellfisheries Association and the Journal of Shellfish Research.*

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

Keywords: sidescan sonar/ trawl impacts/ epibenthic community/ *Modiolus modiolus*/ Strangford Lough/ Northern Ireland

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

Sharp, G. J. and Roddick, D. L. 1980. The impact of *Chondrus* dragraking on substrate stability on southwestern Nova Scotia. Canadian Manuscript Reports of Fisheries and Aquatic Sciences. No. 1593. 14 p.

Keywords: raking/ Irish moss/ sediment stability

Shepard, A. N. and Auster, P. J. 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 (eds.). An International Compendium of Scallop Biology and Culture. World Aquaculture Society, Baton Rouge, Louisiana.

Keywords: scallop damage/ scallop dragging

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

Keywords: effects of trawling/ trawling effort/ geographic range/ benthic communities/ Gulf of Alaska/ Aleutian Islands

Summary: This is an informal paper (with figures) located on the web (at the time this bibliography was published) at http://www.cifar.uaf.edu/fish97/trawling.html discussing the geographic patterns and trawling effort of commercial fishing vessels and government research vessels in the Gulf of Alaska (GOA) and the Aleutian Island (AI) region from 1990 to 1996.

Simboura, N., Zenetos, A., Pancucci-Papadopoulou, M. A., Thessalou-Legaki, M., and Papaspyrou, S. 1998. A baseline study on benthic species distribution in two neighbouring gulfs, with and without access to bottom trawling. Marine Ecology. 19(4) : 293-309.

Keywords: benthic species/ Aegean Sea/ communities/ baseline study/ bottom trawling

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. *Reprinted by permission of Blackwell Wissenschafts-Verlag Berlin, GmbH and Marine Ecology*.

Sinclair, A. F. and Murawski, S. A. 1997. Why have groundfish stocks declined? American Fisheries Society. 71-94.

Keywords: demersal fisheries/ overexploitation

Smith, C. J., Papadopoulou, K., and Diliberto, S. (In press). Impact of otter trawl on eastern Mediterranean commercial trawl fishing ground. ICES Journal of Marine Science.

Keywords: otter trawling/ fishing impacts/ eastern Mediterranean

Smith, C. J., Papadopoulou, K. N., Kallianiotis, A., Catalano, B., and Diliberto, S. 1997. The interaction between otter trawling and the marine environment. Proceedings of the 5th Hellenic Symposium on Oceanography and Fisheries, Kavala, Greece. April 15-18, 1997. Fisheries, Aquaculture, Inland Waters Vol. 2. 33-36.

Keywords: trawling impacts/ benthic community/ community composition/ Agean Sea

Smith, E. M. and Howell, P. T. 1987. The effects of bottom trawling on American lobsters, *Homarus americanus*, in Long Island Sound. Fishery Bulletin. 85(4) : 737-744.

Keywords: bottom trawling/ *Homarus americanus*/ lobster fishery/ Long Island Sound

Abstract: American lobsters from trawl and pot catches were held in controlled conditions for 14 days to determine the level of delayed mortality associated with the two fisheries. Trawl-caught lobsters were exposed to subfreezing (-9.5 degree C) temperatures for periods from 30 to 120 minutes and then returned to seawater to determine the rate of freeze-induced mortality. Major damage rates due to trawling ranged from 12.6-14.0% during molting periods to 0-5.6% during intermolt periods. Delayed mortality ranged from 19.2% during the July molt to 1% during August and appeared to be related to the incidence of damage, molt condition, and temperature. Mortality of American lobsters held in subfreezing temperatures occurred after 30-minute exposure and reached 100% at 120-minute exposure.

Smolowitz, R. 1998. Bottom tending gear used in New England. Pages 46-52 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: demersal fishing gear/ bycatch/ discards/ habitat disturbance/ management strategies/ New England

Summary: The paper discusses various designs and developments of bottom tending gears used in New England, and how they relate with issues of bycatch and discard of non-target species, as well as habitat disturbance. Management issues are addressed and proposals to less destructive fishing strategies are made.

Snelgrove, P. V. R. 1999. Getting to the bottom of marine biodiversity: sedimentary habitats. BioScience. 49(2) : 129-138.

Keywords: marine biodiversity/ sedimentary habitats/ effects of trawling

Summary: This article is a relatively in depth paper describing the biodiversity of organisms living in marine sediments, patterns that have been observed, why these patterns are thought to exist, and why they are important. Mention is made to demersal fishing activities as being a threat to marine sedimentary biodiversity.

Spencer, B. E., Kaiser, M. J., and Edwards, D. B. 1996. The effect of Manila clam cultivation on an intertidal benthic community: the early cultivation phase. Aquaculture Research. 27(4) : 261-276.

Keywords: clam fishery/ fishing effects/ intertidal benthic community

Spencer, B. E., Kaiser, M. J., and Edwards, D. B. 1997. Ecological effects of manila clam cultivation: observations at the end of the cultivation phase. Journal of Applied Ecology. 34 : 444-452.

Keywords: clam/ clam cultivation/ clam harvesting

Spencer, B. E., Kaiser, M. J., and Edwards, D. B. 1998. Intertidal clam harvesting: benthic community change and recovery. Aquaculture Research. 29(6) : 429-437.

Keywords: mechanical harvesting/ clam harvesting/ benthic community/ suction dredging/ sediment disturbance

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 and 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK, and Aquaculture Research.*

Spurr, E. W. 1978. An assessment of the short term effects of otter trawling on large epibenthic invertebrates. New Hampshire Fish and Game Department, Project Report 3-248-R. 12 p.

Keywords: short-term effects/ trawling impacts/ trawling/ benthos

Steele, J. H. and Schumacher, M. 2000. Viewpoint: Ecosystem structure before fishing. Fisheries Research. 44 : 201-205.

Keywords: ecosystem structure/ ecosystem modeling/ marine food webs/ ecosystem effects of fishing

Abstract: Data from early fisheries in the Northwest Atlantic and elsewhere suggest that catch rates of demersal species were very high despite primitive fishing methods. Circumstantial evidence suggests that earlier stocks may have been an order of magnitude greater than stocks in the last half-century. What was the structure of the ecosystem that supported these stocks? Relative to current ecosystem structure, alternative patterns involve very slow growth rates of the demersal species, very small pelagic stocks, negligible invertebrate predators, and efficient transfer of primary production to fish (no "detritus"). Each of these patterns suggests distinctive dynamics in pristine ecosystems, with different implications for the effects of fishing. *Reprinted from Fisheries Research, Vol. 44; Steele, J.H. and Schumacher, M.; ViewpointEcosystem structure before fishing; pages 201-205; Copyright (2000); with permission from Elsevier Science.*

Stevens, B. G. 1990. Survival of king and Tanner crabs captured by commercial sole trawls. Fishery Bulletin. 88(4) : 731-744.

Keywords: trawling impacts/ bycatch/ mortality and injuries/ Bering Sea/ king crab/ Tanner crab

Abstract: King crabs *Paralithodes camtschaticus* and Tanner crabs *Chionoecetes bairdi* captured incidentally by Bering Sea trawlers were examined for immediate mortality, vitality, and injuries resulting from trawl capture. A number were held aboard ship for 2 days in sea-water to determine delayed mortality. Overall survival, including immediate and delayed effects, was 21% (plus or minus 2.0%) for king crabs and 22% (plus or minus 3.6%) for Tanner crabs. Immediate mortality of king crabs decreased significantly with shell age, and increased significantly with time in captivity prior to assessment, from 0% at 3 h to 100% at 17 h. Vitality, an index of spontaneous activity level, was a better predictor of delayed mortality than was the presence/absence of injuries. The effect of leg and body injuries on mortality of king crabs was similar, but injuries to leg segments proximal to the plane of autotomy resulted in higher mortality than injuries distal to the autotomy plane, or automization alone.

Stewart, P. A. M. 1978. Comparative fishing for flatfish using a beam trawl fitted with electric ticklers. Scottish Fisheries Research Report No 11. Department of Agriculture and Fisheries for Scotland, Aberdeen, Scotland. 10 p.

Keywords: trawl/ beam trawl/ electric ticklers/ flatfish

Abstract: Flatfish respond to an electric stimulus by moving away from the electrified zone. Experiment has demonstrated that this reaction is induced most effectively by a pulsed DC field at 20 Hz and that large fish react more strongly than small fish. This behaviour suggested that electric ticklers could usefully replace chain ticklers on flatfish trawls. To investigate this idea two comparative fishing experiments were conducted using a divided beam trawl. In the first experiment one side of the gear was electrified during each haul and it was found that the electric stimulus significantly increased the catch. In the second experiment the non-electrified side of the gear was rigged with a chain tickler, and no significant difference was found between the total catches.

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.

Keywords: fishing effects/ gear modification/ gear impacts

Stokes, R. J., Joyce, E. A., and Ingle, R. M. 1968. Initial observations on a new fishery for the sunray venus clam, *Macrocallista nibosa* (Solander). Florida Department of Natural Resources. Technical Series Vol. 56. 27 p.

Keywords: clam fishery/ sunray venus clam

Swartz, R. C., DeBen, W. A., Cole, F. A., and Bentsen, L. C. 1980. Recovery of the macrobenthos at a dredge site in Yaquina Bay, Oregon. Pages 391-408 *in* R.A. Balcer (ed.). Contaminants and Sediments Volume 2: Analysis, Chemistry, Biology. Ann Arbor Science Publishers Inc., Ann Arbor, MI, USA.

Keywords: dredging/ sediment disturbance/ habitat recovery/ Yaquina Bay/ Oregon

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.

Keywords: bait shrimp fishery/ Biscayne Bay/ Florida

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.

Keywords: clam harvesting/ hydraulic dredge/ fishing effects/ Kilisut Harbor/ Port Susan/ Agate Pass/ Washington

Tasker, M. L., Knapman, P. A., and Laffoley, D. 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 (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: nature conservation/ biodiversity/ ecological integrity/ Common Fisheries Policy/ *Natura 000*, Sea Fisheries Committees

Summary [author's 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 an 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK*.

Taylor, J. L. 1972. Some effects of oyster shell dredging on benthic invertebrates in Mobile Bay, Alabama. Taylor Biological Company. St. Petersburg, Florida. 16 p.

Keywords: dredging/ oyster shell dredging/ Mobile Bay/ Florida

Taylor, J. L. 1972. Some effects of oyster shell dredging on benthic invertebrates in Tampa Bay, Florida. Taylor Biological Company. St. Petersburg, Florida. 16 p.

Keywords: oyster shell dredging/ dredging/ Tampa Bay/ Florida

Taylor, J. L. 1973. Some effects of oyster shell dredging on benthic invertebrates in Tampa Bay, Florida. Taylor Biological Company. St. Petersburg, Florida.

Keywords: dredging/ oyster shell dredging/ Tampa Bay/ Florida

Thompson, G. 1993. Impacts of trawling on the seabed and benthic community. BSAI Groundfish Amendment 24, Appendix F. 5 p.

Keywords: impacts of trawling/ benthic disturbance/ sediment resuspension/ community structure

Summary: This appendix is part of an amendment to a 1993 National Marine Fisheries Service fishery management plan for the North Pacific Fishery Management Council. The appendix summarizes many of the potential effects of trawling on benthic habitats, and the variables that can influence the degree to which damage might occur.

Thrush, S. F., Hewitt, J. E., Cummings, V. J., and Dayton, P. K. 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. 129(1-3) : 141-150.

Keywords: fishing impacts/ habitat disturbance/ scallop dredging/ benthic communities/ scaling-up

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. *Reprinted with the permission of the Queensland Museum and Memoirs of the Queensland Museum*.

Thrush, S. F., Hewitt, J. E., Cummings, V. J., Dayton, P. K., Cryer, M., Turner, S. J., Funnell, G. A., Budd, R. G., Milburn, C. J., and Wilkinson, M. R. 1998. Disturbance of the marine benthic habitat by commercial fishing: Impacts at the scale of the fishery. Ecological Applications. 8(3) : 866-879.

Keywords: benthic communities/ broad-scale changes/ benthic community structure/ fishing impacts/ habitat disturbance by commercial fishing/ habitat disturbance/ broad-scale effects/ marine benthic habitats/ New Zealand/ Hauraki Gulf

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 similar to 17 to 35 m and in sediment characteristics from similar to 1 to 48% mud and from 3 to 8.5 mu g chlorophyll alpha/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, long-lived 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 from 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. *Reprinted with the permission of the Ecological Society of America and Ecological Applications, 1999.*

Tilmant, J. T. 1979. Observations on the impacts of shrimp roller frame trawls operated over hard-bottom communities, Biscayne Bay, Florida. National Park Service Report, Serial Number P-553. 23 p.

Keywords: shrimp roller frame trawls/ trawl effects

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

Keywords: water jet dredging/ *Ensis*/ physical effect/ infaunal effect/ Scotland

Abstract: The effects of water jet dredging for *Ensis* spp. on the seabed and benthos were examined through experimental fishing. Immediate physical effects were apparent, with the dredge leaving visible trenches in the seabed. While these trenches had started to fill after five days, and were no longer visible after 11 weeks, the sediment in fished tracks remained fluidised beyond this period. The majority of the studied infaunal community is adapted morphologically and behaviourally to a dynamic environment, and other than initial removal through dispersal, is not greatly affected by the dredge at the site studied. Species that are likely to be affected (e.g. the heart urchin *Echinocarium cordatum*, *Arctica islandica* and other large bivalves) were very rare in infaunal samples, but present in dredge catches, where damage was noted, and ranged on average from 10 to 28% of individuals. Epifauna were scarce in the study area, and unaffected by the fishing, except that epifaunal scavenging species were attracted to the fished tracks. On the evidence of the present and previous studies, it would appear that there was little difference between the biological impact of hydraulic and suction dredging, although the latter may have a greater physical effect (larger trenches). *Reprinted from Journal of Sea Research, Vol. 43; Tuck, I.D., Bailey, N., Harding, M., Sangster, G., Howell, T., Graham, N. and Breen, M.; The impact of water jet dredging for razor clams, Ensis spp., in a shallow sandy subtidal environment; pages 65-81; Copyright (2000); with permission from Elsevier Science.*

Tuck, I. D., Hall, S. J., and Reid, D. G. 1995. Identification of benthic disturbance by fishing gear using RoxAnn [sea bed classification system]. ICES International Symposium on Fisheries and Plankton Acoustics, June 12-16, 1995, Aberdeen.

Keywords: Loch Gareloch/ Clyde Sea/ benthos/ ecosystem disturbance/ trawling/ RoxAnn/ sidescan sonar

Tuck, I. D., Hall, S. J., Robertson, M. R., Armstrong, E., and Basford, D. J. 1998. Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. Marine Ecology Progress Series. 162 : 227-242.

Keywords: fishing disturbance/ physical disturbance/ trawling/ community dynamics

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 *Nucula 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 recovery. Physical effects, examined with sidescan 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. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Tumilty, J. E., McCormick, R., Van Marlen, B., Fonteyne, R., and Lange, K. 1998. Towed fishing gear reducing discards by consideration of all factors affecting selectivity. Pages 204-206 *in* K.G. Barthel, H. Barth, M. Bohle-Carbonell, C. Fragakis, E. Lipiatou, P. Martin, G. Ollier and M. Weydert (eds.). Third European Marine Science and Technology Conference (MAST Conference), Lisbon, 23-27 May 1998. Project Synopses Vol. 5: Fisheries and Aquaculture (AIR: 1990-94) – Selected Projects From the Research Programme for Agriculture and Agro-Industry Including Fisheries. European Commission DG 12 Science, Research and Development, Luxembourg (Luxembourg).

Keywords: fishing gear/ mesh selectivity/ towed fishing gear

Turner, S. J., Thrush, S. F., Hewitt, J. F., Cummings, V. J., and Funnell, G. 1999. Fishing impacts and the degradation or loss of habitat structure. Fisheries Management and Ecology. 6(5) : 401-420.

Keywords: fisheries management/ fishing/ habitat degradation/ habitat loss/ habitat restoration/ habitat structure/ protected marine and coastal areas/ trawling/ dredging

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 seen as solutions replacing conventional management approaches, but need to 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.

Van Beek, F. A., Van Leeuwen, P. I., and Rijnsdorp, A. D. 1989. Survival of plaice and sole discards in the otter trawl and beam trawl fisheries in the North Sea. ICES CM 1989/G:46. 20 p.

Keywords: survival/ bycatch/ escapement/trawl nets/ fishing gear/ Pleuronectiformes

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. 39(3) : 165-177.

Keywords: mechanical harvesting/ benthic fauna/ Wadden Sea

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. 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 nondisturbed areas. Mechanical harvesting appeared to be more efficient, catching more *Arenicola* per m^2. Disturbance of feeding birds is discussed. People walking and hand diggers cause a serious problem. *Reprinted from Biological Conservation, Vol. 39; Van den Heiligenberg, T.; Effects of mechanical and manual harvesting of lugworms Arenicola marina L. on the benthic fauna of tidal flats in the Dutch Wadden Sea; pages 165-177; Copyright (1987); with permission from Elsevier Science.*

van der Veer, H. W., Bergman, M. J. N., and Beukema, J. J. 1985. Dredging activities in the Dutch Wadden Sea: Effects on macrobenthic infauna. Netherlands Journal of Sea Research. 19(2) : 183-190.

Keywords: dredging/ dredging effects/ benthos/ Wadden Sea

Abstract: Effects of dredging on macrobenthic infauna were studied at several sites and water depths in the estuarine Dutch Wadden Sea. Dredging in tidal flat areas was found to have long-lasting effects: filling-in rates in such areas were extremely slow, sediment composition altered dramatically and recovery of benthos was virtually absent during the long period of filling-in. Such pits on tidal flats persisted for more than 15 years. In subtidal areas recovery of bottom structure as well as the inhabiting infaunal benthos proceeded rapidly, while the original situation may be expected to return. In tidal channels with strong currents both filling in and recolonization took only about 1 to 3 years. In some subtidal areas with low tidal stream velocities, such as tidal watersheds, recovery proceeded less rapidly: it lasted 5 to 10 years. *Reprinted from Netherlands Journal of Sea Research, Vol. 19; van der Veer, H.W., Bergman, M.J.N. and Beukema, J.J.; Dredging activities in the Dutch Wadden Seaeffects on macrobenthic infauna.; pages 183-190; Copyright (1985); with permission from Elsevier Science.*

Van Dolah, R. F., Hinde P., and Nicholson, N. 1983. Effects of roller trawling on a hard bottom sponge and coral community. Final Report to Sanctuary Program Division, NOAA. 89 p.

Keywords: trawling effects/ roller trawling/ sponge/ coral/ communities

Van Dolah, R. F., Wendt, P. H., and Nicholson, N. 1987. Effects of a research trawl on a hard-bottom assemblage of sponges and corals. Fisheries Research. 5(1) : 39-54.

Keywords: trawling impacts/ benthic habitat/ infaunal communities/ beam trawl

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. *Reprinted from Fisheries Research, Vol. 5; Van Dolah, R.F., Wendt, P.H. and Nicholson, N.; Effects of a research trawl on a hard-bottom assemblage of sponges and corals; pages 39-54; Copyright (1987); with permission from Elsevier Science.*

Van Dolah, R. F., Wendt, P. H., and Vonlevisen, M. 1991. A study of the effects of shrimp trawling on benthic communities in 2 South Carolina sounds. Fisheries Research. 12(2) : 139-156.

Keywords: trawling effects/ benthic communities/ benthic infaunal assemblages/ community change

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. *Reprinted from Fisheries Research, Vol. 12; Van Dolah, R.F., Wendt, P.H. and Vonlevisen, M.; A study of the effects of shrimp trawling on benthic communities in 2 South Carolina sounds; pages 139-156; Copyright (1991); with permission from Elsevier Science.*

Van Marlen, B. 1993. Research on improving the species selectivity of bottom trawls in The Netherlands. Fish Behaviour in Relation to Fishing Operations. ICES Marine Science Symposia. Copenhagen. 196 : 165-169.

Keywords: gear selectivity/ fishing gear/ bottom trawling/ gear research/ bycatch/ fishing technology

Van Marlen, B., Van Duyn, J. B., and Blijker, D. J. C. 1985. An introduction of direct observation techniques using a remotely controlled television vehicle on bottom trawls with square mesh cod-ends. International Council for the Exploration of the Sea.

Keywords: trawling/ underwater television/ gear impacts

Van Marlin, B. 2000. Technical modifications to reduce the bycatches and impacts of bottom-fishing. Pages 253-268 *in* M.J. Kaiser and S.J. de Groot (eds.). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science Ltd. Oxford, UK.

Keywords: technical modification/ conservation measures/ bottom-fishing gear/ bycatches/ impact

Summary [author's 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. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

van Santbrink, J. W. and Bergman, M. J. N. 1994. Direct effects of beam trawling on macrofauna in a soft bottom area in the southern North Sea. Environmental impact of bottom gears on the benthic fauna in relation to natural resource management and protection of the North Sea. NIOZ Rapport 1994-11. RIVO-DLO Report CO 26/94. Netherlands Institute for Fisheries Research, Texel. 147-178.

Keywords: beam trawling effects/ macrofauna/ soft bottom/ North Sea

van Santbrink, J. W. and Bergman, M. J. N. 1994. Direct effects of beam trawling on macrofauna in a soft bottom area in the southern North Sea. NIOZ Rapport 1994-11 Netherlands Institute for Fisheries Research, Texel. p. 147-178.

Keywords: beam trawling effects/ beam trawling/ North Sea

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.

Keywords: mechanical harvester/ escalator harvester/ environmental impact

Wahle, R. A. 1997. Consequences of fishing, with regard to lobster fisheries: report from a workshop. Marine and Freshwater Research. 48(8) : 1115-1119.

Keywords: lobster fisheries/ community interaction/ fishing effects

Summary: A workshop report that discusses different types of fishing effects relating to lobster fisheries. Three categories of discussion are particularly focused upon: "(1) the effects of harvesting on the structure and dynamics of the target lobster population, (2) the direct and indirect effects of non-lobster fishing activity on lobster populations, and (3) the effects lobster fishing may have on the associated community and ecosystem." Implications are made that future studies must evaluate interactions between target species and the rest of the community that might possibly be affected by fishing activities or by other environmental factors. The importance of establishing unexploited areas for future comparative research is indicated, as well as the need to apply more demographic (distribution, abundance, and dispersal) data to population models.

Wassenberg, T. J. and Bill, B. J. 1987. Feeding by the sand crab *Portunus pelagicus* on material discarded from prawn trawlers in Moreton Bay, Australia. Marine Biology. 95(3) : 387-393.

Keywords: scavengers/ discards/ trawl fishery/ trawling/ *Portunus pelagicus*/ Australia/ Moreton Bay

Abstract: A field and laboratory study in 1984-1985 using the foregut contents of crabs caught in Moreton Bay, Queensland, when trawling was underway, showed that animals discarded from trawls constituted about 33% of the diet. *Portunus pelagicus* can fill its foregut in about 8 min and clear it completely of tissues in about 6 h, except for fish bone which requires about 24 h. *P. pelagicus* used a zigzag search pattern to find food and moved towards it at a mean point-to-point speed of 290 m/h (8 cm/s). Underwater still photography on the trawl grounds showed that *P. pelagicus* was the most common scavenger attracted to a bait that simulated trawl-discards, and

that it was most active at dusk. Trawler-discards at periods of high food demand in summer may allow larger populations of *P. pelagicus* to exist than would otherwise occur.

Wassenberg, T. J., Burridge, C. Y., Connell, M., and Gribble, N. 1998. A validation of short-duration scientific tows as a representation of long commercial-length tows: comparing the catch rates, size composition and species composition of prawn trawler bycatch in the far northern Great Barrier Reef, Australia. Fisheries Research. 36(1) : 35-46.

Keywords: catch comparison/ catch rates/ shrimp trawl/ tropical fish sampling

Abstract: The duration of tows for scientific trawl surveys in northern Australia is generally 30 min. Commercial trawls may be up to 200 min long. In this study we compare the catch rates, size of fish and species composition for 10 short (30 min) tows paired with 10 commercial length (165 min-not in a straight line) tows at both an inshore and an offshore location in the far northern Great Barrier Reef. Evaluations of this kind have not been reported in tropical Australian multi-species fisheries. Overall, catch rates of fish and invertebrates differed between short and long tows both inshore and offshore. Inshore, the mean catch rate for the fish and the invertebrates was significantly greater in short duration tows ($P < 0.05$). Offshore, the mean catch rate for all fish, and all invertebrates was not significantly different between short and long tows, although higher catch rates of invertebrates were recorded in long tows. Inshore, 12 fish species out of 49 had significantly different catch rates, most being greater in short tows. Only 2 invertebrates out of 16 had significantly different catch rates ($P < 0.05$). The combined weight of species showing significant differences in catch rates represented less than 10% of the total weight in both inshore and offshore samples. Principal component analysis indicated that catch composition was similar between short and long tows both inshore and offshore. The results from our sampling are that the species composition of 30-min trawls is similar to that of commercial length tows, and that size frequencies are equivalent. The implications are that short tows (30 min) can be used in scientific surveys to give a true representation of both size and species composition of commercial length tows, but may overestimate catch rates. *Reprinted from Fisheries Research, Vol. 36; Wassenberg, T.J., Burridge, C.Y., Connell, M. and Gribble, N.; A validation of short-duration scientific tows as a representation of long commercial-length towscomparing the catch rates, size composition and species composition of prawn trawler bycatch in the far northern Great Barrier Reef, Australia; pages 35-46; Copyright (1998); with permission from Elsevier Science.*

Wassenberg, T. J. and Hill, B. J. 1989. The effect of trawling and subsequent handling on the survival rates of the bycatch of prawn trawlers in Moreton Bay, Australia. Australian Fisheries Resources. 7 : 99-110.

Keywords: fishing effects/ trawling/ bycatch/ Moreton Bay/ Australia

Watling, L. 1998. Benthic fauna of soft substrates in the Gulf of Maine. Pages 20-29 *in* E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4, Boston, MA.

Keywords: benthos/ macrobenthic fauna/ Gulf of Maine/ demersal fishing gear

Summary: This paper discusses the various noncommercial species living in soft sediments of the Gulf of Maine, the various physical and biological factors associated with soft sediments, and how these factors influence the fauna composition at differing sediment depths. Special mention is made to sediment oxygen content in relation to depth, and how benthic fauna are vertically distributed in such conditions. Of particular mention is the use of tubes and burrows by larger invertebrate fauna that live in deeper sediments where oxygen is limited or nonexistent. Implications to impacts on these species by bottom fishing gear are made.

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

Keywords: scallop dragging/ dragging effects

Watling, L. and Norse, E. A. 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. Conservation Biology. 12(6) : 1180-1197.

Keywords: disturbance/ bottom trawling/ mobile fishing gear/ fishing gear impacts

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 patchy 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.

West, B. 1987. 1986 Bering Sea trawling impact project. Proceedings of Oceans '87. The Ocean -- An International Workplace. Halifax, Nova Scotia, Canada. 626-631.

Keywords: trawling impacts/ Bering Sea/ underwater TV/ROV

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. *West, B. 1987. IEEE. Reprinted, with permission, from Oceans '87 [The Ocean - An International Workplace]; Halifax, Nova Scotia, Canada, 28 September - 1 October, 1987; pp. 626-631.*

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 Shellfisheries Association. 65(6).

Keywords: mechanical clam harvester/ Washington

Whitelaw, W. 1997. Using videos to study the effects of trawling on the marine habitat. Unpub. report. http://environment.gov.au/marine/coastal_atlas/documentation/standards/biology/whit2.html.

Keywords: trawling effects/ video monitoring/ marine habitat

Wickman, D. A. and Watson, J. W. Jr. 1976. Scuba diving methods for fishing systems evaluation. Marine Fisheries Review. 38(7) : 15-23.

Keywords: fishing systems/ fishing gear

Witbaard, R. and Klein, R. 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.

Keywords: trawling intensity/ shell damage/ tickler chains/ clam fishery/ North Sea

Witbaard, R. and Klein, R. 1994. Long-term trends on the effects of the southern North Sea beam trawl fishery on the bivalve mollusc *Arctica islandica* L. (Mollusca, Bivalvia). ICES Journal of Marine Science. 51(1) : 99-105.

Keywords: *Arctica islandica*/ bottom fisheries/ North Sea

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 beam trawl 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., Eldred, B., Clark, E., Hutton, R. F., and Ingle, R. M. 1957. The live bait fishery off the west coast of Florida (Cedar Key to Naples). Florida Board of Conservation. Technical Series No. 21. 33 p.

Keywords: shrimp bait fishery/ Florida

Wynberg, R. P. and Branch, G. M. 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. 52(3) : 523-558.

Keywords: habitat disturbance/ sandprawn/ mudprawn/ intertidal environment/ bait fishery

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 net 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*.

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

Keywords: trampling/ disturbance/ estuaries/ *Callianassa*/ sandprawn/ bait collection

Abstract: Previous studies have inferred that the side effects of physical disturbance associated with bait-collecting for the sandprawn *Callianassa kraussi* are more deleterious than the actual removal of the prawns. The present study was specifically designed to disentangle the side-effects of trampling and disturbance associated with using suction pumps for bait-collecting. Separate areas were sucked over with a prawn pump at three different intensities, and the prawns collected from these areas subsequently returned to them. A parallel treatment involved trampling the sediment at levels comparable to the 'sucking' intensities, without removing the prawns. The responses of the meiofauna, macrofauna and microflora were assessed six weeks after this disturbance.

Prawn densities were depressed six weeks following both sucking and trampling but recovered by 32 weeks. The meiofauna responded positively to some of the disturbance treatments; macrofaunal numbers on the other hand, declined in most treatment areas, and similarity analysis and multidimensional scaling showed that macrofaunal community composition in the most-disturbed areas was distinct from that in other areas. Chlorophyll levels were reduced at the more intensely-disturbed sites.

The results corroborate the conclusion that trampling per se has almost the same effect as sucking for prawns, on both the prawns and on the associated biota. This has important implications in terms of managing the use of lagoonal and estuarine ecosystems. *Reprinted with the permission of Cambridge University Press and Environmental Conservation.*

Zenetos, A., Simboura, N., Thessalou-Legaki, M., Papaspyrou, S., and Pancucci-Papadopoulou, A. Submitted. Trawling impact of benthic ecosystems (TRIBE) - I: mid-term community changes on sandy and muddy bottoms. National Centre for Marine Research, Agios Kosmas, 16604 Hellinikon, Greece.

Keywords: trawling impacts/ community changes/ sandy and muddy bottoms

Abstract: The mid-term impact of intensive (experimental) trawling on the benthic ecosystems at two Gulfs of the Aegean Sea with different substrata, one open (sandy biotope) and the other closed to otter trawling (muddy biotope) was studied. Monitoring was carried out for a 6 month period during which both areas were closed to trawling so that natural recovery could be detected. Intensive trawling resulted in an increase of organic matter at both sites but did not modify notably the texture of the sediment. Experimental fishing significantly disturbed the benthic communities of the muddy unfished biotope while the additional pressure had a serious impact on the benthic ecosystem of the sandy fished biotope. In the sandy area, the experimental trawling resulted in a decrease of species in contrast to the undisturbed muddy area where experimental trawling caused initially a significant increase of species which was later reduced. No clear trend in the response of the epifaunal or infaunal components over time could be detected in the muddy area, whilst a decrease of epifaunal organisms and to a less degree of infaunal was observed in the sandy areas. The ecosystems had not recovered entirely at the end of the six month study period. *Reprinted with author permission (Dr. A. Zenetos).*