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Mobile Fishing Gear Effects on Benthic Habitats: A Bibliography (Second Edition)

by
Dieter, B. E., D. A. Wion, and R. A. McConnaughey (editors)

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Alaska Fisheries Science Center
7600 Sand Point Way N.E.
Seattle, WA 98115-0070

U.S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary
National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr., U.S. Navy (ret.), Under Secretary and Administrator
National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries

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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 is 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. Also included are a small number of papers that address seafloor impacts of marine aggregates dredging and gravel extraction, as it is likely that these types of projects denature the seafloor in a similar manner to mobile fishing gear. 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 updated version of the bibliography has, in addition to the original 522 citations, 58 abstracts that were previously unavailable to the editors as well as 178 new entries. The growing interest in fishing gear effects amongst scientists, management agencies, the fishing industry, and the general public is reflected in the steady output of new publications addressing the issue. The ability of these parties to have access to the most recent literature calls for publication of a revised bibliography.

This bibliography can be found online as an Adobe PDF document on the AFSC web under Tech Memos at **www.afsc.noaa.gov/Publications/techmemos.htm** and as a searchable, dynamic database at **www.afsc.noaa.gov/race/media/publications/databases.htm**

Acknowledgments

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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

Alaska Department of Fish. 2000. A workshop examining potential fishing effects on population dynamics and benthic community structure of scallops with emphasis on the weathervane scallop *Patinopecten caurinus* in Alaskan waters. Alaska Department of Fish and Game, Division of Commercial Fisheries, Special Publication 14, Juneau, AK, 68 p.

Keywords: fishing effects/ scallop dredging/ *Patinopecten caurinus*/ Alaska

Abstract: This document reviews the results of a workshop on scallop biology and the effects of scallop dredging on benthic communities. The workshop was held in Kodiak, Alaska, during 10-12 June 1999. A review of the history of the Alaskan weathervane scallop fishery was presented. Other speakers presented papers on scallop biology and fisheries in other cold-water areas. Topics of the papers included physical and biological variables influencing distribution, impacts of suspended particles on energetics, modeling approaches to identify dredging impacts, effects of long-term dredging, benthic communities associated with scallops, and the importance of protecting areas from fishing. Following the first day of public presentations, a two-day workshop was convened to develop a viable study program for examining the effects of dredging on the scallop's life history, population dynamics, and associated benthic community. The workshop results were intended to be applied to the Alaskan fishery for weathervane scallops, but they are applicable to many scallop fisheries. The working groups identified ten research topics for which information needs to be gathered. Topics include the importance of spatial distribution on fertilization success, the reproductive output of individuals, the importance of nursery areas, scallop behavior and how it may be altered by dredging, factors that affect growth, fishery induced injury and mortality, causes and rates of natural mortality, long-term factors affecting recruitment, effects of scallop dredging on the benthos, and developing harvest strategies for scallops. Also, the working groups recommended that a monitoring program be established that included short-and long-term data gathering, and they identified methods and tools that might be used for this task.

Aldridge, D. C. 2000. The impacts of dredging and weed cutting on a population of freshwater mussels (Bivalvia: Unionidae). Biological Conservation. 95(3) : 247-257.

Keywords: Population status/ Conservation/ Dredging/ Weeds/ Environmental impact/ Plant control/ Freshwater weeds/ River basin management/ Unio/ Anodonta/ Unio pictorum/ Unio tumidus/ Anodonta anatina/ Anodonta cygnea

Abstract: Regulated lowland rivers generally require management to control macrophytic vegetation and sediment build-up. Such management can have deleterious effects on much of the biota. It has long been a concern that indiscriminant river management has played a part in the worldwide decline in freshwater mussel populations. This study investigated the impact of dredging and weed-cutting on the population size, structure and distribution of four species of unionid mussel: Anodonta anatina, A. cygnea, Unio pictorum and U. tumidus. Dredging removed between 3% (A. anatina) and 23% (A. cygnea) of the mussel population. The weed bucket removed a maximum of 3% of any species, but its higher frequency of use results in removing a similar number of mussels to dredging in the long-term. Marked stones placed in the river during dredging suggest that the excavator drags mussels across the river bed. This is supported by the relatively high density of mussels in the channel closest to the bank from which the excavator habitually operates. Tagged mussels moved only small distances following dredging (generally < 15 cm after 55 days) and showed no tendency to disperse. The impact of river management on unionid populations can be reduced, while retaining its channel maintenance function, by dredging and weed cutting only within the centre of the channel. Marginal vegetation should be cut to 5 cm above the river bed using weed boats with an annual alternation between banks to preserve refugia of invertebrates and fish. *Reprinted from Biological Conservation, Vol. 95; Aldridge, D.C., The impacts of dredging and weed cutting on a*

population of freshwater mussels (Bivalvia: Unionidae); pages 247-257; Copyright (2000); with permission from Elsevier Science.

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. 1968. Cruise Report. Ocean Engineering and Resource Assessment Cruise No. 94, Department of the Interior, U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Seattle, WA. 6 p.

Keywords: cruise report/ clam dredging/ Puget Sound/ Washington

Summary: This is a report on a four-week cooperative clam research cruise between the Bureau of Commercial Fisheries and the Washington State Department of Fisheries. The survey was conducted aboard the M/V John N. Cobb in 1968. Primary objectives of the cruise were to 1) develop clam dredging techniques for use on clam surveys in the coastal waters of Washington and Oregon, 2) determine effectiveness of a modified East Coast-type hydraulic surf clam dredge on littleneck and butter clam beds, and 3) determine availability of clams on Alden Bank, Hale Passage, and northeast of Guemes Island in Puget Sound. Throughout the survey many problems occurred while using the dredge. Many modifications to the dredge had to be made, and despite these efforts, dredge performance was poor. On the best tow, the dredge only caught 27% of the estimated number that should have been caught. The dredge did not work well enough to justify further use.

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. 61p.

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 side-scan 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(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. 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. Pages 59-74 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

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

Abstract: Within the framework of the "Impact"-project, the Alfred-Wegener Institute for Polar and Marine Research in Bremerhaven (AWI) has carried out research on the persistent (mid- and long-term) effects of heavy bottom trawling on macrozoobenthos communities and populations in the German Bight. This research is closely related to long-term studies, initiated 25 years ago, of the variability and possible trends apparent in the North Sea macrozoobenthos. Two contrasting study areas were selected in the German Bight: An area around the wreck of the "West Gamma" platform 60 nm northwest of Helgoland, which is enclosed by 4 buoys and accordingly regarded as protected from heavy fishing for 3 years; the "IMPACT-box" 20 nm west of Helgoland, where the fauna of a strongly fished area is being studied over a long time scale and compared with the fauna of neighbouring areas that are less heavily fished. The macrozoobenthos of these areas has been investigated by drag and small dredge sampling. To increase the effects of bottom gears, the "IMPACT-box" was heavily fished by the German research vessels "Solea" and "Victor Hensen", and the Dutch RV "Tridens". The "IMPACT-box" fauna appears to be very homogeneous, belonging to the Amphiura-fillformis-association (poor variant, about 110 species). Conversely, the macrozoobenthos is less homogeneous in the "West Gamma" area, mainly due to an overall gradient in the composition of the Tellina-fabula-association of the region. It is not yet possible to finally conclude whether the relative richness of this fauna (more than 150 species) is related to the reduced fishing gear stress around the wreck, because of the short duration of this experiment. The finding that some delicate, sensitive species were more abundant inside than outside the wreck area seem to indicate first changes. In addition to the long-term investigations, studies of changes in the diet of demersal fish in the "IMPACT-box" before, during and after fishing have been performed. These studies indicate some changes in the availability of food items and in the feeding behaviour of the predators, which might also contribute to faunal changes.

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 60-120m 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 *Chlaymis islandica* the dominating species are *Stongylicentrotus droebachiesis*, *Ophiopholis aculeata*, *Ophiura robusta* and *Astarte* sp. At Jan Mayen both the sea cucumber *Cucemaria 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. 1. Existing data, reports and literature were compiled and analyzed to provide syntheses of the historical development, landings and effort, and current gear and practices for each fishery. 2. Spatially-explicit databases pertaining to submerged natural habitats within BNP and adjacent areas of Biscayne Bay were obtained, integrated, and

analyzed. The areal extent of each of BNP's five major benthic communities (i.e., seagrass, hardbottom, mixed seagrass/hardbottom, bare bottom, and offshore coral reef) were quantified and mapped. 3. Questionnaires were designed and distributed to commercial trap and trawl fishermen to characterize temporal and spatial fishing effort patterns. About 25% of the bait shrimp trawlers responded. No questionnaires were returned from lobster, stone crab or blue crab fishermen. Bait shrimp trawlers operating within BNP fish areas measuring about 165 km^2 during the wet season (June-November) and 350 km^2 during the dry season (December-May). These areas represent about 24.6% and 52.2% of BNP's entire submerged substrate, respectively. Seagrass habitats are the primary habitats trawled, followed by mixed seagrass/hardbottom, and then hardbottoms. 4. A series of aerial overflights were conducted to estimate the location and numbers of commercial traps from their surface buoys within BNP. Traps were then inspected using SCUBA and snorkeling techniques to characterize the immediate microhabitat upon which the respective traps were set. Trap "footprints" were also captured on video tape. Lobster and stone crab traps were found primarily over *Thalassia* beds, while blue crab traps were found primarily over *Halodule* beds. 5. Controlled trawling experiments were conducted over seagrass and hardbottom communities. Pre-trawl underwater video recordings were compared with post-trawl recordings of five linear transects that had received from one to five rollerframe trawl passes. While we were unable to detect any damage along the seagrass bed transects, damage to sessile invertebrates along the hardbottom transects was conspicuous after one pass. The rate of damage appeared to decrease with subsequent trawling efforts. The sponge *Ircina felix* and the corals of the genus *Pseudoplexaura* appeared to be the taxa most vulnerable to breakage or dislodgement by trawling. 6. Trap experiments revealed that damage to underlying seagrasses depended on soak time, trap type and plant species. For lobster traps, mean *Thalassia* loss was approximately 1% of initial plant cover after one day, 7% after one week, and 26% after one month. For stone crab traps mean loss of *Thalassia* cover was 4% after one day, 27% after one week, and 74% after one month. Blue crab traps reduced *Halodule* coverage by 4% after one day, by 24% after one week and by 70% after one month. 7. The bait shrimp fishery regularly comes in contact with 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. 8. While rollerframe trawling does not appear to damage seagrasses, damage to sessile invertebrates (i.e., sponges and soft corals) in hardbottom communities is conspicuous and is likely to be long-lasting. Hardbottom habitats would undoubtedly benefit from closure of commercial bait shrimping in areas that support high densities of sponges and corals. The feasibility of accurately marking the boundaries of BNP's hardbottom areas and preventing nocturnal trawling within them should be investigated. 9. It is essential to conduct a limited number of additional trawl effects experiments in conjunction with areal closures to obtain precise estimates of habitat recovery rates for sponge and soft-coral habitats damaged by commercial trawling activities. 10. The primary benthic resource that the three major trap fisheries affect is seagrass habitat. The extent of damage to the habitat is a function of gear soak time, trap type, and the particular seagrass species which constitute the habitat. We strongly recommend that additional field experiments be conducted which focus on the rate at which *Thalassia* and *Halodule* recolonize after being impacted by trap-damage. 11. We further recommend that additional measurements of size and spatio-temporal extent of each of the trap fisheries be conducted. These studies are required before definitive estimates of cumulative Park-wide resource damage resulting from commercial trap fishing can be made.

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

Abstract: Remotely operated vehicles (ROVs) are becoming an accepted platform for conducting scientific research in oceans and lakes. Predictably, development of any new technology requires some lag time between availability and when it is finally evaluated and incorporated into the scientific process. ROV use by the scientific community fits into this pattern.

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^o 50' N, 70^o 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. and Shackell, N. L. 2000. Marine protected areas for the temperate and boreal northwest Atlantic: The potential for sustainable fisheries and conservation of biodiversity. Northeastern. 7(4) : 419-434.

Keywords: Refuges/ Fishery protection/ Overfishing/ Biodiversity/ Environmental protection/ Fishery management

Abstract: Year-round no-take marine protected areas (MPAs) can enhance conservation of exploited species and biodiversity overall. MPAs have the potential to sustain living marine resources and their support systems at genetic, population-community, ecosystem, and landscape levels. From a fisheries perspective they can protect spawning and nursery areas of key species, maintain age structure (retain older, proportionately more fecund individuals), protect key habitats, and reduce bycatch. MPAs are used sporadically in management of fisheries and are generally based on predicted responses for populations of exploited taxa. However, identification of representative, rare, and high diversity areas of temperate and boreal marine systems, especially on outer continental shelves, is still in its infancy. There is information available from both the scientific literature and from fishers on the life history and behavior of economically important species, on species assemblage patterns, and on physical structure of the marine environment. Such information could be used as a starting point for identifying areas of particular importance to populations or communities of fishes and for the conservation of diversity at the regional scale. Identification of such areas could serve as a basis to design an experimental network of MPAs. Such MPAs, designated for the purpose of maintaining or developing sustainable fisheries, must explicitly be designed within an experimental context, maintaining flexibility for changes in regulations as new information becomes available. Monitoring change in exploited and non-target populations (intra- and inter-guild), habitat complexity indices, and diversity of sentinel taxa (for assessing maintenance of diversity) will be needed to provide feedback to assess the efficacy of MPAs and to recommend changes in the regulatory framework.

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 a *Nephrops* trawl fishery on the benthos and environment of the Irish Sea. ICES Journal of Marine Science. 57(5) : 1315-1320.

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

Abstract: Short-term effects of fishing on benthos from a mud patch in the northwestern part of the Irish Sea were investigated in 1994-1996 by means of samples taken both before and shortly after (ca.24h) fishing activity. No quantitative historical benthos data are available for the period prior to commencement of the fishery, although limited qualitative data exist. Therefore, studies of medium to long-term effects involved sampling the fauna of areas around wrecks (i.e., unfished pseudo-control sites) for comparison with fished grounds. Attempts were made to calculate the short, medium, and long-term impact of the fishery on the benthos and surrounding environment. Direct (short-term) effects were not quantifiable at a heavily fished offshore site (75m depth); however, some changes were visible in a less fished, shallow (35m depth) site. Medium to long-term effects were more discernible at the offshore site. Only minor changes were observed at the inshore location, suggesting that it is fishing intensity *per se*, rather than the direct impact from passage of the gear, that constitutes the major factor controlling long-term negative trends in the benthos of the Irish Sea *Nephrops* grounds. *Copyright 2000 International Council for the Exploration of the 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, conservaton 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 by-catch from the grounds, mortality of animals discarded, and those damaged by the gear but not retained in the trawl. 5) Otterboard trawling causes visible physical effects on the seabed that may still be discernible after 18 months, in sheltered areas. 6) Such physical disturbance also leads to community changes in the benthos. These include reduction in diversity, biomass and of individual organism size. 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

Barnette, M. C. 2001. A review of the fishing gear utilized within the Southeast Region and their potential impacts on essential fish habitat. U.S. Department of Commerce. NOAA Technical Memorandum NMFS -SEFSC - 449.

Keywords: fishing gear/ impacts/ essential fish habitat

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 bottomfauna 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 stucture

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 time 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. Direct effects of beam trawling on macrofauna in sandy areas off the Dutch coast. Pages 179-208 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

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

Abstract: Direct effects of trawling with commercial 4-m beam trawls on the abundance of benthic species in areas with sandy sediments off the Dutch coast were studied by comparing densities before and after trawling. Various sampling gears were used, including a benthos dredge (Triple-D) developed especially for this IMPACT-project. For a number of species, the mortality due to trawling a study area twice, could be estimated. For these species, mortality was found to be very variable, and was estimated for fish as 2-70% of the numbers initially present on the area, for echinoderms as 0-44%, for molluscs as 0-84%, for crustaceans as 0-82%, and for annelids as 0-24%. Dab, Limanda limanda, was a predominant scavenger on damaged or exposed fauna on a recently trawled seabed.

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: dredge/ benthos/ quantitative sampling

Abstract: Grabs and corers are commonly used to estimate densities of infauna species quantitatively. However, because of the limited sample size, such instruments are not practicable for sampling species of low abundance. With trawls and dredges samples of much larger sizes can be obtained, but the existing types of gear are, at best, semi-quantitative for catching infauna. In this paper a prototype dredge is introduced for quantitative sampling of larger-sized (> 10mm) infauna of low abundance. This 'Deep Digging Dredge' (Triple-D) is rigged with an interchangeable blade to collect a strip of the seabed. During the haul, several hundred metres long, the excavated sediment is sieved through a net with a 1.4 cm stretched mesh size. The prototype was successfully tested on infauna in fine-grained adhesive sediments in Wadden Sea, using a 20-cm-wide blade with a penetration depth into the sediment of 10cm. In field studies on soft and sandy bottoms in the North Sea, the Triple-D estimated the densities of some epifauna and flatfish species higher than a fine-meshed beamtrawl.

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, conservaton 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 the southern North Sea. To achieve an integrated approach to fisheries and ecosystem management, the following measures have to be considered: a significant reduction of trawling effort, development of gears less damaging for habitats and fauna, and designation of areas closed to fisheries for species and habitats that cannot be protected otherwise. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

Bergman, M. J. N. and van Santbrink, J. W. 2000. Mortality in megafaunal benthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea in 1994. ICES Journal of Marine Science. 57(5) : 1321-1331.

Keywords: megafauna/ benthos/ trawling impacts/ North Sea

Abstract: We estimated the direct mortality of benthic fauna caused by one single passage of commercial beam and otter trawls in field experiments. The benthos dredge Triple-D was used to sample megafauna (>1cm), while macrofauna (>1mm) were sampled by means of a Reineck boxcorer and, in some cases, a van Veen grab. Direct mortalities ranging from about 5 up to 40% of the initial densities were observed for a number of gastropods, starfishes, small and medium-sized crustaceans, and annelid worms. For bivalve species, direct mortalities were found from about 20 up to 65%. Mortality per m^2 trawled area due to fishing with a 12-m beam trawl was not higher than that due to a 4-m beam trawl. For all species considered, the direct mortality was largely attributed to 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. In 1994, the 12m beam trawl with tickler chains was the dominant gear type in the Dutch sector, resulting in a mean annual trawling frequency of 1.23. The mean annual trawling frequencies with the 4m beam trawl using tickler chains, the 4m beam trawl with a chain mat, and the otter trawl were 0.13, 0.01, and 0.06, respectively. The annual fishing mortality in invertebrate megafaunal populations in the Dutch sector ranged from 5 up to 39%, with half of the species showing values of more than 20%. For all species studied, the 12m beam-trawl fisheries caused higher annual fishing mortalities than the concerted action of the other fisheries. Only with respect to species restricted to sandy coastal areas did the 4m beam-trawl fleet contribute substantially to the annual mortality. Implications of the impact of trawling on the composition of benthic communities are discussed. *Copyright 2000 International Council for the Exploration of the Sea*.

Bergmann, M., Taylor, A. C., and Moore, P. G. 2001. Physiological stress in decapod crustaceans (*Munida rugosa* and *Liocarcinus depurator*) discarded in the Clyde Nephrops fishery. Journal of Experimental Marine Biology and Ecology. 259(2) : 215-229.

Keywords: Stress/ Fishing/ Biological stress/ Handling/ Anoxia/ Commercial fishing/ Haemolymph/ By catch/ Lobster fisheries/ Liocarcinus depurator/ Munida rugosa/ Nephrops/ ANE, British Isles, Scotland, Firth of Clyde

Abstract: Crustacean discards experience stress during commercial fishing operations, due to increased exercise while in the trawl and aerial exposure during sorting of the catch. Physiological stress and recovery were assessed following trawling of two ecologically important decapod species, regularly discarded in the Clyde Nephrops fishery. Haemolymph samples taken from trawled swimming crabs, Liocarcinus depurator, and squat lobsters, Munida rugosa, had significantly higher concentrations of ammonia (0.308 and 0.519 mmol l super(-1)), D-glucose (0.14 and 0.097 mmol l super(-1)) and L-lactate (6.2 and 0.87 mmol l super(-1)) compared with controls, indicating an impairment of ammonia excretion and a switch to anaerobic metabolism. Concurrently, the haemolymph pH of trawled squat lobsters was low (7.47) compared with controls (7.75); however, the reverse trend was found in L. depurator. Initially elevated lactate (7.98 mmol l super(-1)) and glucose (0.73 mmol l super(-1)) concentrations of trawled and emersed (1 h) L. depurator were restored, 4 h after re-immersion along with pH (7.54). Crabs that had been emersed for 1 h had

significantly higher concentrations of glucose (0.2 mmol l super(-1)) and lactate (5.14 mmol l super(-1)), and had more acidic blood (7.64) than L. depurator subject to 1 h of exercise, indicating that anoxia was the main cause of physiological stress. Crabs and squat lobsters lost 7% and 9% of their initial body wet weight following 1 h of emersion, although blood osmolarities did not change significantly. While all animals survived aerial exposure in our experiments, sorting of the catch on commercial boats takes up to 300 min, which could lead to mortality or sub-lethal chronic biochemical changes that could compromise fitness. *Reprinted from Journal of Experimental Marine Biology and Ecology, Vol. 259; Bergmann, M., Taylor, A.C., Moore, P.G., Physiological stress in decapod crustaceans (Munida rugosa and Liocarcinus depurator) discarded in the Clyde Nephrops fishery; pages* 215-229*; Copyright (2001); with permission from Elsevier Science.*

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

Abstract: 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 mall 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.

Bertrand, J. A., Gil de Sola, L., Papaconstantinou, C., Relini, G., and Souplet, A. 2000. An international bottom trawl survey in the Mediterranean: the MEDITS programme. Proceedings of the symposium on Assessement of demersal resources by direct methods in the Mediterranean and the adjacent seas, Pisa (Italy), 18-21 March 1998. Ressources halieutiques en Mediterranee, Pisa (Italy), 18-21 Mars 1998, Ifremer, Plouzane (France), 2000, no. 26, pp. 76-94, Actes de colloques. Institut Francais de Recherche pour l'Exploitation de la Mer. Brest.

Keywords: demersal trawl fishery/ Mediterraneon

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

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

Keywords: by-catch/ coasts/ estuaries/ extinctions/ fishing/ habitats/ nurseries/ target organisms/ trophic effects/ water quality

Abstract: Estuaries and associated coastal waters support many essential fisheries, a fact which contributes to their disproportionately high economic value. They are, however, also among the most extensively modified and threatened of aquatic environments. Almost all have been strongly affected by human beings, and fisheries are an integral part of human activities on the coast. We have taken a global perspective in synthesizing the effects of fishing on estuaries and coastal waters. Rather than attempt to cover all regions of the world in detail, we review eight process-orientated categories affected by fishing, with case studies for each of them: target organisms, non-target organisms, nursery functions, trophic effects, habitat change, reduced water quality, human environment, and potential for local extinctions. Fishing in the estuarine and nearshore environment has clear impacts on the structure and functioning of these ecosystems, although other, non-fishing issues also effect these ecosystems. This creates multiple interactions and reinforces the need for an integrated approach to coastal zone management. Nonetheless, some form of fish-based action plan could be created, especially within estuaries, which would provide management objectives for a particular system. *(C) 2000 International Council for the Exploration of the Sea.*

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*.

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

Keywords: Scallop dredging/ dredge

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

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

Blanchard, F. 2001. Dynamics of harvested demersal fish communities: analysis of the species diversity in the Bay of Biscay (Atlantic Ocean) and in the Gulf of Lions (Mediterranean Sea). Aquatic living resources/Ressources vivantes aquatiques. Nantes. 14(1) : 29-40.

Keywords: Demersal fisheries/ Stock assessment/ Catch composition/ Population dynamics/ Community composition/ Species diversity/ ANE, Europe, Biscay Bay/ MED, France, Lion Gulf

Abstract: Species diversity variations between the demersal fish assemblages of the Bay of Biscay (Atlantic Ocean) and of the Gulf of Lions (Mediterranean Sea) are analysed on a decade scale. The aim of this study is to interpret the dynamics of these two communities characterised by different level of fishing intensity. Data come from trawl surveys carried out for the direct evaluation of the demersal stocks abundance from 1983 to 1997. Diversity indices used are the Hill's indices N1 and N2, the species richness S, the evenness J', the K-dominance curves and the life strategy of the dominant species. Three demersal fish assemblages are defined in the community of the Bay of Biscay and in that of the Gulf of Lions: coastal, continental shelf, and continental slope. There are neither significant differences between the assemblages of the Bay of Biscay nor between those of the Gulf of Lions. There are no significant differences between years. The assemblages of the Gulf of Lions are characterised by higher values of N2 and S than the assemblages of the Bay of Biscay. The K-dominance curves show that there is a lower number of dominant species in the Bay of Biscay than in the Gulf of Lions. Finally, there are more long-lived species among the dominant one in the Gulf of Lions than in the Bay of Biscay. Then the community of the Bay of Biscay corresponds to a system adjusted to perturbations (unpredictable mortalities) while the Gulf of Lions corresponds to a system adjusted to a less perturbed environment. There is no interpretation of the relationship between the level of fishing intensity and the chosen indices at the scale of this study. It is concluded that dynamics patterns of the communities can be interpreted from the species diversity indices when associated with K-dominance

curves and life strategy characteristics. Original Abstract: Les variations de la diversite specifique entre les assemblages de poissons demersaux du golfe de Gascogne (ocean Atlantique) et du golfe du Lion (mer Mediterranee) sont analysees a l'echelle d'une decennie. L'objectif est d'interpreter la dynamique de ces peuplements dont les niveaux d'exploitation par la peche different. Les donnees utilisees sont issues des campagnes de chalutages realisees de 1983 a 1997 pour l'evaluation des stocks de poissons demersaux. Les indicateurs de diversite analyses sont les indices N1 et N2 de Hill, la richesse specifique S, la regularite J', les courbes K-dominance et les strategies demographiques des principales especes. Chacun des deux peuplements est constitue de trois assemblages d'especes (assemblage cotier, du plateau et de la pente continentale). Il n'existe de difference significative ni entre les assemblages du golfe de Gascogne, ni entre ceux du golfe du Lion. Il n'y a pas non plus de difference significative entre les annees. L'ensemble du golfe du Lion est caracterise par des valeurs N2 et des indices S plus eleves que dans le golfe de Gascogne. Selon les courbes K-dominance, le peuplement du golfe de Gascogne est caracterise par un plus petit nombre d'especes dominantes que dans le golfe du Lion. Enfin, les especes dominantes du golfe du Lion sont caracterisees par une longevite et/ou une taille maximale plus grande que celles du golfe de Gascogne. Le golfe de Gascogne correspondrait a un systeme adapte a l'existence de perturbations (mortalites imprevisibles), tandis que le golfe du Lion correspondrait a un systeme adapte a un environnement moins perturbe. Un impact de l'exploitation n'a pu etre interprete a partir des indices choisis, utilises a cette echelle. Toutefois, lorsque les indices de diversite sont mis en relation avec la strategie demographique des especes, des elements de dynamique des peuplements sont mis en evidence.

Boyd, S. and Rees, H. 2000. The effects of dredging intensity on the macrobenthos in commercial aggregate extraction sites in the English Channel. ICES CM 2000 - E:08 - Annex 6. 15 p.

Keywords: dredging/ macrobenthos/ English Channel

Abstract: A survey was designed to examine the nature of impacts on the benthos arising form commercial aggregate extraction at sites east of the Isle of Wight in the English Channel. Samples of sediments and the associated macrofauna were collected from areas subjected to different levels of dredging intensity. Several of the sampled sediments collected from within areas of intensive dredging contained reduced quantities of gravel. However, changes in particle size were not sufficient to accoutn for differences in assemblage structure between areeas that had only limited exposure to the direct effects of dredging compared with ndredged areas. Samples from intensively dredged sediments differed from undredged sites due to significant reductions ($p<0.05$) in numbers of species, biomass, species richness and diversity. Intermediate values of all calculated univariate measures were also observe din areas of reduced dredging intensity. populations of the reef forming polychaete Sabellaria spinulosa were found to be particularly susceptible to dredging disturbance. This in contrast to Balanus juveniles which were observed to be more numerous in intensively dredged sediments compared with elsewhere, suggesting that some settlement of this taxon occurs even during times of extraction.

Bradshaw, C, Veale, L. O., and Brand, A. R. 2002. The effect of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a Re-analysis of an historical dataset. Journal of Sea Research. 47(2) : 161-184.

Keywords: Benthos/ Long-term/ Historical data/ Scallop fisheries/ Dredges/ Ecosystem disturbance

Abstract: Benthic community data collected between 1938 and 1950 by N.S. Jones were compared with modern samples from seven sites in the Irish Sea. Multivariate and univariate methods were used to compare community change over time and examine the possible impact of scallop dredging over the 60 year time period. A conservative approach to data analysis ensured that observed differences in faunal composition between time periods were not due to differences in sampling methodologies or taxonomic identification. The community composition changed at all sites, though to different degrees. The amount of change was related to how long a site had been fished, rather than fishing intensity. Mobile, robust and scavenging taxa have increased in abundance, while slow-moving or sessile, fragile taxa have decreased. Differences between historical and modern samples were greater than could be accounted for by the natural variability of the system (as indicated by spatial and temporal replication at three sites) and indicate real

long-term change. This study emphasizes that, in the absence of good-quality data series and experiments, the use of `fuzzy' historical data is often the only possible way to judge long-term change and can yield valuable results. *Reprinted from Journal of Sea Research, Vol. 47; Bradshaw, C., Veale, L.O., Brand, A.R., The effect of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a re-analysis of an historical dataset., pages 161-184; Copyright (2002); with permission from Elsevier Science.*

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, conservaton 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 Journal 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

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

Brand, A. R. 2000. North Irish Sea scallop fisheries: Effects of 60 years dredging on scallop populations and the environment. Pages 37-43 *in* A workshop examining potential fishing effects on population dynamics and benthic commuity structure of scallops with emphasis on the weathervane scallop *Patinopecten caurinus* in Alaskan waters. Alaska Department of Fish and Game, Division of Commercial Fisheries, Special Publication 14, Juneau, AK .

Keywords: scallop fisheries/ scallop dredging/ dredging effects/ north Irish Sea/ Isle of Man

A*bstract*: Over the last 60 years very intensive dredge fisheries have developed in the north Irish Sea around the Isle of Man for the scallop *Pecten maximus* and the queen scallop *Aequipecten opercularis*. Through this period there have been changes in gear type and areas fished, so the modern fishery is based on a series of fishing grounds that differ in the duration and intensity of exploitation, as well as in environmental conditions. Since the scallop populations and benthic communities are both well documented, this provides an excellent opportunity to assess the effects of scallop dredging on both scallop stocks and the environment. Changes in scallop abundance, density, and age structure are discussed, together with bycatch mortalities and benthic community changes in areas of known long-term fishing effort and an area closed to commercial fishing.

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: dredge/ scallop fishery/ North Irish Sea

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

Bremec, C. and Lasta, M. 1999. Effects of fishing on faunistic composition of scallop beds in the Argentine Sea. Book of Abstracts: 12th International Pectinid Workshop.

Keywords: Scallop culture/ Scallop fisheries/ Ecosystem disturbance/ Trawling/ Commercial fishing/ By catch/ Pectinidae/ PSW/ Argentina

Abstract: A joint state-industry research program conducted to a new scallop fishery in the argentine continental shelf, after the location of seven new beds of patagonian scallop (Lasta and Bremec, 1998). Studies based on a depletion experiment in a dense patch in Valdes bed (42 degree 15 theta S-58 degree 33 theta W) estimated mean biomass in the range of 0.22-0.23 kg of scallops times m super(-2) and efficiencies of the demersal otter trawl in the range of 21-31 % (Lasta and Iribarne 1997). The structural damage produced by trawling on the benthic habitat, including commercial and non commercial scallops, associated invertebrate species and discarded shells at different levels of disturbance was presented by Bremec and Lasta (1998). The main objective of this study is to estimate the temporal changes in biomass composition of the main faunistic groups that conform the bycatch of the present scallop fishery.

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, E., Dommisse, M., Hills, S., and Finney, B. 2000. Immediate and long-term effects of commercial bottom trawling to benthic communities and substrate in a dynamic soft-bottom environment: Bristol Bay, Alaska. Diving for Science in the 21st Century, American Academy of Underwater Sciences, 430 Nahant Rd Nahant MA 01908 USA. 18p.

Keywords: Ecosystem disturbance/ Environmental impact/ Commercial fishing/ Trawling/ Habitat/ Environmental degradation/ Biodiversity/ Fisheries/ Benthos/ Economics/ Marine fauna/ Ecosystem analysis/ Environmental monitoring/ IN, Bering Sea/ Alaska, Bristol Bay/ benthos/ Trawling

Abstract: Although habitat degradation, loss of biological diversity, and declines in productivity have been well documented in other regions, little is known about the effects of trawl catcher-processors to benthic communities and substrate in the Bering Sea, despite the economic importance of fisheries in this region. This study investigated changes to benthic fauna and substrate associated with commercial bottom trawling for yellowfin sole in the southeastern Bering Sea. During a pilot study in 1999, we noticed apparent differences between control and fished zones for infaunal abundance and biomass, but depth profiles of sediment parameters from cores taken from grabs were inconclusive. In 2000, sediment cores were collected by divers rather than from grabs. Analysis of the multiple data sources from the larger 2000 study will allow assessment of the effects of commercial bottom trawling to benthic communities and habitat in this dynamic, shallow-water, soft-bottom environment.

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.

Butler, A., Williams, A., Koslow, T., Gowlett-Holmes, K., Barker, B., Lewis, M., and Reid, R. 2000. A study of the conservation significance of the benthic fauna around Macquarie Island and the potential impact of the Patagonian Toothfish Trawl Fishery: Final report to Environment Australia Marine Group. CSIRO, Hobart, Tasmania (Australia). 71 p.

Keywords: Zoobenthos / Fishery surveys/ Marine parks/ Resource conservation/ Benthos/ Trawling/ Man-induced effects/ Environmental impact/ Environment management/ Resources/ Baseline studies/ Dissostichus eleginoides/ PSE, South Pacific, Macquarie I./ PSE, South Pacific, Macquarie Ridge/ PSE, South Pacific/ baseline studies/ seafloor sampling/ imaging techniques/ substrata

Abstract: The conservation significance of the benthic fauna around Macquarie Island and the potential impact on it of the adjacent trawl fishery for Patagonian toothfish(Dissostichus eleginoides) is assessed. This preliminary study, based on a three-day survey, combines information from a baseline video survey east of Macquarie Island with samples collected by an epibenthic sled in the region of the island. These results are interpreted in relation to the establishment of a marine park adjoining Macquarie Island that incorporates a strict nature reserve (in which fishing and mining will be banned) surrounded by a resource protected area (in which there will be managed exploitation). The harsh open ocean conditions in the study area, in conjunction with the deep, steep, rocky nature of its seabed, required novel tools and techniques to collect samples. CSIRO developed a towed camera platform (the Deep Video System (DVS)) to provide high quality digital imagery of the seabed and a rugged epibenthic sled to provide physical samples of animals and substrata to 'ground-truth' image data and provide a broader sampling coverage of the Macquarie Ridge area, which revealed a relatively barren seabed supporting approximately 102 benthic invertebrate species. Trawling for the Patagonian toothfish currently favours the deep, sediment filled floors adjacent to seabed slopes. Trawl impacts on muddy substrate biotopes are not fully assessed because the infauna were incompletely sampled and because the physical impacts on deep ocean sediment fauna are poorly understood.

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/ drag/ dredging

Abstract: The efficiency of an 8-ft scallop drag was estimated from population density measurements by scuba divers. Density measurements had to be made with an enclosed quadrat because of scallop swimming activity. Scallops responded to approaching objects by facing away from them and swimming. A steep rise useually preceded level swimming at a mean height of 0.4 m from bottom. Point-to-point swimming distances of up to 4 m were recorded with ground speeds in excess of 67 cm/sec. Few scallops over 100mm could be induced to swim. Despite level bottom conditions, overall drag efficiency was low (2.1%) but increased progressively over the size range encountered (20-150 mm). Direct observations of drag function showed that swimming activity rather than selection by the drag was responsible for the low drag efficiency for the capture of scallops smaller than 100mm. An indirect fishing mortality was established for recessed scallops buried by the drag. Dragging resulted in dislodgement of dead shell to the substrate surface, and aggregation of benthic predators in the drag tracks.

Caddy, J. F. 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.

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

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

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

Cappo, M., Alongi, D. M., Williams DMcB, and Duke, N. 1998. A review and synthesis of Australian fisheries habitat research: Major threats, issues and gaps in knowledge of marine and coastal fisheries habitats: a Prospectus of opportunities for the FRDC 'Ecosystem Protection Program', Volume 2: Scoping review. AIMS, Townsville, Queensland (Australia). 433 p.

Keywords: Marine fisheries/ Coastal fisheries/ Habitat/ Environmental factors/ Research/ Ecosystem management/ Australia Coasts

Abstract: The present suite of Australian fisheries habitats is shaped by combinations of major physical, climatic, geological, palaeohistorical and ecological forcing functions that must be considered in assessing habitat status and change, particularly when assessing anthropogenic threats. The different combinations of these factors along the steep gradients that comprise the entire Australian coast will need a regional scale focus in research and development investment in the Fisheries Research and Development Corporation (FRDC) Ecosystem Protection Program, as there may be relatively few generic applications of results across habitats. Issues identified in this scoping review include: natural dynamics in fisheries habitats and environmental variability; changes to drainage and habitat alteration; nutrient and contaminant inputs; the effects of harvesting on biodiversity and ecosystems and introduced and translocated pests and diseases. Research and development themes and issues have been summarized as a prospectus (volume 1) and the sources of all citations identified through a formal literature search have been provided (volume 3). Both volumes are cited individually in this issue of ASFA.

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

Abstract: Spanish Oceanographic Institute (IEO) and Portuguese Research Institute (IPIMAR, ex-INIP) using their research vessesls "Cornide de Saavedra" and "Noruega" have conducted groundfish surveys in Sanish and Portuguese waters. The results of these surveys have been reported to the relevent ICES Working Groups, communicated to ICES Annual Conferences and/or published in journals of biology and fisheries. Data collected from groundfish surveys were also the basis to carry out assemblage studies and to several advices to the Spanish, Portuguese and European fishery administrations concerning the implementation of technical measures for fish stock management. This communication intends to give information about the past, the present and the future of these surveys, concerning objectives, methodology and publications. Critical aspects and solutions to improve some aspects are presented.

Carr, H. A. and Milliken, H. O. 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.

Carr, H. A. and Milliken, H. O. 1998. The use of video and acoustics to assess net performance and study fish behavior. Proceedings of the FIGEMOD International Workshop on Fishing Gear Measurement and Observation Devices, Nov. 30 - Dec. 4, 1998, Lorient, France. 8 p.

Keywords: video/ acoustics/ fish behavior/ trawl gear observation

Abstract: For over ten years the Division of Marine Fisheries has been collecting video footage, using inexpensive, off the shelf, underwater camera systems on trawl nets and other fishing gears. This video has been invaluable in assisting the researchers and fishermen to improve gear selectivity, reduce bycatch of unwanted or regulated species, and observe the impact of the fishing gear on benthic habitat. The underwater observations are often supplemented with the simultaneous use of acoustic net mensuration gear. Important restrictions related to this work include the small size of the commercial fishing vessels, financial resources for equipment, and the limitations of ambient light and underwater visibility. Because even the same fish species do not react similarly in different locals and at different times of the year, it is important to assess the behavior of these species when trawl modifications are being devised even if the species has been studied in another study in a different area. Appropriate equipment must be designed to fit the needs and application.

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.

Chicharo, L., Regala, J., Gaspar, M., Alves, F., and Chicharo, A. 2002. Macrofauna spatial differences within clam dredge-tracks and their implications for short-term fishing effect studies. Fisheries Research (Amsterdam). 54(3): 349-354.

Keywords: Zoobenthos / Spatial variations/ Clam fisheries/ Man-induced effects/ Dredges/ Checked on load

Abstract: In situ observations of clam dredging showed that the effects of the dredge on the benthic macrofauna may not be constant during a tow. A sand buffer forms in front of the gear approximately 10 m after the beginning of a tow, and this pushes the sediment partially aside. In this study, we analyze differences in abundance, the number of taxa present, diversity, and evenness within sections of dredge-tracks in a disturbed, fished area and a non-fished area along the southern coast of Portugal. These areas were sampled by divers before and after dredge-fishing activity. At each site, three dredge-tracks were produced. These tracks were divided in three longitudinal sections (start, middle and end) and two transverse sections (track and edge). Six quadrats were used to sample macro. *Reprinted from Fisheries Research, Vol. 54; Chicharo, L., Regala, J., Gaspar, M., Alves, F., Chicharo, A., Macrofauna spatial differences within clam dredge-tracks and their implications for short-term fishing effect studies; pages* 394-354*; Copyright (2002); with permission from Elsevier Science.*

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/ stress/ gear selectivity

Abstract: The capture of immature fish in many commercial fisheries is controlled by restricting the use of fishing gears or elements of fishing gears that prevent the escape of immature fish. Improving the selective characteristics of fishing gear is based on the assumption that fish escaping are not seriously damaged and able to make a complete recovery. If fish escape and die as a direct result of stress and injuries or indirectly due to disease and predation associated with gear damage, then increasing the opportunity for escape by improving selectivity my result in an increased level of unaccounted fishing mortality. this paper identifies the main fishing gear types used for harvesting marine and freshwater fish, a range of injuries, stress reactions and mortalities that can occur during capture and escape. It is concluded that immediate and delayed mortalities can occur in fish escaping from fishing gears and that the high variation in mortality rates within experiments is associated with a lack of information on how fish condition is affected by various fishing stressors and the type and severity of physical damage received. Improving selectivity without reducing damage or stress incurred during capture and escape may not be the most appropriate way of protecting immature fish.

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 behaviour 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 behaviour, 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, Jeffrey's Bank and George's 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 side-scan sonar, bottom photographs and fishing records, we identified a set of disturbed and undisturbed sites on the gravel pavement area of northern Georges Bank in the northwest Atlantic. Replicate samples of the megafauna were collected with a 1 m Naturalists' dredge on 2 cruises in 1994. Compared with the disturbed sites, the undisturbed sites had higher numbers of organisms, biomass, species richness and species diversity; evenness was higher at the disturbed sites. Undisturbed sites were characterized by an abundance of 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., Escanero, G. A., and Valentine, P. C. 2000. Photographic evaluation of the impacts of bottom fishing on benthic epifauna. ICES Journal of Marine Science. 57(4) : 987-1001.

Keywords: benthic communities/ bottom fishing/ Georges Bank/ habitat disturbance/ in-situ photography

Abstract: The gravel sediment habitat on the northern edge of Georges Bank (East coast of North America) is an important nursery area for juvenile fish, and the site of a productive scallop fishery. During two cruises to this area in 1994 we made photographic transects at sites of varying depths that experience varying degrees of disturbance from otter trawling and scallop dredging. Differences between sites were quantified by analyzing videos and still photographs of the sea bottom. Videos were analyzed for sediment types and organism abundance. In the still photos, the percentages of the bottom covered by bushy, plant-like organisms and colonial worm tubes (*Filograna implexa*) were determined, as was the presence/absence of encrusting bryozoa. Non-colonial organisms were also identified as specifically as possible and sediment type was quantified. Significant differences between disturbed and undisturbed areas were found for the variables measured in the still photos; colonial epifaunal species were conspicuously less abundant at disturbed sites. Results from the videos and still photos were generally consistent although less detail was visible in the videos. Emergent colonial epifauna provide a complex habitat for shrimp, polychaetes, brittle stars and small fish at undisturbed sites. Bottom fishing removes this epifauna: thereby reducing the complexity and species diversity of the benthic community. (C) 2000 International Council for the Exploration of the Sea.

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

Keywords: benthic organisms/ fishing impact/ habitat disturbance/ meta-analysis/ predictive models

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

benthic communities are badly needed. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK and the Journal of Animal Ecology*.

Committee on Ecosystem Effecs of Fishing. 2002. Effects of trawling and dredging on seafloor habitat. Committee on Ecosystem Effecs of Fishing: Phase 1 - Effects of Bottom Trawling on Seafloor Habitats. National Research Council. 125 p.

Keywords: Trawling/ dredging/ seafloor habitat/ effects

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

Abstract: The effects on cockle (*Cerastoderma edule* L.) populations in Burry Inlet, South Wales of mechanical harvesting using a tractor dredger were investigated with an experimental trial conducted on 29 October 1992. Previously, only hand gathering methods were used, and the trial was intended to assist a licensing decision for mechanical dredging. Six blocks of dredged and undredged (control) plots were set out in each of two areas, one having a low density of cockles, the other high. Approximately 82% of the dredged areas was lifted by the blade of the dredger. The catch consisted almost exclusively of adult cockles (2 years old) over 25 mm in length. Appreciable losses of spat and one-year-olds from the dredged plots were also observed even though they were not taken in the catch. Possible reasons are discussed. Counts of damaged individuals rem-classes showed further mortalities attributable to dredging, and changes to shell growth were either minor or absent. Spatfall success in 1993 was depressed by 11% on dredged plots compared to that on control plots in the low density area, but was increased slightly (not significant $p>0.05$) in the high density area. It is concluded that delayed effects of the dredging on cockle stocks were negligible.

Cotter, Jdir, Reynolds, J. D., Greenstreet, S., Ehrich, S., Alvsag, J., and Jarre-Teichmann, A. 1998. Monitoring biodiversity in the North Sea using groundfish surveys. Third european marine science and technology conference (MAST conference), Lisbon, 23-27 May 1998: Project synopses vol. 6: Fisheries and Aquaculture (FAIR: 1994-98), selected projects from the research programme for Agriculture and Fisheries

including agro-industry, food technology, forestry, aquaculture and rural development FAIR., European Commission DG 12 Science, Research and Development, Luxembourg (Luxembourg). 87-91.

Keywords: Biodiversity/ Fish/ Surveys/ Monitoring/ Fishing vessels/ ANE, North Sea/ fishing

Abstract: The objectives are: 1) To establish the value of existing national groundfish surveys of the North Sea as monitors of fish and epibenthic biodiversity. 2) Where possible, to link trends in fish and epibenthic biodiversity for selected non-commercial species as revealed by these surveys with trends in fishing effort and methods, and/or environmental and ecological factors. 3) To try out and recommend practical methods for enhancing groundfish surveys so that they better monitor fish and epibenthic biodiversity without disrupting their primary functions in the management and assessment of commercial fish stocks. Where necessary, to produce taxonomic aids suitable for use on survey vessels using the recommended methods. 4) To recommend protocols for the reporting and assessment of trends in biodiversity in order to monitor the well-being of North Sea fish and epibenthic ecosystems in relation to commercial fishing. Several nations undertake groundfish surveys in the North Sea. This 3-year project is intended to show how value may be added to these surveys by monitoring biodiversity of non-commercial species in support of the Convention on Biological Diversity (Rio de Janeiro, 1992). The project is divided into four tasks. Firstly, existing groundfish survey data on non-commercial fish, and where possible, epibenthic invertebrates, were analysed for information on biodiversity. It was concluded, as expected, that fish survey trawls are not good sampling tools for monitoring biodiversity. Secondly, a 2-metre beam trawl constructed from steel was tested at stations throughout the North Sea, and found to be a rugged and dependable survey tool for epibenthic biodiversity. Attempts are now being made to standardise towing distances. Thirdly, taxonomic material is being prepared to assist scientists on groundfish surveys to readily identify benthic species caught by the beam trawl. This is taking the form of a computerised database with photographs. A fourth task, to be addressed in the final year of the project is the development of protocols for the reporting and assessment of trends in biodiversity so that the results of any future monitoring can be as relevant and accessible as possible.

Craeymeersch, J. A. 1994. Environmental impact of bottom gears on benthic fauna in relation to natural resources management and protection of the North Sea. Pages 209-235 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

Keywords: environmental impact/ bottom gears/ benthic fauna/ management/ North Sea/ survival rates

Abstract: Some of the possible impacts of fishing with a 4-m beam trawl by Eurocutters on the bottom fauna were examined. Research was carried out on the Flemish Banks, southern North Sea. For each kg marketable flatfish about 1kg undersized flatfish and other fishes, and 8kg invertebrates were caught. Survival experiments were performed with large invertebrates and undersized flatfish discards that have been collected from cod-end, and with species that escaped the cod-end. Almost all of the invertebrates examined, both those discarded and escaping the fishing net, survived. The percentage survival of flatfish was 0-20% for dab, 15% for sole and 70% for plaice. About 90% of the sole that escaped the cod-end survived. Several fish species moved into the trawled area after fishing, predating on the exposed invertebrate species. Different fish species immigrated on the trawled seabed, depending on the benthic composition of that area. Due to lack of statistical power it was impossible to detect effects on densities of the macrobenthic infauna. Moreover, it was uncertain whether the samples taken after fishing were actually situated within a trawl mark, or not. In conclusion, traditional sampling programmes seems to be insufficient to evaluate the impact of fishing with 4-m beam trawls on the macrobenthic infauna.

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, conservaton 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/ modification/ disease mortality

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

eastern and central areas that fishers then abandoned. The commercially exploited area subsequently expanded to the limits of Foveaux Strait. With accelerated modification of oyster habitat, disease mortality has become more important. Attempting to rebuild the fishery by oyster enhancement may be more successful conjoined with habitat restoration.

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

Abstract: An attempt is undertaken to analyse the ground-rope effect on the efficiency of beam trawls in assessing population densities of epibenthic animals, such as demersal fishes, shrimps, crabs, asteroids, ophiuroids, and gastropods, which burrow to a greater or lesser degree. Experimental beam-trawl hauls were carried out with different numbers of tickler chains. The results obtained in sandy as well as in muddy areas are discussed. In general, no significant effect of the number of tickler chains was found at muddy stations. At sandy stations, on the other hand, the number of tickler chains showed a positive effect on the catches of species that burrow occasionally and species that cling tightly to the bottom. In some species the catches reached an asymptotic level with increasing number of chains, whereas in other cases the increase in the catches was still significant even when reaching the maximum of 6 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 x 600 m) experimental plots that were dredged with an intensity and duration similar to normal fishing operations. Dredges were most efficient on soft, flat, muddy sediments (51-56% of commerical-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.*

D'Onghia, G, Politou, C, Mastrototaro, F, Mytilineou, C, and Matarrese, A. 2001. Biodiversity from the upper slope demersal community of the eastern Mediterranean: Preliminary comparison between two areas with and without fishing impact. Scientific council research document. Northwest Atlantic Fisheries Organization. 1(135): 11 p.

Keywords: Biodiversity/ Multivariate analysis/ Trawling/ Fishery surveys/ Water depth/ Environmental conditions/ Ecosystems/ Aristeus antennatus/ Aristeomorpha foliacea/ MED, Ionian Sea

Abstract: Univariate ecological indexes and multivariate analyses (cluster and MDS) were performed in order to evaluate biodiversity in two neighbouring areas of the eastern Mediterranean with different fishing impacts. Data were taken during two trawl surveys (July and August 2000) carried out in two areas of the Ionian Sea: one off the south-eastern Italian coast, where trawl fishing occurs between 300 and 700 m targetting deep-sea shrimps Aristeus antennatus and Aristaeomorpha, the other off northern Greece, where fishing is only carried out as far as 400 m of depth. While univariate ecological indexes did not show convincing differences between the community structure of the two study areas considered as whole, the multivariate analysis showed a clear pattern linked to depths and areas highlighting the distribution of abundance of the various species. Depth played the main role in the group differentiation, indicating the existence of two quite distinct bathyal faunal assemblages: one in the upper slope, the other in the middle slope. The results on the geographic characterization of the biodiversity and of the assemblages were discussed considering the different fishing impact as well as the environmental conditions in the two areas of the same basin.

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

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

Daan, N. and Richardson, K. (eds.) 1996. Changes in the North Sea ecosystem and their causes: Arhus 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. NA(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

Abstract: Three experiments were conducted to measure the overall efficiency of commercial dredges used to survey scallop stocks. Marked animals were laid on four plots located in the Cornish fishery on inshore and offshore grounds ranging from smooth, sandy or muddy gravels to rougher, stony substrates. Efficiency at catching each 5mm size (shell height) class of scallop was estimated by comparing mean numbers of releases and recaptures per l000 m 2 of seabed. The gear was highly size-selective and of low efficiency overall with substrate-dependent variations. For these commercial dredges, with spring-loaded toothbars and 75mm belly and back meshes, mean efficiency at catching legally fishable (>90mm) scallops ranged from 6% (rough ground) to 41% (smooth muddy gravel). On the most widespread offshore ground type (sand and fine gravels) efficiency on two plots averaged 22%, but it fell rapidly with decreasing scallop size to I.4% at 65mm and to only 0.2% at 45mm. Dredge efficiency is the resultant not only of a two-stage selection and retention process (by toothbar and meshes) but of complex interactions between the gear, the seabed, hydrodynamic forces and the behaviour of scallops themselves. Overall, spring-loaded dredges

retain rather few juvenile scallops and, although most effective on moderately soft grounds, their efficiency generally is low.

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 prestine 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. Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater. 5(3) : 205-232.

Keywords: marine environment/ fishing/ environmental impact/ management/ marine fisheries/ fishery management/ environmental protection/ fisheries

Abstract: Some effects of fisheries on the associated biological systems are reviewed and management options and their inherent risks are considered. 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. Other impacts discussed include the destruction of benthic habitat, the provision of unnatural sources of food and the generation of debris. Management options are considered including the designation of marine protected areas, risk aversion, and the burden of proof. 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. Side-scan sonar data from 1995 with 200% coverage were available from the National Oceanic and Atmospheric Administration for the mouth of Narragansett Bay. Analysis of these data indicates that evidence of bottom scarring by the fishing gear is restricted to deeper waters with a seabed composition of soft cohesive sediments, despite the observation that fishing activity is ubiquitous throughout the bay mouth. A quantitative model has been

developed to compare the magnitude and frequency of natural seabed disturbance to mobile fishing gear disturbance. Wave and tidal currents at the seabed are coupled with sediment characteristics to estimate the degree of seabed disturbance. Field experiments designed to compare the longevity of bottom scars indicate that scars in shoal waters and sand sediments are short-lived, as compared to scars in deep water and mud sediments, which are long-lasting. Finally, the model results are compared to the recovery time of sediments disturbed by the interaction of the fishing gear with the seabed. The impact of mobile fishing gear on the seabed must be evaluated in light of the degree of seabed disturbance due to natural phenomena. The application of this model on a larger scale to continental shelf waters and seabed sediment environments will allow for the identification of problematic areas relative to the degradation of essential fish habitat by mobile fishing gear. *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 in 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 Grave, S. and Whitaker, A. 1999. Benthic community re-adjustment following dredging of a muddy-maerl matrix. Marine Pollution Bulletin. 38(2): 102-108.

Keywords: Benthic environment/ Dredging/ Community structure/ Ireland/ Ecosystem disturbance/ Environmental impact/ Community composition/ Omnivores/ Filter feeders/ Man-induced effects/ Anthropogenic factors/ Zoobenthos/ Benthos/ Marine organisms/ Crustacea/ Bivalvia/ Species diversity/ Population dynamics/ Sediment transport/ Ireland, Southwest/ Crustacea / Bivalvia/ ANE, Eire/ community structure/ Bivalves/ Clams/ infauna

Abstract: Changes in the benthic infaunal community structure at a location in south-west Ireland subject to dredging impacts were studied. Dredging of a muddy-maerl matrix takes place with a seasonally varying frequency of 2-5 times per month. The benthic infauna at a currently dredged site was compared to a fallowed portion of the area, at which extraction ceased 6 months prior to the study. As virtually the entire licensed area is dredged in rotation, longer term recovery is not possible at the study site. In contrast to numerous other study, the benthic infauna at the dredged site was not depleted, but did exhibit higher levels of stress and a higher diversity than the fallowed site. A clear shift from the abundance of omniverous crustaceans in the dredged area to filter-feeding bivalves in the fallowing area was observed. These observations are thought to be linked to sediment mobility, the creation of spatial patchiness and the

mobilisation of food resources. *Reprinted from Marine Pollution Bulletin, Vol. 38; De Grave, S., Whitaker, A., Benthic Community Re-adjustment following Dredging of a Muddy-Maerl Matrix; pages 102-108; Copyright (1999); with permission from Elsevier Science.*

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 beamtrawls 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 Boonstra, G. P. 1970. Preliminary notes on the development of an electrical tickler chain for sole (*Solea solea* L.). ICES Gear and Behaviour Committee, CM1970 B:4 : 3 p.

Keywords: trawling impacts/ tickler chains/ electrical tickler chains/ Dutch fisheries

Summary: This paper introduces the possible development of electrical tickler chains in the Dutch sole, *Solea solea* L., fishery as a means of reducing heavy tickler chain impacts to juvenile target species without reducing catch size.

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 side-scan 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/ side-scan 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. 2000. 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

Desprez, M. 2000. Physical and biological impact of marine aggregate extraction along the French coast of the eastern English Channel: Short- and long-term post-dredging restoration. ICES Journal of Marine Science. 57(5) : 1428-1438.

Keywords: environmental impact/ marine aggregate extraction/ Eastern English Channel/ dredging

Abstract: Sediment and associated macrofauna of an industrial extraction site off Dieppe have been monitored during a 10-year period. The original heterogeneous substrate of the shingle bank, characterized by gravels and coarse sands, was progressively dominated by fine sands deposited in dredging tracks. The maximum impact on benthic macrofauna was a reduction by 80% for species richness and 90% for both abundance and biomass. The structure of the community changed from one of coarse sands with *Branchiostoma lanceolatum* to one of fine sands with *Ophelia borealis*, *Nephtys cirrosa*, and *Spiophanes bombyx*, with local dominance of the opportunistic, sessile *Pomatoceros triqueter* on bare shingles. Impact of overflowing sands on benthic macrofauna in the surrounding deposition area proved equally large as in the dredged area. Early stages of recolonization were studied from 1995 to 1997 after cessation of dredging. Species richness has been fully restored after 16 months, while densities and biomass were still 40% and 25%, respectively, lower than in reference stations after 28 months. Nevertheless, community structure differed from the initial one corresponding to the new type of sediment. Impact within and around the

dredging site was classified according to three levels. Exploration of a former experimental site (CNEXO) dredged in the 1970s provided an example of long-term restoration. *Copyright 2000 International Council for the Exploration of the Sea*.

Dineen, C. F. and R.M. Darnell. 1976. The effects of dredging on food habits of fishes of San Antonio Bay. Pages 345-355 *in* A.H. Bouma (ed.), Shell dredging and its influence on Gulf coast environments. Gulf Publishing Company, Houston, Texas. 11 p.

Keywords: dredging/ effects/ food habits/ San Antonio Bay

Abstract: Fishes comprise a very important component of the estuarine ecosystems of the northern Gulf Coast, and their food habis reflect the dynamics of production , availability, and turnover (Darnell, 1958). Many marine species of commercial and recreational significance are known to spend their juvenile stages within the estuaries. Therefore, it is important to assess the impact of dredging activities on the food habits of estuarine fish populations. However, studies of dredging impacts have seldom considered possible effects on eating habits of fish, and this is due, in part, to the fact that it is difficult to design studies that will provide unequivocal answers. Being quite mobile, most fishes can move into or out of mud plumes at will, and regardless of where they are collected, the actual feeding sites remain unknown. On the other hand, placing caged fishes within a mud plume destroys the element of free food selection, and the results of such studies might bear little relation to the natural situation. In the present study, efforts were made to determine the natural food habits of fishes taken from regular stations throughout San Antonio Bay in monthly samples during a full-year cycle. This provides insight into what food material the bay offers to each species and it permits subjective extrapolation of possible dredging and naturla effects. In addition, a few fish collections were made in dredge plumes to provide material for direct comparison with fishes taken outside the plumes. Two general classes of effects might be anticipated--short- and long-term. Short-term effects might include interference with availability, location, or apprehension of food items (due, in part, to increased turbidity) or an increase or reduction in the availability of certain types of food (due to suspension of bottom materials). Long-term effects might include a reduction or increase inthe amount or kinds of food available through modification of bottom topography or bottom sediment composition.

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 sound: stock 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.

Drabsch, S. L., Tanner, J. E., and Connell, S. D. 2001. Limited infaunal response to experimental trawling in previously untrawled areas. ICES Journal of Marine Science. 58(6) : 1261-1271.

Keywords: infaunal/ trawling effects/ untrawled areas

Abstract: There is considerable argument about the effects of bottom trawling on the benthos. Many studies have been done on recently trawled grounds, where community composition has already been modified, and further effects are likely to be minimal. This study tests the effect of trawling on macroinfaunal assemblages in an area where little or no trawling had occured in the previous 15 years. A spatially replicated Before-After, Control-Impact (BACI) design was used, with adjacent trawl and control corridors. Sampling was done in the same two small sites within each corridor before and after trawling to minimise confounding due to spatial variation. Despite this rigorous design, changes consistent with an effect of trawling were not detected. At only one of the three locations was a potential effect detected. These inconsistent results could be due to different disturbance regimes at each location, influencing the vulnerability of fauna to further disturbance. Given the high levels of variability in infaunal assemblages, however, the changes could also be due to asynchronous natural variation. The combination of high spatial and temporal variability, in association with light trawling gear, means that prawn trawling in South Australia does not have consistent effects on infauna. *Copyright 2000 International Council for the Exploration of the Sea.*

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 to 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 a 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

DuPaul, W. D., Brust, J. C., and Kirkley, J. E. 1996. Bycatch in the United States and Canadian sea scallop fisheries. Solving bycatch: Considerations for today and tomorrow. Pages 175-181 *in*, Alaska Sea Grant College Program Report No. 96-03, University of Alaska Fairbanks.

Keywords: bycatch/ discards/ dredge/ scallop dredge/ Alaskan scallop fishery

Abstract: Scallop dredges used by fishermen on the U.S. and Canadian East Coast and in Alaska are large, heavy, and unforgiving as a fishing gear with relatively poor species-specific and size selectivity. Bycatch issues in the U.S. scallop fishery can be characterized as the harvest of undersized or juvenile scallops, the harvest of finfish that are either retained or discarded, the harvest of miscellaneous invertebrates some of which are retained, and the collateral damage to all bycatch animals resulting from either contact with the gear or from handling and exposure on deck. Significant reductions in the harvest of juvenile scallops, or discards, have been achieved by increasing scallop dredge ring sizes and by reducing or omitting chaffing gear. However, collateral damage to discards resulting from the handling of the scallop dredge, culling, and deck operations can exceed 10%. The bycatch of finfish by scallop dredges can be significant and can pose serious problems if retention is not allowed or desirable since mortality rates are high. Dredge rings ranging in size from 3.0 to 4.0 inches (76.2-101.6 mm) are not conducive to the escapement of juvenile fish. Research to determine the effectiveness of scallop dredge modifications for the escapement of finfish has been limited. Modest success in finfish escapement has been reported by changing the mesh of the dredge twine top. The bycatch of crustaceans and other invertebrates by scallop dredges has been documented for the Alaskan scallop fishery, but little has been done elsewhere. Quantities of bottom debris and substrate are often retained in the dredge bag along with bottom dwelling invertebrates. Potential solutions to scallop dredge bycatch include increasing dredge ring sizes, reducing chaffing gear, modifications in dredge design, changes in fishing strategies, and educational programs for the fishermen.

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., 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.*

Ellis, J., Cummings, V., Hewitt, J., Thrush, S., and Norkko, A. 2002. Determining effects of suspended sediment on condition of a suspension feeding bivalve (*Atrina zelandica*): results of a survey, a laboratory experiment and a field transplant experiment. Journal of Experimental Marine Biology and Ecology. 267(2) : 147-174.

Keywords: sedimentation/ suspension feeding/ estuary

Abstract: The horse mussel *Atrina zelandica* (Gray) is a large, suspension feeding pinnid bivalve, common in coastal and estuarine areas of northern New Zealand. As a suspension feeder, *Atrina* is likely to be influenced by suspended sediment loads. We conducted a laboratory experiment to determine the effect of short-term elevations in turbidity levels, such as those commonly recorded during storms, on the physiological condition and clearance rates of *Atrina*. We also conducted a field survey and a 3-month transplant experiment at multiple sites along a gradient of increasing suspended sediment load in a New Zealand estuary. Laboratory clearance rates of *Atrina* declined above a threshold suspended sediment concentration, and *Atrina* physiological condition at the end of this experiment was lower in high cf. low turbidity treatments. Decreases in *Atrina* condition were detected after exposure to elevated levels for only 3 days. The field survey and transplant experiment provided empirical evidence of a strong, negative effect of increasing suspended sediment flux on the physiological condition of *Atrina*. We suggest that

relationships between the physiological condition of suspension feeders and sediment settling flux could provide a link between sediment inputs, which commonly occur as a result of catchment runoff during rainfall events, and the ecological health of estuarine and shallow coastal areas. Our study also demonstrated that *Atrina* have a natural distribution limit controlled by suspended sediment load. Thus, there is potential for larger-scale functional and structural effects on benthic communities in estuarine and coastal areas with high rates of sedimentation. *Reprinted from Journal of Experimental Marine Biology and Ecology, Vol. 267; Ellis, J., Cummings, V., Hewitt, J., Thrush, S., Norkko, A., Determining effects of suspended sediment on condition of a suspension feeding bivalve (Atrina zelandica): results of a survey, a laboratory experiment and a field transplant experiment; pages* 147-174*; Copyright (2002); with permission from Elsevier Science.*

Ellis, J., Schneider, D., and Thrush, S. 2000. Detecting anthropogenic disturbance in an environment with multiple gradients of physical disturbance, Manukau Harbour, New Zealand. Hydrobiologia. 440(1-3) : 379-391.

Keywords: Sewage disposal/ Outfalls/ Ecosystem disturbance/ Environmental impact/ Pollution effects/ Gradients/ Wave effects/ Tidal effects/ Biological sampling/ Zoobenthos/ Disturbance/ Human impact/ Macrofauna/ New Zealand/ New Zealand, Manukau Harbour/ Water Pollution/ Outfall/ Ecological Distribution/ Environmental Effects/ Benthos/ Wastewater Disposal/ Sewage/ Human factors/ New Zealand, North I., Auckland, Manukau Harbour/ PSE, New Zealand, North I., Auckland, Manukau Harbour/ New Zealand/ Gradients

Abstract: Demonstrating spatial or temporal gradients of effects on macrobenthic communities can be a useful way of providing strong empirical evidence of natural or anthropogenic disturbance. Gradient designs for environmental assessment are sensitive to change for point source data, enabling the scale of the effects of a disturbance to be readily identified. If the spatial scale that is sampled from the point source is adequate, problems of selecting control sites can be avoided. However, sources of spatial variation in macrobenthic communities, which are not related to the impact, can confound the use of gradient designs. This can occur if the natural spatial structure overlaps that of the gradient and cannot be identified either as a location or environmental covariable. The ability to detect point source impacts using a gradient design against natural spatial variability was tested using benthic macrofaunal data collected from Manukau Harbour, New Zealand. Treated sewage wastewater is discharged into the north-west area of the Manukau Harbour. Sandflats in the vicinity of the outfall are also subject to physical disturbance from wind-waves and strong tides. Ordination techniques and the testing of a priori predictions were used to try and separate the relative effects of organic and physical disturbance on the benthic communities. While the occurrence of other environmental disturbances along a gradient of anthropogenic disturbance makes interpretation of community pattern more difficult, the use of a gradient sampling layout, ordination analysis and the testing of a priori predictions enabled impacts of the anthropogenic and natural environmental disturbances to be interpreted. Gradient designs, therefore, provide a method of assessing complex impacts that operate over broad spatial and temporal scales.

Ellis, J. I., Norkko, A., and Thrush, S. F. 2000. Broad-scale disturbance of intertidal and shallow sublittoral soft-sediment habitats: effects on the benthic macrofauna. Journal of Aquatic Ecosystem Stress and Recovery. 7(1) : 57-74.

Keywords: Sediments/ Intertidal environment/ Littoral zone/ Benthic environment/ Macrofauna/ Disturbance/ Benthos/ Interstitial environment/ Zoobenthos/ Meiobenthos/ Environmental impact/ Ecosystem disturbance/ shallow subtidal zone

Engas, A., Godo, O. R., and Jorgensen, T. 2000. A comparison between vessel and trawl tracks as observed by the ITI trawl instrumentation. Fisheries Research. 45(3) : 297-301.

Keywords: Trawl Instrumentation/ Trawl Positioning/ Trawl Track/ Fish Schools/ Behavior/ Sea

Abstract: Instrumentation measuring the tracks of a bottom trawl and a towed underwater vehicle relative to the track of the towing vessel was tested under varying towing conditions during a research survey in the Barents Sea in 1998. The measured mean distance between vessel and trawl track (centre of headline) varied from 27 to 213 m during the 15 hauls for which measurements were obtained. The recorded maximum distance between the tracks was 336 m. The deviance appeared to depend on vessel heading relative to wind and current and on warp length. The magnitude of the measured distance between vessel and trawl tracks may strongly affect abundance estimates based on data from trawl catches. Depending on the avoidance reactions of different species and length groups to the approaching vessel, the track of the trawl relative to that of the vessel might influence both species and size composition of the catch. Experiments quantifying the relationship between bottom trawl catches and acoustic recordings under the Vessel will be particularly exposed to errors when trawl and vessel paths diverge. The magnitude of escape responses behind a vessel during trawling has been reported to vary within limited periods and over-restricted geographical areas. These escape responses have been documented using a towed underwater vehicle without knowing the exact position of the vehicle with regards to vessel and trawl. Measurements of the positions of the vehicle with regard to the position of the vessel and trawl during this experiment showed substantial variation both between and within hauls, indicating that at least part of this variability in fish behaviour could be due to the variation in position of the vehicle.

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

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.

Enticknap, B. 2002. Trawling the North Pacific: Understanding the effects of bottom trawl fisheries on Alaska's living seafloor. Alaska Marine Conservation Council's Trawl Report. Available at: http://www.akmarine.org/trawlreport2002.pdf

Keywords: bottom trawl/ impacts/ Alaska/ Bering Sea

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/ by-catch/ 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.*

Fader, G, Pickrill, R, Todd, B, Courtney, R, and Parrott, D. 1999. The emerging role of marine geology in benthic ecology. ICES CM 1999/E:5: 83-94.

Keywords: geology/ habitat mapping/ multibeam bathymetric mapping systems/ photographic systems/ sidescan sonars/ gear impact

Abstract: Over the past decade, marine geologists have become increasingly involoved in the application of marine geoscience to biological issues of habitat characterization, gear impact assessment, and fisheries management. This new application of geoscience information is a direct result of significant advances in the resolution and accuracy of seabed mapping technologies and an understanding of complex seabed processes. Over the past ten years, major developments in seabed mapping technology have occurred that meet many of the requirements of the marine biological community. These include high-resolution sidescan sonars, multibeam bathymetric mapping systems, precise navigation, precision sampling and photographic systems, and advanses in digital data processing and scientific visualization techniques. In this paper is described recent research at GSC Atlantic utilising these seabed mapping techniques to contribute to habitat mapping, ecological research, and fisheries management.

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

Floderus, S. and Pihl, L. 1990. Resuspension in the Kattegat: Impact of variation in wind climate and fishery. Estuarine, Coastal and Shelf Science. 31(4) : 487-498.

Keywords: wind-wave interaction/ demersal fisheries/ eutrophication/ climatic changes/ trawling/ seasonal variations/ ANE, Kattegat/ resuspended sediments

Abstract: The recurrence of various agents of fine sediment resuspension in the Kattegat Sea, notably wind-induced wave action and demersal trawling, and their seasonal variation and long-term trends have been estimated. A comparison between the sediment-water interface and the spatial distribution of theoretical wind/wave impact indicated that the sediment is resuspended by further agents at depths below the permanent halocline between 10 and 20 m depth. The climatic deterioration in 1940-70 had a significant influence on the recurrence of wind-induced resuspension, although this was mostly limited to a 10-30% shortening of the recurrence period.

Fluharty, D. 2000. Habitat protection, ecological issues, and implementation of the Sustainable Fisheries Act. Ecological Applications. 10(2) : 325-337.

Keywords: Habitat protection/ Sustainable Fisheries Act

Abstract: Fishery scientists and managers and the general public are becoming increasingly aware of, and concerned about, the direct, indirect, and cumulative impacts of habitat change on commercial and recreational fisheries, and the effects of these fisheries in an ecosystem context. This set of concerns is coupled with declines in some fish stocks due to mismanagement, such as overfishing, failure to account for bycatch, or gear damage to habitats, and/or changing environmental conditions. At the same time, there are examples of management decisions and habitat restoration efforts that have led to the recovery of depleted stocks and habitats. All of this is happening in the context of new concerns about marine biodiversity, marine reserves, and application of the Endangered Species Act to marine species (e.g., salmonids with extensive riverine, and ocean habitat needs). The Sustainable Fisheries Act (SFA), passed by Congress in September 1996, and signed by President Clinton 11 October 1996, is a wake-up call that mandates, as federal policy, that fishery management move toward better incorporation of information on fish habitats and use of ecosystem approaches in management decisions. Currently, fishery managers in the National Marine Fisheries Service and the eight regional councils are in the process of adapting to these new directions. Habitat-oriented and ecosystem-based approaches offer potential solutions to some of the management problems, but they are not panaceas. Ecosystem approaches carry institutional requirements that demand major changes in research and training and require support from the user communities and the public. Ecologically sustainable fisheries are undoubtedly much different fisheries from many of those now observed. Actions to implement the SFA portend significant progress toward more sustainable fisheries and healthier ecosystems. However, major gaps exist in understanding how to manage the transition from current fishery practices to ecologically sustainable ones, and significant increases in human and fiscal resources are necessary to overcome these gaps.

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 nests 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. Catch composition of 12-m beam trawl and 4-m beam trawl for sole fishing. Pages 95-130 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

Keywords: beam trawl / benthic ecosystem/ discards/ catch composition/ sole fishing

Abstract: The catch composition of commercial beam trawls used for sole fishing has been investigated. Catches of 12-m beam trawls used in offshore areas and catches with 4-m beam trawls used in the coastal areas have been analysed and the catch efficiency of the different trawls are compared. Changes in the catch composition during repeated trawling over the same transect have been analysed. The production of dead discard materials, invertebrates and fish, by commercial beam trawling, has been estimated per hectare (ha) and per kg marketable sole. The total annual production of discards in the southern North Sea was

estimated was 270,000 tonnes dead invertebrates. The effect of sole beam trawl fishing on the benthic ecosystem,and the improtance of discards as food for scavengers, is dicussed.

Fonds, M. 1994. Mortality of fish and invertebrates in beam trawl catches and the survival chances of discards. Pages 131-146 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

Keywords: beam trawl effects/ beam trawl/ discards

Abstract: Survival experiments have been carried out with fish and invertebrates collected from the by-catch of commercial beam trawls for sole fishing. The percentage mortality of discards was very low for starfish (<10%), very high for undersized fosh (>90%) and about 30-60% for most crustaceans and shellfish. Of the latter, only whelks and hermit crabs showed a very low mortality. Mortality was lower for discards from 4-m beam trawls as compared to the much heavier 12-m beam trawls. Mortality of small animals that pass through the 8cm meshes of the nets during trawling ranges from less than 5% for starfish, 10-20% for small fish, 20-30% for crustaceans, to 40-80% for the more vulnerable shellfish.

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, conservaton 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, conservaton 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 side-scan sonar, and changes in sediment characteristics were measured using the RoxAnn seabed classification system. 3) The pressure exerted on the seabed by beam trawls is strongly related to the towing speed. As the speed increases, the lift of the gear increases and the resultant pressure force decreases. At higher speeds, the weight of the gear is fully compensated, and the trawl lifts off the bottom. 4) For the 4-m beam trawl studied, the pressure exerted by the trawl 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 side-scan sonar recordings, since the traces were too weak. 7) The movement of the gear causes the resuspension of the lighter sediment fraction. The changes are most pronounced in areas with finer sand. The suspended particles, however, settle down within a few hours. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK.*

Fonteyne, R. and Polet, H. 2002. Reducing the benthos by-catch in flatfish beam trawling by means of technical modifications. Fisheries Research. 55(1-3) : 219-230.

Keywords: Trawling/ By catch/ Zoobenthos/ Fishing gear/ Bottom trawls/ Mesh selectivity/ Checked on load

Abstract: In the flatfish beam trawl fisheries the by-catch by weight of invertebrates is several times the amount of marketable fish. In order to reduce the impact of beam trawling on the benthic communities, a number of benthos escape modifications to the trawl were tested. A drop-out opening (escape zone without

netting) and large diamond and square mesh escape zones just behind the groundrope were not effective in releasing the benthos by-catch and induced an unacceptable decrease in commercial catch. Square mesh windows inserted in the belly just in front of the cod-end were more promising. With these devices a significant reduction in weight and number of most benthic species could be realized. The penalty is some loss of commercial catch but the results indicate that with an appropriate mesh size in the square mesh window, a balance may be found between a significant benthos by-catch reduction and an acceptable loss of marketable fish. *Reprinted from Fisheries Research, Vol. 55; Fonteyne, R., Polet, H., Reducing the benthos by-catch in flatfish beam trawling by means of technical modifications; pages 219-230; Copyright (2002); with permission from Elsevier Science.*

Fossa, J. H., Mortensen, P. B., and Furevik, D. M. 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: Distribution and fishery impacts. Hydrobiologia. 471(1) : 1-12.

Keywords: Deep-water coral/ *Lophelia pertusa*/ distribution in Norway/ fishery impact

Abstract: The paper presents documentation on the distribution of, and damages to, deep-water reefs of the coral *Lophelia pertusa* in Norwegian waters. The reef areas have traditionally been rich fishing grounds for long-line and gillnet fisheries, and the coral habitat is known to support a high diversity of benthic species. Anecdotal reports claim that trawlers often use the gear, wires, chains and trawl doors to crush the corals and clear the area before fishing starts. To get an overview of the situation, information about the distribution and damage were collected from the literature, fishermen, and our own investigations. The results show that the corals are abundant particularly on the mid Norwegian continental shelf between 200 and 400 m depth. In general it seems that the largest densities are distributed along the continental break and at ridges of morainic origin. The reports from fishermen suggested severe damage to the corals and in situ observations using ROV confirmed the presence of mechanically damaged corals located on trawling grounds. A first estimate of the fishery impact indicates that between 30 and 50% of the reef areas are damaged or impacted. Fishermen claim that catches are significantly lowered in areas where the reefs are damaged. Potential ecological consequences of the destruction are discussed.

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

Fraschetti, S., Bianchi, C. N., Terlizzi, A., Fanelli, G., Morri, C., and Boero, F. 2001. Spatial variability and human disturbance in shallow subtidal hard substrate assemblages: A regional approach. Marine Ecology Progress Series. 212 : 1-12.

Keywords: Benthos/ Ecosystem disturbance/ Man-induced effects/ Mussel fisheries/ Harvesting/ Species diversity/ Environmental impact/ Spatial variations/ Lithophaga lithophaga/ Rhodophyta/ Phaeophyta/ Chlorophyta/ Porifera/ Hydrozoa/ Anthozoa/ Polychaeta/ Gastropoda/ MED, Ionian Sea/ rocky shores/ statistical analysis/ abundance/ check lists/ species

Abstract: Quantitative information about spatial patterns in subtidal hard substrate assemblages is scant. Such information is necessary to understand the responses to anthropogenic disturbances in these habitats. Along the coast of Apulia (Southern Italy), the collection of the European date mussel Lithophaga lithophaga is a strong source of disturbance: harvesting is carried out by demolition of the rocky substrate and causes epibiota disappearance. A hierarchical sampling design was used to quantify the spatial

variability of subtidal epibenthic assemblages and the extent of rock damage due to L. lithophaga harvesting along 360 km of rocky coasts in Apulia. The surveyed coast was divided into 8 adjacent sectors, and replicate samples were taken by visual inspection at each of the 3 sites nested in each sector. Multivariate analyses indicated that assemblages differed consistently with spatial scale, variability being higher at the largest scale. However, variability among sites within each sector was also detected. Patchiness (i.e., average similarity among quadrats) was consistent among sectors. Some species were identified as 'important' in characterising and/or differentiating sectors. The pattern of distribution of these species as well as total cover and number of species were analysed by analysis of variance. Results recorded a considerable source of variation at site level. Damage by L. lithophaga fishing was shown to be extremely widespread. A humped relationship between patchiness and disturbances by L. lithophaga fisheries was obtained. In particular, patchiness at a small scale was highest at 'intermediate' levels of damage, because disturbance produces patches of different size and/or age, leading to 'mosaic' landscapes of epibenthic assemblages. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

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, conservaton 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 by-catch and net damaged organisms and inputs of organic matter in the form of carcasses and offal, and indirectly through alterations in sediment characteristics, altered sediment-water column fluxes, and changes in predation rates through changed abundance and size structure of populations of predatory fish. 3) Separating the effects of fishing from other long-term sources of variation in benthic communities is difficult. However, application of a precautionary approach to ecosystem management would suggest that action needs to be taken when there is sufficient weight of evidence. 4) Current data suggest reduced abundances of long-lived bivalves and increased abundances of scavenging crustacea and sea stars in the German Bight, and altered benthic community composition on at least some fishing grounds. There are also likely to have been major changes in the predation pressure applied by fish to the benthos. This suggests that both direct and indirect effects are manifested in the most intensively fished areas of the North Sea. 5) Managers must recognize that a healthy ecosystem is a requirement and aim of existing international agreements and a prerequisite for healthy fish populations. To date, fisheries management has failed adequately to protect the target species, we should

now seek methods that also provide protection to the wider ecosystem and its functions. *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. and Hall, S. J. 1999. Inferring changes in North Sea benthos from fish stomach analysis. Marine Ecology Progress Series. 184 : 183-188.

Keywords: Benthos/ Ecosystem disturbance/ Stomach content/ Bottom trawling/ Modelling/ Limanda limanda/ ANE, North Sea/ food organisms

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

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

Abstract: In many coastal areas fishing constitutes the dominant anthropogenic impact on coastal ecosystems. That fishing has altered the abundance and size spectra of fish communities is beyond doubt. We use time series of the abundance, in the North Sea, of 8 demersal fish species and data on food consumption rates to reconstruct a time series of benthic predation pressure. The changes in fish biomass that have occurred, primarily due to fishing pressure, have led to a change in the quantity and taxonomic composition of the benthos consumed by fish predators. Such alterations in the flow of material between

ecosystem compartments are likely to cause further changes in ecosystem function as an indirect result of fishing.

Frid, C. L. J., Harwood, K. G., Hall, S. J., and Hall, J. A. 2000. Long-term changes in the benthic communities on North Sea fishing grounds. ICES Journal of Marine Science. 57(5) : 1303-1309.

Keywords: long-term effects/ benthos/ North Sea

Abstract: The North Sea has been subjected to fishing activity for many centuries. However, improvements in both fishing vessels and trawling gears since the early 1900s have meant that fishing intensity has increased. A resultant increase in the areas trawled and the use of heavier and potentially more destructive gears probably had effects on the marine community. Information on benthic communities within the North Sea, from both published and unpublished sources, has been compiled to provide a long-term data set of changes in the marine benthos on five selected fishing grounds over 60 years. In two of these (Dogger Bank and Inner Shoal), there was no significant difference in community composition between the early 1920s and late 1980s. In the remaining three areas (Dowsing Shoal, Great Silver Pit, and Fisher Bank) significant differences were observed. However, these were the result of changes in abundance of many taxa rather than large-scale losses of sensitive organisms. These results suggest that fishing has influenced benthic communities in the North Sea. The possibility remains that fishing-induced changes had occurred at the Dogger Bank and Inner Shoal prior to the 1920s. *Copyright 2000 International Council for the Exploration of the 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, U.S. 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: biatshrimp 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 bivalves: results 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., Sinclair, M., Sainsbury, K, and O'boyle, R. 2000. Symposium overview: Incorporating ecosystem objectives within fisheries management. ICES Journal of Marine Science. 57(3) : 468-475.

Keywords: marine fisheries/ fishery management/ nature conservation/ population genetics/ biodiversity/ rare species/ trophic structure/ environment management/ ecosystems/ ecosystem management/ conferences/ marine fish/ species diversity/ environmental impact/ man-induced effects/ environmental protection.

Abstract: Following an introduction to the broader context of the Symposium, the scope of the oral presentations is summarized under three themes: a global synthesis of fisheries impacts in different ecosystems; an overview of the methods available for quantifying ecosystem impacts; and the integration of fisheries and environmental management. The presentations generated substantial evidence that marine ecosystems have been impacted by fishing. Also there appeared to be a broad consensus that the present approach to achieving conservation objectives of fisheries management does not sufficiently take into account ecosystem considerations. There was not, however, a consensus on what additional restrictions are required, or on what features of ecosystems need to be protected. A way forward is to add ecosystem objectives to the conservation component of fisheries management plans, as well as to the management plans for other ocean-use sectors. The aggregate ocean-use activities would need to be evaluated in a nested manner, at a range of geographic scales, in relation to the more broadly defined conservation objectives. It is suggested that the geographic scales for evaluation of ecosystem considerations could be defined in a pragmatic manner based on the somewhat artificial boundaries of political and administrative systems already in place. The six conservation objectives proposed are maintenance of (1) ecosystem diversity, (2) species diversity, (3) genetic variability within species, (4) directly impacted species, (5) ecologically dependent species, and (6) trophic level balance. Indicators for each objective are discussed, as well as reference points that would trigger management actions. Such a broadening of conservation objectives for fisheries mangement would require both enhanced monitoring and a greater workload added to the process of provision of scientific advice through peer review. Of equal importance would be the challenges of establishing a governance framework to address multiple uses of marine resources. The spirit of the Symposium was that these coupled scientific and governance challenges will be very stimulating.

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 & 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 fisheries: an 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 harvestor 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, D., Gilkinson, K, Kenchington, E, Prena, J, Bourbonnais, C, MacIsaac, K, McKeown, D, and Vass, W. 2002. Summary of the Grand Banks otter trawling experiment (1993-1995): Effects on benthic habitat and communities. Canadian Technical Report of Fisheries and Aquatic Sciences 2416.

Keywords: otter trawling/ impacts/ Grand Banks/ benthic communities/ sandy bottom

Abstract: A three-year experiment was conducted to examine the effects of repetetive otter trawling on a sandy bottom ecosystem at a depth of 120-146 m on the Grand Banks of Newfoundland. The most pronounced impacts were the immediate effects on habitat physical structure. However, these effects were relatively short-lived since the available evidence shows that the habitat recovered in about a year or less. Except for snow crabs and basket stars, direct removal of epibenthic fauna by the otter trawl appeared to be insignificant because of its very low efficiency in catching benthic organisms. Immediately after trawling, the mean biomass of epibenthic organisms (as sampled with an epibenthic sled) was reduced on average by 24%. The most affected species were snow crabs, basket stars, sanddollars, brittle stars, sea urchins and soft corals. Both the immediate and long-term impacts of otter trawling, as applied in this experiment on the resident benthic infauna (as sampled by a large videograb) appeared to be minor. Significant effects could not be detected on the majority of species found at the study site, including all the molluscs. All available evidence suggests that the bioogical community recovered from annual trawling disturbance in less than a year, and no significant effects could be seen on benthic commmunity structure after three years of otter trawling. The habitat and biological cmmunity at the experimental site are naturallly dynamic and exhibited marked changes irrespective of trawling activity, and this natural variability appeared to over-shadow the effects of trawling.
The results of this experiment are specific to the conditions under which it was conducted (i.e. annual otter trawling on a deep sandy bottom with few structure-forming organisms), and one must be very cautious in extrapolating them to other conditions. Further research is needed to improve our knowledge of otter trawling impacts and to develop the information needed to adopt a more ecosystem-oriented approach to fisheries, habitat and oceans management. Information requirements include further gear impact experiments, improving our understanding of the role that benthic habitat and communities play in marine ecosystems, mapping benthic habitat and communities, and mapping the fine-scale spatial distribution of fishing effort. Possible management actions that should be considered to protect sensitive benthic habitat and communities include control of fishing effort, gear usage and modification, gear substitution, and area closures. *Reproduced with the permission of Her Majesty the Queen in Right of Canada, 1999, and Fisheries and Oceans Canada*.

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^{TM}, DRUMS^{TM} 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 by-catch and suspected high rates of mortality have threatened the continuation of this important trawl fishery. To address the problem, scale models of the trawl gear in present use were tested in the 22 foot wide circulating water channel and the 52 foot wide tow tank at the David Taylor Naval Ship R&D Center. This paper describes how these scale model experiments were used to study the effect of trawl design and rigging adjustments on bottom-tending performance. Through the proper selection, rigging, and operation of trawl system components, it was found that sustained contact with the bottom of most portions of the gear can be minimized. *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

Abstract: Damage to fish food species trawled over in the main area of hte North Sea plaice, cannot be serious; otherwise there would be a noticeable difference where trawling is impossible, as close to light vessels or among the under-water sand dunes. Direct attack, covering the ground some five or six times over on the average, did break full-grown heart Urchins, Echinocardium cordatum, and possibly swimming or paddler crabs (Portunus depurator), but appeared not to damage Ophiura albida, nor any of the fragile-shelled plaice food animals: razor shells, Mactra or Tellina. Those forms were not very abundan, but all the 15 specimens taken of fragile animals (other than urchins and paddlers) were undamaged. Such large urchins as were damaged were not plaice food. Doubtless Sabellaria habitations (ross) would be broken and laid low, but they would probably soon be3 reconstructed. Trawling, even with a tickler chain, seems again to escape the so viable indictment.

Grant, J. 2000. Modelling approaches to dredging impacts and their role in scallop population dynamics. Pages 27-36 *in* A workshop examining potential fishing effects on population dynamics and benthic commuity structure of scallops with emphasis on the weathervane scallop *Patinopecten caurinus* in Alaskan waters. Alaska Department of Fish and Game, Division of Commercial Fisheries, Special Publication 14, Juneau, AK .

Keywords: scallop fisheries/ scallop dredging/ target species/ dredging impacts/ *Patinopecten caurinus*/ Alaska

Summary: This paper addresses the weathervane scallop *Patinopecten caurinus* fishery in Alaska, and particularly fishing gear impacts on target individuals that do not make up part of the catch. Unlike other commercially important bivalve species, scallops are a rather "delicate" species that cannot burrow or tightly close. This paper attempts to quantify some of the impacts of scallop dredging on *Patinopecten caurinus* populations and incorporate them into a yield per recruit model of a scallop cohort.

Gray, J. S. 2000. Effects of trawling on the coastal environment: the need for management action. Marine Pollution Bulletin. 40(2) : 93.

Keywords: trawling effects/ coastal environment/ management

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 seas: patterns 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.*

Gregory, R. S. 1990. Effects of turbidity on benthic foraging and predation risk in juvenile chinook salmon. Pages 64-73 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.

Keywords: turbidimetry/ surveys/ feeding behaviour/ predation/ juveniles/ biological surveys/ estuaries/ Oncorhynchus tshawytscha/ Tubifex/ dredging/ environmental impact/ turbidity

Abstract: The foraging behavior of juvenile chinook salmon (Oncorhynchus tshawytscha) in conditions of elevated turbidity was investigated in a series of laboratory experiments. These experiments determined the reaction distance to invertebrate prey, the perceived risk to a model predator, and the foraging rate of chinook on benthic Tubifex worms, in turbidity conditions ranging from 0 to 800 mg/L. Both reaction distance and perceived risk declined inversely with turbidity. Foraging rates on Tubifex were highest at intermediate levels (50-200 mg/L) and lowest at 0 mg/L (control) and 800 mg/L. The results suggested a tradeoff between the effects of reduced reaction distance and perceived risk to predation. The pertinence of these findings to the impact of dredging-induced increases in suspended sediment level on seaward migrating juvenile salmonids was discussed.

Gristina, M, Garofalo, G., Bono, G, and Levi, D. 2000. Effects of commercial trawl fishing in the Strait of Sicily on the diversity of demersal resources. ICES-CM-2000/mini (Poster):13 : 6 p.

Keywords: Bottom trawls/ Fisheries/ Rare species/ Merluccius merluccius/ Parapenaeus longirostris/ MED, Italy, Messina Strait

Abstract: The effects produced by commercial trawl fishing on the diversity of demersal resources in two zones of the Straits of Sicily subject to different fishing effort were analysed. Data were available from a total of 79 hauls, carried out annually in autumn 1997 and 1998 between 200 and 400 meter depth and pertained to the bathyal muddy bottoms biocenosis (Peres and Picard, 1964) on the whole. Data on fishing effort, recorded since 1995, come from the Harbour Office and have been verified from interviews to crews and captains of Mazara del Vallo trawl fisheries. Excluding pelagic and rare (appearing in <= 5% of hauls) species from the analysis, diversity indices, cluster analysis, K-dominance and size spectra were investigated. The cluster analysis (employing the Bray-Curtis similarity matrix among species) shows the presence of two distinct groups of hauls corresponding to the areas with different fishing effort. High values of the main diversity indexes seem to characterize the hauls subject to a maze intensive fishing effort. K-dominance curves for the two areas show that, in "Zone 1" the main part of the catch is concentrated on commercial species (Merluccius merluccius, Parapenaeus longirostris), while in "Zone 2" the catch is

mainly characterized by massive species, Elasmobranchs and Crustaceans with low or null commercial value.

Groenewold, S. and Fonds, M. 2000. Effects on benthic scavengers of discards and damaged benthos produced by the beam-trawl fishery in the southern North Sea. ICES Journal of Marine Science. 57(5) : 1395-1406.

Keywords: scavengers / discards/ benthos/ beam trawl/ North Sea

Abstract: The beam-trawl fishery for flatfish produces large amounts of dying discards as well as damaged and disturbed benthos. The importance of these food sources to scavenging benthic species was investigated. To identify epibenthic species showing scavenging behaviour and to detect their food preferences, traps (370 overall) baited with different kinds of carrion (fish, crustaceans, molluscs, echinoderms, polychaetes) were deployed at 14 locations in the southern North Sea. *Liocarcinus holsatus*, *Pagurus bernhardus*, *Asterias rubens*, ophiurids, and small gadoids were the main active scavengers feeding on different kinds of food, while lyssianid amphipods (*Orchomene nanus*, *Scopelocheirus hopei*) fed mainly on crustacean carrion. Estimated attraction areas were largest for gadoids, hermit crabs, and swimming crabs. Immigration of fish and swimming crabs into experimentally trawled areas was observed by sampling repeatedly in a trawled strip. Differences in the response to trawling (feeding activity, food niche breadth, and resource partitioning) between selected fish species are described. *Limanda limanda*, *Pleuronectes platessa*, *Merlangius merlangus*, *Callionymus lyra*, and *Eutrigla gurnardus* all showed strong responses, using different feeding strategies. *In situ* clearance rates of dead discarded fish exposed on the sea floor were estimated. Discards as well as moribund benthos were consumed within a few days. The balance between the amount of food materials produced by beam-trawl fishery and the amount of food consumed by potential scavengers was translated in a model of the food flows as mobilized by beam trawling. In general, the direct importance of the additional food resource for populations of scavengers is considered to be relatively small. However, the importance may be relatively larger for scavenging fish than for invertebrates. It is estimated that after a single beam trawling about 1.27g m-2ash-free dry biomass, or 6% to 13% of the annual secondary production of macrobenthos per unit area, would suddenly become available to scavengers and to the detritus food chain. It is suggested that beam trawling leads to shortcuts in trophic relationships and therefore may enhance secondary production. *Copyright 2000 International Council for the Exploration of the Sea*.

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

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. (In press). Global distribution and ecological significance of bottom-fishing disturbance. ICES Journal of Marine Science.

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 Sea: An 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. 1998. Conservation issues relating to maerl beds as habitats for molluscs. Journal of Conchology. Suppl. 2 : 271-285.

Keywords: maerl beds/ mollusca/ commercial exploitation/ scallop dredges/ conservation

Abstract: Maerl beds are little studied shallow marine habitats that have a patchy distribution around the British Isles. They ale mixed sediment deposits built by a surface layer of slow growing coralline seaweeds that are of international conservation significance. Baseline information is provided on the high diversity and abundance of mollusc assemblages associated with Scottish maerl deposits. Commercial extraction and the use of towed demersal fishing gears kills the plants upon which survival of this habitat depends. The molluscan fauna of a site impacted by scallop dredging is compared with that of an unimpacted site. The need to conserve maerl habitats is highlighted as there is concern over the extent to which maerl beds are being disturbed in Europe and how activities such as scallop dredging affect the ecology of these fragile nearshore habitats.

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 by-catch species only formed 19% of total catch by weight. Of the 78 taxa caught, lethal mechanical damage varied from <10% in resilient taxa such as hermit crabs to >50% in soft-bodied organisms such as tunicates. A marked plot surveyed using towed UWTV before, then 1 and 15 h after fishing by Rapido trawl showed clear tracks of disturbed sediment along the trawl path where infaunal burrow openings had been erased. Abundant, motile organisms such as *Aequipecten* showed no change in abundance along these tracks although scavengers such as Inachus aggregated to feed on damaged organisms. There were significant decreases in the abundance of slow-moving/sessile benthos such as *Pecten* , *Holothuria*, and *Atrina*. Juvenile pectinids were abundant on the shells of *Atrina*. The introduction of a scheme of areas closed to trawling would protect highly susceptible organisms such as *Atrina* and enhance the chances of scallop recruitment to adjacent areas of commercial exploitation.

Hall-Spencer, J. M. and 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.*

Hall-Spencer, J. M. and Moore, P. G. 2000. Scallop dredging has profound, long-term impacts on maerl habitats. ICES Journal of Marine Science. 57(5) : 1407-1415.

Keywords: scallop dredging/ environmental impacts/ maerl habitat

Abstract: Maerl beds are mixed sediments built by a surface layer of slow-growing, unattached coralline algae that are of international conservation significance because they create areas of high biodiversity. They are patchily distributed throughout Europe (to ~30m depth around the British Isles and to ~120m depth in the Mediterranean) and many are affected by towed demersal fishing. We report the effects of Newhaven scallop dredges on a previously unfished maerl bed compared with the effects on similar grounds that have been fished commercially in the Clyde Sea area, Scotland. Sediment cores were taken to assess the population density of live maerl thalli prior to scallop dredging on marked test and control plots. These plots were then monitored biannually over a four-year period. Live maerl thalli were sparsely distributed at the impacted site, and experimental dredging had no discernible effect on their numbers. The previously unfished ground had dense populations of live maerl and scallops (both *Aequipecten opercularis* and *Pecten maximus*). While counts of live maerl remained high on the control plot, scallop dredging led to a >70% reduction with no sign of recovery over the subsequent four years. The vulnerability of maerl and associated benthos (e.g., the delicate bivalve, *Limaria hians*) is discussed in relation to towed demersal fishing practices. *Copyright 2000 International Council for the Exploration of the Sea.*

Hamilton, A. N. 2000. Gear impacts on essential fish habitat in the Southeastern region. unpublished manuscript. National Marine Fisheries Service, NOAA, SEFSC, 75 Virginia Beach Drive, Miami, Florida 33149. 37 p.

Keywords: essential fish habitat/ Sustainable Fisheries Act / gear impacts/ South Atlantic/ Caribbean/ countermeasures/ shrimping

Summary: This report is a summary of the Southeast Fisheries Science Center's (SEFSC) December 1999 workshop on gear impacts on essential fish habitat (EFH). The agenda included the following topics: Importance of the Essential Fish Habitat Initiative and NMFS mandates for action; The need for collaboration from EFH participants; EFH background events and a definition of terms as in the Magnuson-Stevens Act and the Sustainable Fisheries Act of 1996; The status of gear impact science in the southeast; The South Atlantic, Caribbean and Gulf Councils fishery management plans allowable gears; Existing fishing impact countermeasures; Shrimping effort.

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

Hanson, C. H. and Walton, C. P. 1990. Potential effects of dredging on early life stages of striped bass (*Morone saxatilis*) in the San Francisco Bay area: An overview. Pages 38-56 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific Coast Fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.

Keywords: ecosystem disturbance/ developmental stages/ turbidity/ fry/ hatching/ anadromous migrations/ spawning/ resuspended sediment/ ecosystems/ turbidimetry/ San Francisco Bay/ California, Sacramento-San Joaquin Delta/ Morone saxatilis/ INE, San Francisco Bay/ INE, USA, California, Sacramento-San Joaquin Delta/ dredging

Abstract: Potential relationships between exposure to increased suspended sediment concentrations and striped bass (Morone saxatilis) hatching success, larval foraging, and adult migration and spawning in San Francisco Bay and the Sacramento-San Joaquin Delta, USA, were examined. Very little documented, quantitative information is available on the potential effects on striped bass resulting from exposure to increased turbidity and suspended sediment concentrations associated with either dredging activity or dredge spoil disposal practices. The limited information that is available suggests that striped bass are not effected adversely by exposure to increased suspended sediments at the concentrations encountered. This conclusion is consistent with the observation that striped bass have been able to establish an abundant population in San Francisco Bay and the Sacramento-San Joaquin Delta system - an environment characterized by high naturally occurring suspended solids concentrations and high turbidity conditions.

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

Keywords: trawling/ disturbance/ benthic assemblage/ environmental impact/ variability

Summary: Hypotheses about effects of shrimp-trawling on large benthic macrofauna were tested in a manipulative experiment in Gullmarsfjorden, Sweden. The experiment lasted 1.5 yr and included 3 trawl sites and 3 control sites, each of which was sampled at 4 times before and 4 times after trawling was commenced (a total of 480 samples). Gear and intensities were chosen to approximate those before trawling was prohibited 6 yr before the experiment. The overall trend was that biomass and abundances of animals decreased as a consequence of trawling but few taxa differed significantly among treatments. The mean abundance of echinoderms, in particular the brittlestars *Amphiura* sp., decreased significantly and substantially after 7 to 12 mo of trawling. In general, however, changes in abundances of animals from one time of sampling to another, and from before to after trawling started, differed among sites. General models

based on size and feeding strategy did not accurately predict differences among taxa in sensitivity to disturbances. Differences in overall impacts between this and previous experiments are discussed in terms of fishing intensity, natural variability and experimental design. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

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. 1976. The effects of oyster shell dredging on the biota of the Arkansas National Wildlife Refuge. Pages 221-231 *in* A.H. Bouma (ed.), Shell dredging and its influence on Gulf coast environments. Gulf Publishing Company, Houston, Texas.

Keywords: oyster/ shell dredging/ effects/ Aransas National Wildlife Refuge

Abstract: This study was designed to detect ossible changes in biota, caused by shell dredging activities in San Antonio Bay, on the east and south sides of the Aransas National Wildlife Refuge in particular, and on the margins of San Antonio Bay in general. It was suspected that rooted aquatic and wetland vegetation and the associated terrestrial and aquatic fauna might be affected. Direct effects, such as removal of productive bottoms, were unlikely because the dredges are not permitted to operate less than one mile from shore. It seemed possible, however, that dredge silt could be deposited along the refuge margin and effect biotic changes.

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

Abstract: This study on the effects of oyster shell dredging on the macrofauna of San Antonio Bay involvoed three phases: (1) a study of the seasonal and areal distribution of macrobenthic and nektonic populations on undredged bottom; (2) a comparison of the fauna inhabiting dredg cuts with the fauna on undredged control bottoms to determine the effects of prior dredging operations; and (3) a study of the effects on the fauna of siltation and turbidity generated by a dredge.

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. *Copyright 2000 International Council for the Exploration of the Sea.*

Heessen, H. J. L., Dalskov, J., and Cook, R. M. 2000. The International Bottom Trawl Survey in the North Sea, Skagerrak and Kattegat: A history of one of the "ancestors" of MEDITS. Proceedings of the symposium on assessement of demersal resources by direct methods in the Mediterranean and the adjacent seas, Pisa (Italy), 18-21 March 1998. Ressources halieutiques en Mediterranee, Pisa (Italy), 18-21 Mars 1998, Ifremer, Plouzane (France), Actes de colloques. Institut Francais de Recherche pour l'Exploitation de la Mer. Brest. 26 : 13-36.

Keywords: Fishery surveys/ Bottom trawls/ Bottom trawling/ Fishing gear/ Clupeoid fisheries/ Catching methods/ Catch composition/ Melanogrammus aeglefinus / Gadus morhua/ Merlangius merlangus euxinus/ Trachurus trachurus/ Scomber scombrus/ Trisopterus esmarkii/ Ammodytidae/ Pollachius virens/ Clupea harengus/ Sprattus sprattus/ ANE, North Sea/ age at recruitment/ Haddock/ Atlantic cod/ Pollock/ Atlantic herring/ Atlantic mackerel/ Horse mackerel/ Sand lances/ Norway pout

Abstract: Since its start in 1966 as "a pilot-study for future young herring research in the North Sea", the International Bottom Trawl Survey has been conducted annually, and evolved from a specific herring recruit survey into a much more general 'ffish survey'. The survey provides primarily information which is used by ICES stock assessment working groups and which consists of abundance indices for recruiting year classes of several commercial fish species and data used for tuning the VPA. In addition, the results are used in a wide variety of studies, varying from investigations of the changes in growth and maturity of certain species, to studies into the ecosystem effects of fisheries. The paper describes the history of the survey, its current objectives and methods, and the use that is made of the survey results, both in assessments and in the study of the ecosystem effects of fishing.

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 Sant 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., Brand, A. R., Veale, L. O., and Hawkins, S. J. 1997. Assessment of the effects of scallop dredging on benthic communities. Final Report to Ministry of Agriculture, Fisheries and Food, U.K. (Contract CSA 2332).

Keywords: scallop dredging/ scallop fishery

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-commerical 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* .

Hoffman, E. and Dolmer, P. 2000. Effect of closed areas on distribution of fish and epibenthos. ICES Journal of Marine Science. 57(5) : 1310-1314.

Keywords: closed areas/ recovery/ distribution/ epibenthos

Abstract: The high blue mussel catches in fjord system in Denmark, the visible effects of dredging by resuspension of bottom sediment and the possible destruction of benthic flora and fauna have all raised concerns about the impact on the ecosystem. As a consequence, a formerly lucrative blue mussel fishing area in the fjord was closed on dredging in 1988. This made it possible to investigate changes in the distribution of fish and benthos based experimental fishing with trawl, set net traps, and scuba diving during 1981-1998. The investigations showed no long-term effects of mussel dredging on the distribution of fish and epibenthic invertebrates, and the closed area appeared to have had no influence on the demersal fish and epibenthic fauna. Factors other than mussel dredging appear to determine the observed spatial and temporal variability in the ecosystem.

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 prominant 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.

Hopkins, S. H. and McKinney, L. D. 1976. A review of the literature pertaining to the effects of dredging on oyster reefs and their associated faunas. Pages 3-12 *in* A.H. Bouma (ed.), Shell dredging and its influence on Gulf coast environments. Gulf Publishing Company, Houston, Texas.

Keywords: effects/ dredging/ oyster reefs/ literature review

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

Hughes, S. E. and Nelson, R. W. 1979. Distribution, abundance, quality, and production fishing studies on the surf clam, *Spisula polynyma*, in the Southeastern Bering Sea, 1978. NWAFC Processed Report 79-4., 31 p. + appendix U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115

Keywords: clam dredging/ sleds/ habitat impacts/ S.E. Bering Sea

Summary: This report follows the second and final season (August 1978) of field research aimed at assessing the potentials of a surf clam fishery in the southeastern Bering Sea. Efforts of the 1978 season emphasized production fishing and environmental impact studies. Additional aspects of the overall study initiated in 1977 and continued in 1978 included a second resource-assessment survey, analyses for paralytic shellfish poison, collection of biological data required for resource management decisions, and expanded studies to determine processing and product quality.

Hughes, S. E., Nelson, R. W., and Nelson, R. 1977. Initial assessments of the distribution, abundance, and quality of subtidal clams in the S.E. Bering Sea. NWAFC Processed Report. 43 p. + appendix. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest and Alaska Fisheries Center, 2725 Montlake Boulevard East, Seattle, WA 98112. 43 (+ appendix) p.

Keywords: clam dredging/ sleds/ habitat impacts/ S.E. Bering Sea

Summary: This report was the result of a joint industry/government venture conducted to assess subtidal clam resources in the S.E. Bering Sea. Primary impetus for the venture was the need for additional clam meat supplies due to shortages faced by the U.S. chowder and strip industries, which stemmed from deterioration of Atlantic surf clam landings. The three major goals of the venture were to 1) determine if resource potential and quality exists to support a fishery in the Alaska "surf" or "pink neck" clam (*Spisula polynyma*), 2) obtain biological data required for management and regulatory decisions, and 3) examine some possible short-term effects that such a fishery might place on the environment

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/ trends / species interaction/ long-term effects

Summary: Sections of report include: Quantification of the direct impacts of fishing activities; Trends in fishing effort and type of fishing; Influence of anthropogenic activities other than fishing; Comparing the direct impacts of fishing with the impacts of other anthropogenic influences and natural processes; Species interaction effects and other long-term effects of fishing activities; Possible management conflicts and compromises.

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/ management

Summary: Sections of report include: Overview of Long-term Changes; Quantification of the Direct Impacts of Fishing Activities; Influence of Anthropogenic Activities other than Fishing; Comparing the Direct Effects of Fishing With the Effects of other Anthropogenic Influences and Natural Processes; Long-term Effects of Fishing Activities; Possible Management Objectives, Conflicts and Solutions.

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

Summary: Report contains an inventory of ongoing research related to ecosystem effects of fishing activities as reported by members of the Working Group. The scope of this research is wide and overlap with other Working andStudy Groups is difficult to avoid.

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/ indicator/ indicator species/ closed areas/ discards/ offal

Summary: Sections of report include: Discards and Offal; Indicator Organisms; Analysis of summary parameters; Areas closed to fishing.

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/ communities/ non-target fish populations/ vulnerability/ discards

Summary: Sections of report include: Communities and assemblages; non-target fish populations; Quantifying vulnerability; Effects of reducing fish mortality; Estimating discards and their utilization.

ICES. 2000. Effects of different types of fisheries on North Sea and Irish Sea benthic ecosystems: Review of the Impact II Report. Extract from the 2000 Report of the Advisory Committee on the Marine Environment.

ICES. 2000. The impact of fishing disturbance on benthic nutrient regeneration and flux rate. ICES, Copenhagen (Denmark). 20 p.

Keywords: Ecosystem disturbance/ Energy transfer/ Zoobenthos/ Bottom trawls/ ANE, Atlantic/ primary production/ nitrogen cycle

Summary: Nitrogen products are often thought to be a major limiting factor for photosynthesis by marine primary producers, ultimately, therefore, fisheries yield is dependent on the amounts of new and regenerated nutrients within the system. It is generally held that greater than 90% of marine primary production is remineralised within the marine system. However, the contribution to this figure from sedimentary processes is less well understood. Little attention has, however, been paid to the potential change in nutrient regeneration dynamics and flux rates as a result of fishing disturbance of the seafloor. This study investigates benthic remineralisation and nutrient flux, including consideration of the role of benthic disturbance by fishing vessels. Two mesocosm systems containing sediment from an untrawled area of the North Sea were allowed to stabilise for two months prior to the study. One system was subjected to daily simulated trawl actively while the other system remained untrawled over a four day period. Flux chambers were used to gain data on concentration changes within the chambers for three hours following the 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/ ecosystem models

Abstract: Sections of the report include: Review of ecosystem models as basis for choosing metrics of ecosystem status and evaluating indirect effects of fishing; Ecosystem effects of fishing activities in the

baltic sea; bottom trawl impacts on the benthos in the North Sea and Irish Sea; Ecosystem management objectives.

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, U.S. 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.

Jenkins, S. R., Beukers-Stewart, B. D., and Brand, A. R. 2001. Impact of scallop dredging on benthic megafauna: A comparison of damage levels in captured and non-captured organisms. Marine Ecology Progress Series. 215 : 297-301.

Keywords: Benthos/ Dredging/ Biological damage/ Statistical analysis/ Abundance/ Cancer pagurus/ Asterias rubens/ Neptunea antiqua/ ANE, Isle of Man, Bradda Inshore/ by catch/ fishing mortality / RV: Roagan/ Pecten/ Epifauna

Abstract: The impact of scallop dredging on benthic megafauna was assessed by direct observation of damage, both in the bycatch and in organisms encountering dredges but not captured. Damage was assessed using a simple 4-point scale adapted for different taxonomic groups. Experimental dredging was undertaken on a scallop fishing ground in the north Irish Sea, off the Isle of Man. Divers were deployed immediately after dredges had passed, to record levels of damage to megafauna left in the dredge tracks. Mean damage levels, and the proportions of the 4 damage scores in the bycatch and on the seabed, were the same in most species. Some common species did show differences. The edible crab Cancer pagurus was more severely

damaged when not captured, while the starfish Asterias rubens and whelk Neptunea antiqua received greater damage within the bycatch. Capture efficiency for the megafauna was low, ranging from 2 to 25% among species. The results indicate that the majority of damage to large benthic invertebrates during scallop dredging occurs unobserved on the seabed, rather than in the bycatch. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

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 disturbanc 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 seas: patterns in fishing effort, diversity and community structure. III. International trawling effort in the North Sea: an analysis of spatial and temporal trends; pages 125-134; Copyright (1999); with permission from Elsevier Science.*

Jennings, S, Dinmore, T, Duplisea, D, Warr, K, and Lancaster, J. 2001. Trawling disturbance can modify benthic production processes. Journal of Animal Ecology. 70(3) : 459-475.

Keywords: Trawling/ Disturbance/ benthic habitat/ community structure/ production/ size differences/ eqifauna

Abstract: 1. Trawling disturbance has wide-ranging impacts on the marine environment and is well known to modify benthic habitat and community structure. This has led to speculation about the positive and negative impacts of trawling on ecosystem processes such as production.
2. Existing theory suggests that frequent trawling disturbance may lead to the proliferation of smaller benthic species, with faster life histories, because they can withstand the mortality imposed by trawling and benefit from reduced competition or predation as populations of larger species are depleted. Since smaller species are more productive, trawling disturbance may 'farm the sea', with knock-on benefits for consumers, including fish populations.
3. We conducted the first large-scale studies of trawling effects on benthic production across quantified gradients of trawling disturbance on real fishing grounds in two regions (Silver Pit and Hills) of the North Sea. There were 27- and 10-fold differences in levels of beam trawl disturbance among the Silver Pit and Hills sites, respectively.
4. Size structure was described using normalized size-spectre, and the slopes and intercepts of these spectra were related to levels of trawling disturbance. Production was estimated from the size spectra, using a new allometric relationship between body mass and the production to biomass (P:B) ratio of marine invertebrates. The general validity of the relationship was confirmed using a phylogenetic comparative approach.
5. In the Silver Pit region, trawling led to significant decreases in infaunal biomass and production. The abundance of larger individuals was depleted more than smaller ones, as reflected by the positive relationship between the slope of the normalized size spectra and trawling disturbance. The effects of trawling disturbance were not significant in the epifaunal community. In the Hills region, where the range of trawling disturbance was lower, trawling disturbance did not have significant effects on biomass or production.
6. In the Silver Pit, relative infaunal production (production per unit biomass) rose with increased trawling disturbance. This was attributable largely to the dominance of smaller animals in the disturbed communities. The increase in relative production did not compensate for the loss of total production that resulted from the depletion of large individuals. There was some evidence for the proliferation of small polychaetes at moderate levels of disturbance, but at higher levels of disturbance their biomass and production fell.
7. We conclude that reported increases in the biomass and production of small infaunal invertebrates in the North Sea are attributable largely to recent increases in primary production that were driven by climate change, and not to the effects of trawling disturbance. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK and the Journal of Animal Ecology*.

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., Pinnegar, J. K., Polunin, N. V. C. , and Warr, K. J. 2001 . Impacts of trawling disturbance on the trophic structure of benthic invertebrate communities. Marine Ecology Progress Series. 213 : 127-142.

Keywords: North Sea/ Fishing Effects/ Benthic Infauna/ Benthic Epifauna/ Trophic Relationships/ Stable Isotopes/ Community Structure/ Beam Trawling/ Food Webs/ Southern North-Sea/ Long-Term Changes/ Fishing Disturbance/ Different Habitats/ Stable Isotopes/ Food Webs/ Nephtys-Hombergii/ Arctica-Islandica/ Delta-N-15/ Abundance

Abstract: Bottom trawling causes chronic and widespread disturbance to the seabed in shallow shelf seas and could lead to changes in the trophic structure and function of benthic communities, with important implications for the processing of primary production and the wider functioning of the marine ecosystem. We studied the effects of bottom trawling on the trophic structure of infaunal and epifaunal benthic communities in 2 regions (Silver Pit and Hills) of the central North Sea. Within each region, we quantified long-term (over 5 yr) differences in trawling disturbance at a series of sites (using sightings data from fishery protection flights), and related this to differences in the biomass and trophic structure of the benthic community. There were 27- and 10-fold differences in levels of beam trawl disturbance among the Silver Pit and Hills sites respectively, and we estimated that the frequency with which the entire area of the sites was trawled ranged from 0.2 to 6.5 times yr(-1) in the Silver Pit and 0.2 to 2.3 times yr(-1) in the Hills. The impacts of fishing were most pronounced in the Silver Pit region, where the range of trawling disturbance was greater. Infaunal and epifaunal biomass decreased significantly with trawling disturbance. Within the infauna, there were highly significant decreases in the biomass of bivalves and spatangoids (burrowing sea-urchins) but no significant change in polychaetes. Relationships between trophic level (estimated using nitrogen stable isotope composition, delta N-15) and body mass (as log(2) size classes) were rarely significant, implying that the larger individuals in this community did not consistently prey on the smaller ones. For epifauna, the relationships were significant, but the slopes or intercepts of the fitted linear regressions were not significantly related to trawling disturbance. Moreover, mean delta N-15 Of the sampled infaunal and epifaunal communities were remarkably consistent across sites and not significantly related to trawling disturbance. Our results suggest that chronic trawling disturbance led to dramatic reductions in the biomass of infauna and epifauna, but these reductions were not reflected in changes to the mean trophic level of the community, or the relationships between the trophic levels of different sizes of epifauna. The trophic structure of intensively trawled benthic invertebrate communities may be a robust feature of this marine ecosystem, thus ensuring the efficient processing of production within those animals that have sufficiently high intrinsic rates of population increase to withstand the levels of mortality imposed by trawling.

Jennings, S. and Polunin, N. V. C. 1996. Effects of fishing effort and catch rate upon the structure and biomass of Fijian reef fish communities. Journal of Applied Ecology. 33(2) : 400-412.

Keywords: Fiji/ fishing/ biomass/ community structure/ Pisces/ coral reefs/ sustainable development/ fishing effort/ catch/ effort/ reef fish/ community composition/ ISEW, Pacific, Fiji/ reef fisheries/ man-induced effects

Abstract: An improved understanding of fishing effects is required to assess the sustainability of existing fishing practices and to determine the ecological implications of offering fishing concessions in marine reserves. The effects of fishing were investigated in six Fijian fishing grounds (qoliqoli) subject to different fishing intensities. A visual census technique was used to determine the structure and biomass of the shallow-water reef fish communities targeted by the fishers. A supervised voluntary logbook scheme was used to assess the size and composition of yield from the qoliqoli. The fish communities in the least intensively fished qoliqoli were significantly different from fish communities elsewhere. The significance of these differences was attributable to the greater biomass of invertebrate feeding and piscivorous fishes in the least intensively fished qoliqoli. Annual yields of herbivorous fishes ranged from 0.3 to 5.2% of the biomass estimated by visual census. There were no significant differences in herbivore biomass among qoliqoli subject to different fishing intensities. The biomass of invertebrate feeding fishes was significantly higher in the least intensively fished qoliqoli. The biomass of invertebrate feeding/piscivorous fishes was significantly higher in the two least intensively fished qoliqoli. In the two least intensively fished qoliqoli the estimated annual yields of invertebrate feeding and invertebrate feeding/piscivorous fishes did not exceed 4% of the biomass estimated by visual census. However, yields of these trophic groups approached 20% of biomass in the intensively fished qoliqoli where biomass was significantly lower. The fishing effects observed were primarily attributed to significant differences between the fish communities in the least intensively fished qoliqoli and all others. Thus, at higher fishing intensities, the biomass of target species provided a poor index of relative fishing pressure. The results suggest that the annual removal of 5% of fish biomass may cause significant structural changes in reef fish communities. Thus, it is important to ensure that fishing concessions and poaching activities are carefully regulated in marine reserves. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK and the Journal of Applied Ecology*.

Jennings, S. and Polunin, N. V. C. 1996. Impacts of fishing on tropical reef ecosystems. Ambio. Stockholm. 25(1) : 44-49.

Keywords: tropical environments/ environment management/ coral reefs/ ecosystems/ sustainable development/ reef fisheries/ artisanal fishing/ ecosystem disturbance/ overfishing/ environmental impact/ fishery management/ fishing

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

Jennings, S. and Polunin, N. V. C. 1997. Impacts of predator depletion by fishing on the biomass and diversity of non-target reef fish communities. Coral Reefs. 16(2) : 71-82.

Keywords: Man-induced effects/ Reef fisheries/ Food webs/ Trophic structure/ Predation/ Coral reefs/ Reef fish/ Species diversity/ Census/ Fishery management/ Nature conservation/ Chaetodontidae/ Labridae/ Lutjanidae/ Mullidae/ Scaridae/ Epinephelinae/ ISEW, Pacific, Fiji/ Biomass

Abstract: An understanding of the indirect effects of fishing on predator-prey relationships is required for the development of valid multispecies yield models for reef fisheries and for determining the factors

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

Jennings, S. and 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, K. 2002. A review of national and international literature on effects of fishing on benthic habitats. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-57; 72 p.

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. Sediments in the Port Botany harbour area are expected to become progressively more muddy. Water turbidity in turn may increase as a result of resuspension of fine material by shipping movements. *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 side-scan sonar survey revealed that the observed abundance of trawl marks correlated with the reported levels of fishing at the sampling locations. The incidence of starfish, of both species, with damaged or regenerating arms increased with increasing fishing intensity. The severity of damage, i.e. the number of regenerating arms, also increased with fishing intensity. The proportion of starfish with damaged or regenerating arms may provide a useful short-term (1 to 2 yr) biological 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, conservaton 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^{TM} 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., Broad, G., and Hall, S. J. 2001. Disturbance of intertidal soft-sediment benthic communities by cockle hand raking. Journal of Sea Research. 45(2) : 119-130.

Keywords: Gastropod fisheries/ Man-induced effects/ Zoobenthos/ Ecosystem disturbance/ Intertidal environment/ Cerastoderma edule

Abstract: Recent awareness of the ecosystem effects of fishing activities on the marine environment means that there is a pressing need to evaluate the direct and indirect effects of those activities that may have negative effects on non-target species and habitats. The cockle, Cerastoderma edule (L.) is the target of a commercial and artisanal fishery that occurs in intertidal and estuarine habitats across Northern Europe. Cockles are harvested either mechanically using tractor dredges or suction dredges or by large numbers of individual fishers using hand rakes. This study examined the effects of hand raking on the non-target species and under-sized cockles associated with intertidal cockle beds and the effects of size of the patch of sediment disturbed on subsequent recolonisation. Hand raking led to an initial three-fold increase in the damage rate of under-sized cockles compared with control plots. The communities in both small and large raked plots showed community changes relative to control plots 14 days after the initial disturbance. The small raked plots had recovered 56 days after the initial disturbance whereas the large raked plots remained in an altered state. Samples collected over a year later indicated that small-scale variations in habitat heterogeneity had been altered and suggest that while effects of hand raking may be significant within a year, they are unlikely to persist beyond this time-scale unless there are larger long-lived species present within the community. *Reprinted from Journal of Sea Research, Vol. 45; Kaiser, M.J., Broad, G., Hall, S.J., Disturbance of intertidal soft-sediment benthic communities by cockle hand raking., pages 119-130; Copyright (2001); with permission from Elsevier Science.*

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 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; 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 by-catch than beam trawls. Multivariate analysis revealed that both gears modified the benthic community in a similar manner, causing a reduction in the abundance of most epifaunal species. 4) Although beam trawling disturbed the greatest area of seabed in 1994, the majority of effort occurred on grounds which supported communities that are exposed to high levels of natural disturbance. Scallop dredging, *Nephrops* and otter trawling were concentrated in areas that either have long-lived or poorly studied communities. The latter highlights the need for more detailed knowledge of the distribution of sublittoral communities that are vulnerable to fishing disturbance.

Kaiser, M. J. 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 intertitdal 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 by-catch of commercial flatfish fisheries, and a large proportion of these die, they remain the most abundant flatfish species in the North Sea. Fisheries have selectively removed species that prey upon or compete with dab. Furthermore, fishing activity increases feeding opportunities for dabs. These factors may have contributed to the observed increase in the abundance of dab in the North Sea. *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/ populations

Abstract: Marine fisheries have resulted in large-scale manipulations of predator populations. The practice of discarding by-catch, under-sized fishes and offal from trawlers has led to an increase in the populations of certain scavenging bird species. The greatest population increases have occurred in the most aggressively competitive species, while some subordinate species have decreased in abundance. Several recent studies indicate that a similar situation may exist for epibenthic scavengers. We explore the possibility that enhanced food supply in the form of fisheries-generated carrion may affect the competitive balance between sympatric populations of hermit crabs, Pagurus bernhardus and P. prideaux. Under normal conditions, both species have overlapping diets and occur in equal abundance at the site studied. In laboratory investigations both species consumed the same types of carrion. However field observations revealed that while P. bernhardus aggregate in areas disturbed by trawls where they consume animals damaged in the trawl path, P. prideaux do not. Morphometric analyses revealed that P. prideaux have smaller chelae relative to P. bernhardus. Thus, P. prideaux may avoid dense aggregations of P. bernhardus which are more aggressive. These behavioural differences, coupled with higher fisheries mortality for P. prideaux, may provide a mechanism whereby P. bernhardus could outcompete P. prideaux in areas were fishing disturbance and discarding occur frequently.

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

Keywords: abundance/ biomass curves/ bivalves/ chronic fishing disturbance/ seabed/ shell scarring

Abstract: 1. Bottom fishing using towed nets and dredges is one of the most widespread sources of physical disturbance to the continental shelf seas throughout the world. Previous studies suggest that degradation and ecosystem changes have occurred in intensively fished areas. Nevertheless, to date it has been difficult to attribute habitat and benthic community changes to fishing effort at a spatial scale that is truly representative of commercial fishing activities. 2. In this study we present convincing evidence that chronic bottom-fishing disturbance has caused significant and widespread changes in the structure of two distinct soft-sediment benthic assemblages and habitats. 3. Our study compared the benthic fauna found in areas that have been exposed to either high or low levels of bottom-fishing disturbance over the past 10 years. We were able to validate the fishing effort data in some areas using scars in the shells of a long-lived bivalve mollusc (*Glycymeris glycymeris*) which result from fishing disturbance. Shell scars occurred most frequently in bivalves collected from the area of highest fishing effort. 4. Multivariate analyses and the response of abundance/biomass curves indicated that chronic fishing has caused a shift from communities dominated by relatively sessile, emergent, high biomass species to communities dominated by infaunal, smaller-bodied fauna. Removal of emergent fauna has thus degraded the topographic complexity of seabed habitats in areas of high fishing effort. The communities within these areas currently may be in an alternative stable state.

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.

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 Conservaton 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/ beamtrawl

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. 2000. Fishing-gear restrictions and conservation of benthic habitat complexity. Conservation Biology. 14(5) : 1512-1525.

Keywords: fishing effects/ fishing gear restrictions/ habitat complexity

Abstract: When two commercially important marine species coexist in the same habitat, conflict may arise between different sectors of the fishing industry. A good example of this situation is when fishers using towed bottom-fishing gear (scallop dredges, beam trawls, and otter trawls) operate in the same areas in

which fixed-bottom gear (crab pots) are deployed. We examined an area subject to a voluntary agreement between these two sectors of the fishing industry such that some areas are used exclusively by fixed-gear fishers, some are shared seasonally by both sectors, and others are open to all methods of fishing all year. This agreement was enacted to resolve conflict between the two sectors of the industry. An additional possible benefit of this agreement is the protection of the seabed from towed bottom-fishing gear, which is one of the greatest sources of anthropogenic disturbance of seabed habitats worldwide. Previous studies have demonstrated that complex emergent epifaunal communities are substantially altered by such activities This habitat alteration in turn influences closely associated species, some of which may be of commercial importance. We undertook comparative surveys of the benthic habitat and communities within the area covered by the agreement and compared different areas subjected to a range of fishing disturbance regimes. Communities found within the areas closed to towed fishing gears were significantly different from those open to fishing either permanently or seasonally. Abundance-biomass curves demonstrated that the communities within the dosed areas were dominated by higher biomass and emergent fauna that increased habitat complexity. Areas fished by towed gear were dominated by smaller-bodied fauna and scavenging taxa. Scallop dredges and beam trawls used on more stable habitats appear to have greater impacts on the environment than lighter otter trawls used in shallower water with less stable sediments. It would appear from our data that conflict management in the form of gear-restriction measures has the added benefit of conserving habitats and benthic fauna sensitive to bottom-fishing disturbance.

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/ side-scan 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 side-scan sonar survey of beam trawl tracks 3 h after fishing showed that there were 3.8 times as many shoals of fish over the trawl tracks compared with the adjacent unfished area. Food generated by beam trawling could provide a significant component of the diets of certain opportunistic fish species in some areas subject to intensive beam trawl activity. *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. Estimates of scavenging behaviour in recently trawled areas. Pages 237-257 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

Keywords: scavenging / trawled areas/ gurnards/ dogfish/ whiting/ migration/ beam trawl/ long-term community structure

Abstract: The diets of gurnards, dogfish and whiting 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. All fish increased their intake of prey after fishing. Both gurnards and whiting increased the proportion of hte amphipod, Ampelisca spinipes, in their diets. Beam trawling damaged the burrowing hear urchin, Spatangus purpureus, which was consequently fed on by whiting. Some invertebrate scavengers, such as the prawn, Palaemon serratus, only occured in diets after the area had been fished, suggesting that these animals were also scavenging over the trawl tracks. Observations of the seabed using a side-scan sonar revealed a grreater 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 commmunities occur, beam trawling intensity may be such that it creates a significant food resource for opportunistic fish species. This is possible mechanism whereby long-term community structure coud be altered by fishing activity.

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

Kaiser, M. J. and Spencer, B. E. 1994. A preliminary assessment of the immediate effects of beam trawling on a benthic community in the Irish Sea. Pages 87-94 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

Keywords: immediate effects/ beam trawl/ benthic community/ Irish 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 soft corals and hydroids decreased by ca. 50%. The density of more mobile animals, such as fishes, crabs and prawns 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. common starfish, showed low mortality, whereas those with brittle tests, e.g. sea urchins, were readily damaged leading to high mortality. Mortality in fish was related to the amount epidermal armour such as scales, spines, boney plates and slime. Dragonets. suffered 68-97% mortality wheras between 34 and 38% of plaice and cuckoo rays died respectively. Those animals which have predator/scavenging feeding behaviour, and are able to survive the trauma of geing caught in the codend and handled on deck (e.g. common starfish), may increase in abundance as a result of fishing activities.

Kaiser, M. J. and Spencer, B. E. 1995. Survival of by-catch 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 side-scan sonar survey revealed that the experimental area was characterized by mobile megaripples in the south-eastern sector of the experimental area and stable sediments with uniform topography in the north-western sector. Multivariate analysis of the species abundances from the control areas separated the fauna into two distinct communities which corresponded to the different substratum characteristics. Data from the two regions were therefore treated separately when testing for the effects of trawling. 4) In the north-western sector, trawling led to 58% decrease in the mean abundance of some taxa and a 50% reduction in the mean number of species per sample. Multivariate analysis revealed that differences between control and fished sites were largely due to the reduction or removal of less common species. These effects were less apparent in the mobile sediments of the south-eastern sector, which had a naturally impoverished fauna and high level of heterogeneity. 5) Univariate variables, such as abundance and the total number of species per sample, indicated that the variation between replicate samples increased as a result of trawling disturbance. However, examination of the community data using an index of multivariate dispersion revealed no difference between fished and unfished areas. This suggests that the effects of fishing disturbance are consistent between replicate samples. 6) Fishing with demersal gears modifies communities in relatively stable sediments. Frequent and repeated physical disturbance by fishing gears may lead to long-term changes in the benthic community structure of these habitats. *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, E. L. R., Prena, J., Gilkinson, K. D., Gordon, D. C., Macisaac, K., Bourbonnais, C., Schwinghamer, P. J., Rowell, T. W., Mckeown, D. L., and Vass, W. P. 2001. Effects of experimental otter trawling on the macrofauna of a sandy bottom ecosystem on the Grand Banks of Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences. 58(6) : 1043-1057.

Keywords: Physical Disturbance/ Community Structure/ Temporal Variation/ Benthic Habitat/ Sea/ Impacts/ Sediments/ Megafauna/ Density/ Scale

Abstract: A 3-year otter trawling experiment was conducted on a deepwater (120-146 m) sandy bottom ecosystem on the Grand Banks of Newfoundland that had not experienced trawling for at least 12 years. The benthic macrofauna were sampled before and after trawling and in reference areas. The 200 grab samples collected contained 246 taxa, primarily polychaetes, crustaceans, echinoderms, and molluscs. Biomass was dominated by propeller clams (Cyrtodaria siliqua) and sand dollars (Echinarachnius parma), while abundance was dominated by the polychaete Prionospio steenstrupi and the mollusc Macoma calcarea. The most prominent feature of the data was a natural decline in the total number of species, the total abundance, and the abundance and biomass of selected species between 1993 and 1995. The only immediate effect of trawling was seen in 1994 when the abundance of 13 species, the biomass of 11 species (mostly polychaetes), and the total abundance per grab were significantly lower. There was little evidence of long-term trawling effects. When trawling disturbance was indicated, it appeared to mimic natural disturbance, shifting the community in the same direction in multidimensional scaling ordination; no distinctive trawling signature was observed. However, the results of this experiment should not be uncritically extrapolated to the impacts of commercial trawling.

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 crenatus*, 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 macrobenthos: Early 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 side-scan 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 macrobenthos: Results 2 years post-dredging; pages 615-622; Copyright (1996); with permission from Elsevier Science.*

Kenny, A. J., Rees, H. L., Greening, J., and Campbell, S. 1998. The effects of marine gravel extraction on the macrobenthos at an experimental dredge site off North Norfolk, UK. (Results 3 years post-dredging). ICES CM 1998/V:14: 14 p.

Keywords: Marine crustaceans/ Zoobenthos/ Gravel/ Dredged samples/ Environmental impact/ Mining/ Dredging/ Mineral resources/ Modiolus modiolus/ Dendrodoa grossularia/ Balanus crenatus/ ANE, British Isles, England, Norfolk/ dominant species/ colonization

Abstract: An offshore experimental dredging study was initiated off North Norfolk (UK) in 1992 to investigate the impacts of marine gravel extraction on macrobenthic invertebrates. A dredged `treatment' and a non-dredged `reference' site were selected to evaluate the initial impacts and subsequent processes of recolonisation. A survey of the benthos was conducted prior to the removal of about 50,000 tonnes of marine aggregate (sand and gravel) from the treatment site. Thereafter annual monitoring surveys were conducted, the first commencing immediately after the dredging episode. Preliminary results of this study indicated that whilst the dominant species recolonised quickly (i.e. within 8 months after dredging) the biomass remained significantly lower than its pre-dredged state, suggesting possible long-term effects on the community structure. A follow-up study suggested the substantially reduced biomass at the treatment site, some 24 months after dredging, was due to a local increase in sediment transport caused by tide and wave action occurring mainly over the winter period. This paper presents the physical and biological findings 3 years after dredging, and puts forward a generalised model of macrobenthic response to the effects of physical disturbance caused by dredging.

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., Boechlert, G. W., Gordon, D. M., Haedrich, R. L., Lorance, P., and Parin, N. 2000. Continental slope and deep-sea fisheries: Implications for a fragile ecosystem . ICES Journal of Marine Science. 57(3): 548-557.

Keywords: continental slope/ deep sea/ impacts of fishing/ seamounts/ trawling

Abstract: Exploited deepwater (>500 m) species generally exhibit clear "K-selected" life-history characteristics markedly different from most shelf species: extreme longevity, late age of maturity, slow growth, and low fecundity. Many also aggregate on restricted topographic features such as seamounts, and as a consequence are notably unproductive, highly vulnerable to overfishing, and have potentially little resilience to overexploitation, Since 1964, deepwater fisheries have contributed 800 000-1 000 000 t

annually to global marine fish landings. Underlying this apparent overall stability is the "boom and bust" cycle that has characterized many individual fisheries. The accumulated biomass of previously unfished stocks is typically fished down, often within 5-10 years, to the point of commercial extinction or very low levels. Most deepwater stocks are today overfished or even depleted. Depletion of species from deep-sea environments that dominate mid to upper trophic levels may have long-term ecological implications, but the risks of reduced stock size and age structure to population viability, the potential For species replacement, and the impacts on prey and predator populations are not generally known. However, trawl fisheries have been shown to have potentially severe impacts on the benthic fauna of seamounts. where these fish aggregate. This fauna, dominated by suspension feeders, such as corals, is typically restricted to the seamount environment and is characterized by high levels of endemism, which suggests limited reproductive dispersal. The ability of the benthic community to recover, following its removal by trawling, is not known. *(C) 2000 International Council for the Exploration of the Sea.*

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

Koslow, J. A., Gowlett-Holmes, K., Lowry, J. K., O'Hara, T., Poore, G. C. B., and Williams, A. 2001. Seamount benthic macrofauna off southern Tasmania: Community structure and impacts of trawling. Marine Ecology Progress Series. 213 : 111-125.

Keywords: Species diversity/ Seamounts/ Bottom trawling/ Fishing effort/ Underwater photography/ Hoplostethus atlanticus/ Solenosmilia variabilis/ PSE, Australia, Tasmania/ benthos/ sampling/ biomass/ fishing mortality/ check lists/ A:FRV Southern Surveyor

Abstract: The benthic macrofauna of a group of small seamounts south of Tasmania was surveyed with a dredge and camera to assess the impact of trawling for orange roughy (Hoplostethus atlanticus; Trachichthyidae) and the efficacy of a proposed marine reserve. The seamounts were generally 300 to 600 m high and the peaks ranged from 660 to 1700 m depth. The fauna was diverse: 262 species of invertebrates and 37 species of fishes were enumerated, compared with 598 species of invertebrates previously reported from seamounts worldwide. On seamounts that peaked at depths <1400 m and that had not been heavily fished, the invertebrate fauna was dense, diverse and dominated by suspension feeders, including a matrix-forming colonial hard coral (Solenosmilia variabilis) and a variety of hard and soft (gorgonian and antipatharian) corals, hydroids, sponges and suspension-feeding ophiuroids and sea stars. Of the invertebrate species, 24 to 43% were new to science, and between 16 and 33% appeared to be restricted to the seamount environment. Trawl operations effectively removed the reef aggregate from the most heavily fished seamounts. The benthic biomass of samples from unfished seamounts was 106% greater than from heavily fished seamounts and the number of species per sample was 46% greater. Living S. variabilis was not found on seamounts peaking at depths >1400 m. These seamounts were dominated by sea urchins and had lower biomass and fewer species per sample. However, few species were restricted to either the shallowest or deepest depths sampled. The fauna unique to the region's seamounts appears to be adequately represented within a recently established 'Marine Protected Area' that encloses 12 seamounts that peak at depths >1150 m. *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

Kreiger, K. J. 2001. Coral impacted by fishing gear in the Gulf of Alaska. Pages 106-117 *in* Willison, J., Hall, J., Gass, S., Kenchington, E., Butler, M., and Doherty, P. (eds.), Proceedings of the first international symposium on deep-sea corals. Proceedings of a Symposium held at Dalhousie University, Halifax, Nova Scotia, Canada, July 30 – August 2, 2000. Ecology Action Centre and Nova Scotia Museum, Halifax, Nova Scotia.

Keywords: coral/ fishing gear/ impacts/ Gulf of Alaska/ Primnoa/ trawl/ damage/ seafloor

Summary: In 1997 a manned submarine was used in the Gulf of Alaska (GOA) to observe the seafloor where corals (Primnoa spp.) had been impacted by fishing gear. A 1990 trawl path was observed where 1 ton of corals had been removed with a research bottom trawl at 365 m depth. Thirty-one coral colonies were observed in the path swept by the trawl net, including 13 large colonies (>1 m^3). Damage included five large colonies that were missing 95-99% of their branches, and two small colonies that were missing 80% of their polyps. An estimated 27% of the corals in the net path were detached, and 84% of the detached corals were retained in the net. Detached corals that remained on the seafloor were missing 50-90% of their polyps. No young corals had repopulated the colonies damaged seven years previously. Outside the trawl path there were Primnoa colonies that had been tipped and dragged. All tipped colonies were attached to small boulders (<0.4 m diameter), and the colonies were tipped in different directions. The colonies may have been snagged by longline gear, which is used extensively in the GOS to catch halibut (Hippoglossus stenolepis) and sablefish (Anoplopoma fimbria).

Kroencke, I. 1995. Long-term changes in North Sea benthos. Senckenbergiana maritima. Frankfurt/Main. 26(1-2) : 73-80.

Keywords: long-term changes/ anthropogenic factors/ eutrophication/ biomass/ zoobenthos/ pollution monitoring/ overfishing/ ANE, North Sea

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

Krost, P. 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 side-scan 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, abudance 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. NA(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 side-scan 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 side-scan sonar records. The extent of disturbance per unit area was quantified by relating the area covered by trawl to the total area. Frequency classes were defined and related to sediment type and water depth. The density of trawl tracks is highest below 20 m and in mud areas. Taking into account fishing effort data, it can be concluded that some areas are ploughed at least once a year by the boards alone. *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

Abstract: The soft-shell clam, *Mya arenaria*, has a wide geographic distribution, indicating that it is tolerant of a variety of environmental conditions. Reproductive patterns and biology of this species of clam have been studied in Washington, Maine, and Chesapeake Bay. Information from several studies of the harvester on soft-shell clam stocks, associated biota, water column, and clam flat geology has been summarized and is discussed in this report. Since the invention of the hydraulic escalator shellfish harvester and its commercial operation in Maryland in 1952, many areas of the United States and Canada have used this device for harvesting shellfish. Other than being used to survey and harvest clams, the harvester has been used also to collect quantitative information on sedentary benthic macrofauna. In these studies, it has been shown that the hydraulic escalator shellfish harvester can harvest calms more efficiently and with less breakage than a professional hand-digger. However, an escalator harvester requires a major capital investment. To meet operating costs and to make a profit, a harvester would neeed to either work in areas where soft-shell clams are very abundant or else cover a large amount of the bottom, or both. This may be difficult to accomplish because of the natural high variability in population densities. Since the harvester is, in principle, a dredge, it can alter the area in which it is operated--in some cases improving and in some cases degrading its character as a benthic habitat. The need for continuing studies to determine effects of the harvester is emphasized in this report. Because of the significant cost and possible impact of the hydrauli escalator harvester, an alternative for harvesting bivalves is suggested and discussed. This alternative, a hydraulic clam rake designed to be operated by one person at low tide on an intertidal clam is described.

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 90^{o} 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' and indicates a need to delineate EFH on a more localized scale. 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 communities

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.*

Larson, K. W. and Moehl, C. E. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. Pages 102-112 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific Coast Fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.

Keywords: dredging/ brackishwater fish/ dredges (geology)/ anadromous species/ fish/ Columbia R./ Thaleichthys pacificus/ Ammodytes hexapterus/ Pisces/ INE, USA, Columbia R./ entrainment

Abstract: Studies were conducted at the mouth of the Columbia River, USA, to determine the number and types of estuarine organisms entrained by hopper dredging. As part of the study, information was obtained on the number and types of fish species entrained. Fourteen species or species groups of fish were collected during the four study. Eulachon (Thaleichthys pacificus), was the only anadromous species entrained. No juvenile or adult salmonids were collected. Number of individuals entrained were low for all species except Pacific sand lance (Ammodytes hexapterus), which were collected in moderate numbers throughout the study. None of the species collected showed any seasonality except Pacific sand lance, which were slightly more abundant in the late summer. These results indicated that anadromous species were not entrained in any numbers by hopper dredging at the mouth of the Columbia River.

Lasalle, M. W. 1990. Physical and chemical alterations associated with dredging: An overview. Pages 1-12 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific Coast Fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.

Keywords: ecosystem disturbance/ suspended particulate matter/ resuspended sediments/ sediment chemistry/ industrial wastes/ chemical pollutants/ dissolved oxygen/ turbidity/ dredgers/ literature reviews/ DO/ ecosystems/ physicochemical properties/ sediments/ turbidimetry/ dredging

Abstract: Physical and chemical alterations associated with dredging include increased levels of suspended sediments and the potential for associated dissolved oxygen reduction and release of natural and industrially-derived chemicals. The magnitude and spatial extent of the suspended sediment field around any dredging operation is a function of the type of dredge used, the physical/biotic characteristics of the material being dredged (e.g., density, grain size, organic content) and site-specific hydrological conditions (e.g., currents, water body size/configuration). A generalized "worst case" field can be defined as having suspended sediment levels less than or equal to 500 mg/L at distances less than or equal to 500 m from the dredge, with maximum concentrations generally restricted to the lower water column within 50-100 m, decreasing rapidly with distance. Reduction in dissolved oxygen and chemical release from suspended sediments should be minimal and short lived.

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/ by-catch/ 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 $31^0$20'S and $34^0$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 metres, 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 by-catch 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 by-catch, 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 by-catch 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 by-catch 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 by-catch. 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 by-catch. 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, U.S. 98(1) : 86-95.

Keywords: shellfish harvesting/ biological effects/ oyster reefs

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

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.*

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

Keywords: USA, California, Mission Bay/ dispersal/ community structure/ mud flats/ dispersion/ recuritment/ population structure/ Polychaeta/ INE, USA, California, Mission Bay/ disturbance

Abstract: The effects of differing life histories on the dynamics of dispersal, recruitment, and population maintenance were investigated for a dense infaunal polychaete assemblage on the Kendall-Frost mudflat in Mission Bay, California. Small-scale dispersal was examined by studying petterns of larval availability, recruitment into settling cartons, and colonization of defaunated sediments. The role of dispersal in response to disturbance was examined for two levels of perturbation. Analyses of species' responses revealed colonization ability at recruitment to be distinct from dispersal (migratory) ability. In general, the annual life cycles and flexible small-scale mobilities of most species enable persistence in the face of frequentfine-grained disturbance.

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 import 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 programmes 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 . Effects of trawling disturbances on temporal and spatial structure of benthic soft-sediment assemblages in Gullmarsfjorden, Sweden. ICES Journal of Marine Science. 57(5) : 1369-1376.

Keywords: trawling/ benthic disturbance/ Gullmarsfjorden, Sweden

Abstract: Hypotheses on the effects of shrimp trawling on large benthic macrofauna in a previously protected Swedish fjord were tested in a manipulative experiment. Three trawled sites and three untrawled (control) sites were sampled 1-4 months before, and 8-12 months after, experimental trawling on a weekly basis. Multivariate analyses indicate large temporal changes in assemblages of benthic fauna at both types of sites. The Bray-Curtis dissimilarity measure was used to test the hypothesis that changes in assemblages through time at trawled sites were different from those at untrawled sites. Although changes in average assemblages (centroids) from the start to the end of the experiment were larger at trawled sites, there were marked differences among sites, and differences between trawled and untrawled sites were not significant. There were, however, differences in temporal and spatial variability in structure of benthic assemblages. Variability at untrawled sites tended to be smaller. Thus, spatial and temporal variability in the structure of assemblages after one year of trawling was larger at the trawled sites than at the untrawled sites. Trawling with this particular type of gear at the experimental frequency for approximately one year appears to cause relatively subtle changes in the overall structure of assemblages of large macrofauna compared with changes caused by other factors. Furthermore, the results suggest that tests of hypotheses of changed patterns of variability may be sensitive to detecting effects of impacts of disturbance from trawling. *Copyright 2000 International Council for the Exploration of the Sea* .

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(2) : 155-169.

Keywords: Fisheries/ Human impact/ Benthic environment/ Methodology/ Sweden/ Biological sampling/ Commercial fishing/ Trawling/ Zoobenthos/ Fjords/ Environmental impact/ Ecosystem disturbance/ ANE, Sweden

Abstract: Disturbances due to trawling and dredging is a serious threat to assemblages of benthic marine animals. We tested hypotheses about effects of trawling on benthic assemblages in a manipulative field experiment, using gear and intensities relevant to future management of trawling in a Swedish fjord. Three trawled and three control sites were sampled at several times before and after trawling was initiated. This paper describes how conclusions about effects of trawling might differ between experiments involving replicate sites and experiments using only one trawled and one control site, as in several recent studies. Analyses of selected taxa showed that abundances of many species changed differently among control sites. Differences in temporal change between pairs of single trawled and control sites were also frequent. Neither the quantitative nor the qualitative nature of differences between treatments could, however, be coherently interpreted among the different combinations of trawled and control sites. This is consistent with results obtained from analyses using all sites, which showed no consistent effects of trawling on any of these taxa. These results provide empirical evidence that spatial confounding may cause serious problems to formal interpretation of experiments, which use only one control and one trawled area. Such potential problems can best be solved by ensuring that the study incorporates more than one control site. *Reprinted from Journal of Experimental Marine Biology and Ecology, Vol. 245; Lindegarth, M., Valentinsson, D., hansson, M., Ulmestrand, M., 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; pages* 155-169*; Copyright (2000); with permission from Elsevier Science.*

Lindeman, K. C. and Snyder, D. B. 1999. Nearshore hardbottom fishes of southeast Florida and effects of habitat burial caused by dredging. Fishery Bulletin, U.S. 97(3) : 508-525.

Keywords: Dredging/ Environmental impact/ Fishery management/ Environmental protection/ Fishing gear/ Ecosystem disturbance/ Community composition/ Species diversity/ Check lists/ Substrate preferences/ Reefs/ USA, Florida/ Marine environment/ Habitat/ Biological diversity/ Fisheries/ Haemulon parra/ Diplodus argenteus/ Stegastes variabilis/ Pisces/ ASW, USA, Florida

Abstract: Fish assemblages of nearshore hardbottom habitats of southeast Florida were quantified at three sites from April 1994 to June 1996. Random 2 x 15 m transects were visually censused within two replicate areas at each site. The hardbottom at one site was buried by a dredge project to widen a beach one year into the study. A total of 394 transects were sampled. Eighty-six taxa (77 identified to species) from 36 families were censused. Grunts (Haemulidae) were the most diverse family (11 species), followed by the wrasses (Labridae) and parrotfishes (Scaridae) with seven and six species, respectively. The most abundant species were sailors choice (Haemulon parra), silver porgy (Diplodus argenteus), and cocoa damselfish (Stegastes variabilis) with mean abundances (individuals/transect) of 4.5, 3.8, and 3.7, respectively. Early life stages (newly settled, early juvenile, and juvenile) represented over 80% of the individuals at all sites. Newly settled stages of over 20 species were observed in association with hardbottom reef structure. Outside of lagoons, nearshore hardbottom areas are the primary natural structures in shallow waters of mainland Florida's east coast and were estimated to have nursery value for 34 species of fishes. After one year, burial of approximately five ha of hardbottom habitat at one site lowered the numbers of individuals and species by over 30x and 10x, respectively. Due to their early ontogenetic stage, many of these species may not be adapted for high mobility in response to habitat burial. Dredging effects may be amplified by burial prior to and during spring and summer periods of peak larval recruitment.

Lindholm, James B., Auster, Peter J., Ruth, Matthias, and Kaufman, Les. 2001. Modeling the effects of fishing and implications for the design of marine protected areas: Juvenile fish responses to variations in seafloor habitat. The Journal of the Society for Conservation Biology. 15(2) : 424-437.

Keywords: model/ protected areas/ seafloor habitat/ juvenile fish/ fishing impacts

Abstract: A number of recent studies have linked post-settlement survivorship of Atlantic cod (Gadus morhua) with the complexity of the seafloor to which fish settle. Survivorship is greater in habitats of higher complexity (e.g., pebble-cobble substratum with emergent epifauna> pebble-cobble> sand), where cover provides shelter from predators. Fishing with mobile gear such as bottom trawls and dredges reduces the complexity of seafloor habitats. We used a dynamic model to (1) link patterns in habitat-mediated survivorship of post-settlement juvenile cod with spatial variations in habitat complexity, (2) simulate habitat change based on fishing activities, and (3) determine the role of marine protected areas in enhancing recruitment success. Density-dependent natural mortality was specified as three alternative functional response curves to assess the influence of different predator foraging strategies on juvenile survivorship during the first 12 months of demersal existence. We applied the model to a theoretical patch of hard-bottom substrata and to a case study based on seafloor habitat distributions at Stellwagen Bank National Marine Sanctuary (Gulf of Maine, Northwest Atlantic). Our results demonstrate that patterns in the shape of response surfaces that show the relationship between juvenile cod survivorship and density as well as movement rate were similar regardless of functional response type, that juvenile cod movement rates and post-settlement density were critical for predicting the effects of marine protected-area size on survivorship, and that habitat change caused by fishing has significant negative effects on juvenile cod survivorship and use of marine protected areas can ameliorate such effects.

Link, J. S. and Almeida, F. P. 2002. Opportunistic feeding of longhorn sculpin (Myoxocephalus octodecemspinosus): Are scallop fishery discards an important food subsidy for scavengers on Georges Bank? Fishery Bulletin, U.S. 100(2) : 381-385.

Keywords: Longhorn Sculpin/ scallop fishery/ discards/ scavengers/ Georges Bank

Lopez-Jamar, E. and Mejuto, J. 1988. Infaunal benthic recolonization after dredging operations in La Coruna Bay, NW Spain. Cahiers de Biologie Marine. 29(1) : 37-49.

Keywords: dredging/ zoobenthos/ environmental impact/ ecosystem disturbance/ La Coruna Baby/ Spain

Abstract: In the harbour area of La Coruna Bay (NW Spain) there is a muddy sediment infaunal community dominated by the bivalve Thyasira flexuosa and the polychaete Chaetozone, sp., whose densities are very high (15,000-20,000 individuals. m^-2). Dredging operations carried out near a recently built dock determined that in this area the original community was reduced to a few species having short life cycles and to newly settled specimens. After the completion of the dredging operations, temporal variation of the affected arrea was followed during one year, and it is compared with a nearby area unaffected by dredging. Species number, adensity and biomass increased significantly after the end of the dredging period. On the other hand, similarity between the dredged and the non-dredged areas increased steadily with time. Diversity values increased initially owing to the recruitment of new species, but then decreased because of the great dominance of Thyasira flexuosa. The recovery of the dredged zone is practically attained 6 months after the completion of dredging operations, although biomass takes longer to reach values similar to those of the unaffected area.

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*.

MacKenzie, 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

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 super(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.

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. Side-scan sonar was employed to locate areas of the Lough bed physically impacted by trawling. Otter boards were found to imprint distinct trawl marks on the Lough bed and were identified on side-scan records. During the surveys a Geographical Information System (GIS) was successfully employed as a data management tool. Based on this study, possible

strategies for future management of the queen scallop fishery and Strangford Lough as a Marine Nature Reserve have been discussed. *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.*

Maguire, J. A., Coleman, A., Jenkins, S., and Burnell, G. M. 2002. Effects of dredging on undersized scallops. Fisheries Research. 56(2) : 155-165.

Keywords: Scallop/ *Pecten maximus*/ Dredging effects/ Adenylic energetic charge/ Behaviour

Abstract: There is little information on the effect of dredging on the physiology and behaviour of discarded scallops. The overall objective of this study was to use changes in adenylic energetic charge (AEC) and righting and recessing behaviour as indicators of stress caused by the act of dredging on scallops. Two field experiments using a commercial dredge and four laboratory experiments using a dredge simulator were carried out. AEC levels decreased in the striated muscle from 0.9 to approximately 0.5 after dredging, however, no difference was found between different lengths of tow or length of time in the dredge simulator (15, 30 or 45 min). The AEC levels of dredged scallops returned to normal after 3 days in optimal conditions. Dredged smaller scallops (<65 mm shell height) had a higher AEC level (0.54Ż0.58) and were more active than dredged larger animals (>70 mm shell height, AEC level: 0.41Ż0.46). Dredging followed by emersion had a deleterious effect on AEC levels and on the righting and recessing speed of scallops. Physical movement of the scallops within the dredge bag combined with anaerobic respiration during valve closure has an added stress effect during dredging. Overall, AEC levels were not reduced enough to cause mortality, but the righting and recessing speed of scallops was greatly reduced after dredging. Therefore, these undersized discarded animals may be less able to escape from predators, and may have reduced

chances of survival in the open sea. *Reprinted from Fisheries Research, Vol. 56; Maguire, J.A., Coleman, A., Jenkins, S., Burnell, G.M., Effects of dredging on undersized scallops; pages 155-165; Copyright (2002); with permission from Elsevier Science.*

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

Summary: The rectangular flat board was very stable on both smooth and rough ground, cleared boulders reasonable well, but, owing to its rectangular shape and inability to rise quickly over obstructions, impacts were mostly on the leading edge. The polyvalent board cleared the rough ground with remarkable ease but its lively behaviour led to rapid decreases in spread. Nevertheless, this actioncould possibly help to lift the spreading wires over rough ground. The cambered rectangulara board behaved similarly to the rectangular flat but its ability to spread the gear was superior to that of the other boards tested. The Vee board was stable on smooth ground and cleared the rough ground owing to its tipping actiou on the towing triangle. The warp tension varied with the degree of board reaction and did not necessrily correspond to impacts with the larges obstruction but depended on whether the obstruction was cleared, pushed, or dug out of the sea bed. The "Lossie J" trawl had the ability to pass intact oover rough ground when boulders were up to 2 m high. The success of this gear is probably due to the carefully tailored belly and side panels lifting in parallel with the ground gear and helping to lift the ground gear over large boulders. The "Boris Mystic" held the ground well, but in the rig tested was found susceptible to belly damage on ground with boulders over 60 cm high; this was apparently due to the absence of upward lift from the slacker belly and side panels. Some belly damage could result in both gears from the jamming of lancaster links rolling the fishing line and belly on top of the bobbin rig, a problem increased by the tighter packing of the bobbins on hard ground.

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

Summary: Polyvalent, Vee, flat and cambered boards were used in experiments to study the behaviour and geometry of their sand clouds. The sand clouds created by the turbulence spread from the trawl board inwards along the bridles. The rate and extent of lateral movement is different for the inner and outer edges of the sand clouds produced by each type of board. The sand clouds generated form the polyvalent and cambered boards are narrower in comparison to those of the flat and Vee. With the data from these

experiments, bridle angles can be predicted to ensure thatthe sand clouds pass through the wing ends- of the net. These bridle angles represent practical arrangements with shorter sweeps but not with the longer sweeps tested.

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^{o} 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^{o} 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.. 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 1/2 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

Summary: A two-man diver-operated towed underwater vehicle is described in detail. The instrumentation housed within the vehicle gives towing speed, depth from the surface, depth above the seabed, water temperature in degrees centigrade and the elapsed time of the dive in minutes. Both diver occupants can communicate with each other as well as with the surface control team. The vehicle, which is simple to operate and maintain, is ideally suited for launching from most types of fishing vessles to be towed alongside the trawling gear. By using closed-circuit television recording equipment and still-shot and cine cameras, the behaviour of commercial species of fish to a trawl can be recorded in situ and studied in detail after completion of each haul. The limitation of this towed vehicle system is primarily the relatively short time in which the divers have to make their observations, but by carefully calculating their diving time to avoid decompressing in the sea, well trained operators can make the most of these short dives.

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).

Summary: Direct observations of the reactions of Nephrops norvegicus (L.) to two types of fishing gears wee made in daylight using both divers and a remotely controlled television camera on an underwater vehicle. One net was a standard commercial gear, the other a modified dual purpose fish/ prawn trawl tailored with a second fishing line on a horizontal separator panel which divided the net into two compartments terminating in separatte cod-ends. All the Nephrops seen out of their burrows on the sea bed in line with the track of the trawl mouth passed back into the net Those in the entrance of a burow escaped capture by withdrawing into that burrow as the gear passed over. Most of the Nephrops outside the track of hte mouth of the net (ie in the area between the otter boards and the wing ends) avoided capture by swimming or skipping up a few centimetres allowing the sweeeps and bottom bridles to pas under them. A few Nephrops used repeated tail "flick" swimming movements in an attempt to outswim the approaching trawl, but at a towing speed of 1.3 m s^-1, their short bursts of swimming endurance3 suggested that these animals are quickly exhausted and they then allow the fishing line to overtake them. Covered net experiments with the two-level trawl, designed in a way to retain all Nephrops passing down through the lower half of the net, demonstrated that many nephrops escaped through the lower half of the net, demonstrated that many Nephrops escaped through the 70mm mesh panels in this area. The cover was divided in such a way as to preserve the identity of animals escaping from three areas on the underside of the net. Both small and marketable sized Nephrops were caught in all areas of the cover. Three different cod-ends were compared by subsitituting the standard 70 mm with 80 mm and 90 mm mesh sizes. No animal over 45 mm (carapace length) found a way through the standard 70 mm mesh.

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

Abstract: The efficiencies of the standard and spring-loaded dredges used in the Scottish scallop fishery were assessed on a smooth substratum by noting the proportion of scallops of each age and size group in the path of the dredge that are captured. This was done by direct observation by divers of the scallops left behind in and near the dredge track. The efficiencies were low, only about one-fifth of commercial-sized (>80 mm) scallops being taken, and because the dredge teeth and bag are also selective very few smaller scallops were caught at all. Knowing the distance covered in a dredge tow, it was possible to estimate the density of scallops. On the beds studied in the Firth of Clyde this was up to one scallop per 5 mSUP-2 . The low dredge efficiency can be related to the action of the dredges, which collected a mound of sediment in the mouth, blocking it and resulting in sediment and scallops being pushed out at the side. The technique used here would be useful for estimating the abundance of the exploitable stock in an area if the gear efficiency of a representative number of commercial vessels was known.

Matsushita, Y. 2000. Bycatch reduction technologies for towed fishing gears. Nippon Suisan Gakkaishi. 66(2) : 261-268.

Keywords: bycatch reduction/ towed fishing gear

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 kilometres 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*.

McCabe, G. T., Hinton, S. A., and Emmett, R. L. 1998. Benthic invertebrates and sediment characteristics in a shallow navigation channel of the lower Columbia River, before and after dredging. Northwest Science. 72(2) : 116-126.

Keywords: Dredging/ Columbia River/ navigation channel

Abstract: Little is known about the impact of dredging on benthic invertebrates in navigation channels of the lower Columbia River. To help fill this informational void, we conducted benthic invertebrate and sediment studies in a shallow navigation channel in the river before and after dredging. Benthic invertebrate and sediment samples were collected with a 0.1-m(2) Van Veen grab sampler at seven stations in the Wahkiakum County Ferry Channel, Washington (River Kilometer 70), and at an upstream reference area in 1993-1995. No significant effects ($P > 0.05$) of the ferry channel dredging project on *Corbicula fluminea*, Ceratopogonidae larvae, *Corophium* spp., or total benthic invertebrate densities were detected in the statistical analysis, although benthic invertebrate densities were significantly different ($P < 0.05$) between surveys and areas for some organisms. During all eight surveys, *Corbicula fluminea*, *Corophium* spp., and

Ceratopogonidae (Diptera) larvae were generally the most common benthic invertebrates in both the ferry channel and the reference area. Two measures of community structure, Diversity (H) and Equitability (E), were calculated for each area for each survey. No significant effects ($P > 0.05$) of the ferry channel dredging project on the benthic invertebrate community structure, as measured by H and E, were detected. No significant effects ($P > 0.05$) of the ferry channel dredging project on sediment median grain size or percent volatile solids were detected. Results from this study will provide information to aquatic resource agencies that assess the potential environmental effects of dredging in similar habitats of the lower Columbia River.

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 of the eastern Bering Sea. ICES Journal of Marine Science. 57(5) : 1377-1388.

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.

McGraw, K. A. and Armstrong, D. A. 1990. Fish entrainment by dredges in Grays Harbor, Washington. Pages 113-131 in C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes. Workshop Proceedings, Seattle, WA, September 8-9, 1988. Washington Sea Grant Report WSG-WO 90-01

Keywords: dredging/ entrainment/ Grays Harbor, Washington

Abstract: Fish entrainment data were collected during several different studies conducted on pipeline and hopper dredges from 1978 to 1989 in Grays Harbor, Washington, USA. In general, the highest entrainment rates and numbers of species of fish were observed in hopper dredge samples from the outer harbor. A total of twenty-eight species of fish were identified from entrainment samples, twenty-four of which occurred in outer harbor samples and eight from the inner harbor. Pacific sand lance (Ammodytes hexapterus) were entrained at the highest rate, 594/1,000 cubic yard (kcy), observed in all the studies, followed by Pacific staghorn sculpin (Leptocottus armatus) (92/kcy), and Pacific sanddab (Citharichthys sordidus) (76/kcy). Only one chum salmon (Oncorhynchus keta) fry was caught in all samples taken, and comparison with trawl samples taken during one study indicated that some fish species actively avoid the dredges.

McGraw, K. A., Armstrong, D. A., Weinmann, F. C. , and Pearson, W. H. 1991. An overview of crab mitigation in Grays Harbor, Washington. Journal of Shellfish Research. 10(1) : 305.

Keywords: dredging/ *Cancer magister*/ Grays Harbor, Washington

Abstract: Dredging associated with a navigation improvement project in Grays Harbor, WA, resulted in the unavoidable mortalities of Dungeness crab (Cancer magister). The U.S. Army Corps of Engineers began a small-scale mitigation program in April 1990. Oyster shell is being used to create habitat for juvenile (0+) crab, thus increasing survival and, eventually, offsetting impacts. The approach to mitigation was developed over several years and illustrates coordination, cooperation, and controversy among resource agencies and user groups and the role of scientific studies in the decision-making process. Although much data has been amassed on Dungeness crab in Grays Harbor, agency perspective on two other issues, the presence of eelgrass and possible dioxin contamination on potential mitigation sites, has caused major delays in full-scale mitigation and, possibly, increased costs. At issue in these cases is whether placement of shell on the intertidal impacts eelgrass, and whether certain proposed mitigation sites are more likely to receive up-current contaminants than are other sites.

McGraw, K. A., Conquest, L. L., Waller, J. O., Dinnel, P. A., and Armstrong, D. A. 1988. Entrainment of Dungeness crabs, *Cancer magister* Dana, by hopper dredge in Grays Harbor, Washington. Journal of Shellfish Research. 7(2) : 219-231.

Keywords: dredging/ entrainment/ *Cancer magister*/ Grays Harbor, Washington

Abstract: Grays Harbor, Washington, is a major center for the Dungeness crab (Cancer magister) fishery in Washington state, and potential impacts to the crab resource are a primary concern in the proposed widening and deepening of the existing Grays Harbor Navigation Channel. The Seattle District, U.S. Army Corps of Engineers, conducted crab entrainment studies in Grays Harbor to assess the effectiveness of a modified draghead in reducing crab entrainment and to gather entrainment data for use in impact analyses. Trawl samples were taken simultaneously with entrainment samples to compare entrainment rate with crab density in the navigation channel. Data analyses showed that the modified draghead was not effective in reducing crab entrainment. Entrainment rates varied greatly among different stations in the channel, and comparisons with trawl data showed that, on an area-swept or density basis (i.e., crabs per hectare), the dredge entrained an average of 26% of the crabs present in the area of the channel being dredged. There was a general linear relationship between entrainment rates and crab densities, and these data have been used to predict impacts on Dungeness crabs during project construction and to develop appropriate mitigation plans.

McGraw, K. A., Waller, J. O., Conquest, L. L., Dinnel, P. A., and Armstrong, D. A. 1988. Dredging and Dungeness crabs: Impact assessment and mitigation. Journal of Shellfish Research. 7(1) : 194.

Keywords: dredging/ entrainment/ *Cancer magister*/ Grays Harbor, Washington

Abstract: Grays Harbor, Washington, is a major center for the Dungeness crab (Cancer magister) fishery in the state, and impacts to the crab resource, particularly from dredging, are a primary concern related to the proposed widening and deepening of the existing navigation channel. In a series of meetings with agency representatives, crab biologists, and crabbers, an approach to this problem was developed which included modification of a hopper dredge draghead to reduce impacts, collection of additional entrainment data, and evaluation of a mitigation technique.
The Seattle District, U.S. Corps of Engineers, conducted entrainment studies in Grays Harbor to assess the effectiveness of a modified draghead in reducing crab entrainment. In addition, trawl samples were taken simultaneously with entrainment samples for comparison of entrainment rates with crab densities in the navigation channel. These data were incorporated into a computer model for predicting crab losses due to dredging. The results have been used, in conjunction with previous studies on crab habitat preference, to formulate a suitable mitigation plan utilizing oyster shell. The role of these environmental studies in the planning process is also discussed.

McGraw, K. A., Weinmann, F. C., and Armstrong, D. A. 1991. An overview of crab mitigation in Grays Harbor, Washington. Journal of Shellfish Research. 10(1) : 239.

Keywords: dredging/ *Cancer magister*/ Grays Harbor, Washington

Abstract: Mitigation for dredging impacts to Dungeness crabs (Cancer magister) in Grays Harbor, WA began in April 1990 after several years of planning, negotiation, and discussion among the U.S. Army Corps of Engineers, state and federal agencies, scientists, and crab fishermen. The process leading to mitigation involved basic research on crab biology and life history, crab entrainment studies, dredge modification, site evaluation, implementation and interpretation of environmental regulations and policies, and many other components. A perspective of the process is presented, along with some of the various viewpoints, obstacles, and accomplishments encountered that led to the present solution. Some economic considerations are also provided.

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.

McKinney, L. D., Bedinger, C. A., and Hopkins, S. H. 1976. The effects of shell dredging and siltation from dredging on organisms associated with oyster reefs. Pages 280-303 *in* A.H. Bouma (ed.), Shell dredging and its influence on Gulf coast environments. Gulf Publishing Company, Houston, Texas.

Keywords: shell dredging/ siltation/ oyster reef

Abstract: As part of an extensive study on shell dredging in San Antonio Bay, Texas, the effects of siltation on oysters and their associated fauna under experimental and natural conditions were examined. The Texas Parks and Wildlife Department granted a special 60-day permit to allow dredging within less than 300 feet of a reef complex. Due to delays in obtaining the permit and in agreeing upon the operating site, actual dredging was confined to the two month period from 28 December 1972 to 28 February 1973. During the period 15-24 December 1972, experimental stations were established around the dredging site and adjacent reefs. Two other stations were also set up on the bow and stern of the dredge. Control stations were established in areas around those experimental sites which would not be affected by dredging. An experimental apparatus similar to that described by Wilson (1950a) was placed at each station. This apparatus included: baskets containing oysters, culch bags to act as substrate for spat (young oysters), settling plates for fouling organisms, and commercial crab traps. Experimental data on oyster growth and survival, spat attachment, oyster-associated fauna, fouling organisms, and crab movements were correlated with data obtained by sampling the oyster reef complex in the experimental area. Sites on the reef complex were chosen according to exposure to dredging. The sites included the flanks, high and low crowns on one reef, and the flank of another. These sites were sampled through May 1973, and a subsequent inspection trip of the reef complex, including the experimental area, was made in October 1973.

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 dredge: estimates 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

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

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

Keywords: hydraulic escalator harvester/ clam fishery

Abstract: A modified Maryland-type hydraulic escalator shellfish harvester was used at high tide on intertidal beaches in Nova Scotia to determine its effect on soft-shell clams less than 2 inches long. The boat was equipped with a propeller guard to prevent bottom scouring and three types of experiments were carried out with small, marked clams: (1) Dead clams were released in the scoop to determine their scatter pattern after passing through the harvester. (2) Plots of planted dead clams were dug through to discover breakage rates and distribution. (3) Plots of planted living clams were dug through to see how the harvester affects their distribution and ability to re-establish themselves. Results were observed on the dry beach at low tides. Most of the small clams sifted through the mesh of the escalator belt before they reached the surface of the water. In spite of strong currents from harvester jets and the boat propeller, 90% of the clams were returned to the harvester track within 75 or 100 feet of the place were they entered the harvester. Soil

is heavy and settled first in the track. Clams are lighter and were deposited on the soil surface, not buried and smothered. The harvester broke 7 to 10% of the living clams but the rest dug in again quickly. Because damages so small compared with that caused by conventional clam hoes we think production would be improved if hydraulic escalator harvesters were used.

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

Keywords: clam fishery/ clam hacks

Abstract: The conventional clam hack is a reasonably efficient tool for harvesting soft-shell clams (Mya arenaria). With it the average digger harvests 60% of the market-size stock from the soil he turns. But it is very destructive. At each turning of the soil it kills nearly 50% of the unharvested clams. each digging brings about a total reduction (harvesting and smothering) of 80% of the stock of market-size clams and a reduction of 50% of the stock of under-size clams. Frequently rep3eated digging of the same ground was probably the main cause of the decline in clam production in the Maritime Provinces in the 1950's. Fishing effort seems to have decreased since Then and we cannot explain why the decline is continuing.

Medcof, J. C. and 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., Cadee, 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 harbour 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, U.S. 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) to examine 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.

Moran, M. J. and Stephenson, P. C. 2000. Effects of otter trawling on macrobenthos and management of demersal scalefish fisheries on the continental shelf of north-western Australia. ICES Journal of Marine Science. 47(3) : 510-516.

Keywords: benthos/ demersal/ fish/ habitat/ management/ mortality/ otter-trawl/ sponge

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

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 favor 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

Mueter, F.J. unpublished manuscript. A review of the impacts of fishing gear on sea floor habitat and benthic communities as summarized in the Draft Alaska Groundfish Fisheries Programmatic Supplemental Environmental Impact Statement. prepared for the Marine Conservation Alliance. 35p. Contact the auther at: fmueter@sfu.ca.

Keywords: sea floor habitat/ benthic communities/ gear impacts

Introduction: The purpose of this review is to critically assess the evidence for adverse impacts of mobile fishing gear on benthic habitat and communities as summarized in a recent review by Auster and Langton (1999) Their paper forms the principal basis for the assumption that bottom trawls substantially reduce habitat complexity and benthic biodiversity, which is implicit in Alternative 5 of the Draft Programmatic Supplemental Environmental Impact Statement. Auster and Langton (1999) discuss effects of mobile fishing gear on physical substrate characteristics and on benthic communities in both the short- and long-term. Their conclusions with respect to physical and short-term impacts of trawling have been generally confirmed by experimental studies in different parts of the world. However, these conclusions cannot be generalized to the Gulf of Alaska and Bering Sea for several reasons. First, most of the results in Auster and Langton (1999) were based on heavier fishing gear (dredges and beam trawls) than the otter trawls typically used in Alaska. Several studies have found that otter trawls are the least damaging gear type among the mobile bottom fishing gears examined to date. Second, Auster and Langton (1999) primarily examine studies on hard-bottom or vulnerable biogenic sediment. In contrast many of the trawl fishing grounds in Alaska, particularly in the Bering Sea, are on less vulnerable substrate, although the distribution of different substrate types is largely unknown. Third, fishing intensities in the Gulf of Alaska and Bering Sea are likely to be less than in other heavily fished areas such as the North Sea and the Western Atlantic, where most previous studies were conducted. Fishing intensity is one of the most important factors determining the magnitude and direction of long-term changes. The challenge for management is to determine levels of fishing that are sustainable and will not degrade benthic habitat in the long run. The analysis in the PSEIS on bycatch rates of different gears is a step in the right direction. However, such models need to take into account the distribution of effort at a much finer scale and any changes in effort distribution resulting form different allocations of catches among gears. Furthermore, a review of more recent literature reveals two important shortcomings of the Auster and Langton (1999) paper. First, changes in benthic communities due to fishing must be evaluated in the context of natural variability. A number of recent studies clearly indicate that benthic communities are highly dynamic and that natural variability often exceeds any effects of fishing. This includes large changes over time as well as large spatial variability due to underlying environmental gradients. Second, while many studies have shown statistically significant effects, this does not necessarily imply ecologically important effects. Recent studies that estimate fishing-induced mortality for vulnerable species may help to determine sustainable levels of fishing mortality for benthic organisms. However, such studies are currently not feasible for the Gulf of Alaska or Bering Sea because data on the distribution of most benthic organisms, as well as data on the small-scale distribution of fishing effort is not available. Third, the evidence for long-term changes due to the impacts of fishing gear on benthic communities is relatively weak and often inconclusive. Some of the long-term studies cited in Auster and Langton (1999) were flawed and do not support the conclusion that observed changes in benthic communities were due to the effects of fishing gear. I conclude that the Auster and Langton (1999) paper is not an adequate summary of trawling impacts for evaluating potential benefits from management measures in Alternative 5 of the PSEIS. The conclusion that a reduction of trawling in Alaskan waters and increased allocation of caches to fixed gear will have definite benefits in terms of increased habitat complexity and species diversity is not tenable.

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]. (In press).

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

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

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

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., Hitchcock, D. R., and Seiderer, L. J. 1999. Organic enrichment associated with outwash from marine aggregates dredging: A probable explanation for surface sheens and enhanced benthic production in the vicinity of dredging operations. Marine Pollution Bulletin. 38(9) : 809-818.

Keywords: aggregate dredging/ sediment plume/ organic enrichment

Abstract: Most recent studies of dispersion of sediment plumes generated by marine aggregates dredging, including those reported here, suggest that the zone of settlement of fine material temporarily suspended by the dredging and screening process is smaller than estimates based on Gaussian diffusion models. There is, however, often a relatively larger zone of visible impact which can extend for several kilometres downstream from a dredge during normal loading operations. This paper presents evidence which suggests that the "far field" visibility of the dispersing plume is associated with organic enrichment derived from fragmented marine benthos discharged with the out wash water.
The values which we have recorded for unexploited deposits off Southwold, Suffolk are as high as 1.454 g/l AFDW(ash-free dry weight) of which 0.007 g/l (0.48%) comprises lipids. Such material appears to be of sufficient concentration to match the likely removal of benthos from the sediments by the dredgehead. Even allowing for the dispersion which must occur downstream from the dredge, it seems likely that the organic enrichment derived from fragmented invertebrates in the dredger outwash may account for the enhanced species diversity and population density of benthic invertebrates recorded by others beyond the boundaries of dredged areas. (C) 1999 Elsevier Science Ltd. All rights reserved.

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

Abstract: The present review provides a framework within which the impact of dredging on biological resources that live on the sea bed ("Benthic" communities) can be understood, and places in perspective some of the recent studies that have been carried out in relation to aggregates dredging in European coastal waters. The impact of dredging works on fisheries and fish themselves and on their spawning grounds is

outside the scope of this review. We have, however, shown that empirical models for shelf waters such as the North Sea indicate that as much as 30% of total fisheries yield to man is derived from benthic resources, and that these become an increasingly important component of the food web in near-shore waters where primary production by seaweeds (macrophytes) and seagrasses living on the sea bed largely replaces that by the phytoplankton in the water column. Because dredging works are mainly carried out in near-shore coastal deposits, and these are the ones where benthic production processes are of importance in supporting demersal fish production, our review concentrates on the nature of benthic communities, their sensitivity to disturbance by dredging and land reclamation works, and on the recovery times that are likely to be required for the re-establishment of community structure following cessation of dredging or spoils disposal.
Essentially, the impact of dredging activities mainly relates to the physical removal of substratum and associated organisms from the sea bed along the path of the dredge head, and partly on the impact of subsequent deposition of material rejected by screening and overspill from the hopper. Because sediment disturbance by wave action is limited to depths of less than 30 m, it follow that pits and furrows from dredging activities are likely to be persistent features of the sea bed except in shallow waters where sands are mobile. Recent studies using Acoustic Doppler Current Profiling (ADCP) techniques suggest that the initial sedimentation of material discharged during outwash from dredgers does not, as had been widely assumed, disperse according to the Gaussian diffusion principles used in most simulation models, but behaves more like a density current where particles are held together during the initial phase of the sedimentation process. As a result, the principal area likely to be affected by sediment deposition is mainly confined to a zone of a few hundred metres from the discharge chute.
Our review suggests that marine communities conform with well-established principles of ecological succession, and that these allow some realistic predictions on the likely recovery of benthic communities following cessation of dredging. In general, communities living in fine mobile deposits, such as occur in estuaries are characterized by large populations of restricted variety of species that are well adapted to rapid recolonization of deposits that are subject to frequent disturbance. Recolonization of dredged deposits is initially by these "opportunistic" species and the community is subsequently supplemented by an increased species variety of long-lived and slow-growing "equilibrium" species that characterize stable undisturbed deposits such as coarse gravels and reefs.
Rates of recovery reported in the literature suggest that a recover time of 6-8 months is characteristic of many estuarine muds where frequent disturbance of the deposits precludes the establishment of long-lived components. In contrast the community of sands and gravels may take 2-3 yr to establish, depending on the proportion of sand and level of environmental disturbance by waves and currents, and may take even longer where rare slow-growing components were present in the community prior to dredging. As the deposits get coarser along a gradient of environmental stability, estimates of 5-10 yr are probably realistic for development of the complex biological associations between the slow growing components of equilibrium communities characteristic of reef structures.
Most recent studies show, however, that biological community composition is not controlled by any one, or a combination of, simple granulometric properties of the sediments such as particle size distribution. It is considered more likely that biological community composition is controlled by an array of environmental variables, many of them reflecting an interaction between particle mobility at the sediment/water interface and complex associations of chemical and biological factors operating over long time periods. Such interactions are not easily measured or analyzed, but the results suggest that the time course of recovery of an equilibrium community characteristic of undisturbed deposits is controlled partly by the process of compaction and stabilization that occurs following deposition.
Biological community composition thus reflects changes in sediment composition, but is also in equilibrium with seabed disturbance from tidal currents and wave action, both of which show spatial variations and interactions with water depth. The processes associated with compaction and stability of seabed deposits may, therefore, largely control the establishment of long-lived components of equilibrium communities and account for the dominance of opportunistic species in the initial stages of colonization in unconsolidated deposits of recently sedimented material after the cessation of dredging.

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. 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*.

Northeast Region Essential Fish Habitat Steering Committee. 2002. Workshop on the effects of fishing gear on marine habitats off the northeastern United States, October 23-25, 2001. Northeast Fisheries Science Center Reference Document 02-01. 86 p. National Marine Fisheries Service, NOAA, 166 Water Street, Woods Hole, MA 02543-1026.

Keywords: clam dredges/ scallop dredges/ otter trawls/ pots/ traps/ gill nets/ longline/ beam trawls/ pelagic gear/ model

Summary: This report includes contains individual sections detailing the impacts of specific gears: Clam dredges; Scallop dredges; Otter trawls; Pots and traps; Sink gill nets and bottom longlines; Beam trawls; and Pelagic Gear. it also has sections on a conceptual habitat impact model, prioritizing impacts, and recommendations for action.

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

Abstract: A study of the environmental effects associated with the trestle cultivation of Pacific oysters, Crassostrea gigas Thunberg, was conducted at a commercial cultivation site in the River Exe estuary, Devon, England. Small, but significant, changes were detected in the macrofaunal community sampled beneath oyster trestles compared with that found in adjacent uncultivated areas. These changes were associated with an increase in organic and silt composition and a reduction in the depth of the oxygenated layer of the sediment beneath the trestles. Water velocity was decreased by the presence of the trestles which probably led to the increase in sedimentation rate observed beneath them. Although biological and physical changes were observed, they were relatively minor compared with the extreme environmental changes associated with the suspended culture techniques used for other bivalve species and fishes. However, other studies suggest that the environmental effects associated with oyster cultivation become more severe in areas of large-scale (hectares) cultivation

Oliver, J. S., Slattery, P. N., Hulberg, L. W., and Nybakken, J. W. 1977. Patterns of succession in benthic infaunal communities following dredging and dredged material disposal in Monterey Bay. Tech. Rept. D-77-27, U.S. Army Engineer Dredged Material Research Program, Vicksburg, MS.

Keywords: dredging/ succession/ benthic infaunal communities/ Monterey Bay

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

Palanques, A., Guillen, J., and Puig, P. 2001. Impact of bottom trawling on water turbidity and muddy sediment of an unfished continental shelf. Limnology and Oceanography. 46(5) : 1100-1110.

Keywords: beam trawl / sea/ communities/ disturbance

Abstract: Two experiments were carried out to study the effects of trawling in the muddy prodeltaic deposit of the Llobregat River in the northwestern Mediterranean. Trawling was conducted in two experimental lines, and bottom morphology, sediment texture, and water turbidity were analyzed before trawling and at different time intervals afterward. The tracks of the trawl gears were still observed in sonographs of the bottom 1 yr after the first experiment. The vertical grain size distribution of bottom deposits indicated that the thickness of the sediment removed by the net between the gears was about 2-3 cm on average, though the erosion produced by the gears was deeper. Resuspended aggregates with a high silt content settled during the first hour after trawling, generating a temporary increase in the silt content of the surface sediment. One day after trawling, the surface sediment was mixed and already had a similar grain size distribution to that before trawling. After the beginning of trawling, water turbidity increased first near the bottom for a few hours and later also at shallower levels of the water column within a period of 2-5 d after trawling. At the end of the experiment, about 10% of the sediment affected by trawling was diffused in the water column and the remaining 90% had settled on the bottom. Average turbidity in the water column increased by a factor of up to three for 4-5 d after trawling. This experiment shows that intense and continued trawling on continental shelves has a noticeable effect on water turbidity, which must be considered in addition to natural processes.

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

Pastoors, M. A., Rijnsdorp, A. D., and Van Beek, F. A. 2000. Effects of a partially closed area in the North Sea ("plaice box") on stock development of plaice. ICES Journal of Marine Science. 57(4) : 1014-1022.

Keywords: marine protected area/ plaice/ discards/ effort/ recruitment

Abstract: The "plaice box" is a partially closed area in the North Sea, established in 1989 to reduce the discarding of undersized plaice (*Pleuronectes platessa*) in the main nursery areas, and thereby to enhance recruitment to the fishery. In contrast to the expected positive effects, yield and spawning stock biomass have decreased. The effects of the plaice box are evaluated by analyzing the relevant factors and processes (natural and anthropogenic) that affect recruitment. It is shown that the Dutch beam trawl effort has decreased in two phases. During 1989-1993, when the plaice box was closed only during the second and third quarter, effort was reduced to around 40% of the original level. When the box was also closed in the fourth (1994) and first quarter (1995 onwards), effort decreased to around 6%. The effort reduction would imply a reduction in discard mortality if all other factors had remained constant. However, a reduced growth rate and possibly a higher rate of natural mortality may have counteracted the reduction in fishing effort. The apparent changes in growth and mortality coincided with changes in the North Sea ecosystem that occurred in the early 1990s but may also be related to a response to the change in beam trawl effort. (C) 2000 International Council for the Exploration of the Sea.

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*.

Percival, P and Frid, C. 2000. The impact of fishing disturbance on benthic nutrient regeneration and flux rate. ICES : CM 2000/Z:07: 20 p.

Keywords: Ecosystem disturbance/ Energy transfer/ Zoobenthos/ Bottom trawls/ ANE, Atlantic/ primary production/ nitrogen cycle

Abstract: Nitrogen products are often thought to be a major limiting factor for photosynthesis by marine primary producers, ultimately, therefore, fisheries yield is dependent on the amounts of new and regenerated nutrients within the system. It is generally held that greater than 90% of marine primary production is remineralised within the marine system. However, the contribution to this figure from sedimentary processes is less well understood. Little attention has, however, been paid to the potential change in nutrient regeneration dynamics and flux rates as a result of fishing disturbance of the seafloor. This study investigates benthic remineralisation and nutrient flux, including consideration of the role of benthic disturbance by fishing vessels. Two mesocosm systems containing sediment from an untrawled area of the North Sea were allowed to stabilize for two months prior to the study. One system was subjected to daily simulated trawl actively while the other system remained untrawled over a four day period. Flux chambers were used to gain data on concentration changes within the chambers for three hours following the disturbance.

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, U.S. 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, U.S. 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 by-catch 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/ by-catch 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 by-catch 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

Piersma, T., Koolhaas, A., Dekinga, A., Beukema, J. J., Dekker, R., and Essink, K. 2001. Long-term indirect effects of mechanical cockle-dredging on intertidal bivalve stocks in the Wadden Sea. Journal of Applied Ecology. 38(5) : 976-990.

Keywords: Harvesting / Dredging/ Grain size/ Sediment texture/ Mollusc fisheries/ Recruitment/ Larval settlement / Molluscan larvae/ Commercial fishing/ Environmental impact/ Fishery management/ Stock assessment/ Intertidal environment/ Environmental degradation/ Sediments/ Netherlands/ Wadden Sea/ Ecological Effects/ Mollusks/ Clams/ Benthic Environment/ Fisheries/ Intertidal Areas/ Cerastoderma edule/ Mya arenaria/ Mytilus edulis/ Macoma balthica/ Bivalvia/ ANE, Netherlands, Frieland, Griend I./ ANE, Wadden Sea/ Wadden Sea/ suction-dredging/ Bivalves/ Clams/ Blue mussel/ Baltic macoma/ Softshell clam

Abstract: There is world-wide concern about the effects of bottom-dredging on benthic communities in soft sediments. In autumn 1988, almost a third of the 50-km super(2) intertidal system around the island of Griend in the western Dutch Wadden Sea was suction-dredged for edible cockles Cerastoderma edule and this study assessed subsequent effects. An adjacent area not directly touched by this fishery and an area from which the mussel Mytilus edulis beds were removed, served as reference areas. Sediment characteristics, together with the total stock size and settlement densities of Cerastoderma, Baltic tellin Macoma balthica and soft-shelled clam Mya arenaria, were documented during 11 successive autumns before (August-September 1988) and after (August-September 1989-98) the suction-dredging event in fished and unfished areas. Four other areas in the Dutch Wadden Sea, where changes in densities of juvenile bivalves from 1992 to 1998 were measured, served as additional reference locations. Between 1988 and 1994, median sediment grain size increased while silt was lost from sediments near Griend that were dredged for cockles. The initial sediment characteristics were re-attained by 1996. After the removal of all Mytilus and most Cerastoderma, the abundance of Macoma declined for 8 years. From 1989 to 1998, stocks of Cerastoderma, Macoma and Mytilus did not recover to the 1988 levels, with the loss of Cerastoderma and Macoma being most pronounced in the area dredged for cockles. Declines of bivalve stocks were caused by particularly low rates of settlement in fished areas until 1996, i.e. 8 years after the dredging. A comparison of settlement in the short (1992-94) and medium term (1996-98) after cockle-dredging in several fished and unfished areas spread over the entire Dutch Wadden Sea, showed a significant negative effect of dredging on subsequent settlement of Cerastoderma. Macoma also declined, but not significantly. We conclude that suction-dredging of Cerastoderma had long-lasting negative effects on recruitment of bivalves, particularly the target species, in sandy parts of the Wadden Sea basin. Initially, sediment reworking by suction-dredging (especially during autumn storms) probably caused losses of fine silts. Negative feedback processes appeared to follow that prevented the accumulation of fine-grained sediments conducive to bivalve settlement. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK and the Journal of Applied Ecology*.

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., Craeymeersch, J., Buijs, J., and Rijnsdorp, A. D. 1998. Changes in the benthic invertebrate assemblage following the establishment of a protected area, the "plaice box". ICES CM 1998/V:12 : 18 p .

Keywords: zoobenthos/ environmental protection/ bottom trawls/ North Sea/ plaice box/ species abundance/ scavengers/ fishing mortality

Abstract: In 1989 a protected area in the south-eastern North Sea was established: the "plaice box". At first it was only effective during the 2nd and 3rd quarter, but in 1994 the box was extended to the 4th quarter and since 1995 the box was closed during the whole year. Data of the by-catch of benthic invertebrates of two beam trawl surveys were used to determine the effect the closure of the box had on the benthic invertebrate assemblage. Multivariate analysis on the assemblage together with analysis of the eight most abundant species showed for both surveys a significant effect on the composition of the assemblage. Closing the box during the second and third quarter caused an increase in abundance of several species followed by a decline when the box was closed year-round. A possible explanation is that the most abundant species were scavengers and predators for which the deleterious effect of additional mortality is overruled by a decreased competition for food and risk of predation.

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.

Piet, G. J., Rijnsdorp, A. D., Bergman, M. J. N. , van Santbrink, J. W., Craeymeersch, J., and Buijs, J. 2000. A quantitative evaluation of the impact of beam trawling on benthic fauna in the southern North Sea. ICES Journal of Marine Science. 57(5) : 1332-1339.

Keywords: beam trawl / trawling impacts/ benthic fauna/ North Sea/ quantitative evaluation

Abstract: Data on density of benthos species and on direct mortality caused by the passing of a beam trawl, together with fishing effort data for the Dutch beam-trawl fleet, were used to evaluate the annual population mortality caused by beam trawling in the Dutch sector of the North Sea. The effects of using environmental strata, instead of ICES rectangles for density distributions, and of using higher-resolution fishing-effort data on the population mortality estimates of 21 infauna and epifauna species were investigated. Variation in species abundance was markedly smaller based on sediment-depth strata than based on ICES rectangles, and the resulting population mortality estimates differed significantly among species (ratio ranged from 0.3 to 1.6) depending on the overlap of the spatial distribution of a species and of beam-trawl effort. Changing the resolution of fishing effort from ICES rectangles or sediment-depth strata to 1' minute latitude×2' minute longitude square (±1×1nm) resulted in a systematic reduction of population mortality by a factor 0.7 due to the patchy effort distribution. We argue that annual fishing mortality should preferably be based on relevant environmental strata, and accuracy of the estimates increases markedly when the resolution of spatial fishing effort data sufficiently reflects the patchiness of the fleet's activities. *Copyright 2000 International Council for the Exploration of the Sea*

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.

Pipitone, C., Badalamenti, F., D'Anna, G., and Patti, B. 2000. Fish biomass increase after a four-year trawl ban in the Gulf of Castellammare (NW Sicily, Mediterranean Sea). Fisheries Research (Amsterdam). 48(1) : 23-30.

Keywords: Biomass/ Marine fisheries/ Fishery management/ Season regulations/ Artisanal fishing/ Eledone moschata/ Lepidotrigla cavillone/ Eledone cirrhosa/ MED, Italy, Sicilia, Trapani, Castellammare del Golfo

Abstract: This paper deals with a year-round trawl ban implemented in 1990 in the Gulf of Castellammare (NW Sicily, Mediterranean Sea) over an area of about 200 km super(2), with the purpose of fish stock rebuilding. Artisanal and recreational fishing were permitted in the Gulf. To assess the effect of the ban on the abundance of demersal resources, CPUE from experimental trawl surveys carried out before the ban (spring 1987 and 1989) and 4 years after it was in place (spring 1994) were compared. Sampling design was based on three depth strata (10-50, 51-100, 101-200 m); 21 and 30 hauls were made before and after the ban, respectively. Eleven target species (9 finfish and 2 cephalopods) as well as the total catch were used for comparisons. The total catch underwent an 8-fold increase in biomass after the four-year ban, and all the considered species underwent an increase, ranging from 1.2-fold for musky octopus (Eledone moschata) to 497-fold for gurnard (Lepidotrigla cavillone). The only decrease was for horned octopus (Eledone cirrhosa). A management strategy based on year-round trawling bans may prove useful, especially in areas where multispecies and multigear artisanal fisheries make up a large part of the fishing industry. The promising results obtained in the Gulf indicate an approach which might be practicable in areas where pre-existing data useful for traditional assessment and management are poor, or totally lacking, and where resources are already at risk of overexploitation.

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

Pitcher, C. R., Poiner, I. R., Hill, B. J., and Burridge, C. Y. 2000. Implications of the effects of trawling on sessile megazoobenthos on a tropical shelf in northeastern Australia. ICES Journal of Marine Science. 57(5) : 1359-1368.

Keywords: trawling impacts/ megazoobenthos/ tropical shelf/ northeastern Australia

Abstract: We estimate the possible overall status of populations of attached seabed fauna after 20 years of trawling in Australia's Great Barrier Reef (GBR), based on the key results of a five-year experimental study that provided an understanding of faunal resilience, in terms of removal rates per trawl. The removal rates

of most seabed fauna were between 5 and 20% per trawl (range 0-40%). In attempting to estimate population status, it was also necessary to review patterns of trawl effort intensity and add a simple model for possible recovery dynamics of fauna. Large areas of the GBR are subject to trawling. In 1996, effort was recorded in 1300 statistical grids, each 6 x 6 minutes, an area equivalent to 153 000 km. Effort was highly aggregated among the grids, with about 20% concentrated into <5% of trawled grounds (intensive); at the other extreme, about 20% of the effort was spread over about 60% of the trawled grounds (extensive). Trawling was also highly aggregated at fine scales within grids; consequently a smaller area is actually trawled than is indicated by summing up 6 min grids. The amount of fauna removed each year is related to the resilience of the fauna to removal, the intensity of trawling, and its degree of aggregation. In lightly trawled grids, the annual removal may have been only a low percentage, but in the most intensively trawled grids, more than 80% of the least resilient fauna may be removed each year. In high-effort grids, aggregated trawling removes smaller amounts of benthos than if effort were distributed randomly or uniformly. The average annual removal of fauna over all trawled grids differs for different fauna. A total of about 4% of high-resilience fauna may be removed, similar to 8% of medium-resilience fauna, and similar to 15% of low-resilience fauna. The overall vulnerability of fauna is a combination of resilience and recovery rates. Fauna with no capacity for recovery will eventually be completely removed from all trawled areas. All fauna with a capacity for recovery have the potential for sustaining a population level in balance with the amount removed by trawling, up to certain limits. The most vulnerable fauna may be completely removed from the 5-10% of grids that are trawled with >2000-3000 h of effort. More fauna will be removed from grids with higher effort. Though 50-70% of trawled grids have been trawled only lightly (<700-1000 h) each year, over the last 20 years there has been a cumulative effect. A generalized depletion across all trawled grids is likely, but fauna with low vulnerability may be depleted by only 3% overall; medium vulnerability fauna may be depleted by about 20%; and highly vulnerable populations may be depleted by about 55% overall. Because of differential vulnerability, the composition of the faunal community will be substantially altered in most grids, with a shift to less vulnerable species.

Poiner, I., Glaister, J., Pitcher, R., Burridge, C., Wassenberg, T., Gribble, N., Hill, B., Blaber, S., Milton, D., Brewer, D., and Ellis, N. 1998. Final report on effects of 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

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 organizations as well as GBRMPA, FRDC and AFMA. Following the recommendation of the Workshop, the study was sited in an area known as the Green Zone between about 11^{o} 15' and 11^{o} 45'S that was closed to fishing in 1985 as well as in the areas immediately to the north and south of the Green Zone. The study had several components: 1. A collation and review of all known biological, oceanographic, and fisheries information available on the study area (Chapter 2). 2. A description of the study area. This included a survey of the sediments, epi-benthos (animals living on the seabed), fish and prawns in the region (Chapter 2). 3. Comparisons of the areas that are open to trawling with those that are closed to trawling (Chapter 3). 4. A Before-After-Control-Impact (BACI design) manipulative experiment comparing areas that were subjected to the Impact of a single trawl coverage with untrawled Control areas (Chapter 4). 5. A Repeat trawl experiment in which strips of seabed were trawled up to 13 times (Chapter 5). 6. A description of the composition of prawn trawl bycatch and the fate of discards from prawn trawling and a study of the interactions between seabirds and discards (Chapter 6). 7. The results are summarized here in 10 outcomes categories based on the original objectives of the work. In addition we have summarized a model describing the effects of differential impacts and recovery rates of the seabed fauna (Chapter 7). Finally, implications of the findings of the study for management of the GBR and for management of the East Coast prawn trawl fishery are discussed (Chapter 7).

Poiner, I. R. and Harris, A. 1988. The effects of trawling on the traditional marine resources of the Torres Strait. Pages 172-175 *in* Traditional Knowledge of the Marine Environment In Northern Australia. Proceedings of a Workshop Held in Townsville, Australia, 29 and 30 July 1985. Workshop Series. Great Barrier Reef Marine Park Authority. Townsville. No. 8.

Keywords: shrimp fisheries/ trawling/ environmental impact/ fishery resources/ artisanal fishing/ ISEW, Torres Strait

Abstract: An examination is made of the different ways in which prawn trawling may negatively impact the traditional/artisanal fishing activities in Torres Strait. Details are given of a programme conducted by the CSIRO Division of Fisheries Research to ascertain whether prawn trawling has a significant effect on the fish populations of the Torres Strait.

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 equitability 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 biocenosis, 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/ anthropogenic 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 behavior 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.

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

Keywords: Adriatic Sea/ Fishing Disturbance/ Macrobenthos/ Meiobenthos/ Trawling/ Impact/ Disturbance / Sediment/ Pollution

Abstract: The rapido is a towed gear used only in the Adriatic Sea for fishing scallops in sandy offshore areas and flatfish in muddy inshore areas. The gear is expected to have a high impact on the entire benthic community, mainly on epifauna and organisms living in the upper sediment layers. To obtain information on likely medium- to long-term effects of trawl fishing in the northern Adriatic Sea, an experiment on immediate/short-term effects was carried out in an undisturbed sandy area near a wreck. The rapido produced flat tracks on the bottom that were still clearly visible after a week by means of sidescan sonar. The trawl did not change the sediment grain size, although it did disturb the upper 6 cm of sediment. Experimental trawling induced a modification in the macrobenthic community that was most evident immediately after the haul. Changes to the meiobenthic community were probably due to sediment disturbance and were recorded after 1 week. Comparison between an undisturbed control area and a neighbouring commercially exploited area allowed some evaluation of long-term changes in the benthic community. (C) 2000 International Council for the Exploration of the Sea.

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

Abstract: 1. Benthic invertebrate bycatch was collected during trawling for orange roughy (Hoplostethus atlanticus) at water depths of 662-1524 m on the northern and eastern Chatham Rise, New Zealand, in July 1994. Seventy-three trawl tows were examined, 49 from 'flat' areas and 24 from two groups of 'hills' (small seamounts). Benthos was recorded from 82% of all tows. 2. Some 96 benthic species were recorded including Ophiuroidea (12 spp.), Natantia (11 spp.), Asteroidea (11 spp.), Gorgonacea (11 spp.), Holothuroidea (7 spp.), and Porifera (6 spp.). 3. Cluster analysis showed the bycatch from flats and hills to differ significantly. Dominant taxa from flats were Holothuroidea, Asteroidea and Natantia; whereas taxa most commonly recorded from hills were Gorgonacea and Scleractinia. Bycatch from the two geographically separate groups of hills also differed significantly. 4. The largest bycatch volumes comprised corals from hills: Scleractinia (Goniocorella dumosa), Stylasteridae (Errina chathamensis) and Antipatharia (?Bathyplates platycaulus). Such large sessile epifauna may significantly increase the complexity of benthic habitat and trawling damage may thereby depress local biodiversity. Coral patches may require > 100 yr to recover. 5. Other environmental effects of deep-water trawling are briefly reviewed. 6. There is an urgent need to assess more fully the impact of trawling on seamount biotas and, in consequence, possible conservation measures.

Quigley, M. P. and Hall, J. A. 1999. Recovery of macrobenthic communities after maintenance dredging in the Blyth Estuary, north-east England. Aquatic Conservation: Marine and Freshwater. 9(1) : 63-73 .

Keywords: Benthos/ Population changes/ Community structure/ Dredging/ Estuaries/ British Isles, England/ British Isles, England, Blyth Estuary/ Biological Sampling/ Cores/ Multivariate Analysis/ Taxonomy/

Monitoring/ Estuarine organisms/ Environmental impact/ Zoobenthos / Man-induced effects/ Interstitial environment/ Community composition/ Macrofauna/ Maintenance/ Marine environment/ Capitella capitata/ Tubificoides/ Eteone longa/ Angulus tenuis/ Tubificoides/ Nematoda/ Eteone longa/ Capitella capitata/ ANE, British Isles, England, Northumberland, Blyth Estuary/ Nematodes

Abstract: This paper examines the impact of a dredging event on the benthic community of a polluted estuary in north-eastern England and follows recovery of the community from January until June, 1997. Adopting a BACI (Before, After, Control, Impacted) approach, the benthos were sampled at two sites using a Haps corer (0.0143 m super(2)). Five cores were taken at each site, and the sites were each visited once in January 1997, prior to the 33 day dredging period, and a further five times during the 100 day post-dredging monitoring period ending in June 1997. Fifteen taxa were recorded, of which five contributed 95% of all of the individuals present; Capitella capitata (Fabricius), Tubificoides spp., nematodes, Eteone longa (Fabricius), and the mollusc Angulus tenuis (da Costa). Univariate and multivariate analyses of benthic macrofaunal data showed that dredging had not only impacted the dredged site, but had also affected the control area located 500 m away on the opposite side of the estuary. At the end of the study period the macrobenthic community at the impacted site showed no significant signs of recovery to pre-dredging community parameters.

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., Bergmann, M., Veale, L. O., Richardson, C. A., Kaiser, M. J., Vize, S. J., and Feist, S. W. 2001. Damage, autotomy and arm regeneration in starfish caught by towed demersal fishing gears. Marine Ecology Progress Series. 138(3) : 527-536.

Keywords: demersal fishing gear/ trawling/ starfish

Ramsay, K., Bergmann, M., Veale, L. O., Richardson, C. A., Kaiser, M. J., Vize, S. J., and Feist, S. W. 2001. Damage, autotomy and arm regeneration in starfish caught by towed demersal fishing gears. Marine Biology. 138(3) : 527-536.

Keywords: Autotomy/ Biological damage/ Animal morphology/ Survival / Fishing gear/ Asterias rubens/ ANE, British Isles/ body organs/ histology/ fishing effort/ statistical analysis/ growth

Abstract: Arm damage and loss were examined in the starfish Asterias rubens that had been caught in a variety of towed commercial fishing gears deployed on different sea bed types. Between 7% and 38% of the starfish in each catch lost one or more arms, and arm loss was positively correlated with the volume of the catch for two of the fishing gears examined. Subsequent monitoring of damaged animals showed that arms were autotomised for at least 3 weeks following capture. Mortality was highest in starfish with damaged or missing arms, compared with those that appeared intact after fishing. Arm regeneration was delayed in a small proportion of the animals caught by commercial gears. In a parallel study, 17% of starfish caught by a 4 m beam trawl had a damaged ambulacral ossicle at the point of autotomy (cf. none from a control group that were induced to autotomise under controlled conditions). There was no difference in regeneration rates between the animals caught by commercial gears and a control set (caught by a small trawl and forced to autotomise an arm in the laboratory) once the animals that delayed regeneration were excluded from the dataset. After 1 year under laboratory conditions the starfish had, on average, regenerated the missing arm to 75% of the length of the other four arms. During this time period the lengths of the undamaged arms increased by ca. 50%. The implications of this study for using arm loss in starfish as an indicator of fishing disturbance are discussed.

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 analysed 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. 1997. 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. 2000. Can shell scars on dog cockles (*Glycymeris glycymeris* L.) be used as an indicator of fishing disturbance? Journal of Sea Research. 43(2) : 167-176.

Keywords: shell damage/ bivalves/ indicator/ fishing effort/ growth lines

Abstract: The use of shell damage records as an in situ indicator of past fishing disturbance was investigated using the dog cockle *Glycymeris glycymeris* L. Shell sections of dog cockles collected from four areas subjected to varying levels of fishing disturbance were examined for the presence of damage records or shell 'scars'. Animals from a heavily fished area had significantly higher levels of scarring than those from three lightly fished areas. From an estimation of the age of the shells (from internal growth lines and dating of each line), the year in which scarring occurred was determined and this was compared to yearly records of fishing effort. There was a weak but significant positive correlation between the frequency of shell scars per year and the intensity of fishing effort. Our data suggest that whilst scarring in shells of G. glycymeris cannot accurately be used to estimate past fishing intensity on a year-by-year basis, it can be used to differentiate between severely impacted and lightly fished areas of the sea bed.

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.*

Ramsay, K., Richardson, C. A., and Kaiser, M. J. 2001. Causes of shell scarring in dog cockles Glycymeris glycymeris L. Journal of Sea Research. 45(2) : 131-139.

Keywords: Shells/ Marine molluscs/ Lesions/ Fishing gear/ Environmental effects/ Glycymeris glycymeris/ Cancer pagurus

Abstract: Experimental studies were conducted to investigate the possible causes of shell scars in the bivalve mollusc Glycymeris glycymeris, including fishing disturbance, predator attacks and burrowing activity. Individuals collected from an area of sea bed experimentally fished once by a scallop dredge 12 months previously did not display significantly more shell scars than those collected before fishing or from a control area. In the laboratory, Glycymeris offered to the predatory crab Cancer pagurus had a significantly higher incidence of scars seen in acetate peels of shell cross-sections than control shells. However, scarring on Glycymeris excavated from the sediment and left to reburrow was not significantly different from those in an undisturbed control group. Currently, it is not possible in G. glycymeris to differentiate between scars caused by fishing disturbance or natural disturbances, either on the grounds of visual appearance or position of damage. *Reprinted from Journal of Sea Research, Vol. 45; Ramsay, K., Richardson, C.A., Kaiser, M.J., Causes of shell scarring in dog cockles Glycymeris glycymeris L.., pages 131-139; Copyright (2001); with permission from Elsevier Science.*

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

Reed, J. K. 2002. Deep-water Oculina coral reefs of Florida: Biology, impacts, and management. Hydrobiologia-471(1) : 43-55.

Keywords: *Oculina*/ deep-water/ coral reef/ management/ biology

Abstract: Deep-water *Oculina* coral reefs, which are similar in structure and development to deep-water *Lophelia* reefs, stretch over 167 km (90 nmi) at depths of 70–100 m along the eastern Florida shelf of the United States. These consist of numerous pinnacles and ridges, 3–35 m in height. Coral growth rates average 16.1 mm yr-1 and biodiversity is very rich. Extensive areas of *Oculina* rubble may be due to human

impacts (e.g. fish trawling and dredging, anchoring, bottom longlines) and natural processes such as bioerosion and episodic die-off. Early in the 1970s, the reefs were teeming with fish. By the early 1990s, both commercial and recreational fisheries, including scallop, shrimp, grouper, snapper and amberjack, had taken a toll on the reefs and especially on populations of grouper and snapper. A 315 km2 (92 nmi2) area was designated the *Oculina* Habitat of Particular Concern (HAPC) in 1984, prohibiting trawling, dredging, bottom longlines and anchoring, and legislation was enacted in 2000 for expansion of the *Oculina* HAPC to 1029 km2 (300 nmi2). The United States Coast Guard has been charged with surveillance and enforcement of the ban on bottom fishing and trawling. The primary difficulties in protecting these reefs and other deep-water Marine Protected Areas are their remoteness and time required to engage an enforcement vessel. Education regarding the nature and importance of these rich resources is important for better self regulation and surveillance by the fishing community. Only by bringing deep-water reefs to the public, the fishing community, and enforcement agencies, through video, photos, and education will there be better understanding and acceptance for the need of protection for these unseen resources. This paper reviews the current knowledge on the deep-water *Oculina* reefs, including the biology, geology, human impacts, and history of conservation and management.

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 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).*

Relini, G., Relini, M., and Torchia, G. 2000. The role of fishing gear in the spreading of allochthonous species: the Case of *Caulerpa taxifolia* in the Ligurian Sea. ICES Journal of Marine Science. 57(5) : 1421-1427.

Keywords: fishing gear/ spreading/ redistribution/ *Caulerpa taxifolia*/ Ligurian Sea

Abstract: Qualitative and quantitative changes in fish communities are described when a sea grass (*Cymodocea nodosa*) is replaced by a green alga (*Caulerpa taxifolia*) at Imperia (western Ligurian Sea). In general, the number of species, number of individuals and weight increase when the soft bottom is colonized by the alga, but the catch of valuable fish, and consequently the fishermen's income, decrease. The spreading of the alga is facilitated by fishing activity, in particular by bottom trawlers and trammel nets. Fishermen are themselves strongly affected by the spreading, not only because of the decrease in valuable fish, but also because the massive presence of the alga interferes with the use of the gear. *Copyright 2000 International Council for the Exploration of the Sea.*

Rester, J. K. 2000. Annotated bibliography of fishing impacts on habitat. Gulf States Marine Fisheries Commission. Number 73. Ocean Springs, Mississippi, 168 p.

Keywords: bibliography/ fishing impacts/ habitat disturbance

Summary: A comprehensive literature bibliography on fishing impacts to marine habitat.

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 quadrants. 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 maximum (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 & 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 crenatus*, *Cerastoderma edule*, *Scoloplos armiger*). The subtidal fauna of the Wadden Sea proved to be vulnerable to human disturbance; thus, the present community can no longer be viewed as the outcome of entirely natural processes. *Reprinted with the permission of Biologische Anstalt Helgoland and Helgoland Marine Research (formerly Helgolander Meeresuntersuchungen)*.

Rijnsdorp, A. D., Broekman, P. L. V., and Visser, E. G. 2000. Competitive interactions among beam trawlers exploiting local patches of flatfish in the North Sea. ICES Journal of Marine Science. 57(4) : 894-902.

Keywords: fleet dynamics/ effort allocation/ optimal foraging/ fishing power/ interference competition

Abstract: The fishing pattern of individual beam trawl vessels comprises alternating searching and exploitation phases during a fishing trip. The searching phase is characterized by a below-average catch rate and a long distance between the midpoints of hauls. The exploitation phase is characterized by an above average-catch rate and a small inter-haul distance. During the exploitation of a local concentration of flatfish, the catch rate decreases on average by 10% over a period of 48 h. The rate of decline is a function of the engine power. Powerful vessels experience a small or no decline in catch rate, whereas less powerful vessels experience a decline of up to 16%. It is inferred that the decline in catch rate may be due to interference competition among vessels through a change in the behaviour of flatfish in response to fishing disturbance, although a reduction in local abundance may also have contributed to the decline. Areas with above-average catch rates may change on a weekly basis. (C) 2000 International Council for the Exploration of the Sea.

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., Dol, W., Hoyer, M., and Pastoors, M. A. 2000. Effects of fishing power and competitive interactions among vessels on the effort allocation on the trip level of the Dutch beam trawl fleet. ICES Journal of Marine Science. 57(4) : 927-937.

Keywords: fleet dynamics/ effort allocation/ ideal free distribution/ fishing power/ interference competition

Abstract: Variations in catch rates in relation to the spatial distribution of beam trawlers were analyzed using mandatory logbook data from the Dutch fleet for 1990-1996. Catch rates by trip, corrected for differences in market value, showed a consistent seasonal pattern with the highest values found during autumn and winter. Catch rates showed a log-linear relationship with engine power, indicating differences in competitive abilities among vessels. In 65% of the fishing trips, catch per unit of effort is equalized among fishing grounds. In the remaining trips, catch rates were below average, suggesting that vessels showed exploratory fishing. These results corroborate predictions of the ideal free distribution theory. More powerful vessels were over-represented on better fishing grounds as compared with less powerful vessels. As a special case the effect of vessel density on catch rate was investigated utilizing the convenient fact that a segment of the Dutch fleet stayed in port during one week each year ("week of prayer"). The catch rate of vessels that continued fishing was 10% higher than in the week before or following the week of prayer. No such differences were observed in a reference area where no change in vessel density was observed. Implications of this evidence of competitive interactions among vessels in relation to fisheries management are discussed. (C) 2000 International Council for the Exploration of the Sea.

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 1x1 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 1x1 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 microdistibution 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

Abstract: A comparison of catch rates of demersal fish during beam trawl and otter trawl surveys carried out in the period 1990-1995 and 1906-1909 indicates lower abundance in recent years for the total assemblage as well as for individual groups. There appear to have been shifts in the community associated with reduced diversity and evenness indices. Length-frequency distributions of roundfish and flatfish show a shift towards smaller-sized fish.

Rijnsdorp, A. D. and vanLeeuwen, P. I. 1996. Changes in growth of North Sea plaice since 1950 in relation to density, eutrophication, beam-trawl effort, and temperature. ICES Journal of Marine Science. 53(6) : 1199-1213.

Keywords: beam trawling/ density-dependence/ eutrophication/ growth

Abstract: Annual length increments of female North Sea plaice were back-calculated from distances between rings in otoliths. Growth of the smaller size classes (<25 cm) increased from the mid-1950s and decreased in the 1980s. Length increments of intermediate size classes varied more or less randomly, and those of the larger size classes (>35 cm) increased from 1970. Growth changes of the smaller size classes were significantly correlated with indices of plaice density, eutrophication, and seabed disturbance by beam trawling. Moreover, they could be related to spatial and temporal patterns in variations in eutrophication and beam trawling. No correlation was observed with temperature. The analysis led to a consistent interpretation suggesting that eutrophication and beam trawling have both affected the growth rate of plaice. The contributions of these factors differed in space. Effects of eutrophication dominated in the shallow coastal waters, whereas beam trawling dominated in the waters further offshore. (C) 1996 International Council for the Exploration of the Sea.

Rijnsdorp, A. D. and Vingerhoed, B. 2001. Feeding of plaice *Pleuronectes platessa* L. and sole *Solea solea* L. in relation to the effects of bottom trawling. Journal of Sea Research. 45(3-4) : 219-229.

Keywords: Marine fish/ Bottom trawling/ Man-induced effects/ Stomach content/ Zoobenthos/ Eutrophication/ Pollution effects/ Pleuronectes platessa/ Solea solea/ European plaice

Abstract: Stomachs of plaice and sole were collected in 1996 within and just outside the 'plaice box' (PB), an area in which fishing by vessels larger than 300 hp has been prohibited since 1989. In the mid-1990s the beam trawl fishing effort was reduced by 85% of the pre-closure level. In addition, a comparison was made of the diet composition of plaice and sole between the present and the beginning the 20th century. The diet of both species comprises mainly short-lived, highly productive benthic organisms. No difference could be found between the diets of fish sampled at grounds with different trawling intensities. The comparison of the present-day diet and the diet at the beginning of the 20th century suggests that the preponderance of polychaetes has increased and that of bivalves decreased. These results are consistent with the hypothesis that beam trawling has improved the feeding conditions for the two flatfish species by enhancing the abundance of small opportunistic benthic species such as polychaetes in the heavily trawled areas. However, the changes in diet may also be related to eutrophication and pollution. *Reprinted from Journal of Sea Research, Vol. 45; Rijnsdorp, A.D., Vingerhoed, B; Feeding of plaice Pleuronectes platessa L. and sole Solea solea (L.) in relation to the effects of bottom trawling., pages 219-229; Copyright (2001); with permission from Elsevier Science.*

Roberts, J. M., Harvey, S. M., Lamont, P. A., Gage, J. D., and Humphery, J. D. 2000. Seabed photography, environmental assessment and evidence for deep-water trawling on the continental margin west of the Hebrides. Hydrobiologia. 441(1-3) : 173-183.

Keywords: Surveys/ Photography/ Sediments/ Benthic environment/ Fishing/ Atlantic Ocean/ Fishery management/ Ecosystem disturbance/ Commercial fishing/ Imaging techniques/ Ocean floor/ Baseline studies/ Barite/ Trawling/ Environmental impact/ Man-induced effects/ Continental margins/ Oil and gas exploration/ Human impact/ Population-environment relations/ Fisheries/ Benthos/ Hydrocarbons/ Environmental studies/ Oil and gas industry/ Xenophyophoria/ ANE, Atlantic, Rockall Trough, Hebrides Slope

Abstract: A photographic survey in 1998 of the seabed along depth transects from 700 to 1300 m across the N.E. Atlantic continental slope off north-west Scotland shows clear depth-related change in sediment type and megabenthic community in an environment where biological communities and species distributions are poorly known. Small-scale features, such as trawl marks and dense fields of xenophyophores, were resolved that may have remained unknown using conventional sampling or lower resolution imaging techniques. Because xenophyophores accumulate barite, a constituent of some drilling muds, their local-scale occurrences will be important to baseline environmental survey prior to hydrocarbon prospecting in deep water. Our results indicate that deep-sea trawling is physically impacting the seabed to depths of more than 1000 m. The persistence and biological consequence of this impact is unknown, but may depend on sediment type and natural physical disturbance. Comparison with similar seabed photographs taken from a

neighbouring area in 1988, which show a high incidence of trawl marks, indicates that such impacts have been taking place over at least 10 years.

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% > = 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, R. M. 1976. Distribution of meiobenthic organisms in San Antonio Bay in relation to season and habitat disturbance. Pages 337-344 *in* A.H. Bouma (ed.), Shell dredging and its influence on Gulf coast environments. Gulf Publishing Company, Houston, Texas.

Keywords: Meiobenthic/ disturbance/ habitat/ San Antonio Bay

Abstract: Meiobenthic organisms were first defined as bottom organisms of intermediate size, smaller than those normally included as macrobenthos (crabs, shrimp, clams, etc.), but larger than the microbenthos (bacteria, diatoms, most protozoa, etc.) (Mare, 1942). More recently, the group has been further defined on the basis of sampling and sorting techniques employed in their study (McIntyre, 1969). In the present investigation the meiobenthos includes bottom organisms of the approximate size range of 62um to 1mm, as passed or retained by sieves of these pore diameters. Meiofauna of this size range includes groups such as nematodes, copepods, kinorhynchs, small pelecypods, and small gastropods which may pass their entire lives in association with bottom sediments. In addition, it includes the larval and juvenile stages of certain larger invertebrates in which the adults are too large to be included in the meiobenthos or in which a portion of the life history is not associated with the bottom. Meiobenthic organisms are of great importance as food for larger animals and as young stages of commercially important species. Due to their small size these organisms have an intimate relation with the sediment particles, and this makes them a sensitive biological indicator of the quality of the benthic environment. The present study was carried out to determine whether or not dredging operations affect the distribution and seasonal abundance of meiofauna within San Antonio Bay.

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., Ellis, J. R., and Dann, J. 2001. The association between arm damage of the common starfish, *Asterias rubens*, and fishing intensity determined from aerial observation. Sarsia. 86(2) : 107-112.

Keywords: Environmental impact/ Commercial fishing/ Indicator species/ Regeneration/ Injuries/ Zoobenthos/ Bottom trawling/ Ecosystem disturbance/ Animal appendages/ Asterias rubens/ ANE, Irish Sea/ ANE, British Isles, Bristol Channel

Abstract: The use of the common starfish Asterias rubens as a biological indicator of physical disturbance was investigated during a two year period at 32 offshore sampling sites distributed over a wide geographical area. Starfish were collected from the Irish Sea and Bristol Channel during routine groundfish surveys, and the proportion of each starfish sample with missing or partly re-grown arms was recorded. Significant positive correlations were found between the proportion of damaged starfish, and the intensity of bottom-

trawl activity at the sample sites observed during the previous 2-8 months by aerial reconnaissance flights. The degree of variability in these relationships, however, suggested that arm damage of starfish can be used only as a broad-scale indicator of the intensity of commercial fishing activity. The implications of this for interpreting changes in benthic community structure are discussed.

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 non-target 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., 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.*

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., 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.*

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 Behaviour report, ICES CM 2000/B:03 : 25 p.

Keywords: fishing gear technology/ 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.

Rose, C. S. 1999. Injury rates of red king crab, *Paralithodes camtschaticus*, passing under bottom-trawl footropes. Marine Fisheries Review. 61(2) : 72-76.

Keywords: Man-induced effects/ Trawling/ Injuries/ Crab fisheries/ Paralithodes camtschatica/ Red king crab

Abstract: The rate of injuries sustained by red king crab, Paralithodes camtschaticus, during passage under several types of bottom trawl footropes was examined using a modified bottom trawl in Bristol Bay, Alaska. Crabs were recaptured and examined for injuries after passing under each of three trawl footropes

representing those commonly used in the bottom trawl fisheries of the eastern Bering Sea. Using the injury rate from tows with a floated footrope which minimized crab contact to account for handling injuries, injury rates of 5, 7, and 10% were estimated for crabs passing under the three commercial trawl footropes.

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 He'ral, 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

Abstract: The oyster Crassostrea virginica population in the Maryland portion of Chesapeake Bay, USA, has declined by more than 50-fold since the early part of this century. The paper presents evidence that the mechanical destruction of habitat and stock overfishing have been important factors in the decline, even though it is commonly thought that 'water quality' and, more recently, oyster diseases are critical. Quantitative analysis show that the long-term decline of oysters largely results from habitat loss associated with intensive fishing pressure early in this century, and stock overfishing from early in the century through recent times. Furthermore, the major ecological effects on Chesapeake Bay occurred well before World War II, before industrialization and the reported prevalence of disease. To effect the recovery of the ailing Chesapeake Bay oyster stock, a 4-point management strategy is proposed.

Rowell, T. W., 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 side-scan 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 retrawled 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 47^0 04.00' N, 48^0 11.00' W to 46^0 45.46' N, 48^0 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 side-scan 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. and Kujawski, T. 2000. The impact of trawl fishery on the epifauna of the southern North Sea. ICES Journal of Marine Science. 57(5) : 1389-1394.

Keywords: trawling impacts/ epifauna/ southern North Sea

Abstract: Qualitative historical benthos data (1902-1912) were compared with recent data (1986) to find long-term trends in epifauna species composition in the southern North Sea that may be attributed to fishery-induced changes. In general, the frequency of occurrence of bivalve species declined, whereas scavenger and predator species (crustaceans, gastropods, and sea stars) were observed more frequently in 1986. We suggest that these shifts can be attributed not only to the physical fishery impact, but also to the additional potential food for scavenging and predator species provided by the large amounts of discards and moribund benthos. Our findings are put into the perspective of the general development of the demersal fishery in the southern North Sea. Despite the problems with the historical data set, the comparison presented may be the best illustration achievable of the changes in the benthos from a near-pristine situation

to the present conditions after long-term disturbance. *Copyright 2000 International Council for the Exploration of the Sea.*

Rumohr, H., Schomann, H., and Kujawski, T. 1994. Environmental impact of bottom gears on benthic fauna in the German Bight. Pages 75-86 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

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

Abstract: This subproject concentrated on the investigation of direct effects of beam trawling on benthic fauna (including fishes). This was investigated using imaging methods (video, photo and REMOTS sediment profile photography), and with dredges directly attached to those parts of the gear that might cause damage to benthic animals (shoe, tickler chains). Reference values were obtained by a dredge attached to the beam. The dredge samples clearly revealed the effects of the beam trawl in some bigger taxa such as brittle stars, starfish, larger crustaceans and polychaetes (Aphrodite aculeata) although the sediment texture seemed to play an important role in this context. The "chain"-dredges contained more species than the "beam"-dredges, which is further proof of the effects of the tickler chains. The mean number of fishes was double in the chain dredges, and the species number was 1.5 times higher than in the reference sample. Video records displayed a relatively undisturbed reference area 10 sm SE. REMOTS photographs revealed a disturbed surface layer in the IMPACT-box that showed no signs of layering or bioturbative action. Layers with mollusc damaged compared with intact ones in the control area. The epifauna was reduced in abundance. No inner structures (feeding burrows, living chambers, tubes) were visible in the impacted area. At the control site a rich Ophiura community and Lanice as well as burrowed Aphrodite could be observed both in the video and in the sediment profiles. Close-up video inspections of a 10 m shrimp trawl in the German Wadden Sea showed the relatively low impact of this gear on the sediment and the behaviour of the shrimps in front of the trawl. Sea moss (Sertularia) and Lanice meadows remained relatively undisturbed after the passage of type of gear.

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.

Safina, Carl. 1998. Scorched-Earth fishing. Issues in Science and Technology Online. Spring 1998. Available at: http://www.nap.edu/issues/14.3/safina.htm.

Keywords: trawling/ habitat

Abstract: The use of new fish-trawling gear is doing incalculable damage to the seabed, destroying essential habitat for marine life.

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

Abstract: Fuzzy graph theory is applicable to any dynamical system where the values of all state variables are known for at least two points in time. This type of analysis is useful for detecting early trends in

successional changes of assemblages of organisms. Seventeen successive years of research vessel trawl survey data from the Gulf of Thailand involving 38 species or species groups were amenable to this form of analysis. The compositional dynamics of the species were examined by using three fuzzy relations to describe succession from the same data set. Although fuzzy graphs resulting from these relations showed that successional trends depended somewhat upon the characteristics of the chosen relation, consistent succession to a relatively few short-lived opportunistic species occurred. After the initial perturbation, the system was not strongly time-varying and some prediction was possible from a short data set. This application of methods and algorithms of fuzzy graph theory to analysis of multispecies fishery dynamics suggests that preliminary interpretation of trends in such data can be made with them.

Saila, S. B. 1995. New England groundfisheries -- what next? Maritimes. 38(2) : 1-3.

Keywords: demersal fisheries/ fishery management/ New England

Sainsbury, J. C. 1996. Commercial Fishing Methods, an Introduction to Vessels and Gear. Third Edition. Fishing News Books. Osney Mead, Oxford, England. 360 p.

Keywords: fishing gear/ vessels

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 from 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 of 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-Jerez, P., Barbera-Cebrian, C., and Ramos-Espla, A. A. 2000. Influence of the structure of *Posidonia oceanica* meadows modified by bottom trawling on crustacean assemblages: Comparison of amphipods and decapods. Scientia Marina. 64(3) : 319-326.

Keywords: Crustaceans/ Community Structure/ Habitat Complexity/ Posidonia Oceanica/ Mediterranean Sea/ Water Fish Assemblages/ Mobile Epifauna/ Community Structure/ Southern Australia/ Habitat Complexity/ Trophic Ecology/ Seagrass Bed/ Invertebrates/ Abundance/ Predation

Abstract: The seagrass Posidonia oceanica plays an important role as habitat for invertebrates. A correlative study was done in El Campello (SE Spain) to understand the relationships between assemblage structure of crustaceans and modification of P. oceanica structure caused by bottom trawling. We compared the changes of community structure of the most important groups of crustaceans, amphipods and decapods with changes of cover, density, detritus and rhizome fragments. Sampling was carried out in four control and four impact locations, along a gradient of degradation (17 m depth, August 1992). Multivariate analysis was used for community data (nm-MDS) and P, oceanica structure (PCA). Both groups showed a similar number of species. The amphipod community showed a clear pattern of community changes with significant differences between impact and control locations (global $R = 0.298$, $p<0.001$) and with significant correlation with P. oceanica structure (global $rho = 0.21$, $p<0.05$). Detritus (fine and coarse) and rhizome fragments had the highest influence on amphipod distribution. Spatial variability inside of locations was very high. Few species (Dexamine spiniventris, Lysianassa longicornis or Ampelisca spp.) were responsible for dissimilarity among locations. Decapods did not show a correlation with the structure of P. oceanica. The amphipod community seems to be a strong indicator of the ecological implications of seagrass degradation.

Sanchez-Lizaso, J. L., Guillen Nieto, J. E., and Ramos Espla', 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

Sanchez, P., Demestre, M., Ramon, M., and Kaiser, M. J. 2000. The impact of otter trawling on mud communities in the northwestern Mediterranean. ICES Journal of Marine Science. 57(5) : 1352-1358.

Keywords: otter trawl/ impacts/ Mediterranean

Sarda, R., Pinedo, S., Gremare, A., and Taboada, S. 2000. Changes in the dynamics of shallow sandy-bottom assemblages due to sand extraction in the Catalan Western Mediterranean Sea. ICES Journal of Marine Science. 57(5) : 1446-1453.

Keywords: sand extraction/ Catalan Western Mediterranean Sea

Abstract: Coarse to fine-sand sediments characterize shallow sublittoral soft bottoms in the Northwestern Mediterranean Sea. Within the framework of a wider research project on the littoral ecosystem of the Bay of Blanes (Catalan coast), the dynamics of shallow soft-bottom macroinfaunal assemblages have been followed since March 1992. These assemblages exhibited a highly predictive annual cycle. Abundance and biomass rose sharply during spring, followed by a striking drop through summer, and reaching the lowest values during winter. These cycles were consistent with the temporal variation in several key species. During the summer and autumn of 1994, shallow soft bottoms (10 to 30m depth) off the Tordera River were dredged for beach nourishment. Recolonization in these dredged habitats was fast, and no changes in seasonal trends were detected after dredging. However, density values rose sharply during the following spring and autumn with exceptionally large numbers of *Ditrupa arietina*, *Spisula subtruncata*, and *Branchiostoma lanceolatum*. Dredging activities also led to rapid increases in biomass values, which were significantly higher than those obtained before dredging. After two years, densities were back to normal but biomasses were still high. Other species, such as the filter-feeder *Callista chione* and the carnivorous polychaetes *Protodorvillea kefersteini* and *Glycera* spp., were still clearly reduced after two years, suggesting that a longer period is needed to restructure dredged bottoms to their initial situation. Dredged habitats supported artisanal bivalve fisheries in the harbour of Blanes. The official catch data of bivalves (mainly *C. chione*, *Acanthocardia aculeata*, *Donax trunculus*, and *D. variegatus*) showed a decreasing yield since the end of dredging. *Copyright 2000 International Council for the Exploration of the Sea.*

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

Sartor, P., Sbrana, M., Raele, B., and Belcari, P. 2001. Impact of the deep-sea trawl fishery on demersal communities of the Northern Tyrrhenian Sea (Western Mediterranean). Scientific council research document. Northwest Atlantic Fisheries Organization. Dartmouth NS. No. 01(106), 11 p.

Keywords: Deep-sea fisheries/ Trawling/ Demersal fisheries/ By catch/ Catch composition/ Fishery surveys/ Nephrops norvegicus/ Parapenaeus longirostris/ Merluccius merluccius/ Aristeomorpha foliacea/ Aristeus antennatus/ MED, Tyrrhenian Sea

Abstract: The composition of the catch of the deep-sea trawl fleet of Porto Santo Stefano (northern Tyrrhenian Sea, western Mediterranean) was analysed. In the period 1995-1999 observations were carried out on board of commercial vessels, collecting data for about 500 trawling hours. Nephrops norvegicus, Parapenaeus longirostris and large specimens of Merluccius merluccius were the targets on the fishing grounds from 300 to 450 m, while Aristaemorpha foliacea, Aristeus antennatus and N. norvegicus on the fishing grounds from 450 to 650 m depth. By-catch dominated the biomass caught, and was characterized by a high degree of species richness, as a consequence of the reduced selectivity of the bottom trawl gear. An important fraction of the by-catch was constituted by commercially retained species, which provided an important added value to the landings. Catch of target species was entirely commercialized. Annual average discards were about 20% of the total catch. Discard of commercial species was mostly due to species under commercial size, while discard of non-commercial species was represented by a large number of small size species of fishes and crustaceans. The results seem to indicate that this kind of fishery achieves a fairly good compromise between efficiency of resource utilization and impact on the demersal communities.

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*

Abstract: Incidence of claw loss in commercially caught lobsters (H. americanus) ranged between 5 and 19 per cent but could not be attributed to any single cause, although factors such as rough handling by fishermen, moving fishing gear, and ice in shallow waters may contribute. The incidence of other wounds ranged between 1 and 11 per cent and there was evidence that serious wounding was related to the local practice of harvesting Irish moss by rakes.

Scarratt, D. J. 1973. The effects of raking Irish moss (*Chondrus crispus*) on lobsters in Prince Edward Island. 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).*

Schneider, D. 2000. Trawling for answers. Pacific Fishing. 21(10), p. 3.

Keywords: Trawling effects/ Bering Sea

Schoellhamer, D. H. 1996 . Anthropogenic sediment resuspension mechanisms in a shallow microtidal estuary. Estuarine, Coastal and Shelf Science. 43(5) : 533-548.

Keywords: hydrodynamics/ sediment transport/ anthropogenic factors/ shipping/ wakes/ estuarine dynamics/ resuspended sediments/ suspended sediments/ estuaries/ ships/ USA, Florida, Hillsborough Bay

Abstract: The mechanisms that resuspend bottom sediments in Hillsborough Bay, a shallow, microtidal, subtropical estuary in West-central Florida, were determined by analysing hydrodynamic and suspended-solids concentration data collected during several instrument deployments made in 1990 and 1991. Large vessels in a dredged ship channel can generate forced solitary long waves that cause large water velocities and sediment resuspension at the study sites. An experiment was conducted with a trawler that resuspended bottom sediments, and some of the resuspended sediments remained in suspension for at least 8 h. A secondary impact of vessel-generated long waves and trawling is that sediments that are resuspended and newly deposited are more susceptible to resuspension by tidal currents than undisturbed bottom sediments. Natural sediment resuspension by wind waves and tidal current is less frequent or of smaller magnitude than anthropogenic sediment resuspension. The annual mass of sediment resuspended by vessel-generated long waves is estimated to be one order of magnitude greater than the annual mass of sediment resuspended by wind waves generated by winter storms.

Schratzberger, M., Rees, H. L., and Boyd, S. E. 2000. Effects of simulated deposition of dredged material on structure of nematode assemblages - the role of burial. Marine Biology. 136(3) : 519-530.

Keywords: simulated deposition/ dredge

Abstract: A microcosm experiment was designed to evaluate the effects of the simulated deposition of uncontaminated dredged material on nematode assemblages from estuarine intertidal mud. The main objective was to assess the ability of nematodes to migrate vertically into native muddy and non-native sandy sediment deposited in different amounts and frequencies. Results from univariate and graphical methods of data-evaluation revealed that nematodes were capable of migrating over a wide depth range from the bottom mud layer into the top layer of deposited sand and mud. A diverse mud assemblage of nematodes was able to survive in nonnative fine sand for the experimental period of 2 mo. Multivariate analyses showed that the amount of deposit and the frequency of deposition were interactive factors. A high amount of sediment deposited once at the beginning of the experiment caused more severe changes in assemblage structure than the same amount deposited in more frequent but smaller doses. The response of most species to the experimental treatments appeared to be an integrated response to the enhancing effect of food input accompanying the deposit and the negative effect of burial. Upward migration of nematodes is a process which has often been underestimated in its importance for recolonisation of areas where uncontaminated dredged material is deposited. Active migration of nematodes can significantly affect the recovery of a dredgings disposal site.

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*.

Schueller, G. H. 2000. Scraping bottom. Audubon, March/April, p. 8.

Keywords: trawling impacts/ Hefley bill

Summary: A brief article addressing the apparent adverse effects of trawling, and the proposed moratorium (Hefley bill) on the use of trawling equipment at 16 spots off the east and west coasts of the U.S.

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.*

Segar, D. A. 1990. Turbidity and suspended sediments at the Alcatraz, California, dumpsite. Pages 92-101 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.

Keywords: resuspended sediments/ dredging/ dredge spoil/ estuarine fisheries/ toxicity/ brackish water fish/ waste disposal sites/ sediments/ San Francisco Bay, Alcatraz/ fish/ turbidimetry/ Pisces/ INE, San Francisco Bay, Alcatraz/ turbidity

Abstract: Dumping of dredged material at the Alcatraz dumpsite located in Central San Francisco Bay, California, contributes substantial quantities of suspended sediments to the water column in this deep, tidally-mixed portion of the estuary. Increased turbidity and/or suspended sediment concentrations from increased dumping in recent years have been hypothesized to be the cause of the concurrent declines of fisheries in the Bay. Suspended sediment concentrations and turbidity in this area are below those known to adversely affect fish and other organisms if the suspended sediments are uncontaminated. Therefore, increased turbidity and suspended sediment concentrations due to dredged material dumping are unlikely to be the cause of the observed fisheries decline. However, the toxicity of the suspended sediments from some contaminated dredged materials dumped at the Alcatraz site may be a contributing cause to the observed fisheries declines in San Francisco Bay.

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

Abstract: The relationship between biological community structure and particle size composition is investigated in coastal deposits off the southeast of England. Sediments in the survey area fall into well defined groups when analysed by multivariate techniques, indicating similarities and differences which could not be identified by mere inspection of the data. Biological resources also fall into relatively distinct groups, or communities, when analysed for species composition and population density, although similarity within the groups is lower than that obtained for the sediments. There is, however, little evidence of a close correspondence between the distribution of different sediment types and benthic communities in the survey area: comparison of the similarity matrices yields weighted Spearman rank correlation of less than 0.37. This suggests that factors other than sediment composition play a significant part in controlling biological community structure on the seabed. Still, there is evidence that some species such as the tube dwelling worm *Sabellaria spinulosa* are associated mainly with sands and gravels whilst fine mobile silts and sands are characterized by "opportunistic" species capable of survival in mobile deposits, restoration of sediment composition after cessation of dredging for marine aggregates is not, within broad limits, a prerequisite for establishment of biological communities which are comparable with those that occurred in the deposits prior to dredging.

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. Recovery of benthic communities in Strangford Lough following changes in fishing practice. ICES:CM 1998/V:6 : 11 p.

Keywords: Nature conservation/ Zoobenthos/ Ecological associations/ Anthropogenic factors/ Modiolus modiolus/ Aequipecten opercularis/ Chlamys varia/ ANE, British Isles, Northern Ireland, Down, Strangford L./ Northern horsemussel

Abstract: Strangford Lough is environmentally important being internationally noted for its biodiversity. This has been recognized by its designation as a marine nature reserve in 1995, one of 3 such areas in the UK. Within the lough the benthic communities, in particular those associated with the horse mussel Modiolus modiolus are regarded as being of particular importance. These communities also support

populations of the commercially trawled queen scallop, Aequipecten opercularis. Previous work has established the spatial extent of changes to benthic communities in Strangford Lough (principally within the Chlamys varia/Modiolus community) which can be attributed to impacts associated with commercial fishing. However, this work provided only limited information on temporal changes to these communities. The establishment of exclusion zones within the lough has now closed off areas to trawling allowing this baseline to be used to establish the potential for recovery within impacted areas. Current research is monitoring both epifauna and infauna in areas known to have suffered a range of impacts with the aim of assessing the potential for recovery in areas now protected. Epifaunal studies are centered on the use of underwater video and stills photography coupled with the use of acoustic mapping techniques. This is aimed at mapping the spatial extent of the communities under question and to assist in setting limits for change as part of the management plan for the Marine Nature Reserve. Some effort has been expended on quantifying information obtained from towed video surveys. A more targeted study using conventional infaunal techniques is studying comparative changes between areas still subject to trawling, those trawled in the past but currently protected and areas which have had little if any disturbance. It is hoped that this study can be used to help develop conceptual models for the effects of physical impacts on epibenthic and infaunal communities analogous to those already in existence for the effects of organic enrichment. The wider implications of this work with regard to both the management of marine protected areas and the commercial fishing industry will be discussed.

Service, M. 1998. Monitoring benthic habitats in a marine nature reserve. Journal of Shellfish Research. 17(5) : 1487-1489.

Keywords: Marine Nature Reserve/ RoxAnn/ side-scan 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: side-scan sonar/ trawl impacts/ epibenthic community/ *Modiolus modiolus*/ Strangford Lough/ Northern Ireland

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

Servizi, J. A. 1990. Sublethal effects of dredged sediments on juvenile salmon. Pages 57-63 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.

Keywords: sublethal effects/ resuspended sediments/ histology/ immunology/ fish physiology/ behavioral responses/ juveniles/ ecosystem disturbance/ sediments/ Oncorhynchus/ Canada, British Columbia, Fraser R./ dredging

Abstract: Histological, immunological, physiological and behavioral responses of juvenile salmonids (Oncorhynchus) to suspended sediments were reviewed. Of particular interest were results reported for Fraser River, B.C., Canada, sediments since these naturally occurring sediments are routinely dredged. Histopathology was the least sensitive of the methods for detecting responses. Reports of depressed immunological response owing to suspended sediment exposure were limited. This was considered an area for further research. Biochemical stress indicators were highly sensitive to suspended sediment exposure but appeared to be better suited for detecting effects caused by chronic rather than acute exposures. Feeding and avoidance responses were also highly sensitive. Surfacing response to avoid suspended sediments had implications for short-term exposures since this behavior would increase the potential for predation by birds.

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

Sheridan, P. 2001. Short-term effects of the cessation of shrimp trawling on Texas benthic habitats. Unpublished manuscript. 2 p. Contact the author at: pete.sheridan@noaa.gov.

Keywords: shrimp/ trawling/ Gulf of Mexico/ short-term effects/ benthic/ habitats/ Texas

Abstract: Introduction: There are very few areas of the U.S. Gulf of Mexico continental shelf that are closed to the shrimp fishery, which operates primarily from shoreline to 90 m (50 fm) depths (Nance, 1993). There is a window of opportunity, however, to study the short-term effects of the cessation of shrimp trawling on benthic habitats. In 200, Texas Parks and Wildlife Department enacted a seasonal closure of nearshore waters of the southern Texas coast between Corpus Christi Fish Pass and the U.S.-Mexico border to all shrimp trawling. The Southern Shrimp Zone (SSZ) encompasses waters from the shoreline out 9.3 km (5 nmi) during the period December 1 until the opening of the brown shrimp season, usually during July 1-15 each year. There is a complimentary Northern Shrimp Zone (NSZ) extending from Corpus Christi Fish Pass to the Texas-Louisiana border, but daytime trawling is permitted out to 5.6 km (3nmi). This 7-month SSZ closure permits several types of experimental analyses of the effects of trawl gear, including an initial assessment of the "recovery" of benthic communities and habitats during this first period of zero fishing effort. I intended to determine whether changes in benthic communities and sediment characteristics could be detected at the end of the first SSZ closure.

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 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.

Sigler, J. W. 1990. Effects of chronic turbidity on anadromous salmonids: Recent studies and assessment techniques perspective. Pages 26-37 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.

Keywords: turbidity/ man-induced effects/ resuspended sediments/ behavioral responses/ lethal effects/ sublethal effects/ ecosystem disturbance/ literature reviews/ turbidimetry/ ecosystems/ sediments/ pollution effects/ Oncorhynchus mykiss/ Oncorhynchus kisutch/ Salmo gairdneri/ anadromous species

Abstract: Effects of turbidity on anadromous fish can be classified as behavioral, sublethal or lethal (e.g., changes in activity, reduced performance, and death). Low levels of turbidity affect young steelhead trout (Oncorhynchus mykiss) and coho salmon (O. kisutch). A review of articles relating to various aspects of the effects of turbidity or suspended sediment was completed and data related to research previously completed on steelhead and coho salmon. The difficulty of transposing or extrapolating data from one drainage to another or from one fish species to another is discussed with respect to differences in turbidity measurement techniques and the lack of consistent relationships between optical and physical properties of turbidity causing materials.

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 neighbouring 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*.

Simenstad, C. A. 1990. Summary and conclusions from workshop and working group discussions (dredging impact, anadromous fish). Pages 144-152 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific Coast Fishes. Workshop proceedings, Seattle, September 8-9, Rep. Wash. Sea Grant. pp. 144-152.

Keywords: environmental impact/ marine fish/ anadromous species/ estuaries/ ecosystem disturbance/ environmental protection/ ecosystems/ fish/ marine pollution/ INE, North America/ dredging

Abstract: The general objective of the working group discussions was to pursue consensus among the invited workshop technical expert as to the actual or potential effects on anadromous fishes of dredging activities in Pacific Northwest estuaries. Discussions focus on (1) near-field effects and farfield effects and (2) ecosystem-level effects, which could be considered as direct and indirect effects, respectively. A final

goal was to consider recommendations for future research that would address substantiated, but unresolved, effects of dredging.

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. N., and Diliberto, S. 2000. Impact of otter trawling on eastern Mediterranean commercial trawl fishing ground. ICES Journal of Marine Science. 57(5). 1340-1351

Keywords: otter trawling/ fishing impacts/ eastern Mediterranean

Abstract: Within the scope of the EC Study Project "The environmental impact of demersal fishing gears on the marine environment", a commercial fishing ground on the north coast of Crete, Greece, was studied for otter-trawling impacts. The trawling season is limited to eight months between October and May. The major trawling lane, at 200 m depth off the port of Heraklion, is narrow because of bottom contouring. Four sampling stations were chosen in the vicinity, two in the lane and one on either side. Sediment chemistry and macrofaunal community structure were studied over 11 months, starting before the trawling season and ending well after. During each sampling trip a towed video survey was completed to check seabed conditions. In addition, beam-trawl samples were taken at the beginning and at the end. Video observations revealed the extent of trawling activities and showed higher numbers of epifaunal species outside the lane (particularly the echinoderms Leptometra phalangium, Stichopus regalis, and Ophiura texturata). The epifauna in the beam-trawl samples also showed lower numbers in the lane. Sediments were predominantly clay. Sedimentary organic carbon, chlorophyll, and phaeopigments all exhibited significant differences between stations during the trawling season. Species number, abundance, and biomass were all generally significantly lower in the lane during the trawling season, noticeable particularly in the phyla Echinodermata, Sipuncula, and to a lesser extent the Polychaeta. The closed season did not seem to allow recovery to pre-season levels. Impacts on the less mobile fauna were more pronounced, but degree of robustness also seems to play a major role.

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, U.S. 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 proposed.

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.

Somerfield, P. J., Rees, H. L., and Warwick, R. M. 1995. Interrelationships in community structure between shallow-water marine meiofauna and macrofauna in relation to dredgings disposal. Marine Ecology Progress Series. 127(1-3) : 103-112.

Keywords: dredging/ dredge deposits/ Liverpool Bay

Abstract: Patterns in community structure of macrofauna (Day grab samples), nematodes (Craib core samples and subsamples from Day grabs) and copepods (Craib core samples) along a transect through a dredgings disposal site in Liverpool Bay, UK, are compared, and related to a range of environmental measurements. Disposal of dredged material at the site has different effects on different components of the benthos. Nematodes are more sensitive to sediment structure and the ongoing disposal of dredgings at the site, but the method used to sample them influences the perceived pattern of impact. Subsampling from grabs is not found to be an adequate method of sampling meiofauna in studies designed to examine details of changes in community structure, although such samples may be sufficient for detecting that substantial changes have occurred. Macrofauna are more sensitive to concentrations of metals and longer term events at the site.

Somerton, D. 2001. Environmental effects of bottom trawling: A benthic overfishing model. unpublished manuscript. National Marine Fisheries Service, NOAA, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115. 25 p.

Keywords: bottom trawling/ effects/ model/ production/ invertebrates

Abstract: In pursuit of various target species, the use of bottom trawls and dredges can result in the unintended catch and death of a variety of invertebrate species comprising the benthic community. Although the populations of these species can sustain some level of trawl induced mortality, it is not clear what level should be considered as overfishing. In this paper I develop a simple model of the response of a population to fishing mortality based on Schaefer production model modified to account for the spatial distribution of fishing effort, the change in fishing mortality rate associated with changes in mean body size and the multispecies composition of the benthic community. Parameters of the model are intended to be estimated using field experiments to estimate initial density, fraction of the animals within the swept area killed with one pass of the fishing gear, rate of recovery after trawling and a coefficient controlling the size dependency of the mortality rate. Three overfishing definitions are considered; one based on the maximum production of the entire community; one based on the maximum production of the community when all species are weighted equally and one based on the maximum production of the least productive species in the community (an indicator species). For a specified combination of species, the three measures are arranged from the least conservative (i.e., overfishing occurs at a higher level of effort) to most conservative. The model implicitly includes two control variables to minimize the likelihood of reaching an overfished condition without requiring a reduction in nominal fishing effort. First, fishing mortality per unit of effort may be reduced by utilizing some form of technical modification to the fishing gear that either allows the benthic species to escape or suffer less trauma. Second, fishing effort may be artificially aggregated by the use of closed areas.

Sparks-McConkey, P. J. and Watling, L. 2001. Effects on the ecological integrity of a soft-bottom habitat from a trawling disturbance. Hydrobiologia. 456(1-3) : 73-85.

Keywords: Bottom trawling/ Zoobenthos/ Phytobenthos/ Sediment properties/ Geochemistry/ Environmental impact/ Meiobenthos/ Interstitial environment/ Ecological succession/ Man-induced effects/ Shrimp fisheries/ Demersal fisheries/ Ecosystem disturbance/ Fishing/ Disturbance/ Benthic environment/ Sediments/ Shrimp/ Trawling/ Human Population/ Spatial Distribution/ Temporal Distribution/ Biological Sampling/ Ecology/ Storms/ Habitats/ Cerebratulus lacteus/ Terebellides atlantis/ Anobothrus gracilis/ Euchone incolor/ Thyasira flexuosa/ Yoldia sapotilla/ Chaetozone/ Ennucula annulata/ Flexuose cleftclam/ Short yoldia/ soft bottom community/ Disturbance

Abstract: The effects of trawling disturbance on a soft-sediment system were investigated with a manipulative field experiment in an area that had been closed to shrimp trawling activities for 20 years. The area was also chosen for its weak natural physical agents i.e. no scouring of sediments by storm events or tidal flow, allowing a quantitative assessment of the effects of trawling on the benthic fauna and geochemical properties of the soft substrate. The study examined the ambient spatial and temporal patterns of sedimentological variables and benthic species abundances over a time interval of 16 months for both the reference and the trawl stations before dragging the trawling gear over the predetermined trawl sites. Shifts in the patterns of the benthic infauna and geochemical variables were identified by the post-trawl samples that were collected at both the reference and trawl stations over the next 6 months. Post-trawl changes in the bottom topography did not translate into changes in the vertical profile of the sedimentological variables. Chlorophyll a content of the trawled surface sediments was significantly elevated immediately after the trawling event in comparison to the reference concentrations. Immediately after the trawling disturbance, numbers of species, species abundance and diversity decreased in the trawled area in comparison to the reference area. Sensitive species were found to be the bivalves; Ennucula annulata, Hampson, Thyasira flexuosa (Montagu), and Yoldia sapotilla (Gould), and polychaetes; Chaetozone cf.setosa Malmgren, Anobothrus gracilis (Malmgren), Euchone incolor Hartman, and Terebellides atlantis Williams. In contrast, the carnivorous nemertea, Cerebratulus lacteus Verrill, was the resistant species to field manipulations on account of its predatory behavior; highly effective in seeking out freshly dead (dying) organisms and its active migration. Multivariate analysis confirmed the changes in the trawled community structure immediately following the trawling event and differences in the recovery patterns 6 months thereafter. Although the trawling disturbance was one of low frequency and intensity compared to commercial operations, the biological variables studied indicated that successional processes in this soft-bottom community were altered, at least for a short period, in response to the trawling disturbance.

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

Abstract: With increasing awareness of the use of the coastal zone, it is necessary to understand the potential environmental effects of aquaculture practices. This is especially important when non-native species, which may be competitively superior to native species, are cultivated. A 5-year experiment was established to study the environmental effects of the various stages of Manila clam, Tapes philippinarum Adams & Reeve, cultivation, from seeding, through on-growing, harvesting and post-harvesting. The aim was to monitor changes in biological and physical variables in the sediment which may be useful in formulating an environmental management strategy for the cultivation of this species. This paper describes the biological and physical changes that occur in the sediment during the early phase of clam cultivation. We compared the changes in netted plots (with and without clams) and unnetted control areas, 6 months before and after laying the clams. The clams were planted in April 1992 under netting at a density of 500 m super(-2) (0.16 kg m super(-2)), and in 6 months, had increased their weight to 3.2 kg m super(-2) but decreased their number to 410 m super(-2). A significant, but small increase in organic content (net only plots, 3.37%; control plots 2.42%) and in phaeopigment (netted plots, 8.6 mg m super(-2); control, 5.6 mg m super(-2)) of the sediment in the netted plots relative to the control areas were seen. Short-term sedimentation rates on the netted plots were up to four times higher than in the control areas. The netting

also encouraged the settlement of Enteromorpha sp. which, in turn, attracted Littorina littorea to feed on these plots. The infaunal community in the control areas was similar to that in samples 12 months earlier and continued to be dominated by the predatory polychaete Nephtys hombergii. Netted plots (with and without clams) had a greater abundance of deposit feeding polychaetes, particularly Ampharete acutifrons and Pygospio elegans, which were the dominant fauna in these plots. Within the clam treatments, the density of clams had a negative effect on the abundance of cirratulids, although mean abundance was generally greater than in the control areas. There were few physical changes to the experimental area after 6 months. The most important effect appears to be the increased sedimentation rate over plots with netting, which has led to an increase in productivity of those areas.

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

Abstract: 1. Marine aquaculture has come under close scrutiny by environmental pressure groups, fisheries managers and scientists in recent years, because of a shared concern over the physical and biological effects of farming practices on the marine environment. 2. This paper describes the environmental effects of intertidal Manila clam (Tapes philippinarum) cultivation at the end of the cultivation phase immediately prior to harvesting the marketable-sized clams, which were planted in ground plots 2.5 years earlier at a density of 500 m super(-2). Although survival was poor, with a final density of 26 m super(-2) (0.78 kg m super(-2)), this still represented a significant biological presence relative to other benthic organisms. 3. An experimental approach, using a 3 x 3 Latin Square design, was adopted. The treatments comprised net-covered plots of clams, net-covered plots without clams and control plots without netting or clams. An additional set of controls, 50 m distant from the Latin Square, was established for comparative purposes. 4. The presence of the netting, rather than the clams, increased sedimentation rate which elevated the ground profile by c. 10 cm and caused a small but significant increase in percentage fines and percentage organic content of the sediment. The netting also encouraged higher densities of some species of infaunal deposit-feeding worms which became the dominant fauna. 5. During the first 6 months of the cultivation process, the fauna was dominated by the opportunistic spionid, Pygospio elegans. After one year, the stabilizing effect of the netting on the sediment led to the establishment of species such as Ampharete acutifrons and Tubificoides benedii, which displaced P. elegans as the community dominants. 6. The observed biological responses indicate that organic enrichment occurs within net-covered areas. However, the magnitude of community change is far less than that which occurs in association with some other marine culture practices, which create anoxic sediments and impoverished infaunal communities. *Reprinted with the permission of Blackwell Science Ltd., Oxford, UK and the Journal of Applied Ecology*.

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., Viewpoint: Ecosystem structure before fishing; pages 201-205; Copyright (2000); with permission from Elsevier Science.*

Stephan, C. D., Peuser, R. L., and Fonseca, M. S. 2000. Evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies. Atlantic States Marine Fisheries Commission Habitat Management Series No.5, 38 p.

Keywords: fishing gear impacts/ submerged aquatic vegetation

Summary: This is an in-depth report from the Atlantic States Marine Fisheries Commission (ASMFC) on submerged aquatic vegetation (SAV) habitats, which play an important role in the critical life history stages of over half of the ASMFC's 24 managed fish species. SAV is defined, and the scope specifically targets tidal, estuarine and marine ecosystems. Certain characteristics of SAV are addressed (such as light requirements, reproductive structures, and ability to recover from disturbance), since these characteristics are susceptible to fishing gear disturbance. Below-ground disturbance to reproductive structures, as well as cumulative impacts are of particular concern. Fishing activities identified as being capable of causing below-ground disturbance were hydraulic dredging, "toothed" dredging, clam raking and clam-kicking (a prop wash technique). Other "above-ground" activities such as trawling, toothless dredging, and crab scraping are also discussed. Mitigation strategies are presented in the report, and guidelines for applying the mitigation strategies are identified.

Stevens, B. G. 1990. Survival of king and Tanner crabs captured by commercial sole trawls. Fishery Bulletin, U.S. 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

Stobutzki, I., Blaber, S., Brewer, D., Fry, G., Heales, D., Miller, M., Milton, D., Salini, J., Van der Velde, T., Wassenberg, T., Jones, P., You-Gan Wang, Dredge, M., Courtney, T., Chilcott, K., and Eayrs, S. 2000. Ecological sustainability of bycatch and biodiversity in prawn trawl fisheries. CSIRO, Cleveland, Queensland (Australia) . 512 p.

Keywords: Shrimp fisheries/ Trawling/ By catch/ Potential yield/ Rare species/ Marine organisms/ Biodiversity/ Species diversity/ ISEW, Australia, Queensland/ ISEW, Australia, Northern Terr./ ISEW, Australia, Queensland, Torres Strait/ literature reviews/ monitoring

Abstract: Prawn trawl fisheries are under increasing public and legislative pressure to manage their by-catch sustainably, but by-catch cannot be managed without knowing what and how much is caught. This project focused on the Northern Prawn Fishery (NPF), the Torres Strait Prawn Fishery (TSPF) and the Queensland Banana Prawn Fishery. The objectives of this study were: to undertake a literature review of prawn trawl by-catch and of methods for estimating and monitoring by-catch of prawn trawl fisheries from published information to add to the already substantial literature database on by-catch reduction devices; to compile a detailed description of the by-catch in the NPF and TSPF (tiger and banana prawns) and Queensland East Coast banana prawn fisheries to provide a reference against which future assessment can be made; to measure the impact of prawn trawling on the sustainability of important vertebrate by-catch species, particularly those that may be vulnerable or endangered, and for those by-catch species for which no significant reductions can be achieved; to assess the effects of prawn trawling on the biodiversity of key fish and other vertebrate communities; and to develop cost-effective, accurate and feasible methods of describing and monitoring prawn trawl by-catch that would be acceptable to all stakeholders. The high

diversity of by-catch of these tropical prawn fisheries, and the fact that most species are rare, means that managing the sustainability of the by-catch is a significant challenge.

Stobutzki, I., Miller, M., and Brewer, D. 2001. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. Environmental Conservation. 28(2) : 167-181.

Keywords: Fisheries/ Aquaculture/ Species diversity/ Conservation/ Mortality/ Benthos/ Human impact/ Population-environment relations/ Ecology/ Commercial species/ Diets/ Fishery management/ Sustainable yield/ Stock assessment/ Trawling/ Marine fish/ By catch/ Shrimp fisheries/ Fishing mortality/ Population dynamics/ Man-induced effects/ Nature conservation/ Decapoda/ Pisces/ Callionymidae/ Congridae/ Diodontidae/ Labridae/ Ariidae/ Bathysauridae/ Plotosidae/ Synodontidae/ Tetraodontidae/ Opisthognathidae/ Australia Coasts/ Fishery industry/ Shellfish fisheries/ Crabs/ Crayfishes/ Lobsters/ Prawns/ Shrimp/ Sustainable yield / Cardinalfishes/ Sea catfishes/ Dragonets/ Scotter blennies/ Conger eels/ Congers/ Burrfishes/ Porcupinefishes/ Parrotfishes/ Rainbowfishes/ Wrasses/ Eeltail catfishes/ Lizardfishes/ Blowfishes/ Globefishes/ Puffers/ Rabbitfishes/ Swellfishes/ Toadfishes

Abstract: In tropical prawn (shrimp) trawl fisheries it is daunting to assess the sustainability of bycatch species because they are diverse and there is little historical and biological information for quantitative stock assessments. We developed a process to examine the likely impact of prawn trawling on the sustainability of bycatch species and applied this to fish bycatch in the Australian Northern Prawn Fishery. The 411 fish bycatch species were ranked with respect to biological and ecological criteria that contributed to two overriding characteristics, namely first, their susceptibility to capture and mortality due to prawn trawling, and second the population's capacity to recover after depletion. The rank of each species on these two characteristics determined its relative capacity to sustain trawling, and therefore its priority for research and management. Species that were the least likely to be sustainable came from the families Apogonidae, Ariidae, Bathysauridae, Callionymidae, Congridae, Diodontidae, Labridae, Opisthognathidae, Plotosidae, Synodontidae and Tetraodontidae. These species are highly susceptible to capture by trawls, they are benthic or demersal, their primary habitat is soft sediments, and their diet may include prawns. The recovery capacity of these species is also low, with the estimated removal rate by trawling high. The species that were the most likely to be sustainable came from the families Carangidae, Clupeidae, Ephippidae, Scombridae, Sphyraenidae and Terapontidae. They are less susceptible to capture by trawls, they are generally pelagic, their primary habitat is not in trawl grounds, and they have a broad depth distribution and range in the fishery. These species also have a greater capacity to recover, as most individuals have bred before capture, and a low estimated removal rate by trawling. The final ranking of the species must be used with caution because of the assumptions made in the process. However, the process is a valuable first step towards ensuring the sustainability of the bycatch species. Because of the simplicity of the process, it can be readily used in fisheries, particularly those with diverse bycatch, to manage the sustainability of their bycatch. *Reprinted with the permission of Cambridge University Press and Environmental Conservation*.

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. 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 characterised 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 Inter-Research and Marine Ecology Progress Series.*

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.*

Thrush, S. F., Hewitt, J. E., Funnell, G. A., Cummings, V. J., Ellis, J., Schultz, D., Talley, D., and Norkko, A. 2001. Fishing disturbance and marine biodiversity: the role of habitat structure in simple soft-sediment systems. Marine Ecology Progress Series . 223 : 277-286 .

Keywords: biodiversity/ soft-sediments/ habitat structure/ habitat heterogeneity/ habitat complexity/ disturbance/ fishing impacts/ New Zealand

Abstract: Broad-scale anthropogenic disturbances that reduce the density of epifauna and homogenise surficial sediments can have important consequences for seafloor biodiversity. We investigated the habitat structure and macrofaunal diversity of relatively simple soft-sediment habitats over a number of spatial scales (cm to km) to identify the role of habitat structure in influencing macrobenthic diversity and to assess the validity of using habitat structure in influencing macrobenthic diversity and to assess the validity of using habitat structure as a surrogate measure for biodiversity. We sampled 10 locations with differences in habitat structure using a sampling design that nested macrobenthic core samples within videoed transects of the floor. This allowed us to determine relationships between observable habitat structure and macrobenthic diversity at a number of spatial scales. We characterised elements of habitat structure based on direct counts of surficial sediment characteristics and the presence of other immobile features, many of which were biogenic in origin. We also used multivariate measures (the relative multivariate dispersion, the mean and range of the Bray-Curtis dissimilarity along the transects) to characterise habitat structure at the transect scale. We developed regression models based on measures of habitat structure that explained 74 to 86% of the variance in macrobenthic diversity. This result suggests that removal of habitat structure in relatively low-structure soft-sediment systems will significantly decrease their biodiversity, and consequently that of the wider marine ecosystem *Reprinted with the permission of Inter-Research and Marine Ecology Progress Series.*

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

Trefry, J. H., Sims, R. R. Jr., and Presley, B. J. 1976. The effects of shell dredging on heavy metal concentrations in San Antonio Bay. Pages 161-184 *in* A.H. Bouma (ed.), Shell dredging and its influence on Gulf coast environments. Gulf Publishing Company, Houston, Texas.

Keywords: dredging/ effects/ heavy metal concentrations/ San Antonio Bay/ shell dredging

Abstract: The primary environmental dangers of shell dredging and disposal of dredged material are the adverse effects these operations may have on the biota as a result of increased turbidity and decreased dissolved oxygen. A secondary consideration is the potential release of toxic heavy metals, pesticides, radionuclides, petrochemicals, H2S, or microorganisms to the water column by disturbing the large reservoir which the sediments may represent; such disturbance and resuspension of the subsurface sediments may increase the concentrations of various toxins available to the biota. Of special concern in San Antonio Bay are the economically important shrimp and blue crab populations and the bird life of the Arkansas National Wildlife Refuge. This chapter considers one group of potential toxins-the heavy metals.

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/ side-scan 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 side-scan and RoxAnn, were identifiable immediately after disturbance, but were almost indistinguishable after 18 mo of recovery. Such long recovery times suggest that even fishing during a restricted period of the year may be sufficient to maintain communities occupying fine muddy sediment habitats in an altered state. *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 Sea: effects 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/ beamtrawl

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 quadrants 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 quadrants 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

Abstract: This paper describes current research on selectivity of bottom trawls conducted by the Netherlands Institute for Fisheries Research (RIVO-DLO) with emphasis on fish behaviour. The research is aimed at reducing unwanted by-catch in bottom trawling and beam trawling by changing the design of the net or the rigging. Some release of cod can result from raising the fishing line of a bottom trawl whilst leaving the groundrope on the seabed. Separation of whiting from cod was not complete. Large-meshed top panels in beam trawls are shown to release juvenile cod, but also a substantial amount of marketable whiting. Flatfish catches were hardly affected, but more research is necessary for definite conclusions. It is clear that relatively simple modifications in the design of fishing gears can improve species selectivity.

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 by-catches 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. Pages 147-178 *in* de Groot, S.J. and Lindeboom, H.J. (eds.) , 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.

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

Abstract: Direct effects of trawling with commercial 12-m beam trawls **on the** abundance of benthic species in a soft bottom area in the southern North Sea were studied by comparing densities before and after trawling. Various sampling gears were used, including a benthos dredge (Triple-D) developed especially for this study. After trawling a study area twice, mortality could be estimated for a number of species. For fish species, mortality varied from 4% (small fish) to 75% (larger fish) of the numbers initially present. Mortality exceeded 100% for dab, Limanda limanda, as it rapidly immigrates into the trawled area already during trawling. For invertebrate species, mortality was variable as well, and estimated at 3-19% for

echinoderms, 0-85% for molluscs, 4-74% for crustaceans, <1-56% for annelids, and 70% for anthozoans. Dab was a predominant scavenger on damaged or exposed fauna on the recently trawled seabed. The presence of infauna species in catches of the 12-m beam trawls indicated, that the sediment was disturbed by the tickler chains to a depth of approximately 2 to 4 cm.

Vassilopoulou, V. and Papaconstantinou, C. 2000. Comparative study of fish assemblages in trawl reserves and adjacent areas. 6th Hellenic Symposium on Oceanography and Fisheries. Chios, Greece, May 23-26, 2000. Proceedings. Volume 2. Fisheries, Inland waters, Aquaculture. 6o Panellinio Symposio Okeanografias kai Alieias. Chios, 23-26 Maiou 2000. Praktika. Tomos 2. Alieia, Esoterika ydata, Ydatokalliergeies, NCMR Association of Employees, [Athens (Greece)], Proceedings of the Hellenic Symposium on Oceanography and Fisheries. 2 : 192-194.

Keywords: Comparative studies/ Stock assessment/ Fishery data/ Trawlers/ Demersal fisheries/ MED, Greece, Euvoikos Gulf/ MED, Greece, Pagassitikos Gulf/ MED, Aegean Sea

Abstract: Data are provided on total biomass estimates, diversity of the demersal fish assemblages and body size distribution of certain so-called 'target species' for the trawl fishery in six neighboring regions of the Aegean Sea (Greece), three normally trawled and three closed to the trawlers, in order to investigate the existence of possible differences, that could be related to trawling activities. Total biomass was higher in the untrawled areas in relation to the trawled ones. Diversity indices did not exhibit any particular trend, underlining the effect of habitat type on fish assemblages. Larger specimens of the target species appeared in the untrawled areas. Further research is needed in order to increase information and clarify certain aspects associated with trawl reserves.

Veale, L. O., Hill, A. S., Hawkins, S. J., and Brand, A. R. 2000. Effects of long-term physical disturbance by commercial scallop fishing on subtidal epifaunal assemblages and habitats. Marine Biology. 137(2) : 325-337.

Keywords: Abundance/ Biomass/ Spatial variations/ Exploratory fishing/ Fishing effort/ Ecosystem disturbance/ Pecten maximus/ Aequipecten opercularis/ ANE, Irish Sea/ species diversity/ statistical analysis/ check lists/ biological production

Abstract: This paper examines spatial differences in the distribution of by-catch assemblages from the scallop [Pecten maximus and Aecquipecten opercularis] fishing grounds in the North Irish Sea, during 1995. The sites examined have been exposed to differing known levels of fishing disturbance by scallop dredging, based on unusually high-resolution data extracted from fishermen's' logbooks. Uni- and multi-variate techniques have been used on a production dataset (a value which incorporates both abundance and biomass figures), as well as abundance and biomass data individually. The original species list was reduced to higher taxonomic groupings in line with the theory that the latter is more appropriate for detecting anthropogenic change. Species diversity and richness, total number of species, and total number of individuals all decrease significantly with increasing fishing effort. Species dominance increases with effort. Total abundance, biomass and production, and the production of most of the major individual taxa investigated decrease significantly with increasing effort. Multivariate analysis reveals a significant relationship between fishing effort and by-catch assemblage structure. The taxa most responsible for the differences are the echinoids and cnidarians, but prosobranch molluscs and crustaceans also contribute to the differences. Bycatch assemblage structure is more closely related to fishing effort than any other environmental parameter investigated, including depth and sediment type. We observed an approximately linear decrease in diversity with increasing fishing disturbance, and suggest this is primarily due to selective removal of sensitive species and, more importantly, habitat homogenisation. These results were interpreted in the light of ecological theories relating disturbance to community structure. The argument that invertebrate scavenger populations benefit from prolonged exposure to fishing disturbance was also examined, but no supporting evidence was found.

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

Vorberg, R. 2000. Effects of shrimp fisheries on reefs of *Sabellaria spinulosa* (Polychaeta). ICES Journal of Marine Science. 57(5) : 1416-1420.

Keywords: shrimp fishery/ trawling impacts/ *Sabellaria spinulosa*

Abstract: Intensive beam-trawl fishery on brown shrimps (*Crangon crangon*) occurs along the German North Sea coast. Fishing effort has increased constantly over recent decades. Simultaneously, changes in the benthos of the Wadden Sea have been observed. Besides shifts in species composition of the communities and the disappearance of oyster beds, there has been a distinct decline in the occurrence of *Sabellaria* reefs. Investigations were carried out to establish whether or not shrimp fisheries might be responsible for the decrease of the reefs. Underwater video techniques enabled direct observation to be made of the fishing gear in action on the sea bottom. The pictures revealed that shrimpers may trawl over the robust reef structures without causing visible damage. These findings are corroborated by the results of field experiments performed on the reefs of *Sabellaria alveolata* on the French Atlantic coast, and also by empirical calculations of the load of the fishing gear and the compressive strength of the reef. Reasons for the decline of *Sabellaria* reefs on the German North Sea coast are discussed with respect to natural and anthropogenic changes in the physical environment. *Copyright 2000 International Council for the Exploration of the Sea.*

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.

Wainwright, T. C., Armstrong, D. A., Dinnel, P. A., Orensanz, J. M., and McGraw, K. A. 1992. Predicting effects of dredging on a crab population: An equivalent adult loss approach. Fishery Bulletin, U.S. 90(1) : 171-182.

Keywords: dredging/ crab fisheries/ *Cancer magister*/ Grays Harbor, Washington/ harvesting

Abstract: The effect of benthic dredging on coastal fisheries has been of concern for several decades, but little work quantifying direct population impacts has been published. Modeling approaches have been used extensively to assess effects of power plant entrainment on fishery stocks. Several important differences between power plant and dredge operations prevent direct application of these models to dredge problems: Entrainment by dredges is short-term, has a moving intake, and affects all age-classes of the population. We present an equivalent adult loss model of impacts to the Washington coast Dungeness crab Cancer magister Dana fishery from dredging of a navigation channel in Grays Harbor, Washington. The model is driven by empirical population data to account for spatial and temporal variation in abundance and age-class structure. Results show that impacts are quite sensitive to the type of dredge used and the season in which

dredging occurs. Contrary to initial expectations, the 0 + age-group loss was unimportant relative to losses from older age-classes. Despite many limitations, the model has proven useful for focusing impact assessment work, as a basis for scheduling construction to reduce impacts, and as a basis for scaling mitigation projects.

Ward, T. J. 2000. Indicators for assessing the sustainability of Australia's marine ecosystems. Marine & Freshwater Research. 51(5) : 435-446.

Keywords: Potential yield/ Indicators/ Ecosystems/ Marine environment/ Brackishwater environment/ Standards/ Indicator species/ Habitat/ Renewable resources/ Nonrenewable resources/ Water quality/ Sediments/ Australia Coasts

Abstract: The principles of integrated ecosystem-based management have been used to derive 61 potential environmental indicators for reporting on Australia's marine and estuarine ecosystems. They are focused on tracking the condition of marine ecosystems in the face of a variety of uses and pressures, and are consistent both with the approaches used for assessment of public and private sector environmental activities and with the international standard. The indicators cover issues in protected species, common habitats, renewable and non-renewable resources, water and sediment quality, and integrated management. Gaps in knowledge and technical capacity include: incomplete knowledge of the nature of ecosystems; limited scientific understanding of environmental issues; no determination of the resolving capacity of a monitoring program; the lack of procedures for synthesis and aggregation of data across spatial, temporal and taxonomic scales, or for estimating uncertainty in national summaries; the need for case study trials, reference sites and suitable interpretative models; and the lack of an established procedure for revising and updating the indicators as new knowledge accrues, or if new issues arise.

Ward, T.J. 2000. Indicators for marine ecosystems affected by fisheries. Marine & Freshwater. 51(5) : 447-450.

Keywords: Indicator species/ ecosystem maturity/ exploitation/ trophic levels/ fisheries impacts

Abstract: The paper explores two types of indicators: Odum’s 24 attributes for describing the state of an ecosystem based on its maturity; and the fishing-in-balance (FIB) index for describing how ecosystem exploitation changes over time. Application of the FIB index to the Gulf of Thailand and the North Atlantic fisheries, describing the development in fisheries catches and their trophic levels over time, reveals that the index is straightforward to parameterize and adds an ecological dimension to fisheries catch series; it is a useful indicator for assessing the impact of fisheries on ecosystems.

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 tows: comparing 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 byctach of prawn trawlers in Moreton Bay, Australia. Australian Fisheries Resources. 7 : 99-110.

Keywords: fishing effects/ trawling/ bycatch/ Moreton Bay/ Australia

Wassenberg, T. J. and Hill, B. J. 1990. Partitioning of material discarded from prawn trawlers in Moreton Bay. Australian Journal of Marine and Freshwater Research. 41(1) : 27-36.

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

Abstract: Prawn trawlers in Moreton Bay, Queensland, discard about 3000 t of material each year. About 3% floats, and the rest sinks. The floating component is almost entirely fish. At night, floating discards are eaten by silver gulls (*Larus novaehollandiae*), crested terns (*Sterna bergii*) and, to a lesser extent, dolphins (*Tursiops truncatus*). There is little trawling during the day but the last discards are dumped overboard around drawn. At this time cormorants (*Phalacrocorax varius*) join the scavengers. Birds and dolphins scavenged only fish and cephalopods, and not crustaceans nor echinoderms. Birds are selective as to the size of fish they will eat, but most of the whole fish in the discards are below 50 g, and the largest fish that crested terns ate was 100 g. Dolphins are capable of taking the largest of the discarded fish. Most of the material that sinks is crustaceans (54%) and echinoderms (18%); the rest is elasmobranchs and rubble. At night, about half of the fish that sink are eaten by diving birds and by dolphins. There was no indication of mid-water scavenging of sinking discards, except for cormorants and dolphins in the upper water column. Approximately 11% of the discards that reach the bottom comprise fish and crustaceans, which are eaten by crabs (*Portunus pelagicus*) and fish. The remainder - chiefly crabs, echinoderms and elasmobranchs - reach the bottom alive. Altogether, about 20% of discards are eaten by surface and bottom scavengers. Discards

are probably important in maintaining populations of the major scavengers. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia, and the Australian Journal of Marine and Freshwater Research*.

Wassenberg, T. J., Salini, J. P., Heatwole, H., and Kerr, J. D. 1994. Incidental capture of sea-snakes (*Hydrophiidae*) by prawn trawlers in the Gulf of Carpenteria, Australia. Australian Journal of Marine and Freshwater Research. 45(3) : 429-443.

Keywords: trawlers/ bycatch/ Hydrophiidae/ Gulf of Carpentaria/ Australia/ fishing impacts

Abstract: Sea-snakes were collected from research trawlers and commercial prawn trawlers in the Gulf of Carpentaria during the period from April 1976 to December 1991. The data were analysed on the basis of CPUE (catch per unit effort) for depth, latitude and season. The research trawlers, operating in the eastern Gulf of Carpentaria, and the commercial prawn trawlers, operating in the south-western Gulf of Carpentaria, caught sea-snakes at a rate of 0.028 and 0.026 sea-snakes per meter of headrope length per hour, respectively. *Lapemis hardwickii* was the sea-snake most commonly caught by the research trawlers - 53% of all snakes - and *Hydrophis elegans* was the sea-snake most commonly caught by commercial trawlers - 25% of all snakes. Depth was the most significant factor affecting CPUE, with more than 70% of all sea-snakes being caught in waters less than 15 m deep. When catches of all species were combined, a significant interaction ($P < 0.05$) existed between depth and season. *L. hardwickii* specimens were caught more frequently in shallow coastal waters (< 15 m deep) in spring but in deeper water further offshore in autumn. A significant interaction between latitude and depth was found for *Astrotia stokesii*; specimens were caught more frequently in deeper water at 14^0 S. *Enhydrina schistosa* is generally coastal, with 88% of specimens being caught in water less than 10 m deep. Seasonal movement of sea-snakes between inshore and offshore waters may be linked to their breeding cycles. The estimated number of sea-snakes captured in the Gulf of Carpentaria for the 1991 prawning season ranged from 73,583 to 165,559, with a mean of 119,571. The survival rate of sea-snakes from commercial prawn trawls was about 60% and hence between 29,801 and 67,051 sea-snakes are estimated to have died. *Reprinted with the permission of CSIRO Publishing, Collingwood, Australia, and the Australian Journal of Marine and Freshwater Research*.

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 04573. Unpublished manuscript.

Keywords: scallop dragging/ dragging effects/ soft-sediment/ benthic community/ subtidal

Abstract: The effects of trawling disturbance on a soft-sediment system were investigated with a manipulative field experiment in an area that had been closed to shrimp trawling activities for 20 years. The area was also chosen for its weak natural physical agents i.e. no scouring of sediments by storm events or tidal flow, allowing a quantitative assessment of the effects of trawling on the benthic fauna and

geochemical properties of the soft substrate. The study examined the ambient spatial and temporal patterns of sedimentological variables and benthic species abundances over a time interval of 16 months for both the reference and the trawl stations before dragging the trawling gear over the predetermined trawl sites. Shifts in the patterns of the benthic infauna and geochemical variables were identified by the post-trawl samples that were collected at both the reference and trawl stations over the next 6 months. Post-trawl changes in the bottom topography did not translate into changes in the vertical profile of the sedimentological variables. Chlorophyll a content of the trawled surface sediments was significantly elevated immediately after the trawling event in comparison to the reference concentrations. Immediately after the trawling disturbance, numbers of species, species abundance and diversity decreased in the trawled area in comparison to the reference area. Sensitive species were found to be the bivalves; Ennucula annulata, Hampson, Thyasira flexuosa (Montagu), and Yoldia sapotilla (Gould), and polychaetes; Chaetozone cf.setosa Malmgren, Anobothrus gracilis (Malmgren), Euchone incolor Hartman, and Terebellides atlantis Williams. In contrast, the carnivorous nemertea, Cerebratulus lacteus Verrill, was the resistant species to field manipulations on account of its predatory behavior; highly effective in seeking out freshly dead (dying) organisms and its active migration. Multivariate analysis confirmed the changes in the trawled community structure immediately following the trawling event and differences in the recovery patterns 6 months thereafter. Although the trawling disturbance was one of low frequency and intensity compared to commercial operations, the biological variables studied indicated that successional processes in this soft-bottom community were altered, at least for a short period, in response to the trawling disturbance.

Watling, L., Findlay, R. H., Mayer, L. M., and Schick, D. F. 2001. Impact of a scallop drag on the sediment chemistry, microbiota, and faunal assemblages of a shallow subtidal marine benthic community. Journal of Sea Research. 46(3-4) : 309-324.

Keywords: Scallop fisheries/ Bottom trawls/ Environmental impact/ Zoobenthos/ Community composition/ Sediment chemistry/ ANW, USA, Maine, Damariscotta Estuary

Abstract: Scallops are usually obtained by means of a heavy metal dredge that is pulled over the sea bottom. Most studies of the impact of this gear type have shown that larger invertebrates, in particular, are severely disturbed. These studies, however, have been conducted on coarse sediments, ranging from sands to cobble, and have dealt only with faunal changes. In this paper the impact of a New England type scallop dredge on the fauna and sedimentary nutritional characteristics of a silty sand community is detailed. The site, in the Damariscotta River, Maine, USA, was sampled during the fall and winter prior to, then again immediately following, the dragging event, and twice more over the ensuing six months. Loss of surficial sediment, lowered food quality of the sediment (as measured by microbial populations, enzyme hydrolysable amino acids, and chlorophyll a), and changes in the faunal composition of the dragged site were observed. While some taxa returned to the drag track relatively quickly, others such as the cumaceans, phoxocephalid and photid amphipods, and nephtyid polychaetes, were not seen in abundances comparable to those of the adjacent undragged site until the food quality also recovered. *Reprinted from Journal of Sea Research, Vol. 46; Watling, L., Findlay, R.H., Mayer, L.M., Schick, D.F., Impact of a scallop drag on the sediment chemistry, microbiota, and faunal assemblages of a shallow subtidal marine benthic community., pages 309-324; Copyright (2001); with permission from Elsevier Science.*

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. Unpublished 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

Wion, D. A. and McConnaughey, R. A. 2000. Mobile fishing gear effects on benthic habitats: A bibliography. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-116, 163 p.

Keywords: bibliography/ mobile fishing gear effects/ impacts/ benthic disturbance

Summary: A comprehensive literature bibliography specifically covering mobile fishing gear impacts to benthic habitats. This bibliography is a sub-product of this web site, and is available via the "Bibliography (PDF)" link at the top of this web page.

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
Abstract: Field observations and literature data showed that high numbers of the bivalve mollusc Arctica islandica are affected by beam trawl fisheries. The occurrence of damage mainly on the postventral shell side suggests that tickler chains are the responsible cause. Scars formed in shells which survived after being fished, were used to reconstruct fishing intensity for one site in the SE North Sea for the past 30 years. It was found that the location has been disturbed annually since 1974. The increasing trend in the relative occurrence of scars since that period coincides with the developments of the Dutch fishing fleet for the same period. It is suggested that the method presented might be valuable for estimating actual fishing intensities on very local scales.

Witbaard, R. and Klein, R. 1994. Long-term trends on the effects of the southern North Sea beamtrawl fishery on the bivalve mollusc *Arctica islandica* L. (Mollusca, Bivalvia). ICES Journal of Marine Science. 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 beamtrawl fisheries is illustrated by the high incidence of damage found on shells from heavily fished areas. Between 80 and 90% of the damage was found at the posterior ventral side of the shell. This can be explained by the orientation of the living animal in the upper sediment layer and the horizontal movement of the tickler chains on the bottom. Scars on the external shell surface were dated by internal growth lines, revealing that the sampling site had been disturbed at least once a year since 1974. The observed trends in the occurrence of scars per year show a striking coincidence with the increase in capacity of the Dutch fishing fleet over the period 1972-1991.

Witherell, D. and Coon, C. 2001. Protecting Gorgonian corals off Alaska from fishing impacts. Proceedings of the First International Symposium on Deep-Sea Corals. Pages 117-125 *in* Willison, J., Hall, J., Gass, S., Kenchington, E., Butler, M., and Doherty, P. (eds.), Proceedings of the first international symposium on deep-sea corals. Proceedings of a Symposium held at Dalhousie University, Halifax, Nova Scotia, Canada, July 30 – August 2, 2000. Ecology Action Centre and Nova Scotia Museum, Halifax, Nova Scotia.

Keywords: coral/ Gorgonacea/ fishing impacts/ Alaska/ North Pacific/ essential fish habitat/ habitat areas of particular concern/ trawl closure

Summary: Large deep-sea corals of the order Gorgonacea are found in the North Pacific Ocean off Alaska, USA. The North Pacific Fishery Management Council has identified these corals as essential fish habitat of particular concern, so management measures to reduce the fishery impacts are being considered. These corals have been shown to be (i) important shelter for rockfish and other fish species, (ii) very long-lived, (iii) easily damaged by fishing gear, and (iv) slow to recover from damage. Coral conservation measures previously implemented include trawl closure areas of high coral concentration was proposed and evaluated. The proposal was tabled because available scientific data on coral distribution was at too large a scale to define discrete locations of coral colonies. Additionally, many fishermen using longline and pot gear were concerned about being displaced from areas they had previously fished, and many felt that their gear caused less damage to corals than does trawl gear. Involvement of stakeholders at the local level will allow for better information exchange, including information on coral distribution, fishing gear impacts, and development of appropriate management measures.

Witherell, D., Pautzke, C., and Fluharty, D. 2000. An ecosystem-based approach for Alaska groundfish fisheries. ICES Journal of Marine Science. 57(3) : 771-777.

Keywords: Alaska/ ecosystem/ groundfish/ management

Abstract: An ecosystem-based approach is being developed for the management of groundfish fisheries in the North Pacific Ocean off Alaska, USA. The approach involves public participation, reliance on scientific research and advice, conservative catch quotas, comprehensive monitoring and enforcement, by-catch controls, gear restrictions, temporal and spatial distribution of fisheries, habitat conservation areas, and other biological and socioeconomic considerations. The basic ecosystem consideration employed is a precautionary approach to extraction of fish resources. Off Alaska, all groundfish stocks are considered healthy, while providing sustained yields of about 2 million tonnes annually. Management measures are also taken to minimize potential impacts of fishing on seafloor habitat and other ecosystem components such as marine mammals and seabirds. (C) 2000 International Council for the Exploration of the Sea.

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

Wyman, J. 2001. Will fixed gear inherit the sea? Pacific Fishing. 22(10) : 27-29.

Keywords: Marine fisheries/ Fishery regulations/ Moratoria/ Trawling/ Fishing grounds/ Trawl nets/ Fishing gear/ Gear selectivity/ Nature conservation/ Resource management/ Fishery resources/ IN, North Pacific

Abstract: Roughly 20% of the fishable habitat of the North Pacific is closed to trawling. That's a patchwork of areas totaling some 80,000 square miles, or more no-trawl area than is found in all other U.S. fisheries combined. It is the only gear type that is prohibited; there is no such thing as a fishing area open to trawling but closed to longlining, jigging, or pot gear. Though all commercial fishing gear is banned from certain ecologically sensitive or protected areas, it's fair to say that, when conservation issues arise, trawling is the first gear type scrutinized and cast out of the fishing grounds.

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*, benefited 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).*

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