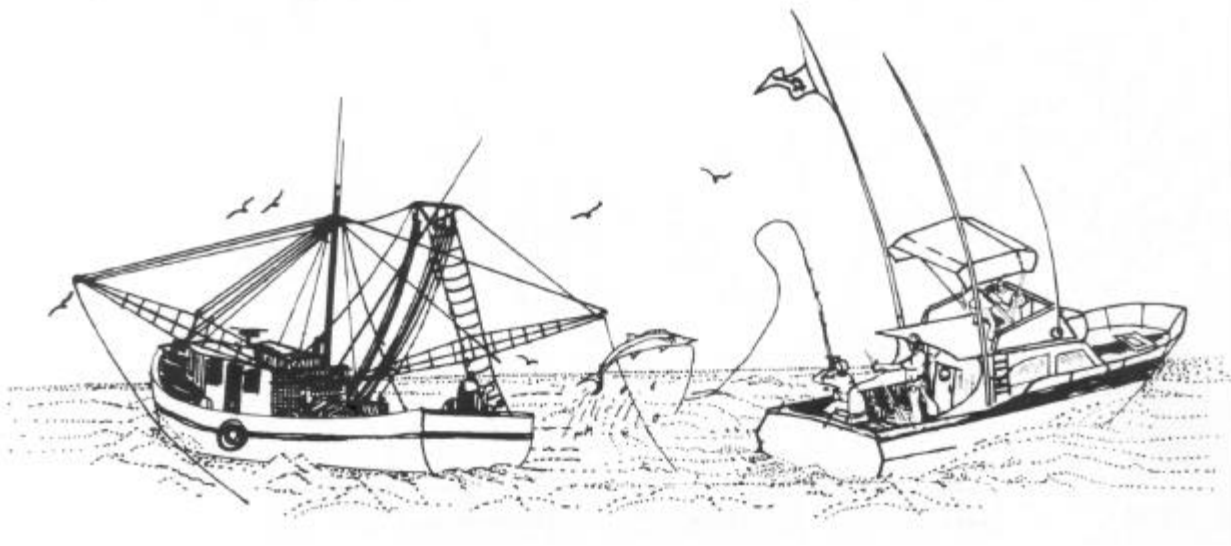


ANNOTATED BIBLIOGRAPHY OF FISHING IMPACTS ON HABITAT - OCTOBER 2001 UPDATE



Gulf States Marine Fisheries Commission

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**Annotated Bibliography of Fishing Impacts
on Habitat - October 2001 Update**

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Introduction

This is second in a series of updates to the Gulf States Marine Fisheries Commission's *Annotated Bibliography of Fishing Impacts on Habitat* originally produced in February 2000. The Commission's Habitat Subcommittee felt that the gathering of pertinent literature should continue. The second update contains 55 new articles since the publication of the original bibliography and first update. The update uses the same criteria that the original bibliography and first update used to compile articles. It attempts to compile a listing of papers and reports that address the many effects and impacts that fishing can have on habitat and the marine environment. The bibliography is not limited to scientific literature only. It includes technical reports, state and federal agency reports, college theses, conference and meeting proceedings, popular articles, and other forms of nonscientific literature. This was done in an attempt to gather as much information on fishing impacts as possible. Researchers will be able to decide for themselves whether they feel the included information is valuable.

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

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

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

Ball, B., G. Fox, and B.W. Munday. 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. Vol. 57(5):1315-1320.

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.

Ball, B., B. Munday, and G. Fox. 1999. The impact of a *Nephrops* otter trawl fishery on the benthos of the Irish Sea. Journal of Shellfish Research. Vol. 18(2):708.

Abstract: The fishery for the Norway lobster (*Nephrops norvegicus*) is concentrated on a mud patch in the north western part of the Irish Sea. The fishery commenced in the early '40's as a small-scale summer fishery, but the season has now extended to include most times of the year. Fishing intensity is estimated to be high (each square meter is trawled c. 5-10 times per year). No quantitative historical data on the benthos is available for the period prior to commencement of the fishery, although some limited qualitative data exists. This paper reports on studies of the benthos undertaken in the period 1994-1996. Short term effects of fishing on the benthos were investigated by means of samples taken both before and shortly after (c. 24 h) fishing activity. Studies of the medium to long term effects involved sampling the fauna of areas around wrecks (i.e., unfished pseudo-control sites) for comparison with fished grounds. From the available data, 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 (75 m water depth), however, some changes were visible in a shallow (35 m water depth), low fishing intensity site. The medium to long-term effects are more easily detectable at the offshore site, while only minor changes are visible at the inshore location. It would appear, therefore, that it is fishing intensity *per se*, rather than simply 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.

Barnette, M.C. 2001. A review of the fishing gear utilized within the Southeast Region and their potential impacts on essential fish habitat. NOAA Technical Memorandum NMFS-SEFSC-449. 62pp.

Summary: This paper reviews the scientific literature on fishing gear impacts, specifically targeting fishing gears that are used in the southeastern United States and Caribbean. The review analyzes impacts from mobile gear, static gear, and other allowable gear. For each gear type, a brief overview of the gear is given. Each gear type analysis also includes any gear impacts, recovery from impacts, and management recommendations.

Bergman, M.J.N., and J.W. van Santbrink. 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. Vol. 57(5):1321-1331.

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 m² 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.

Bradshaw, C., L.O. Veale, A.S. Hill, and A.R. Brand. 1999. The effect of scallop dredging on Irish Sea benthos: experiments using a closed area. Journal of Shellfish Research. Vol. 18(2):709.

Abstract: A 2 km² area off the southwest coast of the Isle of Man (Irish Sea) has been closed to commercial fishing with mobile gear since March 1989. This area was heavily fished for *Pecten maximus* prior to closure, and the seabed immediately surrounding the closed area is

still one of the most heavily dredged in the Irish Sea. Two methods have been used to study the effect of scallop dredging on the benthos in this closed area and adjacent fished areas. Firstly, divers have carried out visual transect surveys of the epibenthos regularly since closure. Secondly, biannual fine-meshed dredge and grab sampling of experimental plots inside and outside the closed area since 1995 has enabled comparisons of the benthic infauna and epifauna of experimentally dredged plots, undredged control plots and plots exposed to commercial dredging. Since 1989, there have been consistent significant increases in the mean numbers of many species in the closed area, including *Pecten maximus* and *Luidia ciliaris*, and upward trends in numbers of hermit crabs, spider crabs and brittlestars have also been recorded. Conversely, the common starfish, *Asterias rubens*, appears to be decreasing in abundance. Communities of experimentally disturbed plots have become less similar to adjacent undisturbed control areas and more similar to commercially dredged areas. At each sampling date, similarity between samples was greater outside the closed area than inside. These results present strong evidence that scallop dredging alters benthic communities and suggest that the closure of areas to commercial dredging may allow the development of more heterogeneous communities and allow the populations of some species to increase. A common problem with studying fishing disturbance is the lack of good control sites and this work also demonstrates the value of closed areas to scientific studies of bottom fishing.

Bullimore, B.A., P.B. Newman, M.J. Kaiser, S.E. Gilbert, and K.M. Lock. 2001. A study of catches in a fleet of "ghost-fishing" pots. *Fishery Bulletin*. Vol. 99(2):247-253.

Abstract: Pots are a form of trap used to capture fishes, crustaceans, or gastropod mollusks. Occasionally, these traps are lost at sea, where they have the potential to fish for many years because they are constructed of robust man-made materials. The present study quantified the mortality and number of animals caught by a fleet of crustacean pots (12 pots) that were set on the seabed and left to fish continually in a manner designed to simulate ghost-fishing off the coast of Wales, UK. The bait originally placed in the pots was consumed within 28 days of the beginning of the experiment. Spider crabs and brown crabs dominated the catches within the pots throughout the experiment. The CPUE of spider and brown crabs declined as an inverse function of time and reached a minimum between 125 to 270 days after initial deployment in August 1995. After this period, CPUE increased again, although it did not attain the rates associated with the beginning of the experiment. The fleet of twelve pots caught a minimum of 7.08 spider and 6.06 brown crabs per pot per year and killed a minimum of 6.06 brown crabs and 0.44 lobsters per pot per year. Other species caught in the traps included velvet swimming crab, lobster, ballan wrasse, dogfish, and triggerfish. The pots continued to catch animals into the second year of the experiment. These results suggest that pots have the potential to fish for extended periods. The wider use of biodegradable escape panels is recommended because currently there is no national legislation in the UK to enforce such escape measures.

Cohen, B.F., D.R. Currie, and M.A. McArthur. 1998. Epibenthic community structure in Port Phillip Bay, Victoria, Australia. MAFRI Interim Report No. 10. MAFRI, Queenscliff, Victoria. 34pp.

Abstract: In 1997, the scallop (*Pecten fumatus*) dredge fishery in Port Phillip Bay, Victoria (Australia) was closed following intense public debate about the environmental effects of dredging. Experimental studies in the early 1990s to assess the short term impacts of dredging showed that densities of most common species were reduced by 20-30% and changes in infaunal community structure were smaller than seasonal, inter-annual and spatial differences. Impacts of dredging on most large epibenthic species were not able to be accurately quantified. In 1998, epibenthic community structure was examined from quantitative diver samples and differences between communities were compared using Bray-Curtis dissimilarity indices, multidimensional scaling and analysis of variance. The strong trend of decreasing abundance, biomass and species diversity with depth can be attributed to decreases in the abundance of the heavy, mat forming ascidian (*Pyura stolonifera*) with depth.

Collie, J.S., G.A. Escanero, and P.C. Valentine. 2000. Photographic evaluation of the impacts of bottom fishing on benthic epifauna. ICES Journal of Marine Science. Vol. 57(4):987-1001.

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.

Dolmer, P., T. Kristensen, M.L. Christiansen, M.F. Petersen, P.S. Kristensen, and E. Hoffmann. 1999. Short-term impact of blue mussel dredging (*Mytilus edulis* L.) on a benthic community. Journal of Shellfish Research. Vol. 18(2):714.

Abstract: The short-term effect of mussel dredging in a brackish Danish sound was studied. A diver identified a commercial dredging track and an analysis of the species composition

inside the track and at an adjacent control area showed that dredging changed the community structure by reducing the density of small polychaetes. In order to investigate the extent and the duration of the dredging impact experimental dredging was conducted. The experimental dredging removed 50% of the mussels in the two dredged areas. Immediately after dredging, a significantly lower number of species was measured inside the mussel beds in dredged areas compared to control and boundary areas. This effect lasted for at least 40 days. The analysis of the species composition showed that the dredged area had a significantly lower density, particularly of small polychaetes compared to the boundary area. An increased number of species was recorded outside the mussel beds just after dredging, but this effect lasted for less than 7 days. After dredging, brown shrimps, *C. crangon* invaded the dredged areas. This species is an important predator of smaller invertebrates, and it is suspected that it was feeding on small vulnerable polychaetes exposed at the sediment surface after dredging. The dredging process was observed to form 2-5 cm deep furrows in the seabed, but the sediment texture and the organic content of the sediment were not affected. The biomass accumulation of individual blue mussels was significantly lower in the dredged area compared to the boundary area. This indicates that the disturbance of the mussel bed structure reduced growth and that the lowering of intraspecific food competition caused by a reduced density of mussels did not increase the accumulation of biomass in the mussels that remained in the dredged area.

Donaldson, W.E. 1990. Determination of experimentally induced non-observable mortality on red king crab. Unpublished Report. Alaska Department of Fish and Game, Division of Commercial Fisheries. Kodiak, Alaska. Grant Number NA89ABH00014.

Abstract: This study attempted to estimate the non-observed mortality of crabs that are encountered by a bottom trawl. Large hardshell male red king crabs were tethered in the path of an Aleutian combination trawl. Six tows were made to estimate the impact of trawl gear on injury rates of crabs that were in the trawl path, but not caught by the gear. In total, 169 of the tethered crabs were estimated to be in the six trawl paths as defined by the spread of the doors. Crabs recovered in the trawl onboard the vessel accounted for 21.3% of these crabs. Divers recovered 46.2% of the crabs within the trawl path, leaving 32.5% unrecovered. Three of the 36 (8.3%) crabs recovered in the trawl were injured while two of the 78 (2.6%) crabs recovered by divers were injured. This latter value is an estimate of the otherwise non-observable injury rate of Aleutian combination trawl gear on king crabs under the conditions tested. Only one crab, which was caught in a trawl, had injuries assumed to be fatal.

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

Eno, N.C., D.S. MacDonald, J.A.M. Kinnear, S.C. Amos, C.J. Chapman, R.A. Clark, F.S.P.D. Bunker, and C. Munro. 2001. Effects of crustacean traps on benthic fauna. ICES Journal of Marine Science. Vol. 58(1):11-20.

Abstract: We examined the effects of fishing with crustacean traps on benthic species in Great Britain by means of qualitative and quantitative experiments. Experimental sites were selected where fishing using pots or creels was practised regularly and where species perceived to be potentially sensitive to damage were present. The effect of Nephrops creels on different sea pen species was studied in Scottish sea lochs. Sea pens were observed to bend in response to the pressure wave before the creel made contact. After smothering and even uprooting, they re-established themselves when in contact with muddy substrate. Observations of lobster and crab pots being hauled from rocky substrates in southern England, revealed that the habitats and their communities appeared relatively unaffected by potting. The slow-growing, long-lived, pink sea fan *Eunicella verrucosa* were observed to flex under the weight of pots as they passed and then returned back to an upright position. Quantitative studies, undertaken in south England and west Wales, were based on surveys carried out along transect lines before and after a month of pot fishing for crabs and lobsters. The results suggest that four weeks of fairly intense fishing did not have immediate detrimental effects on the abundance of the species selected for study, although some individual rosette coral colonies (*Pentapora foliacea*) were damaged.

Escanero, G.A. 1997. Effects of bottom fishing on the gravel-substratum benthic megafauna of Georges Bank. M.S. Thesis. University of Rhode Island. 111 p.

Abstract: The effects of human activities on ocean ecosystems during the second half of the 20th century are pervasive, preponderant and for the most part they are destructive. Georges Bank, once one of the most productive fishing areas of the world, is a good example. The collapse of its fisheries, a result of overfishing, has raised questions about the condition of the habitat and the effects of bottom fishing on the benthos. This study combines dredge samples and underwater images obtained during 1994-1995 to characterize habitats and species assemblages from disturbed and undisturbed sites. The sites located on the gravel pavement of northeastern Georges Bank were selected from sonograms based on the presence/absence of tracks left by fishing gear. Multiple sample replicates allowed robust statistical analyses. The establishment of a closure in December 1994 permitted testing for the effects of the elimination of the mechanical disturbance on the megafauna at one of the previously sampled sites. Dredged sites lacked the complex habitat created by emergent bushy epifauna and its associated species assemblage composed of fragile, sessile or slow moving invertebrates such as worms, arborescent hydroids and bryozoans, shrimps, polychaetes, and juvenile fish. The most heavily disturbed site has a very reduced species assemblage mainly composed of large, hard-shelled mollusks, scavenging crabs and echinoderms. Significant differences between dredged and undredged areas were found for all variables tested. The 1994 closure to fisheries had positive effects as the area recently protected showed a significant increase in biomass and increases in abundance and diversity.

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

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.

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

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.

Gibson, M.R. and T.E. Angell. 1996. Assessment of gear induced damage and mortality on American lobster (*Homarus americanus*) in Rhode Island coastal waters. Rhode Island Department of Environmental Management, Division of Fish and Wildlife. 26 p.

Summary: This study investigates an alleged problem that the otter trawl fishery in Rhode Island for lobsters killed and wasted lobsters, especially during the molting period. The Rhode Island Department of Environmental Management researched this issue. They concluded that more sublegal lobsters were damaged and killed by the otter trawl fishery than by the trap fishery. Discard mortalities actually exceeded the landings by otter trawl.

Goudey, C.A. 1999. Progress in reducing the habitat impact of trawls and dredges. MIT Sea Grant College Program Report, MITSG 99-8. 35 p.

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

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 lysianid 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⁻² ash-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.

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

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.

Hebert, M., G. Miron, M. Moriyasu, R. Vienneau, and P. DeGrace. 2001. Efficiency and ghost fishing of snow crab (*Chionoecetes opilio*) traps in the Gulf of St. Lawrence. *Fisheries Research*. Vol. 52(3):143-153.

Abstract: Experiments were conducted in the southwestern Gulf of St. Lawrence from 1988 to 1993 to: (1) evaluate the catch performance of three types of conventional commercial snow crab traps; (2) evaluate the catch rates of soft-shelled crabs in normal and modified conical traps; and (3) investigate ghost fishing by lost traps. Our results showed that pyramidal and conical traps captured larger-sized males than conventional rectangular traps. Pyramidal traps also obtained significantly higher catch rates of commercial male crabs than conventional rectangular traps. The recent increased use of conical and pyramidal traps may result in a considerable reduction of the most reproductively important component of the male population. Close monitoring of the population reproductive potential is necessary to ensure a healthy population in the long-term. Our experimental conical traps, modified by attaching a 18 or 24 cm plastic panel around the top, caught significantly less soft-shelled crabs while maintaining the same catch rate of commercial crabs as compared to the conventional conical trap. This modified trap will play an important role in avoiding unnecessary mortality of crabs and ensuring the long-term conservation of the stock. Results from the ghost fishing experiment suggested that baited snow crab traps set in summer captured snow crab to their saturation level. The number of crabs then slowly decreased due

to cannibalism and predation over winter. The mortality rate of snow crabs trapped inside conical traps was estimated at 94.6% per year. The catches increased again to their saturation level before the following spring, due to the self-baiting effect, which re-initiated a ghost fishing cycle.

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

Abstract: The high blue mussel catches in a 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 on experimental fishing with trawl, set net and 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.

Humborstad, O.B., D.M. Furevik, S. Lokkeborg, and N.R. Hareide. 2000. Catches of Greenland halibut (*Reinhardtius hippoglossoides*) in ghost fishing gillnets on the Norwegian continental slope. ICES CM 2000/J:8. 10 p.

Abstract: Catches in deliberately "lost" gillnets were studied during a ten-day cruise conducted a Storegga 70 nm off the coast of mid-Norway in July 2000. Gillnet fleets were deployed at depths of between 537 and 677 m, and soak time varied from one to seven days. Four fleets set 45 days earlier were also retrieved during the cruise. Most of the catch consisted of the target species Greenland halibut. All individuals were categorized according to seven condition stages ranging from "alive with no injuries" to "only bones remaining". Results revealed that fish could be fully decomposed/consumed within a 24 hour period, probably due to amphipod and isopod scavenger activity. A decline in total catches was first observed after five days whereas catch composition remained stable during the first seven days. After 45 days a relatively high total catch was obtained but only 25% were still at stages 1-4. The cumulative catch after 45 days was estimated at 2.7 and 3.0 tons on the basis of two different methods. Gillnets retrieved after 45 days were evaluated as being highly effective, with gear saturation being the only factor leading to decreased efficiency.

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

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.

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

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-spectra, 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.

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

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, $\delta^{15}\text{N}$) and body mass (as log₂ 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 $\delta^{15}\text{N}$ 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.

Kaiser, M.J., F.E. Spence, and P.J.B. Hart. 2000. Fishing gear restrictions and conservation of benthic habitat complexity. *Conservation Biology*. Vol. 14(5):1512-1525.

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 closed 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., G. Broad, and S.J. Hall. 2001. Disturbance of intertidal soft-sediment benthic communities by cockle hand raking. *Journal of Sea Research*. Vol. 45(2):119-130.

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.

Kenchington, E.L.R., J. Prena, K.D. Gilkinson, D.C. Gordon, K. MacIsaac, C. Bourbonnais, P.J. Schwinghamer, T.W. Rowell, D.L. McKeown, W.P. Vass. 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*. Vol. 58(6):1043-1057.

Abstract: A 3-year otter trawling experiment was conducted on a deepwater 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 calcaria*. 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.

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

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.

Lenihan, H.S., C.H. Peterson, J.E. Byers, J.H. Grabowski, G.W. Thayer, and D.R. Colby. 2001. Cascading of habitat degradation: Oyster reefs invaded by refugee fishes escaping stress. *Ecological Applications*. Vol. 11(3):764-782.

Abstract: Mobile consumers have potential to cause a cascading of habitat degradation beyond the region that is directly stressed, by concentrating in refuges where they intensify biological interactions and can deplete prey resources. We tested this hypothesis on structurally complex, species-rich biogenic reefs created by the eastern oyster, *Crassostrea virginica*, in the Neuse River estuary, North Carolina, USA. We (1) sampled fishes and invertebrates on natural and restored reefs and on sand bottom to compare fish utilization of these different habitats and to characterize the trophic relations among large reef-associated fishes and benthic invertebrates, and (2) tested whether bottom-water hypoxia and fishery-caused degradation of reef habitat combine to induce mass emigration of fish that then modify community composition in refuges across an estuarine seascape. Experimentally restored oyster reefs of two heights (1 m tall "degraded" or 2 m tall "natural" reefs) were constructed at 3 and 6 m depths. We sampled hydrographic conditions within the estuary over the summer to monitor onset and duration of bottom-water hypoxia/anoxia, a disturbance resulting from density stratification and anthropogenic eutrophication. Reduction of reef height caused by oyster dredging exposed the reefs located in deep water to hypoxia/anoxia for >2 wk, killing reef-associated invertebrate prey and forcing mobile fishes into refuge habitats. Refugee fishes accumulated at high densities on reefs in oxygenated shallow water, where they depleted epibenthic crustacean prey populations. Thus, physical disturbances can impact remote, undisturbed refuge habitats through the movement and abnormal concentration of refugee organisms that have subsequent strong trophic impacts. These results have implications for the design of Marine Protected Areas (MPAs), showing that reserves placed in proximity to disturbed areas may be impacted indirectly but may serve a critical refuge function on a scale that matches the mobility of consumers.

Lindegarth, M., D. Valentinsson, M. Hansson, and M. Ulmestrand. 2000. Effects of trawling disturbances on temporal and spatial structure of benthic soft-sediment assemblages in Gullmarsfjorden, Sweden. *ICES Journal of Marine Science*. Vol. 57(5):1369-1376.

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.

Linnane, A., B. Ball, B. Munday, B. van Marlen, M. Bergman, and R. Fonteyne. 2000. A review of potential techniques to reduce the environmental impact of demersal trawls. Irish Fisheries Investigations (New Series). No. 7:1-39.

Summary: The first half of this review examines the physical and biological effects of beam and otter trawling. It examines penetration depth, sediment resuspension, habitat disturbance, and the effects on non-target fish and benthic invertebrates. The second half examines potential gear modifications that would reduce beam and otter trawling impacts. It reviews electrical stimulation, chain configuration and net modifications, water jet stimulation, codend modifications, and roller ball modifications.

McConnaughey, R.A., K.L. Mier, and C.B. Dew. 2000. An examination of chronic trawling effects on soft-bottom benthos of the eastern Bering Sea. ICES Journal of Marine Science. Vol. 57(5)1377-1388.

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 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 for the benthos. Using this approach, macrofauna populations in a shallow (48m average) soft-bottom area were studied during 1996. Samples of 92 taxa (reduced for analysis) were collected at 84-1nm² 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 characteristics, 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.

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

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.

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

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 activity 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. Results indicate that nutrient concentration and flux are greatest immediately following a trawling event from sediments that have equilibrated. Nutrient concentrations and flux rates are reduced from sediments disturbed on successive days. Using these flux data, trawling within the ICES statistical sub-rectangle 39E8 is estimated to increase the annual flux by 1.4% for nitrite, 1.8% for ammonium, 0.4% for nitrate and 2.4% for phosphate.

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

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 $\times$ 2' minute longitude square ($\pm 1 \times 1$ nm) 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.

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

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 $\times$ 6 minutes, an area equivalent to ~153000

km². 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 6min 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, ~8% of medium-resilience fauna, and ~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 >2000-3000h of effort. More fauna will be removed from grids with higher effort. Though 50-70% of trawled grids have been trawled only lightly (<700-1000h) 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.

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

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

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.

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

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.

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

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 300hp 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.

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

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.

Robinson, S.M.C., S. Bernier, and A. MacIntyre. 1999. The impact of scallop drags on sea urchin populations and benthos in the Bay of Fundy, New Brunswick, Canada. *Journal of Shellfish Research*. Vol. 18(2):727.

Abstract: The fishery for the green sea urchin (*Strongylocentrotus droebachiensis*) began in New Brunswick in the late 1980s in response to increasing demand from Asian markets. Fishing was initiated by members of the scallop fishery and the harvesting practices were based on familiar gear and similar operations in Maine. Because of the potential harvesting impact on the shallow water benthic populations a study was initiated in 1993 to document 1) the proportion of sea urchins damaged during the harvesting operation, 2) the impact and subsequent recovery time of the associated benthic flora and fauna and 3) the impacts on the bottom substrate. Two representative sites were chosen for the study. At each site, a towing lane was created parallel to shore and divided into a treatment section and control section. Divers used a fixed line transect method to survey the control and treatment plots prior to and after the harvesting operation (2 m Digby drag). Further surveys were scheduled three and six months later. The results from the study showed a significant increase in the number of broken sea urchin tests after the harvesting operation from 0.05 m² to 1.4 m² at the

Passamaquoddy Bay site. Similar trends were found in Grand Manan. On both sites in the experimental plot, there was an increase in the density of mobile predators such as hermit crabs, starfish, whelks and sculpins. While the lobster density declined to zero in the experimental plot, the lack of body parts suggested they moved out of the area. The dragging operation also adversely affected a number of macrophytes.

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

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 regrown 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.

Ruffin, K.K. 1998. The persistence of anthropogenic turbidity plumes in a shallow water estuary. *Estuarine, Coastal and Shelf Science*. Vol. 47(5):579-592.

Abstract: Increased turbidity and light attenuation (K_d) in the suspended sediment plumes created by hydraulic clam dredging were examined in Chesapeake Bay, MD, U.S.A. Turbidity and K_d values were measured along transects in areas with and without dredge plumes. The turbidity and K_d of individual plumes were tracked as they returned to background levels using both Lagrangian and Eulerian techniques. Existing aerial photographs and a geographical information system (ARC/INFO) were used to examine plume sizes and dredge boat locations in relation to bathymetry. Hydraulic clam dredging produced plumes with significantly higher turbidity and light attenuation compared to background values. Plume characteristics were determined primarily by bottom sediment type and water depth. The greatest increase in turbidity and light attenuation occurred when dredges operated in shallow water (<1.0 m) where bottom sediments had increased amounts of silt and clay. Plume turbidity and K_d dissipated exponentially over time. The initial change in concentration of suspended sediments was rapid as the coarse sediments settled to the bottom. The rate of plume decay slowed as diffusion and resuspension acted on the finer sediments remaining in suspension. Some Lagrangian rates of plume dissipation were faster than Eulerian rates due to resuspension in shallow waters. Examination of aerial photographs indicated that 72% of the dredge boats digitized in the Chester River were

operating in less than 2 m water. The area of a plume measured per boat in the Chester River was highly variable, ranging from 0.01 to 0.64 m².

Rumohr, H., and T. Kujawski. 2000. The impact of trawl fishery on the epifauna of the southern North Sea. ICES Journal of Marine Science. Vol. 57(5):1389-1394.

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.

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

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 $r = 0.21$, $p < 0.05$). 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, P., M. Demestre, M. Ramon, and M.J. Kaiser. 2000. The impact of otter trawling on mud communities in the northwestern Mediterranean. ICES Journal of Marine Science. Vol. 57(5):1352-1358.

Abstract: We report the findings of an experiment conducted in the northwestern Mediterranean to evaluate the short-term effects of otter trawling on a muddy-sediment infaunal community. A commercial fishing vessel, using conventional otter trawling gear, fished two waylines repeatedly until each had been disturbed entirely either once or twice. Infaunal samples were collected from replicate sites located within the fished and adjacent undisturbed control areas. Univariate analyses of species richness and diversity indicated that the infaunal community did not alter during the first 102h after fishing in the area that was trawled once. However, the abundance of a number of species decreased significantly on the unfished line compared with the fished line 150h after fishing. No differences were detected on the line that was fished twice, but this part of the experiment was terminated after 72h. Multivariate analyses revealed that the communities in both fished and unfished areas changed in a similar manner through time and that there was no apparent effect of fishing until 150h after fishing. These short-term changes are discussed in the light of recent studies of infaunal changes in other habitats.

Schleyer, M.H., and B.J. Tomalin. 2000. Damage on South African coral reefs and an assessment of their sustainable diving capacity using a fisheries approach. *Bulletin of Marine Science*. Vol. 77(3):1025-1042.

Abstract: Coral reefs in a marine reserve at Sodwana Bay (27°30' S) make it a premier dive resort. Corals are at the southern limits of their African distribution on these reefs which are dominated by soft corals. The coastline is exposed and turbulent. An assessment of the degree to which sport diving damages the reefs is needed for their management. This study showed that recognizable diver damage is generally concentrated in heavily dived areas. This damage and that of unknown cause probably attributable to divers exceeded natural damage on the reefs, despite the normally rough seas. Fishing line discarded in angling areas caused considerable damage by tangling around branching corals which become algal fouled and die. Heaviest damage was caused in isolated areas by a minor crown-of-thorns outbreak. A linear regression indicated that 10% diver damage occurs at 9,000 divers per site p.a. Taking uncertainty into account, a precautionary limit of 7,000 dives per dive site p.a. was recommended. Further recommendations are that the reefs be zoned in terms of their sensitivity to diver damage, depth and use by divers according to qualification, and a ban be placed on the use of diving gloves to reduce handling of the reefs.

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

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.

Smith, C.J., K.N. Papadopoulou, and S. Diliberto. 2000. Impact of otter trawling on an eastern Mediterranean commercial trawl fishing ground. ICES Journal of Marine Science. Vol. 57(5):1340-1351.

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 200m 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.

Thrush, S.F., J.E. Hewitt, G.A. Funnell, V.J. Cummings, J. Ellis, D. Schultz, D. Talley, and A. Norkko. 2001. Fishing disturbance and marine biodiversity: role of habitat structure in simple soft-sediment systems. Marine Ecology Progress Series. Vol. 221:255-264.

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 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 seafloor. 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.

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

Abstract: This paper examines spatial differences in the distribution of by-catch assemblages from the scallop [*Pecten maximus* (L.) and *Aequipecten opercularis* (L.)] 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. By-catch 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 homogenization. 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.

Veale, L.O., A.S. Hill, S.J. Hawkins, and A.R. Brand. 2001. Distribution and damage to the by-catch assemblages of the northern Irish Sea scallop dredge fisheries. *Journal of the Marine Biological Association of the United Kingdom*. Vol. 81(1):85-96.

Abstract: The major by-catch species retained during twice yearly dredge surveys of great scallop, *Pecten maximus*, and queen scallop, *Aequipecten opercularis*, (both Mollusca: Pectinidae) populations on 13 fishing grounds in the northern Irish Sea, over a period of five years, were identified and enumerated. Additionally, the damage sustained by the by-catch was assessed and related to a range of physical parameters recorded during the survey. A number of species captured in the springtoothed dredges exhibited differences in abundance

and damage sustained between years, and also between the start and end of the closed season for great scallop fishing (1 June-31 October). The by-catch assemblage varied geographically, dependent upon the underlying community structure, as well as putative factors including gear efficiency and substratum type. Two clear assemblage types were identified by multivariate analysis, one to the south-west of the Isle of Man, the other covering fishing grounds to the north, east and south of the island. There is a hierarchy of species sensitivity to damage in great and queen scallop dredges, probably related to morphological and behavioural characteristics. This selective mortality of a fraction of the community may have long-term implications at the ecosystem level. The degree of damage sustained by many species is related to both the volume of stones retained in the dredge, and the total volume of the catch (dredge fullness). If these were reduced, the overall magnitude of incidental by-catch mortality would be lower.

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

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.