NATURE CONSERVATION IMPLICATIONS OF DAMAGE TO THE SEABED BY COMMERCIAL FISHING OPERATIONS

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SUMMARY

This report reviews the main impacts of commercial fishing operations on the seabed and their significance for marine nature conservation. Sources of information are from scientific journals, unpublished research reports, the fishing press, anecdotal comments from divers and fishermen and reports of ICES Committees.

Brief descriptions are provided of the main categories of fishing operations which may damage seabed communities and habitats; trawling and dredging, hydraulic dredging, potting and tangle netting. The impact of these activities on the benthos and their marine nature conservation implications are described. Several proposed Marine Nature Reserve sites have recently been damaged by fishing operations. The impact of fisheries on sea mammals and seabirds is also covered, but in outline since other studies have either been carried out or are underway on these subjects.

The report concludes that the impact of modern fishing methods can have a severe impact on the seabed and benthic communities, particularly the epifauna, long-lived infaunal species, maerl and seagrasses. British nearshore areas have been considerably altered by these widespread activities and the impact will be most damaging in areas of diverse habitat close inshore.

Recommendations for research are outlined, including studies of the impacts of commercial fishing operations on the seabed, benthic communities and non-target organisms. The results of most previous investigations are now out of date due to recent intensification of fishing methods. Marine Nature Reserves (MNRs) may be used for studies of the recovery of areas damaged by fishing operations and as control sites for monitoring the effects of inshore fisheries in adjacent areas. Manipulative research on fishing impacts should not be undertaken in proposed or designated Reserves.

The conservation of marine sites will usually require controls on fisheries activities. Such controls should be sought as a matter of urgency when these sites are identified to avoid the type of damage which has recently occurred in several proposed MNRs awaiting designation. This damage has arisen from the introduction of a new fishery or the expansion or intensification of an existing fishery. It will be important to ensure that planning for marine site management takes careful account of the potential for this sort of change in fisheries activity.

1. Introduction

This paper reviews the main impacts of commercial fishing operations on the seabed and their significance for marine nature conservation. Sources of information are from scientific journals, unpublished research reports, the fishing press, anecdotal comments from divers and the fishing community and, most importantly, from reports of the Gear and Behaviour and Fish Capture Committees of the International Council for the Exploration of the Sea (ICES). A list of all relevant references is appended, including a number not referred to in the following text and some which were collated by Redant (1987) for the ICES Benthos Ecology Working Group and not obtained in time for review for this document.

The main categories of fishing operation considered are the 'active' trawling and dredging operations: otter trawls, beam trawls (with tickler chains or chain matrixes), oyster, scallop and hydraulic dredges. Also considered are tangle nets and potting for crustacea, as these methods can damage benthic organisms, particularly where set on hard ground where fragile, slow-growing organisms are present.

Generally of less significance in the context of this paper are drift nets, set nets and fish traps, midwater trawls and seines or long-lining and jigging, since this equipment is either permanently fixed or does not generally come into contact with the seabed. The effects of these and other fishing methods on seabirds, seals, otters or cetaceans are noted in outline in section 8, but not covered in detail since other studies have either been carried out or are underway on this subject.

2. Trawling

2.1 Types of gear commonly used

Otter trawls: These trawls may be used on the bottom for shrimp, fish and *Nephrops*. They are pulled by one vessel, with the otter boards keeping the mouth of the net open.

Pair trawls: Used for demersal (cod and whiting) or pelagic (herring and mackerel) fishing. Otter boards are not necessary to keep the net open when two vessels are towing.

Beam trawls: The original type of trawl. These are used for fish (particularly flat fish) and shrimp. The beam keeps the mouth of the net open, and 'shoes' at each end of the beam keep it off the bottom.

Tickler chains are more commonly in use on demersal trawls and heavy chains on pair trawls, with weights of up to 900 kg per side for 600hp vessels. Tickler chains create sand clouds to direct fish into the trawls and move bottom-living fish into the water column where they can be caught. Chain matrices are designed to prevent the entry into the net of large stones and other debris which might cause damage to the catch or equipment.

The gear used by UK beamers varies depending upon the type of ground fished and the target species. In the North Sea, larger vessels use beams up to 12m in length with relatively light tickler chains. In the southern North Sea and English Channel the beam size is usually 4 to 8m, heavily rigged with chain mats to fish on hard and stony ground. The Irish Sea has a generally rough seabed and chain matrices are also used here. The typical weight of a 4m beam with heavy chain mat is 3,500kg. The complete fishing gear for a Belgian 10m beam trawl weighs 6000kg.

2.2 Fishing effort

ICES Report 1988/B:56 reviews available information on fishing effort and gear. There has been a considerable increase in the numbers of large, powerful vessels operating in European waters over the past decade, particularly beam trawlers. Data on catches and the spatial distribution of fishing effort are incomplete and not fully up to date, which does not allow quantification of the effects of bottom trawling. Figures available from the Netherlands for statistical rectangles in 1975 have been used by Rauck (1985) to calculate overall fishing effort in certain heavily fished areas. The results indicate that each m2 of seabed had, on average, been fished 3 to 5 times a year by the Dutch fleet alone. Some areas will actually have been fished many more times than this, and this concentration of effort must have increased markedly in the past 14 years.

Although total numbers of vessels are now falling in the UK, there has been a significant increase in beam trawling and scallop dredging effort in England and Wales. Scallop dredging effort has reduced in Scotland since the early 1980s, but beam trawling has now been introduced there and may increase in relative importance.

2.3 Impact on the seabed

Most of the literature available on the subject of damage to the benthos deals with this fishing method, which is frequently the subject of conflict with other fishing interests. De Groot (1984) in his review of the literature notes some of the earliest complaints on the subject, dating from the 13th, 14th and 16th centuries. More recently, these were repeated in the 19th century and have been regularly voiced during the past few decades. (See de Groot 1984 for detailed references).

In the early 1970s the International Council for the Exploration of the Sea undertook an investigation of the effects of trawls and dredges on the seabed, following complaints about the damage being caused by the Dutch beam trawlers with their heavy chains and chain mats. A number of papers were produced for this investigation (Bridger 1970 and 1972, de Clerck and Hovart 1972, de Graaf and de Veen 1973, de Groot 1972, de Groot and Apeldoorn 1971, Houghton et al 1971, Margetts and Bridger 1971) and are reviewed by de Groot (1984). These experiments and other papers demonstrated a certain amount of damage to the seabed and to benthic organisms, particularly when chains were used with beam trawls. The ICES Committee was concerned primarily with the question of damage to commercial fisheries, ie spawning grounds or food sources. Although certain groups of benthic organisms were shown to be severely damaged by trawls, the impact on commercial fisheries was negligible. The gear used for this work was light and the researchers only considered the short-term impact of a single passage of a trawl towed by low-powered vessels at low speeds, in comparison with the intensive efforts of today's larger and more powerful fishing fleets.

More recent work has considered the long-term effects of man's fishing activities on the benthos. Reise (1982) and Riesen and Reise (1982) compare survey data from the Wadden Sea in the 1920s with that for the present day. Three benthic habitats have disappeared (oyster <u>Ostrea</u> <u>edulis</u> beds, <u>Sabellaria</u> <u>spinulosa</u> reefs and <u>Zostera</u> <u>marina</u> beds) together with many species associated with these communities. Molluscs have been particularly affected by these changes, many of which are caused by human interference including overfishing and damage by fishing gear. The eliminated species have been replaced by others, including many polychaetes, so that overall diversity remains the same. Holme (1983) records the increasing evidence of man-made influences on the benthos of the western channel, by the use of heavy fishing gear. As well as the damage and loss of infauna, epifaunal hydroid and bryozoan colonies (which form an important nursery area for small crustaceans) may be dislodged from the sand. Pearson et al (1985) noted a general decrease in populations of echinoids and molluscs in the Kattegatt in comparison with survey data from 1911-12, while ophiuroids and annelids had increased. The effects of trawling were among the potential causes suggested for this change, although eutrophication was considered by the authors to be the most significant factor in this case. (Pollution and the physical impact of trawling are two environmental stresses which may have similar effects in terms of changes in benthic community composition). The most recent bibliography of the effects on fishing gear on the benthos was produced for ICES by Redant in 1987. This was obtained shortly before the completion of this report and includes many additional papers not obtained in time to be reviewed here.

The changes described above do not necessarily result in a deterioration of the commercial fishery. Even if the benthic population structure is altered, the new species and communities may be of equal value, if not greater benefit to fisheries as 'fish food'. The 1988 ICES report records that an increase in growth rate of flatfish species, especially those feeding on polychaetes (ie soles) has been observed in areas regularly disturbed by bottom trawls. This indicates an increase in the quantities of food available. Additionally, the action of trawls and dredges is frequently seen as beneficial to fisheries because they expose or damage invertebrates, making them accessible to commercial fish. Fishermen take advantage of this by trawling in the track of other vessels, thus capturing fish which move into the area to feed on exposed fauna. Recruitment of flatfish populations has not reduced, indicating that nursery areas are not deteriorating from trawling pressure.

Mechanical effects on the physical nature of the seabed caused by trawling are also a source of concern. Scraping, penetration and pressure from fishing gear can affect both hard and soft substrata. Heavy gear towed by large, powerful vessels can pull boulders out of the seabed and make the area unsuitable for smaller, inshore fishing vessels which require a more uniform ground for towing lighter, less robust equipment. There has been concern voiced about the flattening of soft chalk reefs in the subtidal off the Sussex coast, where an important crab fishery is located. This habitat destruction may affect crustacean fisheries, as well as the associated problem of static gear (lines of pots) being towed away by trawlers. These mechanical effects have been the main causes for complaint over the use of heavy fishing gear.

Bradstock and Gordon (1983) report on the impacts of trawling on extensive 'coral' grounds off Tasmania. These are important nursery areas where juveniles of valuable commercial fish species were associated with large clumps of erect bryozoans (Celleporaria agglutinans and Hippomenella vellicata - similar in appearance to Pentapora foliacea). Traditional natural fibre nets were damaged by these growths and fishermen avoided the area until the advent of strong, buoyant synthetic nets. Trawl nets with chains, sledges and rolling bobbins were designed to fish these grounds. This equipment with otter boards and sweep wires destroyed the bryozoan growths and subsequently reduced the numbers of juvenile fish. This ground has since been closed to 'power-fishing' methods (trawling, Danish seining and dredging) to allow recovery of the habitat and conservation of the fishery. Damage to seagrass Posidonia oceanica beds by bottom trawling is recorded by Ardizzone and Pelusi (1983).

Sediments may be disturbed to various depths, depending upon their physical characteristics and the speed and weight of gear being towed. From work undertaken in the 1970s with a light trawl, penetration of tickler chains occurs to 3-10mm on hard ground and 30-40mm on soft ground (Bridger and Margetts, 1972). Similar work has not been carried out on the effects of the much heavier equipment now in use.

Sediments are suspended in the water column by the passage of trawls over the seabed. In naturally turbid areas exposed to water movement this may not have much effect on the benthos, however in sheltered areas there may be smothering of organisms not adapted to cope with siltation. Additionally, increased light attenuation will be caused by high levels of turbidity, with implications for the survival of photosynthetic organisms. Winnowing out of fines from disturbed sediments may also occur, resulting in a change in the type of seabed and associated infaunal species. These effects are described in section 4.3.

2.4 Implications for marine nature conservation

Certain groups of non-target invertebrates are affected by trawling, particularly where heavy modern equipment is used. Epifauna and shallow-burrowing infauna, including coelenterates, tube-building annelids and many mollusca are particularly susceptible to damage. Populations of large, long-lived echinoderms and molluscs are very severely affected due to the vulnerability of these animals to physical damage and long recovery times of the populations. Some species can survive being trawled, even if suffering some damage (eg the common starfish <u>Asterias</u>, whelks and hermit crabs). Most, however, will be killed after incurring damage by the passing fishing gear, in the trawl or during exposure on deck. Habitat changes caused by the destruction of <u>Sabellaria</u> reefs and removal of dead shells or stones which provide attachment for epifauna will also reduce diversity and interest and eelgrass <u>Zostera</u> <u>marina</u> beds will be vulnerable to trawling in shallow water. The result will be a change from natural benthic populations to those influenced by man, with a higher proportion of opportunistic species, particularly polychaetes, and fewer of the long-lived, slow-growing groups. The former, semi-natural communities are generally of much less marine nature conservation interest than the latter, which may become restricted to areas where trawling pressures are reduced or excluded by natural or man-made obstacles to this type of fishing.

Very large areas of British coastal and offshore waters which are heavily trawled are uniform in character and, particularly on flat sandy ground, of no significant site-related marine conservation interest because of their wide-spread nature and the very common benthic communities present. There will always be refuge areas in areas closed to active fishing, (ie near pipelines and cables) where undisturbed examples of these sediment communities will be retained. It is only where trawling activity takes place close inshore or in areas of rough ground with a more diverse benthos that conflict with marine nature conservation interests is likely to take place. Thus in the Loch Sween proposed Marine Nature Reserve, an area opened to trawling by the Inshore Fishing (Scotland) Act 1984, trawling for Nephrops now takes place at the head of the loch in an area which is notable for the high diversity of macrofauna which excavate semi-permanent burrows in soft sublittoral muds. Not only have populations of Nephrops (one of the major components of this community) been reduced by this activity but many seapens Virgularia mirabilis have also been stripped from the seabed by trawling. Concern has also been voiced by divers over the physical impact of trawls on the offshore chalk reefs of the south coast, a habitat of particular nature conservation interest in this area. The experience described by Bradstock and Gordon (1983) outlined in section 2.3 demonstrates how damaging heavy trawling can be over areas of rough ground.

3. Dredging

3.1 Types of gear used

The most basic type of dredge in use is the oyster dredge, which has a simple reinforced opening and picks up objects which are raised off the seabed. This is very similar to the naturalist's dredge and has relatively little impact on the benthos. In some traditional fisheries it is dragged along by hand or by a sailing vessel. Modified oyster dredges have been used for a clam (Mercenaria mercenaria) fishery in Southampton water. Mussels are taken from mud banks in estuaries with a variety of dredges, including hydraulic dredges (see section 4).

The scallop dredge also developed from this design. Some 'clam dredges' in use in North America are untoothed, but those used in Britain have a set of teeth along the leading edge to enable scallops which are recessed into the seabed to be picked up. The belly of the dredge is of chain to reduce damage by abrasion. It is a fairly inefficient piece of equipment and causes damage both to the target species (caught and uncaught) and to other benthic animals (Caddy 1968, 1973, Chapman et al 1977, Gruffydd 1972, Medcof and Caddy 1971). The original short-toothed scallop dredge was further developed to enable new areas of rough ground to be fished and minimise damage to the equipment by the addition of longer and narrower spring-loaded teeth. Spring-loaded dredges meet these objectives, but Chapman et al (1977) record that efficiency was reduced in comparison with a standard dredge on smooth ground. Dredges are now decreasing in size (from 122 to 76cms) to enable them to stay closer to the bottom, particularly in rough areas. Most recently a new adaptation of the scallop dredge has come into use. The French dredge (Anon 1989b) has still longer teeth and is rigged with vanes to make it dive and dig deeply into the seabed on clean grounds. Powerful engines are needed to tow this equipment, the effects of which are causing concern among other fishermen. Most research on dredging has concentrated upon scallop dredging since this is the most widespread and damaging of these gears.

3.2 Fishing effort

United Kingdom data for 1984-87 are available in the ICES 1988 paper. The numbers of vessels scallop dredging in Scotland has remained fairly constant over this period, while the number of hours spent fishing decreased markedly between 1984 and 1985, but may now have stabilized. The same paper records a significant increase in scallop dredging effort in England and Wales and this appears to have taken place mainly among the larger vessels, which also beam trawl. The main species taken are the scallop *Pecten maximus* and the queen scallop *Aequipecten opercularis*, although where populations of some other large bivalves living close to the surface are present (eg *Arctica icelandica* or *Glycymeris glycymeris*), these may occasionally also be taken by scallop dredges (pers. obs.).

Oyster dredging is a very localised activity and generally confined to traditionally managed oyster beds or Several Fisheries. Mussel dredging takes place mainly in estuarine areas, with spat (young mussels) frequently being dredged and relaid in areas where faster growth rates will be obtained, then dredged again at harvesting. Mechanical cockle dredging is not a widespread means of harvesting this species. Traditional fisheries are usually carried out by hand raking, but the hydraulic dredge is now becoming more widespread.

3.3 Impact on the seabed

Fewer studies have been carried out on the impact of scallop dredging on the seabed than on that of trawling, for although the physical effect is more severe, it is a less wide-spread activity. Most research had been confined to the damage and mortality of the target species, both captured and left in the dredge track. Caddy (1968 and 1973) describes damage and mortality to uncaptured scallops caused by a towed untoothed scallop dredge and noted that numerous benthic predators were attracted into the path of the dredge. Levels of incidental mortality and harvesting efficiency were both about 13-17% per tow. Average efficiency of capture by fixed tooth dredges was 20% and spring-loaded dredges about 13-14% in the study by Chapman et al (1977). The latter damaged more scallops caught or left in the track. Gruffydd (1972) investigated damage to scallops on a Manx bed and found about 15% efficiency for dredges. About one third of scallops were removed by dredgers, but another 10-56% died through natural and indirect fishing mortality, many of these in the younger age-groups. Medcoff and Caddy (1971) examined the operation of a clam dredge in an *Arctica icelandica* bed. These bivalves burrow quite deeply into sand. The dredge was less than 1% efficient and broke the shells of 80% of uncaught clams and 50% of the clams it caught.

There are few studies of the impacts of clam dredging on non-target organisms. One of the first such reported was the NCC study on the impacts of scallop dredging within the proposed Skomer Marine Nature Reserve (Bullimore 1985). This study comprised surveys before and after scallop dredging, together with observations of dredges in action on the seabed and recovery studies. The area (which had been dredged in previous years) was of mixed sediments with very rich infauna. Many epifauna were collected or destroyed by the dredge and dead and damaged organisms were found in the dredge track. As a result of this study it was agreed to enact a bye-law to prohibit trawling and dredging within the Reserve.

During the same period, DAFS carried out a study of the impact of scallop dredging in a sandy bay in a west coast loch (Eleftheriou, pers. comm.). The results of this study are to be published in due course, however it was apparent that the epifaunal benthos was completely destroyed after about 8 passes of the dredge. Thousands of sandeels were killed and a population of the large bivalve Ensis eliminated. Follow-up studies were not planned, but it was assumed that recovery of the benthos would take about 1 year to 18 months for most species (equivalent to their life cycle), although rather longer for the long-lived bivalves with sporadic recruitment.

Also in Scotland, studies of scallop dredging in the Clyde area demonstrated that beds of the calcareous seaweed, maerl, were completely destroyed and buried by this activity (G Fisher, pers. comm.). Work is currently underway around the Isle of Man to investigate the scallop fishery there, including recovery of recently established fishing exclusion zones. Fonseca et al (1984) record that the fishery for the bay scallop Argopecten irradians on the east coast of North America is dependent upon the eel grass Zostera marina meadows in which this species settles as post-larvae and lives as adults. Scallop dredging damages the Zostera beds and consequently reduces recruitment to the fishery, which therefore requires very careful management.

In areas where scallop dredges are used over mixed sediments and bedrock reefs, epifaunal species will be dislodged from rock. Specimens of the long-lived, very slow-growing sea fan Eunicella verrucosa are sometimes seen lodged in the teeth of scallop dredges operating in southwest England and it is assumed that the damage caused to benthos by scallop dredges operating over rocky ground must be severe.

The most recent study to be reported describes the impact of trawling for queen scallops in the proposed marine nature reserve at Strangford Lough, Northern Ireland (Brown, in press). One of the most important benthic communities in the lough is that based on the horse mussel Modiolus modiolus beds, which support a very rich association of species, including the scallop Aequipecten opercularis. The closely knit clumps of mussels provide a habitat for epifauna and protection for infaunal species and juvenile mussels, scallops and other species. The community is dependent upon stable conditions. The recent introduction of scallop dredging has removed large quantities of non-commercial species and other seabed material, with the destruction of the Modiolus community in trawled areas. The sediments are left largely bare, with an impoverished fauna. Recovery of a Modiolus community from even small-scale damage is known to be a slow process. Because scallops still migrate from undamaged areas into the trawled zones, the fishery is continuing. Nevertheless, it may not prove to be sustainable if the scallops are heavily dependent upon the Modiolus beds for successful recruitment to the adult population. Unfortunately, at the time of writing, the Fisheries Division does not appear to take this relationship into consideration when considering management of the fishery, nor do they consider that there is evidence that this area of high nature conservation interest is being degraded. This is an interesting contrast with the careful management of the scallop fishery described by Fonseca et al.

Another site of high nature conservation importance which has recently been damaged by the introduction of scallop dredging is the proposed Marine Nature Reserve, Rathlin Island, Northern Ireland. Among the unusual subtidal communities surveyed during the Northern Ireland Subtidal Survey (NISS, Erwin et al 1986) off the Rathlin coast were some very diverse muddy gravel areas. These were scattered with occasional cobbles and boulders embedded in the gravel and several rare species were recorded. The stability of the community was demonstrated by the presence of cupcorals, abundant and diverse hydroids and erect bryozoa growing on small stones. Rare, long-lived and slow-growing sponges were also found on the boulders and cobbles. The report providing supporting information for the designation of this site (Picton and Erwin) notes that similar examples of such sites known in Scotland have been extensively dredged, with the consequent removal of most of the cobbles, causing permanent damage to the habitat. At the time of the survey these sites were completely undisturbed, although their vulnerability to scallop dredging was noted. The NISS recommended that urgent protection in the form of full Marine Nature Reserve (MNR) status should be sought to protect the area against the threat of scallop dredging. Unfortunately MNR designation has not taken place and scallop dredging is now causing extensive damage to these areas (Picton pers. comm.). Boulders are being rolled by the towed gear, the diverse epifauna on pebbles and cobbles destroyed and undoubtedly the rich infauna also damaged. Since the start of this scallop dredging activity, large numbers of lobsters with damaged carapaces are apparently being caught in pots set in adjacent areas. These are thought by local fishermen to have been damaged by the towed dredges.

The mechanical effects of dredging on the seabed are similar to those described above for trawling, but more severe since the gear is designed to dig into the seabed and is also used on areas of rough ground. Large, powerful vessels may cause significant disturbance to both sedimentary areas and outcrops of rocky habitats on the seabed. Divers report the movement of boulders "the size of small cars" in areas dredged by large, powerful vessels in the Sound of Jura.

In many areas scallop dredging tends to take place close inshore; fishermen will exploit very small sections of seabed where good scallop stocks are present. With the introduction of side scan sonar and sophisticated Decca charts on which all seabed obstacles may be mapped, there are now very few refuge areas of scallops which are not dredged.

3.4 Implications for marine nature conservation

The general effects of scallop dredging will be similar to those noted in section 2.4 for trawling, but in many cases this fishing method will have a greater effect on marine nature conservation interests because the areas dredged may frequently be closer inshore in areas of high habitat and species diversity, as described above. Thus scallop beds may be found in areas with some tidal flow, in association with other interesting species or diverse communities, or the scallops themselves form an important microhabitat for cessile species in finer sediments. The only research which appears to be in progress to examine the recovery of a scallop-dredged area appears to have started recently at the Port Erin Marine Laboratory, Isle of Man. Growth and recovery of maerl in dredged areas does not seem to have been studied at all. The opportunity to observe the rate of recovery of dredged <u>Modiolus modiolus</u> beds or rich gravel communities may now be provided in the Northern Ireland sites, if these are successfully protected by Marine Nature Reserve legislation in the future.

4. Hydraulic dredging

4.1 Types of gear

A number of types of hydraulic dredge have been developed, mainly for bivalve fisheries. They tend to use water jets to loosen the sediment and an air lift to bring the sediment and contents to the surface. Discharge of the air lift may be above water into a box on the side of the vessel from which the catch is sorted, or into a box below the water line with a conveyor belt used to bring the larger items caught up to the side of the boat. Other versions of the hydraulic dredge reported on in the fishing press appear to dispense with the air lift. One such is a diver-operated water jet which washes large bivalves out of the sand so that they may be picked up by hand and another is towed, but uses divers to collect the shellfish from the dredge track. Even within a single fishery the range of dredges in use can vary and many different designs are in use around the country, with a variety of dredge widths and powers.

The earliest use of hydraulic dredges in northern Europe appears to have been in the Dutch cockle fishery. These bivalves are present close to the surface of intertidal sandy sediments and need only be lifted a short height from the cockle beds to the fishing boats while the tide is in. Cockle dredges have now been in use in the Thames Estuary for several decades. They recently replaced the traditional method of 'blowing' for cockles in the Wash and have been introduced to fisheries in the Solway Firth, the Swale and North Wales. They have the advantage of being economic on sparse beds (where hand raking is not cost-effective) and can also be used to exploit cockle beds in the shallow subtidal. (Blowing, now largely discontinued, uses the action of a vessel's propeller in very shallow water to wash cockles out of the sand. The fishing boat moves in concentric circles around its anchor, moving the cockles inward to the centre. They are bagged up by hand at low tide).

Similar dredges have also been used in North American clam fisheries and for a <u>Mercenaria</u> fishery on the south coast of England. More recently a number of hydraulic dredges have been developed in Scotland to exploit large bivalve populations, particularly <u>Ensis</u>, in deeper water. Lugworm collection in the Netherlands has used a mechanical variant on this theme, with the sediment being taken up by a large scoop, then washed through with water jets. This method of lugworm collection for bait has now been introduced to the Essex coast.

4.2 Fishing effort

There is little information available on the overall levels of fishing effort with hydraulic dredges in Britain. Many of these fisheries appear to be prosecuted by 'nomadic' vessels, particularly when large, slow-growing bivalves are taken because the populations of these species are localised and slow to recover. Additionally the opening of a large new fishery, as in the Solway area in 1988, will encourage investment in new equipment or the movement of fishing vessels with hydraulic dredges from other fisheries around the coast.

4.3 Impact on the seabed

Hydraulic dredging fluidises the top layers of sediment in the fished area. Cockle dredging only requires a depth of 2-5 cms to be disturbed to remove these shallow-burrowing bivalves. Larger or deeper burrowers require a stronger air lift or greater depth of disturbance. <u>Mercenaria</u> dredgers in Southampton Water leave furrows exposed at low water spring tides which are 10-20 cms deep and about 60 cms wide. Diver observations while dredging for <u>Ensis</u> species in Scotland noted that the moving dredge excavated trenches 1 m wide and 20-30 cms deep on very hard compressed sand. If the dredge stopped, the air lift created holes up to one metre deep and 0.5 m across (pers. comm, DAFS divers). Van den Heiligenberg (1987) notes that mechanical digging for lugworms in the Wadden Sea, where the dredged sediment is strained through a sieve with water jets, leaves gullies 40 cm deep and 1 m wide, bordered on each side by a 1.5 m wide ridge a few cms high.

Following disturbance, the rate of recovery of the sediment surface will depend on the size of the trenches dug and the energy of the marine environment in the area. Franklin and Pickett (1978) observed that the tracks from cockle dredges could be seen for several months after fishing had ceased, though could disappear very quickly in bad weather. Observations made in Italy (CoSPAV, Chioggia) of suction dredged subtidal areas demonstrated a change in the benthos from predominantly sandy conditions to gravels and sand, presumably due to winnowing out of fine sediments (J Munford, pers. comm.). Diver observations of an hydraulic dredge in Scotland noted that a large cloud of sediment was produced during operation, from the discharge of the airlift. Large particles drop almost immediately to the bottom, but finer material will remain in suspension and may be carried out of the area by tidal currents. Anderson and Meyer (1986) describe sediment erosion and transportation from disturbed intertidal areas.

Deep dredging in sheltered areas, such as occurred in the short-lived Mercenaria fishery in Southampton Water and other south coast harbours, causes concern over the potential release of toxic materials and heavy metals 'locked up' in deep anoxic sediments until exposed to oxygenated conditions by the action of the dredge. In such conditions the action of an hydraulic shellfish dredge may have similar effects to a mechanical harbour dredge, except that the polluted sediments are immediately released in the source area, not removed to a designated dumping ground, well away from sensitive sites.

The impact of hydraulic dredging on commercial species has been studied by a few authors. Medcof and Caddy (1971) report on the efficiency of two types of hydraulic dredge used in an Arctica fishery. Both were nearly 100% efficient. The shells of more than 80% of the few uncaught clams were broken during the passage of the dredge, and 20% of those collected were damaged. In effect, almost the whole population was removed or destroyed by the fishery. This very high efficiency can have a significant impact on stocks of long-lived, slow growing and infrequently recruiting bivalves. Large individuals of Arctica (ie> 80mm long) may be as much as 100 years old, with individuals of 50 yrs in age not uncommon in a population (D W McKay, pers. comm.). Other species may also be long-lived, with species of Ensis in populations sampled in Scotland being recorded at up to 10 to 22 years old. An hydraulic dredge fishery for such species may well be non-sustainable, with no recovery of the populations once the initial harvest has been taken.

The impact of hydraulic dredges on cockle stocks has been examined by MAFF in England (Franklin and Pickett 1978). Undersized cockles are returned to the water, but their survival was found to be very poor (50 to 80%, depending upon the intensity of the fishery). Mortality of these bivalves may be due primarily to the mechanical damage sustained during passage through the dredge but also to stress from repeated exposure and reburial, or to predation. Perkins (1988) records the presence of numerous undersized cockles washed up around rocks and on the strandline of a bay fished by a hydraulic dredge in the Solway Firth. Reducing the density of cockles by dredging generally results in an improved survival of subsequent spat settlements due to less competition.

The change from a finer to a coarser habitat in the Italian hydraulic clam fishery mentioned above also resulted in a change in the main commercial benthic species from Chamelea gallina (Venus striatula) to Venus verrucosa. The former species is usually found on sandy or muddy sand, and the latter on sandy gravels. Fortunately for the fishery, the latter is as valuable a commercial species as the original, however such a change in habitat type may in other cases prevent the recovery of commercial populations after dredging. Perkins (1988) records a reduction in silt content after cockle dredging in the bay he studied. Cohesion of the sediment was reduced as a result and redeposition of sand towards the top of the bay was apparently occurring. Concern was expressed that the unstable nature of the sand affected by dredging appeared to be spreading to previously unaffected areas of the bay. Deposition of mud on top of saltmarsh has been seen on the upper shore after cockle dredging took place in the Caerlaverock National Nature Reserve (C Eno, pers. comm.).

Impacts on non-commercial species have been less thoroughly studied. Macoma balthica is badly affected by cockle dredging. Perkins (1988) records a significant decrease in numbers of this species in his study site. Lugworms Arenicola marina which live at greater depths in the sediment were apparently not affected. Elsewhere in the Solway, a 'wreck' of Macoma has been seen on the strandline in another area dredged for cockles (R Mitchell, pers. comm.). A major impact of cockle dredging in Perkins' site was the loss of the eel grass Zostera marina in the dredged areas. The changing nature of the sediments in the bay was thought potentially to threaten the Zostera beds even in the undredged areas. This species is of particular interest for its associated communities and is of importance for feeding waterfowl. Heavy deposits of sediment on to saltmarsh vegetation could also affect these communities.

One useful reference actually deals with mechanical lugworm dredging in the Wadden Sea (van den Heiligenberg, op. cit.)

and compared this with hand digging. Although the sediment is removed mechanically from the seabed, the sieving process uses water jets and the effect on animals released back to the sea is likely to be similar to that of an hydraulic dredge, albeit less traumatic (since lugworms are fairly fragile animals in comparison with cockles). For every gram of <u>Arenicola marina</u> removed (and the whole population is successfully harvested), 9 to 13.4 g of other benthic invertebrates are removed from the area. This compares to about 1.9 g per gram of lugworms removed by hand digging. Recovery of benthic invertebrates in the dredged areas is quick for species able to migrate into the area, but will depend upon the timing of the successful recruitment of other animals. This may be swift, or take over a year for larger species where spatfall is not always successful.

Mackenzie (1982) examined the effects of hydraulic dredging on non-commercial benthic species within clam beds, but found no significant difference in mean numbers and species composition between fished and unfished beds. Sheader studied the effect of intensive dredging for <u>Mercenaria</u> on sublittoral benthic community structure in Southampton Water, comparing survey results from a period when modified oyster dredges were in operation with the results of a repeat survey when hydraulic dredges were in use. The latter fishery had resulted in a significant decrease in the total abundance of macrofauna in a previously diverse area.

4.4 Implications for marine nature conservation

Deep hydraulic dredging for large bivalves has very serious implications for marine nature conservation interests, as well as being a non-sustainable fishery in many cases where long-lived, slow recruiting bivalves are taken. Not only are the bivalves themselves of nature conservation importance (and it may be surmised that they are virtually relict populations because of their age structure), but many large bivalves are associated with very stable habitats and diverse infaunal communities which are completely destroyed by dredging. The long-lived nature of some of the non-target species affected may mean that complete recovery of the community will not occur before the commercial populations are replenished, allowing further fishing, or perhaps even for some decades. The indirect effects of settlement of fine sediment onto adjoining areas could be severe where organisms are not resistant to smothering and the release of anoxic sediments with pollutants could also be detrimental to benthic communities. Evidence from Italy demonstrates how this sort of fishery can alter the benthic habitat and associated communities.

Cockle dredging may take place in areas where a virtual mono-culture of this bivalve is found and in sandy habitats where sufficient water movement exists to quickly fill in the trenches dug. In such areas the infaunal community is unlikely to have a high intrinsic interest and populations of this short-lived bivalve should recover quickly. Nevertheless, these low diversity littoral infaunal communities may be of considerable importance for feeding birds, particularly those dependent upon our sand flats and estuaries for successful overwintering and migration. The destruction by hydraulic dredging of eelgrass beds and their associated communities is also of great concern. One possible advantage of the use of hydraulic dredging during high water on some shores is that bird disturbance at low tide caused by working the beds by hand during high water is avoided. On the other hand, it is apparent from the work on lugworm dredging that there could be very high rates of loss of other infauna as well as the commercial species, and this may have ramifications for feeding birds if a large proportion of the intertidal is covered by the fishery. The results of the current study commissioned by the Nature Conservancy Council as part of its commissioned research programme are required to assess the nature conservation implications of this fishery.

5. Potting

5.1 Types of gear

The traditional crab or lobster pot has evolved considerably in the last few decades and is now manufactured in a variety of styles (for different fisheries) and in long-lasting modern materials. Pots or creels are also used for whelks Buccinum, the Norway lobster Nephrops norvegicus, the velvet swimming crab Liocarcinus puber and even the shore crab Carcinus maenus and some of the small squat lobsters. It is particularly significant that mechanical pot haulers are now in use to lift much longer, heavier strings than was previously the case. This means that higher numbers of pots may be used and that the lines of pots can be dragged along the seabed, causing more damage each time they are laid and retrieved than was the case for pots laid entirely by hand.

5.2 Fishing effort

No attempt has been made to quantify potting effort in Britain, but a wider range of species and larger areas are being fished than in the previous few decades. The fishing pressures on many traditional areas such as south west Britain have also increased considerably, to a state where it seems unlikely that current levels can be sustained. Not only are established fishermen using many more pots than was the case a few years ago, but part-timers are also joining the fishery in many regions.

5.3 Impact on the seabed and nature conservation implications

There is obviously an immediate impact on the benthos when a pot lands on the seabed. This may not be significant in fairly exposed areas where no fragile species are present, but erect and delicate organisms (seafans, bryozoans, sponges and corals) may be damaged or detached by such an impact. Until recently the level of potting was low enough in potentially sensitive areas for this not be of concern. The use of powerful mechanical pot haulers can now cause strings of pots to be dragged along the seabed, affecting a much larger area each time they are laid or retrieved. This development, combined with the increasing levels of potting activity, is now certainly cause for concern in areas where fragile species and communities of high nature conservation interest are present. Examples of these will be deep circalittoral communities on rock in Scottish sealochs and southwest Britain.

The proposed Marine Nature Reserve at Skomer has been one of the areas affected by an increase in the scale of potting effort in the southwest. Large colonies of the ross coral Pentapora foliacea are particularly vulnerable to pots being laid on or dragged over the seabed and many other epifaunal species will also be affected by such mechanical damage. Pots are now being laid in many of the more sensitive areas of the reserve and monitoring of the impacts of this fishery within the reserve will be carried out. The potential for damage from potting was recognised in the management plan for the Lundy Marine Nature Reserve. This incorporates a fisheries bye-law excluding potting from an area around the Knoll Pins, an area with a particularly diverse circalittoral fauna including erect sponges, corals, seafans, hydroids and bryozoans. This type of community is very vulnerable to physical disturbance.

6. Fixed gill and tangle nets

6.1 Type of gear used

Gill nets are a single wall of netting hanging vertically in the water. A tangle net is also single walled, but hung loosely to drag on the seabed and catch crustacea (mainly crawfish) or bottom-living skates or rays. Tramnell nets have three walls of netting, the outer two coarser and the inner fine and slack. Fish are caught when they pass through the outer walls, and are trapped in a pocket of the inner netting pushed through the outer net. Although theoretically only tangle nets are designed to fish on the seabed and some nets (with a very large mesh size) can only be used for this purpose, it is possible to use some set nets either as gill nets if set in the water column, or as tangle nets if set on the seabed. Gill or tramnel nets may also be forced onto the bottom when tidal streams are running. Natural fibre nets were traditionally used by the fishing industry, but have now been replaced by synthetic multi or monofilament netting which is much cheaper and more durable. Milner (1985) provides a very useful overview of the use of anchored gill and tangle nets in England and Wales.

6.2 Fishing effort

Milner (1985) records the considerable increase in the use of static fishing gear in the early part of the last decade and Northridge (1988) also provides data showing the expansion of set net fisheries in England and Wales from 1982 to 1984. Gill net fisheries are increasing markedly, particularly in the southwest. In contrast, there was a slight decrease in effort in Scotland in the mid 1980s, which may have been due to the ban on the use of monofilament nets in that country. This overall increase in effort is due in part to the cheapness and ease of use of modern, synthetic fibre nets, which has encouraged leisure and part-time fishing as well as the inshore fleet. Milner (1985) suggests that the increase in use of these methods will continue and may be taken up by larger vessels. Modern set nets may also be more widely used in conditions where there is a greater chance of damage or loss, compared with the former cautious use of natural fibre nets. Thus nets are now commonly set on rough rocky grounds and around wrecks, areas formerly unsuitable for the more fragile traditional nets.

The use of set nets is generally one of a number of fishing strategies used by inshore fishermen with small boats, depending upon prevailing conditions, and overall effort will vary seasonally and from year to year. Although set nets account for less than 5% of the total landings in England and Wales (Milner op. cit.), these methods provide nearly one third of the total catch for the inshore fleet as a whole and in south west England, over half the catch.

The main use of tangle nets is in Cornwall, where the fishery was originally for crawfish, but now includes rays, angler fish and monkfish. In Wales, tangle netting for rays is more common (Milner 1985). Nets are generally fished for 3-4 days before being retrieved.

6.3 Impact on the seabed and nature conservation implications

Any net can become entangled in more than its original target. Where tangle nets are set for several days on rocky ground, a wide range of epifauna and flora may be damaged or removed from the seabed in addition to the target species. As noted above, in areas with tidal streams nets set in the water column may also come into contact with the seabed and cause damage. Nets may be lost, if markers are detached or they are caught on obstructions on the seabed. They can then continue to operate for long periods, slopping backwards and forwards across the seabed in tidal currents and wave surge. The introduction of tangle netting within the Skomer proposed Marine Nature Reserve is causing concern because of the potential damage to benthic communities of high nature conservation interest (including bryozoans, seafans, hydroids and corals). Tangle netting could potentially cause greater damage to epibenthic communities than potting (described above). In areas of high nature conservation interest the effect can be very damaging.

'Ghost' fishing has been a subject of considerable interest over the past few years, particularly with regard to the use of monofilament gill nets. When such nets are lost, they may potentially continue to fish in the water column for some time. The weight of the catch will eventually cause the net to sink to the bottom, but decay of the fish may result in the net clearing and rising to recommence fishing again. Canadian studies off Newfoundland in depths of 300-350 metres depth have suggested that this may occur over perhaps a two year cycle. There is concern over the impacts of this on fish, mammal and bird populations (see section 8). In shallow inshore waters the nets will tend to become rolled up by wave and current action or entangled on obstructions on the seabed, and thus the effect is more likely to be damage to the benthos, as described above, than true ghost fishing.

The increased use of set nets has had such an impact on some commercial species that their decline has almost become a nature conservation issue, as well as one of concern for fisheries conservation interests. The common skate is a species which has apparently been fished to virtual extinction in the Irish Sea because of the very large size of the immature fish (Brander, 1981). These are not protected by the minimum net sizes in use and are taken (by trawling as well as netting) in the commercial fish catch long before they attain maturity and are able to reproduce. The bass is a valuable commercial species which has been very heavily exploited by gill netting in its nursery grounds (inlets on the south coast) and at sea. The marked decline in the stock of this species has resulted in the proposal by MAFF of stricter controls over the fishery in Britain, which were supported by NCC on nature conservation grounds.

7. Other fishing methods

A number of fishing methods have not been covered, mainly because they are not generally a cause of damage to the seabed in the same way that are the techniques noted above. For example, many types of fishing gear such as purse seines, midwater trawls and long lines virtually never come into contact with the seabed. Others are rarely damaging; beach seines are usually operated over sand or pebbles, but could cause damage in certain cases to eel grass Zostera beds. Stake nets are set out in shallow water or the intertidal, but have a very localised effect on the benthos. These fishing methods are more likely to conflict with bird or mammal populations.

8. Birds and mammals

Although not strictly within the scope of this report, the impact of commercial fisheries on bird and mammal populations is mentioned here in outline because of the very considerable nature conservation significance of this issue. Other studies have been carried out or are underway into the effects of commercial fisheries on these groups, and these are referred to below.

8.1 Sea mammals

Sea mammals (seals, cetaceans and, in coastal waters, otters) may be caught by static and mobile fishing methods. Larger mammals (seals and small cetaceans) are quite commonly trapped and physically damaged or drowned in nets or trawls, either by chance or while investigating fish caught in the gear. Otters are more frequently caught and drowned in traps, such as eel fyke nets or pots, and populations may be significantly affected in some areas by these fisheries.

Northridge (1988) has provided a detailed account of the conflicts between marine mammals and commercial fisheries in British waters. This covered both the effects of fisheries on the populations of marine mammals and the damage that mammals cause to fishing gear (competition between marine mammals and fisheries for commercial species was excluded from the study). Information is presented on a regional basis, from data provided by fisheries departments and interviews with local fisheries officers and fishermen. It proved to be difficult to assess the scale of conflict between fisheries and marine mammals, although Northridge concludes that incidental catches of marine mammals 'are by no means as rare as might have been thought.' Gill nets are more likely to inflict large catches than other fisheries and the harbour porpoise may be most vulnerable to incidental catches. Recommendations for alleviating these conflicts in British waters and for future research are made by Northridge.

The growing concern over the Pacific gill net fisheries and their impact on marine mammals and seabirds has also been the subject of increased international concern in 1989, but has not been reviewed for this report.

8.2 Seabirds

Concern over the impact of commercial gill net fisheries on bird populations has been voiced in many regions of the world. The entanglement and death of auks is a common feature of inshore fisheries, particularly where nets are set close to breeding colonies, or in offshore fisheries where these coincide with auk wintering areas. Incidental death of auks through commercial fisheries is thought to be one of the greatest threats to this group of seabirds. The accidental capture of seabirds in nets is also of concern to fishermen, in that the removal of entangled birds is difficult and time-consuming, reducing the efficiency of the fishery.

There is an extensive literature on the subject of seabird deaths in fishing gear, which is currently being reviewed as part of a study commissioned by the Royal Society for the Protection of Birds (RSPB) and which will be completed in 1990. This study will also investigate the intensity of use of monofilament nets in the UK and their conflict with seabird populations, particularly in southwest England, where auk deaths in nets set close to colonies in bad weather appear to be on the increase with the growing inshore set net fishery. A few references were reviewed for this report to provide some examples of this issue, but the RSPB study will give a much more detailed overview.

Atkins and Heneman (1987) provide an overview of the conflicts between seabirds and fisheries in North American waters, with a review of the biological and legal aspects of two case studies: the Japanese North Pacific drift net fishery off Alaska and the Californian set net fishery. The Japanese drift net salmon fishery operated with 4 processing vessels (mother ships) and 172 catcher boats in 1983, with an estimated 127,610 kms of net set in that year (the nets, averaging 16.5 kms in length, are fished at night). A number of estimates of seabird mortality have been presented for this fishery, annual overall figures ranging from 96,000 to 251,400 during 1981 to 1984, 80% of these being caught in United States waters. Shearwaters and puffins made up the bulk of this catch. King (1984) reports that the Japanese gillnet fishery throughout the northern North Pacific and the Bering Sea drowns an estimated 250,000 to 750,000 birds annually (shearwaters and auks). King suggested that the populations of these large alcids from some of the north Pacific islands would not be able to sustain their current level of loss, although the total North Pacific populations would probably not be seriously affected.

The California gill net problem arose in the early 1980s when thousands of auks and shearwaters were stranded on beaches in Monterey Bay. Sea otters were also affected by the increased use of gill nets in the area. In 1981 an estimated 20,000 seabirds were killed in the Bay. In 1983 about 25,000 to 30,000 Common Murres were estimated to have been killed in gill nets: about 12-14% of the breeding population. These levels fell during the 1980s, to about 6,000 to 8,000 per year, but the fall corresponded to a drop in the breeding population. A monitoring programme suggested that about 75% of the decline in the Murres population could be attributed to gill netting. Cetaceans were also being affected. A high level of public and government concern eventually resulted in the enactment of regulations to solve the problem of seabird and marine mammal take, including the prohibition of gill netting in many important areas.

A 90% reduction in some auk populations has been experienced in Norway in the past 20 years. Figures for seabird catches in cod and salmon gill and drift nets in North Norway indicate that this decline could easily be explained by the drowning of adults in fishing nets (Strann et al, in prep.). Spring and summer fisheries provide the most serious threat to the bird populations. At least 200,000 birds (mainly common guillemots) are thought to have been killed in cod nets set by 40 vessels in the Auvaer area of North Norway in April 1985, with initial catches of several thousand per vessel per night declining over the study period. Drift net fisheries for salmon also caught between 20,000 to 50,000 birds in a season, although this fishery was banned in 1989 to protect salmon stocks, which may enable some recovery of the auk population. Set salmon pound nets, which are generally not thought to present a danger to seabirds, were also found to catch auks when set under bird cliffs (one fisherman reported capturing over 10,000 auks in 5 nets during a single season).

Nettleship and Piatt (1982) suggest that there is high seabird mortality from gillnet fisheries in Newfoundland from the inshore herring, cod and salmon fisheries and the cod fishery offshore. Up to 16% of breeding guillemots and 2% of breeding puffins are taken each year by the inshore fisheries, mainly during the summer period when capelin are inshore and within 60km of the colonies. Mortality from the offshore fishery is difficult to assess, but also likely to be severe and to affect birds from other areas of the north Atlantic. In Greenland, seabird populations have been affected by over-hunting as well as incidental capture by fishing nets. The former is more significant, but the combination of these two threats has resulted in a major decline (possibly to 10% of its former level) in the population of one species of guillemot in the last 30 years (Evans, 1984).

The reasons for the decline in the sandeel stocks in many areas of the northern North Sea has been the subject of much debate over the past year. Avery and Green (1989) review the history of the decline of the fishery around Shetland and the breeding failure of terns in the islands since 1984. The sandeel fishery in Shetland started in 1974 and grew rapidly until 1982, since which time there has been a decline in landings. The authors point out that there is no firm proof that the shortage of sandeels for breeding birds is caused by the fishery (other natural fluctuations may be the cause) but that the high level of exploitation of immature '0-group' fish makes such a fishery very vulnerable to changes in levels of recruitment and a subsequent crash. It is certain that the numbers of small sandeels required by breeding birds to feed their young have not been available in the surface waters around Shetland. As a result, tern chicks in Shetland have been starving to death. The breeding of puffins and kittiwakes has also failed due to the unavailability of sandeels, with other small seabirds dependent upon sandeels having experienced reduced breeding success. Other commercial sandeel fisheries in the North Sea rely upon catches of older fish, and seabird colonies away from Shetland have not been affected by this breeding failure.

The threats to seabird populations from competition for food by commercial fisheries is reviewed by Furness and Ainley (1984). They note that seabirds will consume about 20% of pelagic fish production. Commercial fishing fleets generally take 50-70% of stock production, leaving little for natural predators; marine mammals, fish and squid as well as seabirds. The authors note several examples of seabird population failures due to overfishing of previously unexploited fish stocks at lower trophic levels (sandeels, capelin, anchoveta and sardines). Conversely, the exploitation of large predatory fish will result in an increase in stocks of their smaller prey species, which are also likely to be the preferred prey of seabirds and some marine mammals. Seabird populations could therefore increase in this way as a result of commercial fisheries, or through the offal and discarded fish from trawlers made available to species able to scavenge from vessels.

9. Conclusions and Recommendations

9.1 Benthic impacts of fisheries

Trawling with modern, heavy gear (beams and tickler chains) towed by large powerful vessels and dredging can have a very severe impact on the seabed and benthic communities. Most of our British inshore areas have been considerably altered by these widespread activities. These fishing methods are particularly damaging to marine nature conservation interests where carried out close inshore or in areas with rocky reefs. The introduction of towed bottom fishing methods to inshore areas which have not previously or recently been exploited using these methods will result in considerable changes to the marine communities present.

The groups of organisms most seriously affected are the epifauna, long-lived infauna (molluscs and echinoderms), maerl beds (calcareous algae) and the seagrasses. Habitat destruction is a particular problem where there are diverse communities based on fragile species such as *Sabellaria alveolata*, *Modiolus modiolus* and *Zostera marina*, where the physical habitat is altered by the removal of stones and shell which provide substrata for epibenthic species, or where very stable communities with long-lived species are disrupted by these fishing practices. In many situations, the continuation of these fishing activities will conflict with nature conservation objectives, particularly if heavier gear is introduced or the intensity of effort increases. The introduction of new active fishing methods to an area of marine nature conservation importance will not generally be compatible with the conservation of the habitats in the area.

Hydraulic dredging is a relatively new and localised fishing method in Britain. Cockle dredging in many areas may be of little nature conservation significance, but in certain situations could be of concern, particularly where the food species of shore birds is affected or where other interesting species and communities are present. Deep hydraulic dredging for bivalves may have more serious implications, ranging from the destruction of stable habitats and diverse communities which could take decades to recover, to the release of pollutants from anoxic sediments in very sheltered conditions.

Potting and tangle netting (or the setting of other nets in areas where they may come into contact with fragile epibenthic species and communities) are now recognised as being potentially damaging activities over areas of rocky seabed. Despite being 'traditional' fishing activities, the scale of use of these methods is undergoing a considerable growth in some areas of the country (especially the southwest) and the new materials and mechanisation now in use have increased the impact of these inshore fisheries on the benthos. Conflict will tend to occur in the presence of erect species of nature conservation interest and communities which are vulnerable to physical disturbance. Since some of the more fragile circalittoral epibenthic communities of high marine nature conservation interest in Britain are confined to the southwest where these fishing methods are on the increase, this is currently a particular cause for concern. There appears to be no reason why this growth in inshore fisheries should not spread to other parts of the country (with the exception of monofilament netting in Scotland), and management planning for the conservation of marine sites must take this into account.

There are potentially very serious conflicts possible between commercial fisheries and seabird and mammal populations. These are the subject of separate studies and are not considered in detail here.

9.2 Research requirements

There is an urgent requirement for further research into the impacts of commercial fishing operations on the seabed, benthic communities and non-target species. The results of investigations into the impact of trawling upon non-target species and the seabed in general which were carried out by the ICES Committees in the 1970s are now out of date due to the considerable differences in the fishing gear now in use. These studies should now be repeated. It is also necessary to assess the implications of the much greater intensity of fishing effort throughout most British waters. Research into the recovery of sediment areas from heavy trawling pressures would be of interest and could best be carried out in areas closed to active fishing methods due to the construction of pipelines or other structures on the seabed. This work should be the responsibility of Fisheries Departments.

Some work has been undertaken on scallop dredging, but further opportunistic research could be useful to examine effects on a wider range of habitats. The study carried out by the Department of Agriculture and Fisheries for Scotland (DAFS) may provide some additional data. It would, however, be most unwise to encourage the experimental dredging of areas of undisturbed habitats of nature conservation importance which have previously escaped this activity, since these are now so scarce in Britain. Research is particularly required to assess the recovery of dredged areas. This would be a subject for study ideally suited to newly established Marine Nature Reserves. Several sites mentioned in section 3 were recently damaged by dredging and their recovery could be monitored as part of the reserve management plan research programme. Such work could be carried out in cooperation between Fisheries Departments and the nature conservation bodies responsible for reserve management. The results would provide very useful data for both fisheries and nature conservation management planning. This should be addressed as a priority area for research.

Research into the effects of hydraulic cockle dredging is currently underway as part of NCC's commissioned research programme. The results of this study will be required to assess the impacts of this activity and may suggest other areas for investigation. One such area of work may be the impact of this activity on feeding birds. It will probably be necessary to assess sites on an individual basis before determining whether cockle dredging is likely to conflict with their nature conservation interest. Deep hydraulic dredging for bivalves is more likely to provide cause for concern, for the reasons outlined above. Fisheries Departments should be responsible for further studies of this activity and NCC should seek to be involved in any research to ensure that the effects of this activity on non-target organisms is fully assessed.

Now that the damaging effects of potting and tangle netting upon areas of sublittoral marine nature conservation interest have been acknowledged, it is essential to assess the extent of these effects for the future management of fragile areas. It is recommended that the Skomer Marine Nature Reserve is used to monitor the effects of the local inshore fishery and that experimental work is carried out in adjacent, unprotected areas. This should be a priority area for research and carried out in cooperation between nature conservation and fisheries interests. Other fragile sites could also be suitable for such research on an opportunistic basis. Manipulative research in such sensitive areas is not recommended.

Some of the incidents of damage caused by fishing operations to inshore areas of marine nature conservation interest appear to arise from fisheries which are considered by the authorities to be self-regulating. They are exploited for a while, then abandoned when the fish stocks no longer provide a commercial return (ie do not provide a sustainable yield in the long-term). Nature conservation bodies should encourage fisheries authorities to take a new view of the management of such stocks to ensure that these small and relatively unimportant fisheries resources are not exploited in such a way as to destroy the areas on which they are dependent, particularly where these are also of nature conservation importance. The advantage of protected source areas for research and recruitment of stock into adjacent exploited areas should also be stressed.

9.3 Requirements for the conservation of marine sites.

Commercial trawling and dredging operations are not compatible with the management of most inshore areas of marine nature conservation interest. There are now very few extensive undamaged areas of mixed sediment remaining in British inshore waters. Even very small and formerly inaccessible areas may be affected by scallop dredging or hydraulic dredging. Experience has shown that commercial fishermen may move into a previously undredged area without warning and from distant ports. It is therefore not possible to guarantee the maintenance of previously unexploited areas in an undamaged condition without controls on fisheries. These controls should be implemented as a matter of urgency when areas of marine nature conservation are identified.

Potting and tangle netting may also be damaging to rocky areas with fragile epibenthic communities. Although potting is one of the more 'traditional' fishing methods still practised by the inshore fisherman, and less damaging than most active fishing methods, it may still conflict with marine nature conservation objectives. Controls may therefore be required on this activity. These may have to take the form of exclusion zones in the most fragile areas, limits on the amount of potting taking place in a reserve, or both. It is likely that the high levels of potting currently being experienced in the southwest will fall during the next few years. In many cases a return to the level of activity which was normal a decade or more ago may be advisable. Tangle nets are likely to be more damaging than pots in many cases and should ideally be excluded from sites where they may cause damage to marine communities.

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