A review of the effects of fishing within UK European marine sites

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Produced for:
The UK Marine SACs Project
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Preface

The 1990s are witnessing a “call to action” for marine biodiversity conservation. The global Convention on Biodiversity, the European Union’s Habitats Directive and recent developments to the Oslo and Paris Convention have each provided a significant step forward. In each case marine protected areas are identified as having a key role in sustaining marine biodiversity.

The Habitats Directive requires the maintenance or restoration of natural habitats and species of European interest at favourable conservation status, with the management of a network of Special Areas of Conservation (SACs) being one of the main vehicles to achieving this. Among the habitats and species specified in the Annexes I and II of the Directive, several are marine features and SACs have already been selected for many of these in the UK. But to manage specific habitats and species effectively there needs to be clear understanding of their distribution, their biology and ecology and their sensitivity to change. From such a foundation, realistic guidance on management and monitoring can be derived and applied.

One initiative now underway to help implement the Habitats Directive is the UK Marine SACs LIFE Project, involving a four year partnership (1996-2001) between:

! English Nature
! Scottish Natural Heritage
! Countryside Council for Wales
! Environment and Heritage Service, Department of the Environment for Northern Ireland
! Joint Nature Conservation Committee, and
! Scottish Association of Marine Science.

The overall goal of the Project is to establish management schemes on 12 of the candidate marine SAC sites. A key component of the Project is to assess the interactions that can take place between human activities and the Annex I and II interest features on these sites. This understanding will provide for better management of these features by defining those activities that may have a beneficial, neutral or harmful impact and by giving examples of management measures that will prevent or minimise adverse effects.

Seven areas where human activity may impact on marine features were identified for study, ranging from specific categories of activity to broad potential impacts. They are:

! port and harbour operations
! recreational user interactions
! collecting bait and shoreline animals
! water quality in lagoons
! water quality in coastal areas
! aggregate extraction
! fisheries.

These seven were selected on the grounds that each includes issues that need to be considered by relevant authorities in managing many of the marine SACs. In each case, the existing knowledge is often extensive but widely dispersed and needs collating as guidance for the specific purpose of managing marine SACs.

The reports from these studies are the result of specialist input and wide consultation with representatives of both the nature conservation, user and interest bodies. They are aimed at staff from the relevant authorities who jointly have the responsibility for assessing activities on marine SACs and ensuring appropriate management. But they will also provide a valuable resource for industry, user and interest groups who have an important role in advising relevant authorities and for practitioners elsewhere in Europe.

The reports provide a sound basis on which to make management decisions on marine SACs and also on other related initiatives such as the Biodiversity Action Plans and Oslo and Paris Convention. As a result, they will make a substantial contribution to the conservation of our important marine wildlife. We commend them to all concerned with the sustainable use and conservation of our marine and coastal heritage.

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Summary

The report

The objective of this project is to bring together literature relating to the methods of commercial fishing (not including angling) which take place within European marine sites - marine Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) - and summarises their potential effects on the nature conservation interests within them. In so doing, the report aims to inform relevant authorities in the development and implementation of management schemes on European marine sites so the potential effects of fishing can be taken into account.

The principal sources of information were ICES reports, journals, and research papers. The original reports and papers were examined wherever possible but reference has also been made to a number of useful overviews. The relevant sections of the papers used are summarised in Annex 1.

The scope

The European marine sites in the UK lie close inshore and are subject to a variety of commercial fishing operations. It is clear that most types of inshore fishing practised around the UK take place in at least one of these sites. This report reviews the potential direct effects of many of these fishing activities on specific marine features and species.

Potential indirect effects of fishing activity have not been examined within this report but should be borne in mind. These include concerns about fishing activities leading to imbalances in ecosystem function with changes in trophic and competitive interactions and, consequently, knock-on effects on non-target species. Depletion of prey for birds and marine mammals, and species replacement leading to shifts in community structure have been mentioned in this regard but evidence is often unclear with interactions complex and difficult to quantify (Jennings & Kaiser, 1998). This is therefore an area which requires more detailed examination.

The potential effects of fishing on Annex I and II habitats and species

This report shows that there are a wide variety of effects, with differing implications depending on the habitats or species in question, and on the particular conditions at the sites. While it may be difficult to extrapolate these effects and to interpret their longevity due to the lack of comparison with similar unfished areas, existing understanding and knowledge of fishing effects provides the basis for making management decisions.

Fishing effects are cumulative although fishing has most impact when a previously unfished area is fished for the first time. Fishing effort (intensity and scale) has not been assessed in this report, it will be a significant factor in determining the potential effects of fishing activities in European marine sites.

Mobile demersal fishing gears are commonly used in estuaries, inlets, bays, and on sandbanks. Here, the impact depends on the substrate, currents, and the depth of penetration of the gear. There are considerable direct effects on some benthic species as certain groups of animals suffer heavy damage although others are less affected. Evidence suggests that commercial beam trawling affects the structure and composition of the benthic communities in the North Sea to the point where they are dominated by short-lived opportunistic species.

Similar types of habitat and species damage may be seen following scallop dredging. The surface sediment can be sorted, epifauna and shallow infauna damaged, and if there is little current movement, the physical effects may remain visible for weeks or months. The suspension of sediment can smother species in the path of the dredge track as well as nearby areas so the effects are not necessarily limited to the immediate area of operation. There can be significant decreases in the abundance and number of species in dredged areas, and the maximum impact may not be immediate as exposed organisms become more vulnerable to predation and can be predated upon later. Harder substrate habitats such as reefs are more robust although fragments can be broken off in areas of softer rock. Slow growing, fragile species are particularly vulnerable, their recovery to pre-fishing condition may take years or, if the area is fished on a regular basis, recovery may not be possible.

The effects of fishing on intertidal or subtidal areas for cockles, oysters, mussels and razor shells are relevant to the conservation of shallow bays and estuarine habitats. The effects are likely to be most significant if there are stable environmental conditions. Areas with mobile sediments where the fauna are more used to disturbance may suffer effects in the short term, but the density and abundance is likely to be restored more rapidly. The longevity of any effect varies with the conditions at the site but even if the area is left undisturbed for a period, the outcome will not necessarily be identical to pre-dredging conditions.

Aquaculture has different effects. In the case of finfish, the use of chemicals is known to have sublethal and toxic effects on some species even some distance from the sites. The benthos beneath the cages can be smothered and the habitat become anoxic.

For marine species listed in the Habitats Directive (Annex II), entanglement in fishing gear is a further consideration. Set nets are the most widely reported fishing gear causing incidental capture of Annex II species, particularly harbour porpoise, and seabirds, but other gears may also have an incidental catch. Otters are known to get caught and drown in traps and nets set in shallow waters and although otter guards can prevent this in the case of eel fyke nets, trapping in pots is more difficult to solve. The extent to which this is a problem has still to be assessed as has the issue of ‘ghost fishing’ in discarded nets and other types of fishing gear.

Other species listed in the Habitats Directive are the shads, lampern, sea lamprey and sturgeon. There are reports of incidental catch of these species in drift nets, salmon nets and by sports anglers but it is water quality, man-made obstructions and habitat damage in the freshwater phase of their life cycle which are the principal issues which need to be tackled in these cases.

The potential threat to seabirds will depend on the netting effort and concentrations of birds. This will be different from place to place and the timing of any fishing will be important. Gill netting is the most likely method where relatively large incidental catches of seabirds can occur. Generally species that pursue their prey underwater or aggregate in dense foraging groups are at greatest risk. The catch can be very variable with the greatest by-catch when the prey are in areas frequented by the fisheries. Net mesh size, distances they are set from colonies and abundance of prey are all additional factors. There can be serious implications for birds because their slow reproductive capacity and low fecundity makes them highly vulnerable to even moderately increased mortality but it is difficult to assess the impact of mortality on British seabird populations.

Only some of the studies on the effects of these fisheries have been carried out in cSACs and SPAs. It should nevertheless be possible to gain some understanding of the likely effects elsewhere with information on the sediment characteristics and exposure of a site, as it is these factors which appear to have the greatest influence on the type and longevity of any effects of the different fishing practices.

Table 1. Summary of conclusions

- Most types of inshore fishing practised around the UK take place in at least one European marine site.
- It may be difficult to extrapolate the effects seen in recent studies and to interpret long term effects as there is rarely an opportunity for comparison with similar unfished areas, however, existing understanding and knowledge of fishing effects provides the basis for making management decisions.
- Fishing effects are cumulative although fishing has most impact on habitats and species when a previously unfished area is fished for the first time.
- The level of fishing effort will affect the impact of the fishing activity and the opportunity for habitats and species to recover.
- Physical disturbance of the seabed from certain gears can be substantial but will generally be shorter lived on species and habitats that have adapted to or, been shaped, by frequent natural disturbances in comparison to those species and habitats in less exposed conditions.
- There can be significant decreases in the abundance and number of species in fished areas. The maximum impact may not be immediate as exposed organisms become vulnerable to predation.
- Slow growing, fragile species are particularly vulnerable and do not recover rapidly or, if the area is fished on a regular basis, may not recover at all.
- Mobile fishing gears (trawling, dredging) can affect the structure and composition of benthic communities to the point where they are dominated by short-lived, opportunistic species.
- Gill nets can have an incidental bycatch of species listed on Annex II of the Habitats Directive and Annex I of the Birds Directive. The significance of this is difficult to assess, but marine mammals and some sea bird species which have slow reproductive rates and low fecundity are known to be highly vulnerable to even a moderate increased mortality.
- Sediment characteristics and exposure of a site appear to have the greatest influence on the type and longevity of fishing effects.
- Aquaculture
    - Finfish - The use of chemicals is known to have sublethal and toxic effects on some species even some distance from the sites. Anoxic conditions develop under cages.
    - Shellfish - Intertidal lays can change the local conditions and infaunal communities, the extent to which this happens depends on the scale of operation. Sediment and communities beneath suspended mussel culture may be affected.

Table 2. Summary tables of potential effects of fishing on Annex I & II habitats and species

Fishery	Methods	Potential effects
Estuaries, mudflats and sandflats		
Cockle	Tractor towed dredge Hydraulic dredge	! Intertidal dredge tracks visible for varying amounts of time, ie. months in stable sediments, a tide in mobile sediments. ! Sediment layers may be altered causing erosion to cockle bed. ! Significant reduction in biomass of target and non target species immediately after fishing operation. Likely to be more pronounced with extended recovery times, ie many months, in areas with diverse communities and stable conditions.
Oysters and mussels	Dredge	! Subtidal and intertidal dredge tracks visible for varying amounts of time, ie. months in stable sediments, hours in mobile sediments. ! Top 10-15 cm of substrate disturbed and sediment plumes created ! Change in benthic flora and fauna as a consequence of repeated dredging.
Clams	Hand gathering	! Holes and tailings left on the intertidal visible for varying amounts of time, ie. months in stable sediments, a tide in mobile sediments. ! Under size target species damaged or exposed to predation, desiccation or freezing.
Large shallow inlets and bays, and sandbanks		
Demersal fin fish, shrimp	Beam trawling Otter trawling	! Trawl tracks visible for varying amount of time, ie. days or months ! Top 10 - 60 mm of substrate disturbed. ! Resuspension of sediment. ! Sediment structure may change from coarse grained sand/gravel to fine sand/coarse silt. ! Significant reduction in biomass of target and non target species immediately after fishing operation. Likely to be more pronounced with extended recovery times, ie. many months, in areas with diverse communities and stable conditions. ! Considerable variation in damage or mortality to affected species. Fragile, long lived, slow moving or sedentary species most vulnerable. ! Repeated trawling may cause benthic community structure to change, favouring more mobile species, rapid colonisers and juvenile stages.

Large shallow inlets and bays, sandbanks - continued		
Fishery	**Methods**	**Potential effects**
Demersal fin fish	Beam trawling, Otter trawling	! Influx of scavenging species post fishing operation. ! Biogenic reefs, eg. *Sabellaria*, and species that stabilise sediments, eg. eel grass, may be severely damaged resulting in resuspension of sediment. Repeated trawling may cause benthic community structure to change, favouring more mobile species, rapid colonisers and juvenile stages. ! Influx of scavenging species post fishing operation. ! Biogenic reefs, eg. *Sabellaria*, and species that stabilise sediments, eg. eel grass, may be severely damaged resulting in resuspension of sediment.
Demersal fin fish	Gill nets	! Incidental catch of marine life including marine mammals and birds. ! 'Ghost fishing', dependent on condition of gear. In rocky, less exposed areas may be active for months, on clean exposed ground, days to weeks.
Scallops	Scallop dredge	! Dredge tracks visible for varying amount of time, ie. days or months. In stable conditions a relatively minor fishery may have a significant cumulative effect on bottom micro topography. ! Top 60 -100 mm of substrate disturbed. ! Resuspension of sediment. ! Significant reduction in biomass of target and non target species immediately after fishing operation. Likely to be more pronounced with extended recovery times, ie many months, in areas with diverse communities and stable conditions. ! Maerl crushed, smothered and killed. ! Associated biota of Maerl either caught, damaged or smothered by resuspended sediment.
Razor shell	Hydraulic dredge	! Subtidal dredge tracks, deeper than a conventional hydraulic cockle dredge (eg 0.5 - 3.5 m wide, 0.25 - 0.6 m deep). Visible for weeks/months in mobile sediments. ! Substantial physical disturbance of substrate ! Significant reduction in abundance of non-target species immediately after fishing operation. Weeks/months to recover to pre fishing levels in mobile sediment.

Large shallow inlets and bays, sandbanks - continued		
Fishery	**Methods**	**Potential effects**
Aquaculture	Salmon cages	! Smothering of benthic communities with faecal and waste food. ! Anoxic conditions underneath cage. ! Raised levels of dissolved gases, hydrogen sulphide, ammonia. ! Sublethal effects of chemical disease and sea lice treatments on lug worm.
Aquaculture	Shellfish cultivation	! Increased sedimentation and effects on infauna beneath mussel cultures. ! Manila clam cultivation in lays increases density of benthic species, changes in infauna and increased sedimentation. ! Harvesting with hand raking reduces species diversity and abundance by 50 %,¬suction dredging reduces species abundance by 80-90%. Recovery to pre-harvesting levels may take long periods eg. 7 months. ! Trenching up to 10 cm deep, may take months to fill eg. 4 months in one study. ! Accidental introduction of alien species.
Reefs		
Crab, lobsters, *Nephrops*	Potting and creeling	! Fragile, brittle species such as Ross coral crushed when pots make contact. ! 'Ghost fishing' - parlour pots can continue to fish in excess of 270 days. A cycle of capture, decay and attraction of species of commercial and non commercial interest takes place.
Scallops	Spring loaded Scallop dredge	! Relatively soft rocky outcrops can be subject to physical damage. ! Soft, fragile species vulnerable to mobile gear.
Demersal fin fish	Rock hopper trawl	! Relatively soft rocky outcrops can be subject to physical damage. ! Soft, fragile species vulnerable to mobile gear.
Grey and common seal		
Demersal fin fish	Gill netting	! Accidental capture whilst foraging in or around nets. ! Legal shooting by fishermen to prevent damage to nets or the fish within the nets. This is likely to be localised and limited in extent and has not had a deleterious effect on UK seal populations.
Salmon farming	Fish cage	! Entanglement in anti-predator nets. ! Legal shooting by fish farm operators to prevent damage to nets or the fish within the nets. This is likely to be localised and limited in extent and has not had a deleterious effect on UK seal populations.

Bottlenose dolphin and harbour porpoise		
Fishery	**Methods**	**Potential effects**
Mid-water Pelagic	Trawling	! Accidental capture in mid-water trawls but in-sufficient data regarding species and numbers.
Demersal fin fish	Gill netting - drift nets, trammel nets set nets	! Accidental entanglement and capture. It is considered that this is the most frequent cause of death of the harbour porpoise and, with their slow reproductive rate, means that there could be a serious threat to sustainability of discrete populations.
Finfish farm	Fish cage	! Entanglement in anti-predator nets
Otters		
Eels	Fyke nets	! Inquisitive and foraging otters accidentally caught in these nets has led to mandatory use of otter guards.
Crustaceans	Pots and creels	! Inquisitive and foraging otters accidentally caught in these traps. Occurrence of accidental capture may be linked to season and availability of food.
Allis and twaite shad		
Demersal fin fish, pelagic mid-water	Trawling, netting	! Accidental by catch, but main reason for decline due to poor water quality and obstructions in migration routes.
Lampern and sea lamprey		
Demersal fin fish	Long line, Trawling	! Accidental by catch, but main reason for decline due to poor water quality and obstructions in migration routes.
Sea birds listed in the Birds Directive		
Demersal fin fish, Pelagic fin fish	Gill netting	! Accidental capture of diving birds foraging for food in and around nets. ! Increase in scavenging seabird species due to discarding of unwanted catch and offal.
Salmon farming	Fish cage	! Entanglement in anti-predator nets
Intertidal molluscan shellfish	Hydraulic & tractor dredge, hand gathering	! Short term increase in scavenging seabirds due to increased food ! General disturbance of feeding and roosting birds.

1. Introduction

1.1 UK Marine SACs Project

This reference document has been prepared as part of the UK marine SACs Project. The overall aim of this Project is to promote the implementation of the Habitats Directive in marine areas through trialing the establishment of management schemes on twelve sites in the UK and by guidance and information to practitioners in the UK and Europe.

To support the establishment of these management schemes, the Project is undertaking a series of tasks to collate and develop the understanding and knowledge needed. One of the areas for providing guidance to those developing the schemes concerns the interaction between human activities and marine features. Human activities have an important role in the management of marine features and may have both beneficial and damaging impacts. This report is one of seven studies bringing together guidance on these impacts and promoting the means of avoiding significant damage to features, the others being:

- *Port and harbour operations* (ABP Research, 1999)
- *Recreational user interactions* (Saunders, C.)
- *Collecting bait and other shoreline animals* (Fowler, S.L.)
- *Water quality in lagoons* (Johnson, C.M.)
- *Water quality in coastal areas* (Cole, S. *et al.*)
- *Aggregate extraction* (Posford Duviver)

1.2 The objectives of this report

- To bring together literature relating to the methods of commercial fishing (not including angling) which take place within European marine sites - marine Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) - and summarises their potential effects on specific nature conservation interests within them.

- To inform relevant authorities in the development and implementation of management schemes in European Marine Sites so the potential effects of fishing can be taken into account.

The principal sources of information were ICES reports, journals, and research papers. The original reports and papers were examined wherever possible but reference has also been made to a number of useful overviews. The relevant sections of the papers used are summarised in Annex 1.

Potential indirect effects of fishing activity have not been examined in this report but should be borne in mind. These include concerns about fishing activities leading to imbalances in ecosystem function with changes in trophic and competitive interactions and, consequently, knock-on effects on non-target species. Depletion of prey for birds and marine mammals, and species replacement leading to shifts in community structure have been mentioned in this regard but evidence is often unclear with interactions complex and difficult to quantify (Jennings & Kaiser, 1998). This is therefore an area which requires more detailed examination.

While recognising that angling, either recreationally or commercially, takes place in many of the proposed SACs there was a general lack of information on the potential effects and so it has not been included in this report.

2. Background to European marine sites

2.1 Habitats and Birds Directive

In May 1992, the member states of the European Union adopted to the *Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora*. This is more commonly referred to as the Habitats Directive. The main aim of the Directive is to promote the maintenance of biodiversity and, in particular, it requires member states to work together to maintain or restore to favourable conservation status certain rare, threatened, or typical natural habitats and species. These are listed in Annex I and II respectively.

One of the ways in which member states are expected to achieve this aim is through the designation and protection of a series of sites, known as Special Areas of Conservation (SACs).

The Birds Directive (*Council Directive 79/409/EEC on the conservation of wild birds*) complements the Habitats Directive by requiring member states to protect rare or vulnerable bird species through designating Special Protection Areas (SPA's). Together, the terrestrial and marine SPAs and SACs are intended to form a coherent ecological network of sites of European importance, referred to as *Natura 2000*.

2.2 Habitats Regulations

The requirements of the Habitats Directive have been transposed into UK legislation through the Conservation (Natural Habitats &c.) Regulations 1994 and the Conservation (Natural Habitats &c.) (Northern Ireland) 1995, known as the Habitats Regulations.

Unlike on land where SACs and SPAs are underpinned by Sites of Special Scientific Interest, there is no existing legislative framework for implementing the Habitats Directive in marine areas. Therefore the Habitats Regulations have a number of provisions specifically for new responsibilities and measures in relation to marine areas.

The Regulations place a general duty on all statutory authorities exercising legislative powers to perform these in accordance with the Habitats Directive. The term European marine site is defined to mean any SPA and SAC or part of a site that consists of a marine area, and "marine" includes intertidal areas. The new duties in connection with the management of marine sites are summarised below.

2.3 Management schemes

In the UK, management schemes may be established on European marine sites as a key measure in meeting the requirements of the Habitats Directive. Each scheme will be prepared by a group of authorities having statutory powers over the marine area - the relevant authorities. The Regulations set out which authorities have responsibilities for managing these sites and how they are to be managed, as described below:

- Relevant authorities are those who are already involved in some form of relevant marine regulatory function and would therefore be directly involved in the management of a marine site, and may include the following:

- country nature conservation agency
- local authorities
- Environment Agency
- Sea Fisheries Committees
- port and harbour authorities
- navigation authorities
- lighthouse authority

! A management scheme may be established by one or more of the relevant authorities. It is expected that one will normally take the lead. Once established, all the relevant authorities have an equal responsibility to exercise their functions in accordance with the scheme.

! Each site can have only one management scheme.

Whilst only relevant authorities have the responsibility for establishing a management scheme, government policy (DETR guidance on *European marine sites in England and Wales* 1998) strongly recommends that other groups including owner and occupiers, users, industry and interest groups be involved in developing the scheme. To achieve this, it suggests the formation of advisory groups and a process for regular consultation during the development and operation of the scheme.

Within the Regulations, the nature conservation bodies have a separate and special duty to advise the other relevant authorities as to the conservation objectives for a site and the operations that may cause deterioration or disturbance to the habitats or species for which it has been designated. This advice forms the basis for developing the management scheme.

The scheme will encourage the wise use of an area without detriment to the environment, based on the principle of sustainability. European marine sites have been selected with many activities already taking place and it is recognised that these are normally compatible with the conservation interest at their current levels. Only those activities that would cause deterioration or disturbance to the features for which a site has been designated need to be subject to restrictions under a management scheme.

The primary focus of a management scheme is to manage operations and activities taking place within a European marine site, promoting its sustainable use. However, it may also provide guidance for the assessment of plans and projects particularly those of minor or repetitive nature. A plan or project is any operation which requires an application to be made for a specific statutory consent, authorisation, licence or other permission. Not all types of plan or project fall within the statutory functions of relevant authorities, but are consented or authorised by other statutory bodies, termed competent authorities (e.g. central government departments).

2.4 UK marine SACs

There are presently 42 sites that have been forwarded to the European Commission as candidate SACs. See Figure 1. In addition to these, Yell Sound in the Shetlands has been forwarded to the Commission for its otter interest.

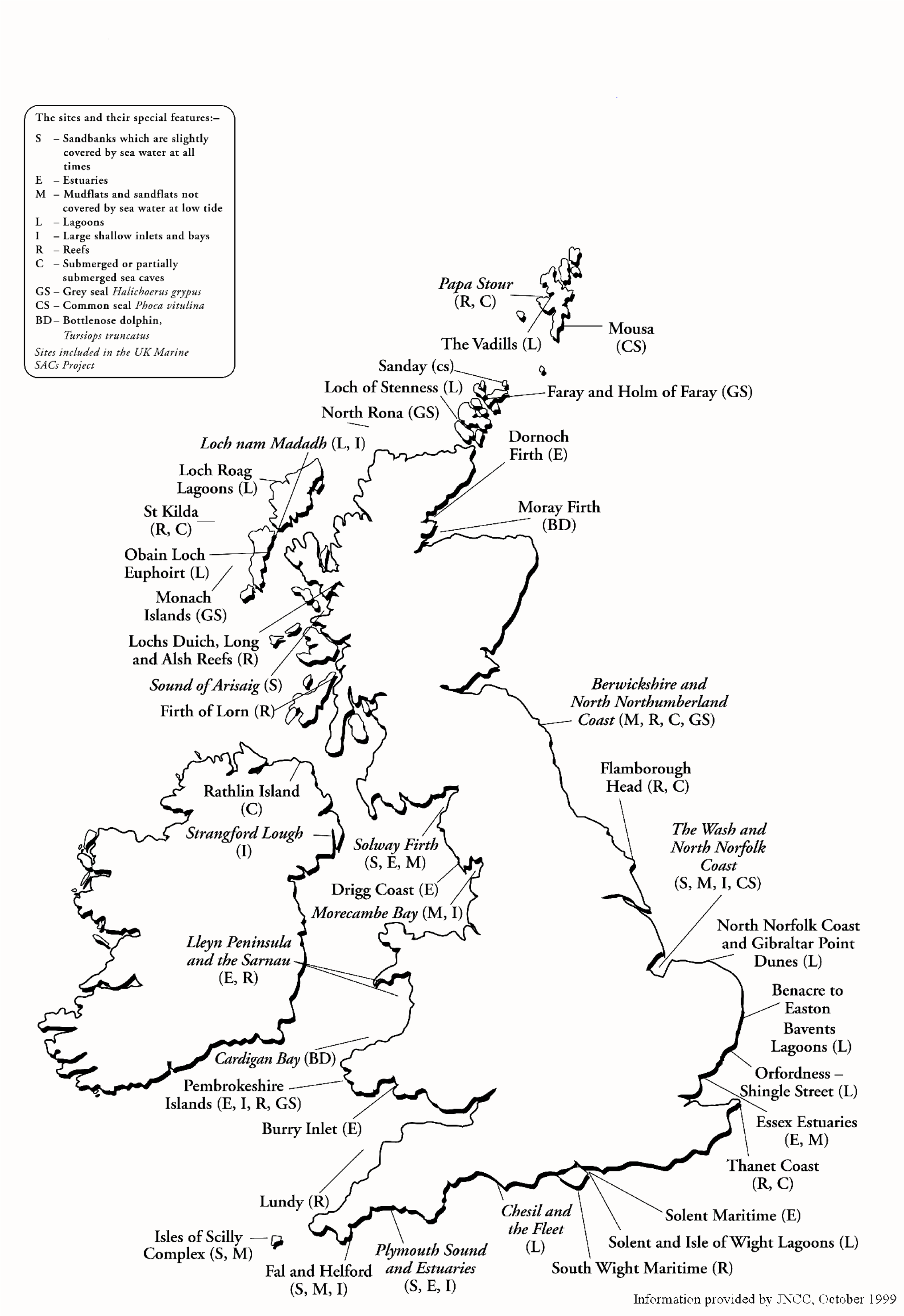

Figure 1. Candidate marine Special Areas of Conservation

3. Assessing environmental effects

A fundamental objective in developing management schemes is the identification by the statutory nature conservation agencies and agreement of activities, in this case related to fisheries, which have the potential to adversely affect interest features. The process of assessing environmental effects will be informed by this report.

The reason for which individual SAC sites have been proposed for designation are varied and there are a range of different conservation features at each site.

The environmental issues caused by the wide range of fisheries activities and the significance will vary from site to site.

However, the extent to which particular fisheries activities interact with and / or affect the defined interest features within the overall extent of a European marine site may depend upon one or more of the following:

- spatial overlap or proximity of the fishery to the defined conservation features;
- intensity and scale of the fishing operation or activity;
- the sensitivity of habitats and species, comprising the conservation features, to fishing activity and the capacity to recover;
- timescale of recovery relative to likely intervals between fishing events;
- exposure of the site to natural disturbance (eg. wave exposure, tidal range, depth, currents, rate of mixing);
- secondarily it will be influenced by a wide range of variables, such as:
    - Sediment characteristics (eg. particle size, density)
    - Background environmental quality (sediments, water, air)
    - Seasonal variability
    - The way fishing gear is operated or rigged
    - Timing by season, tide or time of day.

Given the large number of variables that need to be considered in determining whether a fishing activity is likely to have an adverse effect on the interest features within a European marine site means that this can only be done on a site by site basis.

Therefore specific guidance on which fishing activities will affect which marine sites cannot be given and would be misleading. Instead information has been provided on the potential effects that may occur as a result of fishing activities.

In comparison with terrestrial conservation, information and understanding of marine conservation is more limited and dispersed, and information gaps exist on the potential cause and effect of fisheries activities in European marine sites. This lack of information is at least in part due to the highly complex, dynamic and largely unobserved nature of the marine environment.

In the spirit of sustainable use a precautionary approach may be necessary - if there are real threats of serious damage to the interest features within the site, lack of full scientific certainty should not be used as a reason for postponing measures to prevent such damage (DETR, 1998).

Whether the precautionary approach should be invoked over specific issues will need to be agreed as part of each SAC management scheme.

These additional management measures will only be required under the SAC management regime if:

- an acitivty will affect a feature or species for which the site has been designated;
- existing management measures are proven to be insufficient;
- the activity effect will affect the integrity of the site;
- existing mechanisms by the fisheries regulators cannot be adapted to deliver the conservation objectives.

4. The potential effects of fishing on Annex I habitats in European marine sites

The majority of European marine sites which have been put forward lie close inshore. Fishing is one of the most common and widespread uses within these sites.

Table 3 shows the fishing methods that take place within the candidate and proposed SACs. It is clear that most types of inshore fishing practised around the UK take place in at least one European marine site. Using this information the potential effects of these fishing methods on the marine habitats and species listed in Annex I and II of the Habitats Directive and Annex I of the Birds Directive were investigated within the literature review. It should be noted that it was not possible to find information on the potential effects of all the fishing methods in table 3. (A brief description of the fishing techniques is given in Annex 2 of this report.)

4.1 Marine habitats

Some of the habitats listed in Annex I of the Habitats Directive are physiographic features, encompassing several habitats (eg. estuaries, large shallow inlets and bays) and others are more discrete habitats (eg. caves). This means there will inevitably be some overlap of the management issues between sites. For example, considerations relating to the 'mudflats and sand flat' category are also likely to be relevant for 'estuaries'.

For the purposes of this report, habitats which are likely to occur as a component of broader habitats are discussed within the same section as their relevant physiographic feature.

The effects of particular fisheries are described in the habitat where that type of fishing is most likely to take place but not exclusively so. Reference is therefore made to other relevant sections to ensure that the necessary links are made. This approach has been taken to minimise duplication of text. The references used are summarised in Annex 1.

In assessing the effect of a fishing activity on a habitat, it is important to consider the sensitivity of the specific features of an interest. This is considered in the following chapter. For further information, reports have been produced on the sensitivity and ecological requirements of the following marine features:

- Zostera Biotopes (Davison, D.M., et al. 1998)
- Intertidal Sand and Mudflats & Subtidal Mobile Sandbanks (Elliott, M. 1998)
- Sea Pens and Burrowing Megafauna (Hughes, D.J. 1998)
- Subtidal Brittlestar Beds (Hughes, D.J. 1998)
- Maerl (Birkett, D.A. *et al.* 1998)
- Intertidal Reef Biotopes (Hill, S. *et al*. 1998)
- Infralittoral Reef Biotopes with Kelp Species (Birkett, D.A. *et al*. 1998)
- Circalittoral Faunal Turfs (Hartnoll, R.G. 1998)
- Biogenic Reefs (Holt, T.J. *et al*. 1998)

Table 3. An overview of the known current commercial fishing activities in possible and candidate special areas of conservation

Candidate/ Possible SAC	Otter trawl	Pair trawl	Beam trawl	Demersal seine	Beach seine	Scallop dredge/trawl	Mussel & oyster dredge	Cockle dredge	Gill net	Tangle net	Trammel net	Salmon net and trap	Eel net and trap	Pot/creel	Long line	Hand line	Angling
Benacre to Easton Bavents Lagoons																	
Berwickshire & North Northumberland	U				U				U	U	U	U		U			U
Burry Inlet																	
Cardigan Bay	U		U		U	U			U	U	U	U		U			
Chesil and the Fleet										U			U		U		
Dornoch Firth							U										
Drigg Coast																	
Essex Estuaries	U	U	U				U	U	U	U	U		U	U	U		U
Fal & Helford	U	U			U	U			U	U		U	U	U	U	U	U
Flamborough Head	U	U				U			U	U	U	U		U	U		U
Isles of Scilly	U					U			U	U	U			U			U
Lleyn Peninsula and Sarnau						U			U	U				U			
Loch Duich, Long and Alsh Reefs	U					U								U			
Obain Loch Euphoirt Lagoons														U			
Loch nam Madadh														U			
Loch Roag Lagoons														U			
Loch of Stenness													U				
Lundy									U	U	U			U			
Monach Islands										U				U			
Moray Firth	U		U	U		U	U	U				U		U		U	
Morecambe Bay	U		U		U		U		U	U	U	U	U		U		U

Candidate/ Possible SAC	Otter trawl	Pair trawl	Beam trawl	Demersal seine	Beach seine	Scallop dredge/trawl	Mussel & oyster dredge	Cockle dredge	Gill net	Tangle net	Trammel net	Salmon net and trap	Eel net and trap	Pot/creel	Long line	Hand line	Angling
Mousa						U								U			
North Rona	U		U											U			
Orfordness - Shingle Street																	
Papa Stour														U			
Pembrokeshore Islands			U		U				U	U	U	U		U		U	U
Plymouth Sound and Estuaries									U			U	U	U		U	U
Rathlin Island																	
St Kilda	U													U			
Severn Estuary	U		U						U			U	U	U		U	
Solent and Isle of Wight Lagoons																	
Solent Maritime	U						U		U			U	U	U		U	U
Solway Firth	U		U	U		U			U			U		U		U	
Sound of Arisaig	U					U								U			
Strangford Lough	U					U		U						U			U
Thanet Coast									U		U		U	U			
The Vadills														U			
Wash and North Norfolk	U		U				U	U	U					U	U		
Faray and Holm of Faray														U			
Sanday	U													U			
Firth of Lorn	U					U				U				U			U
Yell Sound						U								U			

4.2 Estuaries, mudflats and sandflats not covered by seawater at low tide

Candidate and possible SACs for estuaries: Solway Firth, Drigg Coast, Llyn Peninsula & Sarnau, Pembrokeshire Island, Bury Inlet, Severn Estuary, Plymouth Sound & Estuaries, Solent & Isle of Wight Maritime, Essex Estuaries, Dornoch Firth.

Candidate and possible SACs for mudflats and sandflatsnot covered by seawater at low tide : Solway Firth, Morecambe Bay, Severn Estuary, Isles of Scilly Complex, Fal and Helford, Essex Estuaries, the Wash and North Norfolk Coast, Berwickshire & North Northumberland Coast.

Estuaries are one of a number of types of inlet found along the UK coastline. The Nature Conservancy Council's 'Estuaries Review' defined nine different categories (on the basis of geomorphology and topography), and identified 155 estuaries around the British coastline (Davidson *et al*., 1991). As well as being physiographic features in their own right, estuaries are habitat complexes. Tidal flats, saltmarshes, areas of shingle, rocky shores, lagoons, sand dunes and coastal grassland may be elements of coastal and intertidal areas, and muddy and sandy seabed, gravels and rocky areas may be found in the subtidal zone.

There is a rich source of invertebrates within the sediments of many estuaries, making them extremely productive areas as well as important feeding and overwintering grounds for waders and wildfowl. The UK has the largest single national area of estuaries in Europe, making up around one quarter of the total estuarine habitat of North Sea shores and the Atlantic seaboard of western Europe (Davidson *et al.*, 1991).

Mudflats and sandflats which are uncovered at low tide are one of the habitat types found within estuaries and embayments. They can cover large areas and are often the most extensive habitat in many estuaries. The characteristics of the flats will depend on a combination of factors, the most important being degree of exposure to wave action, particle size, position on the shore and salinity regime. There may be a gradation of sediment types with fine muds on the sheltered upper shore, and coarser grained sediments on the lower shore. Species diversity may be low but these flats often support very dense populations of invertebrates so the overall biomass of the area can be extremely high. Sand flats appear to be more common in northern and western parts of the country and finer grained flats more common in southern and eastern areas.

4.3 Fisheries associated with estuaries, mudflats and sandflats not covered by seawater at low tide

A variety of fisheries and associated methods take place in estuaries and on the mudflats and sandflats which are exposed by the tide. Of these, molluscan shellfisheries are considered most prevalent and are considered below. The other fisheries and methods that may occur are described in section 4.4 (large shallow inlets and bays; sandbanks) and 4.6 (reefs).

4.3.1 Cockles

Cockles are generally associated with the intertidal but can be found in the subtidal. Most studies on the effects of dredging for cockles (*Cerastoderma edule*) have examined the use of mechanical dredges which use a plough-like blade to remove sediment from which the cockles are subsequently sorted.

Tractor harvesting - Studies have shown that tractor-towed harvesters leave vehicle tracks as well as dredging furrows which remain visible for varying amounts of time depending on the conditions at the site[5]. In an area of stable sediment (poorly sorted fine sand) dredge tracks may be visible for long periods (more than 6 months have been recorded) whereas in more mobile sediments there may be no alteration in sediment parameters [6]. On areas of cohesive sediment the tracks appeared to act as lines from which erosion of the surface layer spread out. This appeared to accelerate the erosion phase of a natural cycle of cohesion of the surface sediment by worm tube mats[62]. Dredged areas often had a lot more dead shell scattered on the surface, an effect which can persist for several months. In undisturbed beds, most dead shell is normally under the surface which can create a shell layer limiting the depth to which small drainage channels can normally erode into a cockle flat [62].

The effect on infauna also depends on the exposure of the site [6,18,36]. Research to date suggests that in an area of stable sediments, as well as large reductions in the target species, mechanical dredging can result in a significant decline in numbers of the lower spire shell (*Hydrobia ulvae*) and decreased numbers of *Pygospio elegans*, a segmented worm whose tubes may be removed by the dredge[6,18]. These effects may still be apparent 6 months later [6]. The sand mason worm (*Lanice conchilega*), on the other hand, has more robust tubes and can retract below the depth disturbed by the dredge[18, 62] and although the distribution of white ragworm (*Nephtys hombergii*) was affected by dredging, populations have been shown to recover within six months [6].

In Scotland there is a general prohibition on dredging for cockles from or by means of any vehicle, eg. tractor dredging. This was specifically adopted following concerns as to the direct effects of large scale dredging operations on cockle stocks and the indirect effects to the intertidal habitat [15,36,93]. In England and Wales some Sea Fisheries Committees have in place byelaws which specify the design or type of equipment that can be used to target cockles. In this way, tractor dredging has been prohibited in many areas.

Suction dredging - Suction dredgers or hydraulic continuous lift dredgers - to be more accurate - are deployed from specially adapted or specially built shallow draft vessels and are used to harvest cockles in the Wash and Thames in particular. Depending on the stability of the sediment surface at the time and the prevailing tide or wind conditions, evidence of the tracks left by the dredge head, can persist for several months [62]. Where dredging was carried out in a sheltered area with eel grass (*Zostera*) beds, (Auchencairn Bay, Solway Firth), breaking the sward allowed erosion that produced clearly visible grooves down the shore [62]. The immediate effect of hydraulic dredging on the infauna can be significant. Studies have shown up to 30% reductions in the number of species and 50% reduction in number of individuals. Comparison between dredged and undredged areas have shown recovery times varying from 14-56 days [93].

In general the overall decrease in biomass of target species and non-target species is likely to be more pronounced in areas with stable environmental conditions and diverse communities. In sites with moderately mobile sediments it is possible for natural disturbances to have a greater effect than dredging [6, 77]. Sites with more tube dwelling and sedentary species appear to take longer to recover to pre-fishing levels than areas with more mobile fauna.

The time of year of exploitation will also influence recovery [36]. Avoiding dredging during periods of larval settlement or spawning for example, can reduce time required for the restoration of infaunal communities. The sediment may change, at least in the short term, but how long this remains the case also depends on the exposure and stability of the site.

Effects on birds are varied. In some cases short-term increases of gulls and waders in the harvesting area, followed by a long term significant reduction in feeding opportunities for these birds' has been noted[5]. In contrast, research linked to the Solway fishery concluded that because natural changes are very large the fishery may not have a significant effect on bird numbers unless a high proportion of the cockles are harvested [62].

A simulation model tested on the Exe estuary has been developed to explore the consequences of changes in fishing activities and bird numbers on commercial shellfish stocks and on the birds themselves[63]. Key predictions include that where a number of conditions apply it is possible to exploit shellfish stocks without increasing the winter mortality of shorebirds, that the effects of a given intensity of shellfishing depend crucially on local conditions of the climate and general abundance of food and that as fishing effort increases, shorebird mortality may be hardly affected initially but then may suddenly increase dramatically once a threshold level of fishing effort has been reached[63].

Hand gathering - Hand gathering for cockles is the only permitted form of cockle fishery in some areas. No information was found on the effects of large scale hand gathering for cockles. However, disturbance to feeding and roosting birds, which is a concern in relation to bait digging on intertidal flats could also be an issue for cockle gathering from intertidal areas. This issue is addressed in more detail in the related report on collecting bait and other shoreline animals (Fowler, S. 1999).

4.3.2 Oysters, mussels, clams

In many of the situations where dredges are used to gather these species it will be as part of a bottom cultivation operation. The shellfish are often from artificial beds established by the operator. In other circumstances dredges may be used to gather immature shellfish from ephemeral beds to be relaid in more stable situations.

Dredging - Investigations into the effects of oyster dredging and the use of modified oyster dredges to harvest clams have been shown to have direct effects on the sediment and associated fauna. The top 10-15 cm may be removed by the action of the dredge, sediment plumes created, and tracks made on the seabed. The gravel fraction in the sediment can be reduced and sediments become more anoxic after dredging [21]. All infauna to that depth can be removed in the short term. Segmented worms appear to be the most badly affected group whereas bivalves tend to be redistributed nearby[21]. The suspended sediment may also have an indirect effect on species some distance from the dredging operation if they are smothered and there can be detrimental effects on eel grass beds.

A study looking at the effects of mussel dredging in a sheltered fjord in Denmark showed an increase in suspended particular matter but a return to initial conditions after 1 hour [32]. There was a significant decrease in oxygen levels as a result of the dredging but generally little change in nutrient levels except in the case of ammonia. This work suggests that water quality can be reduced by mussel dredging because of increasing nutrient loads, oxygen consumption and possibly phytoplankton production. The total annual release of suspended particles as a consequence of mussel dredging at this site was nevertheless considered to be relatively unimportant compared with the total annual wind-induced resuspension [32, 54]. Similarly the nutrient load entering the system from land was more significant than that caused by mussel dredging. Changes in the benthic flora and fauna as a consequence of repeated mussel dredging [32] were considered to have a more severe effect than suspension of sediments and increased nutrient loads caused by the action of the dredges[54].

Recovery of habitats and species from these forms of dredging can take place but the timescale will vary depending on the conditions at the site and the outcome will not necessarily be identical to pre-dredging conditions[78]. Tracks are likely to become infilled, although at low energy sites this may be with fine sediment, creating some habitat variation [21]. Species do not recover immediately (one short-term study showed no change within 8 days). However, with time, opportunistic polychaetes (bristle worms) and the surviving bivalves are thought to be likely early colonisers. Active polychaetes such as *Eteone longa* and more stable habitat species, such as *Cirriformia tentaculata*, may follow although continual disturbance will prevent recovery of communities typical of stable habitats [21].

Hand gathering - Laboratory experiments studying the effects of digging on the short-shelled clam or sand gaper, *Mya arenaria*, suggest that the negative effects are likely to be limited to removal of market size clams and shell breakage of remaining ones [26]. Exposure of other clams, and the placing of spoil on clams in adjacent areas, may however increase the susceptibility of unharvested clams on the flats to predation, desiccation, or freezing, depending on the substrate. Mortality is likely to be greater on muddy substrates compared to medium fine sand as clams exposed on sandy surfaces were able to re-establish their normal living depths whereas those on mud reburrowed to abnormally shallow depths. This work suggests that breaking up clumps in the tailings in sandy areas will make little difference to their survival as burial of clams in these conditions will probably not result in mortality whereas reducing tailing piles in muddy areas is likely to improve survival of buried and exposed clams [26].

Table 4 provides a summary of the potential effects of fishing on estuaries, mudflats and sandflats not covered by seawater at low tide.

Table 4. Summary of the potential effects of fisheries on estuaries, mudflats and sandflats not covered by seawater at low tide

Fishery	Method	Potential effects
Cockle	Tractor towed dredge Hydraulic dredge	! Intertidal dredge tracks visible for varying amounts of time ie. Months in stable sediments, a tide in mobile sediments. ! Sediment layers may be altered causing erosion to cockle bed. ! Significant reduction in biomass of target and non target species immediately after fishing operation. Likely to be more pronounced with extended recovery times, ie many months, in areas with diverse communities and stable conditions.
Oysters and mussels	Dredge	! Subtidal and intertidal dredge tracks visible for varying amounts of time, ie. months in stable sediments, hours in mobile sediments. ! Top 10-15 cm of substrate disturbed and sediment plumes created ! Change in benthic flora and fauna as a consequence of repeated dredging.
Clams	Hand gathering	! Holes and tailings left on the intertidal visible for varying amounts of time, ie. months in stable sediments, a tide in mobile sediments. ! Under size target species damaged or exposed to predation, desiccation or freezing.

4.4 Large shallow inlets and bays, and sandbanks slightly covered by seawater all the time

Candidate SACs for shallow inlets and bays: Loch Nam Madadh, Strangford Lough, Morecambe Bay, Pembrokeshire Islands, Fal and Helford, Plymouth Sound & Estuaries, The Wash and North Norfolk Coast.

Candidate and possible SACs for sandbanks Sound of Arisaig, Solway Firth, Severn Estuary, Isles of Scilly complex, Fal and Helford, Plymouth Sound, The Wash and North Norfolk Coast, Berwickshire and North Northumberland Coast.

There are many examples of large shallow inlets and bays around the UK coast. Some are distinctive physiographic types such as rias and fjards but others are less easy to categorise. The seabed in these areas is likely to be dominated by soft sediments but bedrock, boulders, and gravels may also be present. Sublittoral sandbanks are often present and can be important areas for fisheries, support seagrass beds, maerl, and other communities depending on their exposure to wave action and currents, sediment type, and depth.

Other categories of habitat listed in the Habitats Directive which occur within large shallow inlets and bays are estuaries, mudflats, sandflats, reefs and lagoons. Reference should therefore be made to sections 4.2, 4.6 and 4.8 to get a fuller picture of the effects of fisheries on this habitat type.

4.5 Fisheries associated with large shallow inlets and bays, and sandbanks slightly covered by seawater all the time

Table 3, which lists the fishing activities taking place in candidate and possible SACs, shows they are all represented in the sites which have been put forward as large shallow inlets or bays, or sand banks slightly covered by seawater all the time. Demersal fin fish, shrimp, razor shell, and scallop fisheries are considered here with beam trawling, otter trawling gill/trammel netting, hydraulic and scallop dredging identified as the main methods of fishing. Fin and shell fish aquaculture are also reviewed. The effects of other types of fisheries and fishing methods, such as potting, creeling and forms of dredging, are described in other sections of the report.

4.5.1 Demersal finfish and shrimp

Demersal finfish and shrimp (pink shrimp *Pandalus montagui* and brown shrimp *Crangon crangon*) are caught using various designs of beam and otter trawls. There is a considerable amount of recent research on the effects of beam trawling on seabed sediments and associated infauna and epifauna. In common with other fisheries, the most significant effects occur when an area is previously unfished [77] and, the severity of accumulated fishing effects depends on the sediment type, conditions at the site and the scale and intensity of the activity [77, 78, 95].

Beam trawling - The gear used by beam trawlers digs into the seabed leaving tracks and disturbs the surface sediments. The extent to which the seabed is affected depends on the type of fishing gear, the substrate and its physical characteristics [46, 67, 77, 78] . On sandy ground the gear may penetrate 10 mm and on muddy ground 30 mm [52], although there are also reports of tickler chains digging 60 mm into the sediment.

Changes in benthic community structure are known to occur following beam trawling but the effects can be variable [58, 77, 78]. One study which examined the effects of three passages of a trawl over 2 days recorded a significant lowering of densities of echinoderms such as the common starfish, *Asterias rubens*, small sea potatoes, *Echinocardium cordatum*, and of polychaete worms such as the sand mason, *Lanice conchilega*, (by 40-60 %)[1]. Decreases in the densities of small crustaceans and larger tellin shells, *Tellina fabula*, and sea potatoes were also recorded but were not as significant (10-20 %). The impact appears to be greatest on densities of small individuals, possibly because larger animals live deeper in the sediment or have better escape possibilities [1]. Some increases in numbers may also occur following beam trawling as illustrated by the considerable increase in the polychaete worms, *Magelona papillicornis*[1], *Chaetozone setosa*[74] and *Caulleriella zetlandia*[74] in various studies and, in the latter case only returning to similar numbers after 18 months with no fishing. For other species, eg. small brittlestars, *Ophiura*, and molluscs (with the exception of *T. fabula*) there were no significant direct effects. In contrast, 90% of the Icelandic cyprine, *Arctica islandica*, caught in the trawl were severely damaged [1]. The incidence of shell scars on this species has been used to assess the long-term effects of beam trawling in the North Sea and shows a striking coincidence with the increased capacity of the Dutch beam trawling fleet since 1972 [4].

Differences between effects in areas with different sediment characteristics are also apparent. In an area of uniform, stable, flat seabed, the abundance of 19 of the top 20 most common taxa at the site was lowered at fished sites[2]. Fragile infauna (eg. bivalves, sea cucumbers etc) were particularly vulnerable to damage or disturbance but the abundance of sedentary and slow-moving animals was also significantly lowered. In contrast, there were no detectable differences in the diversity and abundance of taxa in areas characterised by mobile sediments and subject to frequent natural disturbance [2]. Changes in such areas may also be masked or insignificant compared to natural changes [66].

Animals damaged by beam trawling rapidly attract scavengers [2,11,22,46, 78]. Large numbers of whelks, *Buccinum undatum,* (98%) have been shown to survive beam trawling and they are capable of exploiting a wide variety of prey, feeding on damaged and moribund animals in the trawled areas[22]. It has been suggested that in areas of intense beam trawling, damaged animals could make up a considerable proportion of their diet. Fish such as gurnard, whiting and dogfish, and the sea urchin *Strongylocentrotus pallidus,* are also known to aggregate over beam trawl tracks to feed[11, 69]. Recent research on hermit crabs indicates that scavengers are far more selective than previously presumed and may provide a mechanism whereby fishing could change crustacean scavenger populations [65].

Areas which have been intensively trawled for several years still support profitable fisheries which would not be possible without ample benthic food. Therefore it has been suggested that it is not unlikely that the benthic community in these areas has shifted towards a dominance of highly productive, opportunistic species such as polychaetes[56, 68, 77]. At the same time the effects of bottom trawling have been described as the marine equivalent to forest clearcutting acting as a major threat to biological diversity and economic sustainability [76].

Otter trawling - With otter trawls the passage of the trawl doors mounds sediment as well as creating a scour furrow[94]. There may be no alteration of the surface roughness in a relatively uniform, stable, flat area, whereas it can be lowered in an area characterised by sand waves and ripples [2,74]. The sediment structure may also change because the physical disturbance can resuspend sediment, nutrients, and contaminants with implications for nutrient cycling in bottom trawled areas[70], and relocate stones and boulders which provide different micro-habitats in areas of predominantly soft sediment [45]. New surfaces for settlement will be created by the exposure of shell and gravel although at the same time epibenthos on surfaces which were overturned by the action of the trawl will be smothered [2]. As well as fine material being suspended and washed away from the surface layers, there are reports of the seabed surface appearing to have altered from coarse grained sand or gravel to one with fine sand and coarse silt which has collected in the trawl marks [24]. The effects may be long term and there have been definitive changes of the substrate and habitat complexity with implications for the benthic communities [9,24,76]as well as potential effects on recruitment to harvestable fish stocks [71]. In other cases no changes in particle size distribution have been reported [2].

Tracks from otter trawls may still be visible in muddy sediments in sheltered areas after 18 months[78] and trawl door displace bivalves in the scour path [94].Otter trawling can result in a considerable by-catch[8] as can shrimp fisheries [90, 91] and beam trawling. Analysis of by-catch data from the Netherlands beam trawl fisheries between 1965-1983 suggests that such fisheries had a considerable impact on the abundance of several by-catch species [72]. While the by-catch may include species of commercial value, eg. crabs and scallops, much will be discarded. The mortality of affected species shows considerable variation - around 10 % in starfish to 90 % in the Icelandic cyprinid, *Arctica islandica* after a single passage of a trawl. Reefs formed by the polychaete *Sabellaria spinulosa*; beds of the eel grass, *Zostera marina*, and native oyster, *Ostrea edulis*, beds are also known to have been severely damaged by trawling and may be replaced by deposit feeding polychaetes which may influence the recovery of suspension feeding species[8,9,13,68]. The intense disturbance from repeated trawling may select for more tolerant species, communities becoming dominated by juvenile stages, mobile species and rapid colonists[8, 68]. It can also lead to significant decreases in habitat heterogeneity [68] although in more current swept areas, natural inter-annual changes in sediment grain size may be more pronounced than those caused by experimental trawling [69].

Gill nets - Bottom set gill nets are used to catch demersal fin fish and can result in the incidental catch of marine mammals and birds as well as other marine life (see sections 5.1, 5.2 and 6.1). They also have the potential to continue fishing after being lost or discarded, an effect which has been described as “ghost fishing”. A study into the effects of ghost nets reported catches of large number of elasmobranchs, crustaceans and fish [53]. Initially more fish were caught than crustaceans but the situation reversed by day 20. The greatest catches of crustaceans came more than a month after initial deployment of the nets. All the crustaceans caught are known to scavenge carrion. Other species such as the common starfish, *Asterias rubens*, and the brittle star, *Ophiothrix fragilis,* also aggregated to feed on animals in the nets.

The study showed that environmental conditions and the type of habitat on which the nets were lost were the main factors in affecting how long the net maintained a catching capability [53]. Nets lost in shallow water during spring and summer months when storms are infrequent could be active for up to 6 months, whereas, nets lost in winter storms are likely to have a limited life. Nets lost on fine ground may only last a few weeks in reasonably good weather. Nets lost on reefs, very rocky ground or wrecks may have a longer period of activity as their meshes can snag on features and be held open. Limited observations on the fate of nets lost in deep water, where the effects of storm events will be less, indicate a continued fishing capability even after 1 year [80].

4.5.2 Razor shells

Razor shell fisheries (*Ensis siliqua, Ensis ensis, Ensis arcuatus*) are still in their developmental stage, particularly in England and Wales. Information on the effect of this method of fishing is limited. Razor shells occur in intertidal and subtidal habitats. Owing to their relatively deep burrowing ability, adapted hydraulic cockle dredges, which allow for deeper penetration into the substrate, are required to harvest these species.

Studies have indicated that the fishing operation initially causes substantial physical disturbance to the substrate with trenches and holes throughout the fished area (0.5 - 3.5 m wide and 0.25 - 0.6 m deep)[27]. The length of time these features remain depends on the sites exposure. In one study, undertaken in a relatively exposed area, fished tracks were no longer visible after a 40 day period. This included a period of stormy conditions which may have caused exceptional sediment disturbance [27].

The same study showed that this fishing method can reduce the abundance of a significant proportion of the species in a fished area immediately after the fishing operation. Recovery to pre-fishing levels of non-target species was shown after 40 days. The effect on long lived bivalve species, which includes the target species, could be more serious - *E.siliqua* is estimated as living to 25 years[27].

A comparative study of the effects on *E.arcuatus* showed that suction dredging directly affected the size-class structure of the population and that shells from the dredged site showed signs of damage. Animals subsequently returned to the seabed were slow to re-bury and were considered to be highly vulnerable to attack from predatory crabs [79].

Migration and passive translocation may help sites return to pre-fishing levels. Local population reductions may only persist if the population or the sediments in which they live are immobile or the affected area is large relative to the remainder of the habitat so a dilution effect cannot occur. It has been suggested that neither of these conditions are likely to hold because the current technology limits the use of hydraulic dredging for razor shells to shallow water (around 7 m). This would tend to be in areas which are strongly influenced by wind and tide-induced currents and therefore with mobile sediments [27]. In calmer seasons the effects may persist for longer. Because of limited knowledge of the relative importance of various processes which contribute to animal movement, any cascading effect caused by the removal of razor shells on the structure of benthic communities, is unknown.

Experimental studies of the use of water jet dredgers concluded that there was little difference between the effects of this gear when compared to suction dredgers. In a sandy area swept by strong tidal flow where the gear was tested, trenches were created, there was fluidisation of sediments and although an immediate reduction in species abundance and biomass was apparent the biological effects were only considered to be short-term[75].

4.5.3 Scallops

A number of effects on the seabed habitats result from scallop dredging. Tracks are created on the seabed, fine sediments are lifted into suspension and large rocks can be overturned [30,40,42,45]. A mound of sediment may be carried in front of the toothed bar and deposited around the sides in distinct ridges, most obviously in the case of the spring-loaded dredges [33].

There are reports of the top 100 mm of sediment being disturbed by scallop dredging which has the effect of smoothing out the surface with pits and depressions being filled in and mounds removed[3]. These physical changes as well as the track marks may still be present months later depending on the conditions at the site. Where there is little current movement the tracks may be visible for a long time and even a relatively minor fishery may have a significant cumulative effect on bottom microtopography[30].

Significant decreases in the abundance and number of species have been recorded from dredged areas although, depending on the conditions at the site, seasonal and inter-annual changes such as storm events, may be greater than those caused by dredging [3,16,44,69]. It should also be noted that the maximum impact may not be immediate, suggesting that some indirect ecological changes such as exposed organisms becoming more vulnerable to predation, may be taking place [3]. In one study a 20-30 % decrease in abundance of most species was recorded 3.5 months after dredging, and some differences were still apparent after 8 months. Fragile groups such as *nemerteans* (unsegmented worms) were directly affected and showed considerable damage [3]. In another study more than 50 % of the common taxa of macrofauna were affected and significant differences from adjacent reference plots were still apparent after 3 months [88]. The collection and sorting of stones and shells by the dredge can also have an impact by removing encrusting sponges, hydroids, and small anemones and, by reducing habitat complexity may lead to increased predation on juveniles of some harvestable species [71]. Burrowing and tube dwelling infauna may be less affected than epifauna [42]. In a study carried out in the Skomer Marine Nature Reserve the numbers of sea anemones, *Cerianthus lloydii*, *Mesacmae mitchellii*, and the sand mason worm, *Lanice conchilega*, within and alongside dredge paths were similar to pre-dredge levels several weeks later. Fragile species such as the bristle worm, *Filograna implexa*, and the ross coral, *Pentapora foliacea*, appear to be particularly vulnerable [42,44]. Slow growing species will not be able to recover to pre-dredging numbers or sizes even if there is no dredging for several years.

In common with other forms of dredging, predatory fish, whelks and hermit crabs are attracted to the track to feed on damaged and exposed animals [30,33].

Effects of scallop dredging across seagrass beds have also been investigated and show significant reduction in seagrass biomass and shoot numbers on both soft and relatively hard seabeds with the potential for both short and long-term effects on settlement of juvenile scallops and other invertebrates [85].

Investigations into scallop dredging across maerl beds show a major effect on the structure of the habitat and its associated biota [16]. The teeth of the dredge may penetrate up to 100 mm and as sediment is suspended by the trawl, fine fractions can be eroded away. Microtopographical effects can be clearly visible 8 months after dredging. Large macroalgae can be torn up and large animals, including highly mobile species can be caught by the dredge. Maerl is crushed and killed through burial which in turn limits opportunities for habitat recovery. The deposition of fine sediment over adjacent areas, smothering of photosynthetic organisms and stress on filter feeders may also occur. Scallop dredging can also have an impact on harder substrates as discussed in the section dealing with reefs (4.6).

On gravelly seabeds around the Isle of Man, community composition has been shown to be related to the intensity of commercial dredging effort [86]. Effects may differ from those in areas of soft sediment due to the extreme patchiness of animal distribution, greater abundance of epifauna and the combined effect of the toothed gear and stones caught in the dredges. Impacts may also be apparent in lightly dredged areas, including the loss of a number of species including some potentially fragile tube-dwellers [85].

There are very few studies which compare the fauna of dredged and undredged areas and therefore give clues about possible long term effects of dredging which may be different from short or medium term effects. One example is a study currently underway off the Isle of Man [57, 86]. Provisional results show differences in the epifaunal communities including greater species numbers in the area closed to fishing even under conditions of considerable seasonal variation. A higher density of shallow burrowing and epibenthic species (particularly those noted for their vulnerability to dredging such as the bryzoan, *Cellaria fistulosa*, and the common sea urchin, *Echinus esculentus*) have been recorded at the undredged sites. Long-lived and slow recruiting epifauna such as sponges and ascidians are likely to be particularly vulnerable. There is no evidence of longer-lived benthic species being more prevalent at the undredged sites at the moment and it is suggested that this could be due to the relatively short time since effective closure of the area to dredging giving another indication of the time scales required for these species to become re-established in dredged areas.

4.5.4 Aquaculture

Both forms of aquaculture, finfish and shellfish, take place in shallow inlets, bays and lagoons (see section 4.9). In the UK, aquaculture has become most highly developed in Scotland, and in particular in the sea lochs and voes of mainland west coast, Western and Northern Isles. There are a variety of potential environmental impacts from aquaculture (NCC, 1989) however for the purposes of this review discussion below is limited to impacts on the benthos.

Finfish Culture - Atlantic salmon (*Salmo salar*) is the most commonly farmed species although there are farms for halibut (*Hippoglossus hippoglossus*) and turbot (*Scophthalmus maxima*). The farming of cod is currently being investigated. The overwhelming majority of farms consist of floating cages at sea although there are some land-based farms utilising pump-ashore technology.

To date, studies have shown that the most obvious benthic impacts of finfish culture relate to the depositition of organic material (faeces and uneaten food) and dispersion of nitrogenous wastes in solution. Benthic impact has been well documented and tends to be restricted to the immediate vicinity of the cage group, with the extent and severity of impact being most pronounced at low energy locations where water exchange and/or wave action is limited. Monitoring practices at farm sites are closely related to the extent of this "footprint" on the seabed. As well as impacting on the benthos, the release of hydrogen sulphide from anoxic sediments below cages has implications for the health of the farmed fish [82] Over the past few years a trend has developed in the salmon industry away from the most sheltered sites to those with greater tidal exchange which helps to ameliorate direct impact on the benthos. Studies on the recovery of the benthos following organic enrichment from salmon farming indicate varying periods of recovery depending on prevailing hydrographic conditions, with the majority of sites studied showing some recovery within two years. Clearly, pump-ashore farms offer the potential for treatment of effluent prior to discharge.

A further potential impact on the benthos within shallow inlets and bays arises from the use of chemicals and medicines. A variety of compounds are employed ranging from anti-fouling treatments to antibiotics and treatments for sea lice infestation of salmon. Anti-biotics are of concern due, for example, to their potential to impact on microbial processes and through the development of drug resistance in fish pathogens.

There are concerns about the potential impacts on benthic communities in proximity to salmon farms from the discharge of medicines used to control sea lice infestations as active compounds are effectively being discharged directly into the environment. These medicines can be split into two broad categories: those delivered orally in medicated feed, and bath treatments which are added to the cages in solution. The most commonly used sea lice treatment has been the organophosphate dichlorvos, a bath treatment, although use has declined due to "Red List" status and the development of resistance in sea lice. Studies on environmental effects of dichlorvos demonstrated sublethal effects in intertidal invertebrate communities. Other bath treatments are currently in varying stages of development with cypermethrin and azamethiphos being recently authorised for use. In general, it is probably true to say that the greater dispersive characteristics of high energy sites are beneficial in ameliorating the impact of bath treatments. Sites with restricted exchange (lagoons) can be considered most vulnerable. In-feed treatments have a direct route to the benthos via any uneaten food. Recent studies of one such compound, ivermectin, demonstrated mortality in sediment dwelling worms with potential consequences for the recovery of the seabed [82.]

A major research study has recently been started to investigate the environmental impact of sea lice treatments but no results are yet available with which to inform this review.

Shellfish - A number of different methods of shellfish cultivation are used in UK waters with issues for consideration at the seed collection, on-growing and harvesting stages of the process [64]. Depending on the species, molluscs may be suspended in lantern nets, laid in trays or poches (large meshed sacks) on the shore, attached to ropes suspended in midwater or relaid in more suitable areas for re-growing. Collection of seed mussels is not considered to have an environmental impact in the UK as it is not extensive and only licensed from unstable beds [64]. In the Wadden Sea however, massive mortalities of eider ducks have been associated with greatly reduced mussel stocks as a consequence of harvesting spat for aquaculture [82]. Intertidal collection may result in some effects such as from trampling and disturbance of foraging birds.

There has also been concern about the inadvertent introduction of alien species (such as the seaweed *Sargassum muticum*) on shellfish which are imported as seed stock for cultivation.

The effects of on-growing depend on the habitat, type and scale of cultivation. Changes in sediment composition and benthic community structure have been observed under long-lived cultures of *Mytilus edulis* for example. A three year study showed that faecal matter and detached mussels increased sedimentation under the lines at a rate of 10 cm/yr. The effects on the sediment under the culture were reduced grain size, high organic content and a negative Redox potential. Benthic fauna were replaced by opportunistic polychaetes and only limited recovery was observed when the site was re-sampled 6 months after harvesting [89]. In these respects the effects are similar to those beneath finfish cages.

Examination of the sediment structure and the infauna beneath Manila clam lays revealed no significant differences in particle size, organic content or photosynthetic pigment between control areas and the lays while the clams were growing [20]. There were also no significant differences in the faunal diversity beneath the lays when compared to control sites, but there was a greater density of benthic species under the lays. The infauna were dominated by deposit feeding worms, *Lanice conchilega,* and the bivalve, *Mysella bidentata,* compared to the white ragworm, *Nephtys hombergii,* in the control area. In another study, species effects were seen in the first 6 months with the infauna dominated by opportunistic species [92]. The nets used to contain the clams and provide protection from predation, increased sedimentation and settlement of green macroalgae and are likely to have had a major influence on some of the infauna [92]. Effects on benthic communities of small scale culture may be limited and localised. If the area covered is large there is potential for conflict with bird feeding or roosting sites [64].

The harvesting stage of cultivation has also raised various concerns relating to physical disturbance. Harvesting of clams by hand raking has been reported as causing a 50 % reduction in diversity and abundance of infauna [97]. Suction dredging may be another method which is used. In one study this caused an 80-90 % reduction in non-target fauna and left a trench 10 cm deep [20]. A sediment plume was created but reduced to background levels within 40 days. Regeneration of species diversity and abundance, after harvesting in the winter, was completed by the summer - a period of 7 months. Natural sedimentation had nearly restored the sediment structure to pre-harvesting conditions after 4 months suggesting that there may be minimal long term effects if sites are left to recover. In Scotland Manila clam has only been trialed; no commercial production has taken place. Restricting harvesting to early winter could ameliorate site restoration if the main mechanisms for recolonisation is by larval settlement.

Table 5. Summary of the potential effects of fisheries on large shallow inlets and bays, and sandbanks

Fishery	Method	Potential effects
Demersal fin fish, shrimp, *Nephrops*	Beam trawling, Otter Trawling	! Trawl tracks visible for varying amount of time, depending on substrate, gear and tidal conditions ie. days or months. ! Top 10 - 60 mm of substrate disturbed. ! Resuspension of sediment. ! Sediment structure may change from coarse grained sand/gravel to fine sand/coarse silt. ! Significan t reduction in biomass of target and non-target species immediately after fishing operation. Likely to be more pronounced with extended recovery times, ie. many months, in areas with diverse communities and stable conditions. ! Considerable variation in damage or mortality to affected species. Fragile, long lived, slow moving or sedentary species most vulnerable. ! Repeated trawling may cause benthic community structure to change, favouring more mobile species, rapid colonisers and juvenile stages. ! Influx of scavenging species post fishing operation. ! Biogenic reefs, eg. *Sabellaria*, and species that stabilise sediments, eg. eel grass, may be severely damaged resulting in resuspension of sediment.
Demersal fin fish	Gill nets	! Incidental catch of marine life including marine mammals and birds. ! 'Ghost fishing', dependent on condition of gear. In rocky less exposed areas may be active for months, on clean exposed ground, days to weeks.
Razor shell	Hydraulic dredge	! Subtidal dredge tracks, deeper than a conventional hydraulic cockle dredge (eg. 0.5 - 3.5 m wide, 0.25 - 0.6 m deep) visible for months in mobile sediments. ! Substantial physical disturbance of substrate ! Significant reduction in abundance of non target species immediately after fishing operation. Weeks/months to recover to pre fishing levels in mobile sediment.

Fishery	Method	Potential effects
Scallops	Scallop dredge	! Dredge tracks visible for varying amount of time ie. days or months in stable conditions a relatively minor fishery may have a significant cumulative effect on bottom micro topography. ! Top 60 -100 mm of substrate disturbed. ! Resuspension of sediment. ! Significant reduction in biomass of target and non target species immediately after fishing operation. Likely to be more pronounced with extended recovery times, ie many months, in areas with diverse communities and stable conditions. ! Maerl crushed, smothered and killed. ! Associated biota of maerl either caught, damaged or smothered by sediment.
Aquaculture	Finfish cages	! Impact on benthic communities through deposition of organic material (faeces and waste food). ! Development of anoxic conditions in sediment and water column in low energy site with subsequent outgassing of hydrogen sulphide and ammonia. ! Potential for hypernutrifiaction in low energy locations. ! Potential effects of sea lice treatments, antibiotics and antifoulants.
Aquaculture	Shellfish cultivation	! Increased sedimentation and effects on infauna beneath mussel cultures. ! Manila clam cultivation in lays increases density of benthic species, changes in infauna and increased sedimentation. ! Harvesting with hand raking reduces species diversity and abundance by 50 %,–suction dredging reduces species abundance by 80-90%. Recovery to pre-harvesting levels may take long periods eg. 7 months. ! Trenching up to 10 cm deep, may take months to fill eg. 4 months in one study. ! Accidental introduction of alien species.

4.6 Reefs

Candidate SACs for reefs: Papa Stour, St.Kilda, Lochs Duich, Long and Alsh Reefs, Llyn Peninsula and the Sarnau, Pembrokeshire Islands, Lundy, Solent and Isle of Wight Maritime, Thanet Coast, Flamborough Head, Berwickshire & North Northumberland Coast, Firth of Lorn.

Reefs are a common feature in inshore waters around the UK. They are very diverse, varying in size and in the different communities supported. This variation depends on, among other factors, the rock type, degree of exposure to wave action and tides, size and location. Numerous micro-habitats may be present within a reef. Unbroken bedrock has limited habitat diversity whereas a surface cut by gullies and crevices and overlain by boulders provides much more variety and localised areas of shelter supporting different communities on vertical surfaces, overhangs, gullies and outcrops.

4.7 Fisheries associated with reefs

4.7.1 Crabs, lobsters and crawfish

The main fishery likely to be encountered on or near reef habitats is potting and creeling for crustaceans.

Reefs may be vulnerable to fishing as they are often surrounded by areas of soft sediment making recolonisation from surrounding areas difficult. A variety of types of pots and creels may be used on or near areas of rocky seabed to catch lobsters and crabs but there is limited information on their impacts on reef habitats, communities and species. A recent study on this issue in the UK noted little effect during deployment and hauling of pots and, in general, the habitats and communities investigated appeared to be relatively unaffected by this type of fishing. The Ross coral, *Pentapora foliacea*, which has a fragile structure and which is thought to provide important microhabitats for other species, was the only species found to be damaged after hauling when pots came into contact with colonies. The seafan, *Eunicella verrucosa*, which is slow growing and thought to be highly vulnerable to damage, was found to bend under the weight of pots and return to an upright position once the pots were hauled. No significant differences in the abundance of monitored species were observed at the study site after one month's active fishing. Long-term and cumulative effects were not investigated as part of this study [14]. Impacts on otters are discussed in Section 5.3.

The likely effects of lost pots have also been investigated. An experimental simulation of lost parlour pots revealed that they continued to fish throughout the 270 day period of the study[14]. Catch rates were highest during the first month and there were some differences in the pattern of capture between the species caught. There was a slight temporary decrease in catches of brown crab after the bait was depleted followed by fairly constant capture, whereas catches of spider crab declined steadily throughout the period of the experiment. The condition of the catch in the pots deteriorated with time, indicated by the increased loss of limbs from crustaceans and fish with skin damage. A similar study in British Columbia of pots used to catch Dungeness crab (*Cancer magister*) reported that lost pots continued to attract crabs - catch rates were as high after 1 year as they were 2 weeks into the study[84]. The information to date suggests that it is clearly possible for catches to continue for a considerable period and various management suggestions are made, within the reports, to decrease ghost fishing.

4.7.2 Finfish and scallops

Mobile gears such as trawls may also operate on or near reefs eg. rock hopping gear, but rocky seabeds are generally avoided because of the potential damage to gear. The same applies to scallop dredging although spring-loaded or 'Newhaven dredges' have been designed to cope with these conditions allowing sandy/gravelly pockets of sediment within reefs to be fished in this way. Gill netting can also take place over reefs as well as other habitats. For ease of reference their effects and those of trawling are described in sections dealing with shallow inlets and bays and sandbanks (4.5). The main discussion about scallop dredging is also in section 4.5.3. although there is some consideration of its effects on reefs below.

The use of rock hopping and spring loaded dredges allows trawling and scalloping to extend beyond areas of soft seabed and on to reefs. This is particularly the case if the rock is relatively soft, making them vulnerable to structural damage as well as removal of epifauna, as shown by a study in Lyme Bay, South Devon[12]. This study showed that hydroids, anemones, corals, bryozoans, tunicates and echinoderms are vulnerable to mobile fishing gear.

Biogenic reefs may also suffer impacts from fishing activity. There are reports of *Sabellaria spinulosa* and oyster beds being severely damaged by trawling activity [8].

Table 6. Summary of the potential effects of fisheries on reefs

Fishery	Methods	Potential effects
Crab, lobsters, crawfish	Potting and creeling	! Fragile, brittle species such as Ross coral crushed when pots make contact. ! 'Ghost fishing' - parlour pots can continue to fish in excess of 270 days. A cycle of capture, decay and attraction of species of commercial and non commercial interest takes place.
Scallops	Spring loaded Scallop dredge	! Relatively soft rocky outcrops can be subject to physical damage. ! Soft, fragile species vulnerable to mobile gear.
Demersal fin fish	Rock hopper trawl	! Relatively soft rocky outcrops can be subject to physical damage. ! Soft, fragile species vulnerable to mobile gear.

4.8 Lagoons

Candidate SACs for lagoons: The Vadills, Loch of Stenness, Loch Roag Lagoons, Loch Eport Lagoons, Loch Nam Madadh, Chesil & The Fleet, Solent and Isle of Wight Lagoons, Orfordness-Shingle Street, Benacre to Easton Bavents Lagoons, North Norfolk Coast and Gibraltar Point Dunes.

Lagoons in the UK are essentially bodies, natural or artificial, of saline water partially separated from the adjacent sea. They retain a proportion of their sea water at low tide and may develop as brackish, fully saline or hyper-saline water bodies. They provide important habitat for waterfowl, marshland birds and seabirds and the presence of certain indigenous and specialist plants and animals.

4.9 Fisheries associated with lagoons

Commercial fisheries are rare in the lagoons which have been proposed for SAC status although some aquaculture does take place. This fishing activity is more common in inlets and bays and is therefore discussed in section 4.5.4, however, lagoons are more vulnerable to aquaculture related impacts due to their restricted water exchange.

4.10 Submerged and partly submerged sea caves

Candidate SACs for caves: St.Kilda, Thanet Coast, Flamborough Head, Papa Stour, Berwickshire & North Northumberland Coast, Rathlin Island.

Caves are generally unsuitable areas for fishing and are therefore unlikely to be damaged or deteriorate as a result of fishing activity. There may however be some potential for effects on species using these areas. Grey seals haul out in intertidal caves and use these sites for pupping. Disturbance is likely to be the main threat to them in these situations. No references were found on the effects of fishing activity on this habitat.

5. The potential effects of fishing on Annex II species

5.1 Grey seal (*Halichoerus grupus*) and common seal (*Phoca vitulina*)

Candidate SACs for grey seal: North Rona, Monach Islands, Pembrokeshire Islands, Berwickshire & North Northumberland Coast, Faray & Holm of Faray

Candidate SACs for common seal: Mousa, Wash & North Norfolk Coast, Sanday.

The two species of seal found in UK waters (grey seal and common seal) are both listed in Annex II of the Habitats Directive. Grey seals tend to live in rocky wave exposed sites and form large breeding aggregations on land during autumn. The pups remain on shore for 3-5 weeks. Although generally having a coastal distribution, grey seals are known to travel considerable distances. Common seals favour more sheltered inshore areas, using islands and sand banks as haul out sites. They tend to be more localised than grey seals, staying in the same general area to breed, feed and rest, and do not form as large breeding colonies. The pups usually leave the shore on the first high tide after birth.

Seals have been caught in mobile fishing gear but in most cases they are associated with static gears. Incidental catch of grey seals and common seals in gill nets has been widely reported [19,43]. Mortality of grey seals consistent with being entangled in gill nets has been recorded and it has been suggested that young seals are more likely to become caught in this way [10,19].

Mortality may also result from capture in anti-predator nets set around salmon farms [19,41,59]. Fish farm operators and fishermen are permitted to shoot seals, under the Conservation of Seals Act 1970, to prevent damage to their nets or any fish within them. The impact of this is difficult to assess but is probably localised and limited in extent. Although it could have a significant effect on local populations[89], seal mortality around fish farms and other fishery related mortality has not had a deleterious effect on the seal population in UK waters [19,41].

Some of the studies looking at the effects of fisheries on seals have information from areas in and around European marine sites (Cardigan Bay [10], Farne Islands [19], Orkney[43]) but the more general studies, for example covering the North Sea [9,43], are also relevant as this type of mortality can occur far from the breeding and haul out sites which have been selected as European marine sites. This is particularly the case for grey seals where non-breeding adults have been tracked more than many hundreds of kilometres from capture sites. Common seals are more likely to stay in the vicinity of breeding sites although they can switch to other sites.

Table 7. Summary of the potential effects of fisheries on grey and common seal

Fishery	Methods	Potential effects
Demersal fin fish	Gill netting	! Accidental capture whilst foraging in or around nets. ! Legal shooting by fishermen to prevent damage to nets or the fish within the nets. This is likely to be localised and limited in extent and has not had a deleterious effect on UK seal populations.
Salmon farming	Fish cage	! Entanglement in anti-predator nets. ! Legal shooting by fish farm operators to prevent damage to nets or the fish within the nets. This is likely to be localised and limited in extent and has not had a deleterious effect on UK seal populations.

5.2 Bottlenose dolphin (*Tursiops truncatus*) and harbour porpoise (*Phocoena phocoena*)

Candidate SACs for Bottlenose dolphin: Cardigan Bay, Moray Firth
Proposed SACs for Harbour porpoise: None

Bottlenose dolphin and harbour porpoise are two of the thirty five species of whales and dolphins which have been recorded in European seas. The bottlenose dolphin is commonly seen in coastal waters and resident or semi-resident groups are known from a number of locations around the UK. Large schools, which do not appear to be linked to any particular area, may also be seen in coastal waters. Harbour porpoise are also seen regularly in certain coastal areas with peak numbers between March and April and July to November. They are not confined to coastal areas, moving offshore at other times of year.

Cetaceans are accidentally caught by trawlers and seiners but set net fisheries, which include gill nets, drift nets & trammel nets, account for the majority of marine mammal by-catch in British waters[23,34]. The harbour porpoise is considered to be one of the more vulnerable cetaceans to entanglement in nets[8,9,31,43,34,35]. Analysis of stranding data collected between 1990-95 records this as one of the most frequent causes of death of harbour porpoises (38% of those examined)[23]. The annual by-catch from the Danish set net fishery in the eastern North Sea has been estimated to be more than 5,000 animals.

There are reports of harbour porpoise being caught by long-line fisheries, entangled in creel or pot lines and salmon stake nets but the numbers are not thought to be significant [19]. There are also reports of dolphins (unspecified) being caught in anti-predator nets around fish farms [19,59]. These and other reports suggest that certain nets and locations may precipitate catches of cetaceans. It is reported, for example, that harbour porpoises are more likely to be entangled during storms or at night and it has been suggested that modification in fishing methods or use of reflective knots in netting and acoustic warning devices may reduce the occurrence of entanglement [19]. There are presently experiments to examine the effectiveness of these under the EU-funded BYCARE programme.

The impact of incidental capture on porpoises populations around the UK is not known. However it has been suggested that incidental by-catch could be a significant contributory factor in the overall decline in abundance of harbour porpoise in European waters [9] and a serious cause of concern in relation to Celtic Sea populations in particular [81]. In other parts of the world there are examples where decline in populations are considered to be at least partly a result of entanglement in gill nets. A study of incidental catch of harbour porpoise in SW Bay of Fundy (Canada), for example, suggested that significant changes in length frequencies of the porpoises could be attributed to the fishery, and that sustained adult mortality in the gill-net fishery may have compressed the size, and possibly the age structure of the population [31]. Given the slow reproductive rate of the harbour porpoise, these catches were considered to be a serious threat to the relatively discrete harbour porpoise population in the area.

"Ghost fishing" by discarded and lost netting may also have an impact on marine mammal populations[8,9,45] but no quantitative information on likely effects was found during this literature review.

Table 8. Summary of the potential effects of fishing on bottlenose dolphin and harbour porpoise

Fishery	Methods		Potential effects
Mid-water Pelagic	Trawling	!	Accidental capture in trawls but insufficient data regarding species and numbers.
Demersal fin fish	Gill netting, drift nets, trammel nets set nets	!	Accidental entanglement and capture. It is considered that this is the most frequent cause of death of stranded harbour porpoise in the UK and, with their slow reproductive rate, means that there could be a serious threat to sustainability of discrete populations.
Salmon farming	Fish cage	!	Entanglement in anti-predator nets

5.3. Otter (*Lutra lutra*)

Candidate marine SAC: Yell Sound Coast, Afon Teifi

Otters live on the coast as well as along inland water courses. In coastal environments they forage in intertidal and shallow rocky areas, feeding on fish and crustaceans, and therefore come into contact with certain types of fishing gear. They are known to be attracted to eels, fish, and crustaceans which are used as bait or caught in fyke nets and creels. There is documented evidence of otter mortality in fyke nets, creels (for lobsters, crabs and prawns), fish farm nets and wade nets[19,48,49] as well as through entanglement in lost fishing net [50]. A survey of drowned otters in lobster creels off the Uists revealed that the majority drowned while foraging in depths of 2-5 m and that mortality increased with the incorporation of a parlour in the creels used in the area [46]. Crab creels did not appear to pose such a threat as the gear was usually set on sandy seabed in deeper water, further offshore, and therefore outside the favoured foraging area of otters[47].

The majority of documented deaths of otters in these types of fishing gear are of adult females[46,48]. The areas of capture correspond to sites where the fisheries operate near otter populations but data suggest that eel fyke nets can also attract and kill otters living at very low densities[51]. A marked concentration of drownings in autumn and winter has been recorded and may be partly explained by the seasonality of fish and the fact that this is when their main food may not be as easily available, leading them to investigate prey in nets and pots [51]. Various types of otter guards have been tested and some form of guard is now mandatory for eel fyke nets. No suggestions have been put forward on how to reduce the threat from crustacean traps nor is there a clear indication of whether mortality from this cause is a conservation problem.

Table 9. Summary of the potential effects of fishing on otters

Fishery	Methods	Potential effects
Eels	Fyke nets	! Inquisitive and foraging otters accidentally caught in these nets has led to mandatory use of otter guards.
Crustaceans	Pots and creels	! Inquisitive and foraging otters accidentally caught in these traps. Occurrence of accidental capture may be linked to season and availability of food.

5.4 Allis shad (*Alosa alosa*) and twaite shad (*Alosa fallax*)

Candidate SACs: Afon Tywi, River Wye, River Usk

Allis shad (*Alosa alosa*) and Twaite shad (*Alosa fallax*) migrate up rivers to spawn, the adults returning immediately and juveniles at a later stage. The population of the Allis shad in the UK has declined since the mid-nineteenth century to the point where it has a sporadic distribution around the coast with no known spawning grounds/rivers. The Twaite shad has also declined and spawning populations are thought to be restricted to the Severn, Usk, Wye and Twyi and possibly rivers feeding the Solway Firth.

Static gear fisheries operate in the locations frequented by both species and there are reports of catches in drift nets and salmon nets as well as occasional catches by anglers [61]. The main reasons for the decline of these species are considered to be poor water quality and obstructions in rivers which prevent migration for spawning rather than any impact associated with fisheries [61].

Table 10. Summary of the potential effects of fishing on allis and twaite shad

Fishery	Methods	Potential effects
Demersal fin fish, pelagic mid-water	Trawling, netting	Accidental by catch, but main reason for decline due to poor water quality and blocked migration routes.

5.5 Lampern (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*)

Candidate SACs: River Wye, River Usk

The lampern (*Lampetra fluviatilis*) is widespread in the UK with substantial populations in some rivers and streams although not present in others where they used to be common. The main populations are probably those which migrate into the Severn estuary from the Bristol Channel and adjacent offshore waters. The sea lamprey (*Petromyzon marinus*) is uncommon in the UK and although found around the coast, the main population centres are concentrated on the Bristol Channel. Both species migrate up rivers to spawn and spend the larval stage buried in the muddy substrates in freshwater. Once metamorphosis takes place the adults migrate to the sea where they live as a parasite on various species of fish.

The sea lamprey has been commercially fished throughout its European range but this is now generally limited to some small local fisheries. The main reasons for its decline and that of the lampern are considered to be poor water quality, and obstructions in rivers which prevent migration for spawning rather than any impact associated with fisheries [61].

Table 11. Summary of the potential effects of fishing on lampern and sea lamprey

Fishery	Methods	Potential effects
Demersal fin fish	Long line, Trawling	Accidental by catch, but main reason for decline due to poor water quality and blocked migration routes.

5.6 Sturgeon (*Acipenser sturio*)

Possible SACs: None

The west European (Atlantic) population of the common sturgeon (*Acipenser sturio*) is known to have had a range extending from the Atlantic coast of France to the Severn Estuary and Pembrokeshire in western Britain, and up to the Firth of Forth on the Scottish east coast and the Limfjord on the west coast of Denmark in the North Sea. There are now few catches in these waters and the only location where a spawning stock is known to remain in this range is the Gironde basin in France. The adults migrate into estuarine and brackish waters to spawn and juveniles move between estuaries and the sea. The causes of its decline in Europe have been a directed fishery, pollution of the lower reaches of rivers, damage to spawning grounds and man-made obstacles restricting migration. There have also been reports of accidental catches in trawls and nets at sea and in estuaries when fishing other species, which add another pressure on stocks[60].

The sturgeon is only occasionally reported in UK waters and unlikely to be found moving into estuaries to spawn. Reintroduction programmes are being considered in France and if sturgeon do become more common in UK waters as a result, the reduction of physical obstacles for migrating fish, safeguarding spawning grounds in rivers and estuaries, and care over any incidental catch will be important factors in assisting any recovery [60,61].

Table 12. Summary of potential effects of fishing on sturgeon

Fishery	Methods	Potential effects
Demersal fin fish	Trawling, netting	Accidental by catch, but main reason for decline due to poor water quality and blocked migration routes.

6. Seabird species

Classified SPAs with significant inter-tidal element* : Alde-Ore Estuary, Alt Estuary, Benacre to Easton Bavents, Benfleet and Southend Marshes, Blackwater Estuary, Breydon Water, Burry Inlet, Castlemartin Coast, Chesil Beach and The Fleet, Chichester and Langstone Harbours, Colne Estuary, Coquet Island, Deben Estuary, River Crouch Marshes, Dengie, Duddon Estuary, Exe Estuary, Farne Islands, Flamborough Head and Bempton Cliffs, Foulness, Gibraltar Point, Glannau Aberdaron and Ynys Enili, Glannau Ynys Gybi, Grassholm, Great Yarmouth North Denes, Hamford Water, Humber Flats Marshes and Coast, Lindisfarne, Medway Estuary and Marshes, Mersey Estuary, Minsmere-Walberswick, Morecambe Bay, North Norfolk Coast, Old Hall Marshes, Pagham Harbour, Portsmouth Harbour, Ramsey and St Davids Peninsula Coast, Ribble and Alt Estuaries, Rockcliffe Marches, Severn Estuary, Skokholm and Skomer, Stour and Orwell Estuaries, Tamar Estuaries Complex, Teesmouth and Cleveland Coast, Thanet Coast and Sandwich Bay, The Dee Estuary, The Swale, The Wash, Traeth Lafan, Upper Solway Flats and Marshes, Ynys Feurig, Cemlyn Bay and the Skerries, Monach Isles, North Uist Machair & Islands, Dornoch Firth and Loch Fleet, Moray & Nairn Coast (Moray Basin Firths & Bays), Loch of Strathbeg, Ythan Estuary Sands of Forvie & Meikle Lochs, East Sanday Coast, Gruinart Flats, Bridgend Flats (Islay), Montrose Basin, Cromarty Firth, Inner Moray Firth, Loch of Inch and Torrs Warren, South Uist Machair & Lochs.

Potential SPAs with significant inter-tidal element* : Dungeness to Pett Levels, Northumberland Coast, Poole Harbour, Southampton Water and Solent Marshes, Thames Estuary and Marshes, Inner Clyde Estuary, Firth of Tay and Eden Estuary, Firth of Forth.

* As at September 1999

The Birds Directive is concerned with the conservation of all species of naturally occurring birds in the wild state in the territory of Member States. Measures are required to preserve, maintain or re-establish a sufficient diversity and area of habitats for these species through the creation of protected areas, the upkeep and management of habitats inside and outside these areas, and the re-establishment of destroyed biotopes and creation of biotopes. The site protection measures require the classification of Special Protection Areas (SPAs) for species listed in Annex I of the Directive. Eleven of these are seabirds which occur around the UK (see Table in Annex 1) although some, like the Mediterranean gull, and Cory's shearwater are only observed on an occasional basis. The Directive also specifies that special conservation measures should be taken with regard to the habitats of regularly migrating species not listed in Annex I (see Table in Annex 2 to this report). The effect of various fishing practices on seabirds and migrating birds are discussed below.

6.1 Static and drift net fisheries

Set nets of various types are a particular hazard to diving seabirds and have been implicated in the decline of seabird populations in some parts of the world [7,8,9,17,29]. In northern Norway, for example, the breeding populations of guillemots at two sites are estimated to have declined by 95% from the early 1960's to 1989, a figure which could be explained entirely on gill net mortalities based on observed catch rates. The numbers of birds killed in nets depends on their abundance, diving habits and distribution within the fishery area [7]. Species which have been caught in these nets include shearwaters, red-throated divers, Leach's petrel, gannet, shag, guillemot, razorbill, and great northern diver. Ducks such as the common scoter and long-tailed duck are also known to have become entangled and die in set nets [7].

Inshore gill nets can have a relatively high incidental by-catch around diving seabird colonies or where there are high densities gathered on the water surface, making it inadvisable to set nets in such areas. Large numbers of razorbills are known to have drowned in gill nets at the mouth of the Tagus estuary in Portugal, for example, where this species congregates on occasions [43]. Nets set for bass have caught large numbers of diving birds (mostly razorbills and divers) and in one incident in the UK an estimated 900 auks were caught over 8 days in nets set below seabird colonies[17]. Herring nets and bottom-set cod nets have also killed large numbers of diving seabirds (an estimated 25,000 in the southeast Kattegat between 1982 and 1988), most of which were found in the bottom-set cod nets[45], and catches of shags in trammel nets may be a threat to populations of this species in Spain [43]. The threat will depend on which species are present at the time nets are put out, weather, tidal fluctuations and fishing effort. Gill and tangle net fisheries in Cardigan Bay, for example, often occur at or near the cormorant colony but to date there has been no major entanglement problem [10].

High incidental catches of guillemots, razorbills and divers have been reported in drift nets from Danish fisheries, and significant catches of auks in the salmon driftnet fisheries in Ireland and Denmark[43]. Anti-predator nets around aquaculture facilities are also known to entangle seabirds[59,82]. Ghost fishing by lost nets and fragments of nets is also known to entangle birds but the scale of mortality associated with this is unknown [45]. Similarly, the effect of non-net fisheries, such as long lining and pots, and in mobile nets is not well known in UK waters although catches are reported from elsewhere.

The direct and indirect effects of molluscan shellfisheries and aquaculture on birds are mentioned in sections 4.3.1 and 4.5.4.

An indirect effect of some finfish fisheries has been an increased food source for some seabirds resulting from the discarding of by-catch and offal. The discards are taken by species such as fulmar, gannet, great skua, common gull, great black-backed gull and herring gull and appear to have contributed to the rapid growth of some seabird populations. It is now considered to be such an important component of the diet of scavenging seabirds in the North Sea that changes in the amount of discards may affect the relative and absolute abundance of various species. Using fisheries data from the late 1980's and early 1990's, the number of seabirds potentially supported by the fishery waste from North Sea fisheries has been estimated to be around 5.9 million and an area based analysis suggests that discards may easily support all scavenging seabirds in southern and southeastern sub-regions of the North Sea[55].

Table 13. Summary of potential effects of fishing on sea birds listed in the Birds Directive

Fishery	Methods	Potential effects
Demersal fin fish, Pelagic fin fish	Gill netting	! Accidental capture of diving birds foraging for food in and around nets. ! Increase in scavenging seabird populations due to the increased availability of food caused by discarding of unwanted catch and offal.
Salmon farming	Fish cage	! Entanglement in anti-predator nets
Intertidal molluscan shellfish	Hydraulic & tractor dredge, hand gathering	! Short term increase in scavenging seabirds due to increased food ! General disturbance of feeding and roosting birds.

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Annex 1. Summaries of reviewed publications

Details are limited to information relevant to the UK marine habitats and species listed in the Habitats Directive and the Birds Directive.
[pr] indicates that the paper is from a peer reviewed journal or report

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 1 **Sandbanks** **Shallow inlets and bays** (Fine to medium hard sandy sediments)	Beam Trawling	Pre and post experimental investigation, within 30m depth contour, with 7 tonne, 12m beam trawl including 5x22mm and 3x18mm tickler chains, 3x20mm and 8x14mm net tickler chains, mesh size of 9cm in the cod-end. Area trawled three times over 2 days and samples taken up to 2 weeks after trawling. <u>Habitat effects</u> **-** Tickler chains penetrate at least 6cm into the sediment surface indicated by catches of *Echinocardium cordatum* and *Arctica islandica*. Tracks made by the beam trawl shoes still apparent on sidescan sonar after 16hrs. <u>Species and community effects</u> **-** Some benthic species show a 10-65% reduction in density after trawling the area three times. There was a significant lowering of densities (40-60%) of echinoderms *Asterias rubens* and small *E. cordatum*, and of polychaete worms *Lanice conchilega* and *Spiophanes bombyx*. Vertical distribution in sediment appears to be an important factor in catchability. Decrease in density (10-20%), although not significant for small crustaceans and larger *Tellina fabula* and *E. cordatum*. Except for the starfish *A. rubens* most of these animals live in the sediment at a depth up to 15cm. The effect of beam trawling on densities of small individuals tends to be much greater than on densities of large individuals (larger animals tend to live deeper or have better escape possibilities). The polychaete worm *Magelona papillicornis* showed a considerable increase in numbers, this may be attributable to a change in the vertical distribution of the species in the sediment. The numbers of small *Ophiura* living in the top centimetre of sediment did not change after trawling the area three times, suggesting the species escape unharmed through the net mesh. Also no direct effect on densities of molluscs (except *T. fabula*) and worms (except *Magelona papillicornis*, *L. conchilege* and *S. bombyx*). Less abundant worm species (including *Spio filicornis Scolelepsis bonnieri*, *Scoloplos armiger* and *Owenia fusiformis*) and less abundant molluscs (including *Thracia sp. Venus striatula*, *Montecuta ferruginosa* and *Mysella bidentata*) showed no change in total density after trawling. About 90% of *A. islandica* caught by the 22m trawl were severely damaged. Conclusions were that direct effects on some benthic species in the area appears to be considerable and that beam trawling may contribute to changes in benthic systems in the North Sea. However, direct effects cannot be extrapolated to interpret long-term effects as there was no comparison with untrawled areas.	Southern North Sea	Bergman M.J.N. & Hup M. (1992) Direct effects of beam trawling on macro-fauna in a sandy sediment in the southern North Sea ICES Journal of Marine Science. 49:5-11 [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 2 **Sandbanks Shallow inlets and bays** (Coarse sand, gravel and broken shell)	Beam Trawling	Experimental beam trawl over a 4x2km area, at a depth between 26 and 34m. commercial beam trawl, weighing 3.5 tonne fitted with a chain matrix and 8cm diamond mesh cod-end used. Waylines were fished either 10 or 20 times to adequately disturb trawl area. <u>Habitat effects</u> **-** Physical characteristics of the surface sediment were altered by the passage of the beam trawl but effects varied in different parts of the experimental area. Surface roughness of the relatively uniform, stable, flat areas were not altered by trawling but lowered in fished sites in the SE sector which was characterised by sand waves and some ripples. In the latter case the surface ripples were flattened but the megaripples were unaffected. Passage of the chain matrix may have caused sediment to become unconsolidated as shell and gravel currents. Conclusions were that particle size distribution was not affected and observed changes may only be in the superficial layers of the sediments. Newly exposed shell and gravel material would provide surfaces for recolonisation and settlement, epizoites on surfaces which were overturned would be smothered. <u>Species and community effects</u> **-** Beam trawling altered the benthic community structure in the uniform, stable, flat areas having a measurable deleterious effect on the number, abundance and diversity of taxa. Of the top 20 most common taxa, abundance of 19 were lowered at fished sites, 9 of which were statistically significant. Fragile infaunal species which live on or within the surface sediments (bivalves, holothurians, gastropods) were particularly vulnerable to damage or disturbance. The abundance of sedentary and slow-moving animals organisms was significantly lowered. Some animals were fatally injured or crushed, others only damaged (eg cropping of *Mya* siphons). Tissues of animals damaged by beam trawling rapidly attract scavengers. Analysis of diet indicated they were feeding on the damaged animals, most notably *Ampelisca* spp. There were no detectable differences in the diversity and abundance of taxa in the areas characterised by mobile sediments and subject to frequent natural disturbance.	Liverpool Bay	Kaiser M.J. & Spenser B.E. (1996) The effects of beam trawl disturbance on infaunal communities in different habitats. Journal of Animal Ecology. 65:348-358. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 3 **Sandbanks** **Shallow inlets and bays**	Scallop Dredging	Large scale investigations on soft sediment communities depth between 12-15m, 2km offshore. Six vessels towing 3m wide commercial ‹Peninsula' dredge with scraper/cutter bars not extending below the dredge skids. Site dredged for 3hrs day^{-1} over 3 days covering the dredge area at least twice. Dredging intensity typical of local commercial fishing intensity. <u>Habitat effects</u> **-** Typically top 2cm of surface sediment disturbed but up to 6cm. Observations 8 days after dredging revealed seabed formations such as pits and depressions filled in and mounds formed by burrowing shrimps removed. Parallel tracks from dredge skids apparent after dredging. Physical changes in the seabed still apparent one month post-dredging. Six months post dredging most physical features reformed (abundance and size of callianassid mounds similar to those present before dredging) however some flattened areas still apparent. No physical differences between dredged and control sites after 11 months. <u>Species and community effects</u> **-** Number of species in dredged areas decreased significantly. Maximum impact did not occur immediately after dredging suggesting some indirect ecological changes such as uncovered organisms becoming more vulnerable to predation by invertebrates and demersal fish. Most species decreased in abundance by approximately 20-30% in the 3.5 months after dredging. The duration of the decrease in abundance species varied with effects still apparent in some species after 8 months and in two species up to 14 months although this was possibly due to undersampling in the pre-impact period. 11 animals not found in the sample area after dredging, mostly sedentary and therefore unable to re-establish except by larval recruitment. Susceptibility to dredging not correlated to feeding type or rarity. Fragile groups such as nemerteans were greatly damaged by dredging, polychaetes probably cut and killed by passing dredge. Other species may have been affected by high rates of dredging induced sedimentation, which may be 2-3 orders of magnitude greater than storm produced sedimentation, or buried when depressions filled in. Two species showed significant increase in abundance following dredging (*Diamorphostylis cottoni* and *Oedicerotid sp.*) whereas the isopod *Natalolona carppulenta* decreased sharply and then increased to be consistently higher on the dredged plot for 8 months possibly due to greater availability of prey. Seasonal and interannual changes in community structure much greater than those caused by dredging. Long-lived and slow recruiting epifaunal species (eg sponges and ascidians) likely to be	Port Phillip Bay, Australia	Currie D.R. & Parry G.D. (1996). Effects of scallop dredging on a soft sediment community: a large scale experimental study. Marine Ecology Progress Series. 134: 131-150. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 4 **Shallow inlets and bays** **Sandbanks** (Soft sediment)	Beam Trawling	*Artica islandica* used as an indicator species for investigation of long-term effects of beam trawling intensity in the North Sea. <u>Species and community effects</u> **-** A high incidence of damage found on shells of *Artica islandica* from highly fished areas particularly in the south eastern North Sea. In specimens with two values only 10% of the SE North Sea specimens were undamaged and in other areas around 40% undamaged. 80-90% of the damage found on posterior ventral side of the shell explained by the orientation of the living shell in the upper sediment layer and the horizontal motion of tickler chains. Observed trends in the occurrence of shell scars per year show a striking coincidence with the increased capacity of the Dutch beam trawling fleet since 1972. Another effect may be on age frequency distribution as juveniles (1-4cms) were rarely found in the SE North Sea. Less resistance to damage may be a factor although the authors indicate that other researchers have contradictory information on this.	North Sea with sampling clusters in the NW, mid-west and SE	Witbaard R. & Klein R. (1994). Long-term trends on the effects of the southern North Sea beamtrawl fishery on the bivalve mollusc *Artica islandica* L. (mollusca, bivalva). ICES Journal of Marine Science. 51: 99-105. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 5 **Estuary** **Mudflats and sandflats** (Waders and wildfowl)	Mechanical cockle dredge	Experimental dredging using tractor towed cockle harvester. Habitat effects **-** Vehicle tracks and dredging furrows created. Species and community effects **-** Dredging attracted black-headed and common gulls which fed on very small prey items lying on the surface of harvested furrows including *Crangon*, *Corophium*, broken cockles, intact small cockles which pass through the drum, and polychaetes. The number of birds attracted and the places they fed depended on the abundance of prey items revealed by harvesting and presence of people. Peak count at Llanrhidian was 200 black-headed gulls and 55 common gulls, mostly adults which fed preferentially in the most recently harvested furrows. Other species present were curlew, dunlin and oyster catchers. The increased feeding activity of birds was short lived, 14 days for oystercatchers and 7 days for gulls and small waders. Significant reduction in bird feeding activity apparent thereafter and still detectable after four months. Oystercatchers responded more quickly to changes suggesting harvesting may have been less disruptive or recovery quicker. Overall the short term increase in the number of gulls and waders in the harvesting area was followed by a long term significant reduction in feeding opportunities for bird species. Birds may then leave to find food elsewhere, leading to the considerable alteration in normal seasonal distribution pattern of shorebird populations. Average density of birds were reduced in this trial by between 15 and 75% in harvested area.	Burry inlet (east of Whiteford Point and northern edge of Llanrhidian marsh)	Ferns P.N. (1995). The effects of mechanised cockle harvesting on bird feeding in the Burry Inlet. p11-18. In Burry Inlet & Loughor Estuary Symposium, March 1995. Part 1. Burry Inlet and Loughor Estuary Liaison Group.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 6 **Estuary** **Mudflats and sandflats**	Mechanical cockle dredge	Experimental dredging of sandflats with mechanical cockle dredge. Two distinct sites sampled. Site A: Poorly sorted fine sand with small pools and *Arenicola marina* casts with some algal growth. Site B: Well sorted fairly coarse sand, surface sediment well drained and rippled as a result of wave activity. Habitat effects **-** Dredge track visible after 6 months at Site A (stable sediments). No alteration in sediment parameters by dredging at Site B (mobile sediments). Community effects **-** Effects of dredging on biota apparent at Site A after 3 months may be attributed to destruction of seabed algal covering, destruction of permanent tube dwellings, mortality of eggs/broods, interference with predator prey relationships or changes in sediment characteristic. Seasonal perturbation eg produced by winter storms produce community changes of greater magnitude than those caused by dredging in unstable high energy environments such as Site B. Site A (stable sediments): Decreased number of *Pygospio elegans* no recovery to pre-dredging numbers by six months. Disappearance of *Scoloplos armiger* from some dredged plots. Distribution of *Nephtys hombergii* disturbed by dredging recovery after six months. Large decline in numbers of *Hydrobia ulvae*, statistical difference between dredged sites and control sites up to six months post-dredging. *Cerastoderma edule* numbers reduced by dredging, significant reduction in numbers compared with the control still apparent up to six months post-dredging. Site B (mobile sediments): Populations of *Bathyporeia pilosa* exhibit greater fluctuations in numbers of individuals post-dredging. Initial reduction in the population densities of *Hydrobia ulvae, Pygospio elegans, Cerastoderma edule*, *Nematoda spp.* and *Psammodrilaida* after dredging followed by rapid recovery (no difference between control and experimental plots after 14 days). Increase numbers of Nematode attributable to dredging.	Llanrhidian Sands, Burry Inlet.	Rostron D.M. (1995). The effects of mechanised cockle harvesting on the invertebrate fauna of Llanrhidian sands. P111-117. In Burry Inlet & Loughor Estuary Symposium, March 1995. Part 2. Burry Inlet and Loughor Estuary Liaison Group.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 7 **Red throated diver** **Great North diver**	Set Nets	Review paper. Coastal net fisheries have been implicated in declines of numerous seabird populations but there are substantial difficulties in establishing cause of a population decline. Synthetic nets have been implicated as a major contributor to the decline of several auk populations. Species effects **-** Diving seabirds more vulnerable to entanglement in set nets. Number of birds killed depends on their abundance, diving habits and distribution within the fishery area. Incidental catch of seabirds can be very high around colony sites. Large numbers of shearwaters have been caught in nets. Species of particular importance in European terms known to be caught in nets include: red-throated divers, Leach's petrel, gannet, shag, Brunnich's guillemot and razorbill. In Britain Great northern diver, Slavonian grebe, scaup, common scoter, long-tailed duck and guillemot can be added to the list. Threat to wildlife depends on netting effort and wildlife concentrations. There is temporal and spatial variation in these threats which may be reduced by manipulating where and when fishing takes place.		Harrison N. & Robins M. (1992). The threat from nets to seabirds. RSPB Conservation Review 6: 51-56.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 8 **Estuaries** **Shallow marine inlets** **Mudflats and sandflats** **Sandbanks** **Reefs** **Grey seal** **Common seal** **Harbour porpoise** **Bottlenose dolphin** **Seabirds**	Longline Gill nets Scallop dredging Mussel dredging Purse seine Hydraulic dredging Otter trawling	Review paper covering many fishing techniques. Habitat effects - Subtidal rocky habitats characterised by encrusting communities that are resilient to predation and invasion are extremely vulnerable to mussel dredging as these organisms often have poor dispersal mechanisms and slow growth rates. Desertification of such habitats recorded in Italy following intensive and destructive mussel dredging. Reefs extremely vulnerable to fishing as they often represent islands in seas of soft sediments making recolonisation from surrounding areas unlikely. Intertidal and subtidal soft sediment communities are vulnerable to fishing and as they are often close to areas of population density, heavily fished. Bottom fisheries have resulted in the destruction of *Zostera* beds and saltmarsh vegetation. Calcareous algal bed of maerl destroyed by 8 passes of a dredge in Scotland. Reef building polychaete *Sabellaria spinulosa*, seagrass *Zostera marina* and oyster beds *Ostera edulis* destroyed by trawling. Hydroid and brozoan habitats lost in English Channel. *Zostera marina* indirectly impacted by increased turbidity, replaced by deposit feeding polychaetes, community composition shifts such as these may resist the recovery of suspension feeding species. Epifauna often play key roles in influencing the structure and stability of benthic communities, modifying benthic boundary flow which further influences sediment characteristics and so the settlement of larvae. Epifauna may also provide a refuge for juvenile species from predators. Organisms which stabilise the seabed can also mitigate the effects of natural disturbances such as storms. Modification of microbial activity induced by bottom fishing, resuspension of pollutants, increased benthic/pelagic nutrient flux. With repeated trawling the intense disturbance may select for species with the appropriate facultative responses, communities will become dominated by juvenile stages, mobile species and rapid colonists. Large amounts of discards falling to the seabed cause anoxia in bottom sediments the discards decay using up oxygen, kills scavenging organism attracted by the discards. Decaying discards may also harbour disease and have caused the elimination of a scallop fishery in Australia. Species effects - Diving seabirds more vulnerable to entanglement in set nets. Number of birds killed depends on their abundance, diving habits and distribution within the fishery area. Incidental catch of seabirds can be very high around colony sites. Large numbers of shearwaters have been caught in		Dayton P.K., Thrust D.F., Agardi M.T. & Hofman R.J. (1995). Environmental effects of marine fishing. Aquatic conservation: marine and freshwater ecosystems. 5:205-232. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
		Species and community effects - Longline: Swordfish fishery North Western Atlantic took several times more shark than swordfish resulting in grey seal population rising from 3000 to 45000. Grey seals *Halichoerus grupus* acted as a primary host for parasites which then infected cod. Population density may have increased stress in seals causing a population decline. Gill nets implicated in the extinction of several species. Adult survivorship is extremely important for marine mammals and birds as they have slow reproductive capacity and low fecundity therefore they are high vulnerable to even moderately increased mortality. Incidental by-catch of highly mobile predatory marine mammals likely to be higher than less mobile species as they are efficient foragers and are likely to be attracted to nets laden with fish. Approximately 500-1000 harbour porpoise caught annually in Danish waters. Catch rate of harbour porpoise approximately 0.1 individuals/km of net/day probably an underestimate. Porpoise populations substantially reduced by the Pacific tuna purse seine fishery. Ghost fishing by discarded and lost netting may be significant and persistent, impacting not only on non-target species such as birds and marine mammals but also on fisheries themselves. Complete loss of sessile fauna on rocks and cobbles caused by the action of fishing gear on the seabed. Hydraulic dredging causes complete loss of sessile benthic fauna which are killed by the heat. Otter trawling causes massive amount of by-catch including crab, scallops, starfish. Mortality for some species can range from 10% in starfish to 90% in *Arctica islandica* after a single trawl this may increase drastically with increased trawling intensity.		

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 9 **Estuaries** **Shallow inlets and bays** **Reefs** **Mudflats and sandflats** **Sandbanks** **Grey seal** **Common seal** **Harbour porpoise** **Bottlenose dolphin** **Seabirds**	Beam and Bottom Trawling Gill nets	Review paper. Habitat effects **-** Towed fishing gears such as bottom and beam trawls physically disturb the seabed causing alterations in microbial communities, resuspension of particles, nutrients and pollutants and the relocation of stones and boulders. Inshore fisheries have led to destruction of reefs built by species such as the polychaete worm *Sabellaria* or by calcareous algae. Fishing has led to structural changes in habitat that have resulted in changes in species assemblages. Species and community effects **-** Fixed nets such as gill nets are more likely to entangle non-target species. Diving seabirds are especially vulnerable to entanglement in fixed nets such as gill nets. No evidence that mortality due to entanglement has precluded the observed increase in population size of many species of seabirds which has taken place during this century in the North Sea. Harbour porpoises especially vulnerable to entanglement in gill nets. Recent estimate of the by-catch of the Danish gill net fishery in the eastern North Sea gave an annual by-catch of 4629 porpoises. Incidental by-catch could be a significant contributing factor to the overall decline harbour porpoise abundance in European waters. Seal populations have been able to sustain or increase their populations whilst subject to fishery induced mortality. No species exists in isolation, fishery-induced changes in the density of one species will have repercussions on its predators, prey and competitors Heavy towed gears in contact with the sea bed can kill or injure animals living in the top most layers of sediment. The percentage of benthic organisms caught in a beam trawl which die varies from zero for hermit crab, whelks and starfish to 100% for shells such as *Artica islandica*. Beam trawl is the most important fishing gear which penetrates the seabed. General fisheries generated mortality results in reduced abundance of long-lived benthic species and increased abundance of short-lived species. By-catch and offal produced by gutting the fish at sea thrown overboard provides food for seabirds and other scavenging animals. Changes in the amount of discards may affect the relative and absolute abundance of various species of seabirds. Increased abundance of scavenging seabirds since the start of the century. Large or unattractive discard items will fall to the seabed where they can become available to sub-surface scavengers. Fishing produces litter in the form of lost gear and other waste comparable with that produced by shipping in general. Litter from fishing such as lost or discarded nets may entrap seabirds and mammals	North Sea	Gislason H. (1994). Ecosystem effects of fishing activities in the North Sea. Marine Pollution Bulletin 29: 520-527. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 10 **Grey seal** **Harbour porpoise** **Red throated diver** **Seabirds**	Gill nets Tangle nets	Notes on recorded entanglement casualties in Cardigan Bay. <u>Species effects</u> **-** Potential threat to red-throated divers from gill and tangle nets high. May have knock on effects at the birds breeding grounds. During 14 inspections of beach set nets between September 1991 and December 1992 no seabird by-catch was noted despite red-throated divers observed diving within 20m of nets. Ten harbour porpoises *Phoecoena phocoena* reported as casualties of gill nets in 1991. Author considers that Harbour porpoise is the only cetacean under severe threat of extinction from static fishing gear in Cardigan Bay. 24% of UK deaths of harbour porpoises caused by entanglement in fishing gear. One Grey Seal *Halichoerus grupus* found stranded in 1991 with injuries consummate with gill net entanglement. Net inspected in September 1992 no by-catch recorded despite close proximity of grey seal. Young seals more likely to suffer from entanglement. Juvenile dolphin recorded tangled in net. Author concludes no major entanglement problem in Cardigan Bay.	Cardigan Bay	Thomas D. (1993) Marine wildlife and net fisheries in Cardigan Bay. RSPB/CCW report.
REF: 11 **Shallow inlets and bays** **Sandbanks** (Area of coarse sand, gravel and broken shell)	Beam trawling	Experimental 4m commercial pattern beam trawl fitted with chain matrix and 8cm diamond mesh cod-end. Towing speed 2m s^{-1}. Initially trawl lines fished 3-4x in succession repeated after 2 hours. <u>Species and community effects</u> **-** Gurnards and whiting aggregate over beam tracks to feed on animals damaged by the beam trawl or on other scavengers that are attracted to the trawled area. There was a particularly clear increase in the proportion of the amphipod *Ampelisca spinipes* in their diets and some mobile invertebrate scavengers such as *Pandalus* spp. only occurred in diets after the area was fished. Number of prey items eaten by gurnards and whiting increased after trawling. Dogfish did not increase their intake after trawling but did take *Pandalus* spp. and *Crangon* spp. only after the area had been trawled. Results suggest that fish rapidly migrate into the area to feed. Additional resources such as those made available by trawling, may favour certain species that exhibit opportunistic feeding patterns such as gurnards and whiting.	Off east coast of Anglesey	Kaiser M.J. & Spenser B.E. (1994). Fish scavenging behaviour in recently trawled areas. Marine Ecology Progress Series. 112: 41-49 [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 12 **Reefs** **Shallow inlets and bays**	Scallop dredging Oyster dredging	Pilot survey of reefs subject to bottom trawling/dredging on a variety of seabed types; flint shards; sand, broken shell and dead maerl; sand, gravel, broken shell and dead maerl overlain with cobbles and small rocks; reef of mudstone ledges. Clear differences in epifaunal communities between areas considered to be worked by mobile fishing gear and those not, however different sediment types in these areas is another influence. Reefs highly vulnerable to removal of epifauna and erosion caused by the action of the gear. Reefs with large boulders or severe topography which prohibits the use of fishing gear considered to be self protecting. Complex areas of sandy pockets, cobbles and boulders the size of which do not prohibit the use of rock hopper or spring loaded dredges, which support slow growing and numerous hydroids, anemones and corals, bryozoans, tunicates and echinoderms particularly vulnerable to highly mobile fishing gear. Recolonisation and recovery likely to be slow. Potential loss of productivity, habitat, and food caused by highly mobile fishing gear, may lead to the direct mortality of commerciality exploitable reef dwelling species.	Lyme Bay	Devon Wildlife Trust (1993). Lyme Bay: A report on the nature conservation importance of the inshore reefs and the effects of mobile fishing gear. Survey report carried out by the Devon Wildlife Trust.
REF: 13 **Estuaries** **Mudflats and sandflats** **Inlets and bays** **Sandbanks**	Trawling	Changes in the balance of the benthos, particularly the loss of *Sabellaria* reefs and oyster beds attributed to over-fishing and trawl damage. Comparable shifts in dominance with certain polychaete species commonly favoured over more vulnerable groups such as echinoderms anticipated at regularly fished sites, and is, in principal, reversible. Recent trend towards the deployment of larger, heavier demersal fishing gear enhances the possibility of benthic changes in intensively fished areas. Shrimp fishery in Wadden Sea observed a long term decline in the number of by-catch species notably *Carcinus* and *Pomatoschistus* spp. Biomass of by-catch remained constant with compensating increase in dab, sprat and cod.	North Sea	Rees H.L. and Eleftheriou A. (1989). North Sea benthos: A review of field investigations into the biological effects of man's activities. J. Cons. Int. Explor. Mer. 54(3): 284-305 [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 14 **Reefs** **Shallow inlets and bays**	Potting	Experimental study on the effects of *Nephrops* creels and lobster and crab pots on benthic habitats and communities in a number of locations/habitats. Quantitative effects of one month's fishing using crab and lobster pots. <u>Species and community effects</u> **-** Sites in Scotland **-** Descending creels build up a small pressure wave which caused the sea pens *Pennatula phosphorea*, *Virgularia mirabilis* and *Funiculina quadrangularis* to bend before the creel made contact. This removed the tip of the sea pen from damage through impact. After smothering or uprooting all three species reinserted and uprighted themselves when in contact with muddy substrate. No lasting effects on muddy substrates. Devon/Wales **-** Rocky substrate habitats and communities at a depth no deeper than 23m below chart datum subjected to lobster and crab potting relatively unaffected by fishing activity. Experimental and control plots 30mx12m in Devon and 50mx20m in Wales. *Pentapora foliacea* found broken after hauling although unclear whether this was due to fishing. *Eunicella verucosa* bend under the weight of pots and then return to an upright position afterwards. Slow growing and long lived *Eunicella verucosa* previously considered highly vulnerable to damage. One month's active fishing using crab and lobster pots caused no difference in abundance of species between control and experimental study plots. Abundance of some species increased after potting in comparison with their abundance before potting. Potting did not have a detrimental effect on the abundance of species studied. Experimental simulation of 12 lost parlour pots revealed that they may actively fish for up to 270 days and remain baited for between 8 and 27 days. Catch rates highest during first month. Brown crab catches showed slight temporary decrease after bait depleted and subsequently fairly constant. Spider crab catch declined steadily. In time condition of the catch deteriorate, wrasse showed skin damage and limb loss increased markedly the longer crustaceans remained in the pot. Incidental observations in the vicinity of the pots shows several had moved over and broken *Pentapora* colonies. Pots moved down the gently sloping seabed until constrained by mainline tightening.	Loch Broom, Bardentarbot Bay, Lyme Bay, Skomer, Pembrokeshire coast.	Eno N.C., MacDonald D.S. & Amos S.C. (1996). A study on the effects of fish (crustacea/mollusc) traps on benthic habitats and species. Report to the European Commission.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 15 **Estuary** **Mudflats and sandflats**	Mechanical cockle dredging	Experimental investigation on the effects of cockle dredging on spat settlement using a 71cm mechanical dredge with revolving riddle. <u>Species and community effects</u> **-** A single pass of the dredge reduced both fishable and juvenile stocks of cockles substantially. Adult cockles more damaged by dredge than juveniles. No subsequent difference in cockle mortality between dredged and undredged plots. New spat settlement not affected.	Burry Inlet	Walker P. Cotter A.J.R & Bannister R.C.A. (1995) A preliminary account of the effects of tractor dredging on cockles in Burry Inlet, South Wales.
REF: 16 **Shallow inlets and bays** **Sandbanks**	Scallop dredging	Preliminary findings of experimental investigation of 3x77cm rock hopper scallop dredges with 9x10cm dredge teeth on each dredge, on maerl beds including visual evidence of impacts. <u>Species and community effects</u> **-** Cobbles and boulders up to $1m^3$ overturned by dredge mouths or towbar. Dredge teeth penetrated the maerl beds up to 10cm. Cloud of suspended sediment created by trawl. Large macroalgae torn up. Large animals including highly mobile species such as plaice either mangled, entrained on the bottom or flicked into the dredge bags. Dredge efficiency in terms of catch thought to be 88% on maerl beds. Fine sediments eroded, maerl crushed and killed through burial compromising habitat integrity and recovery. Fine sediments deposited over adjacent areas smothering photosynthetic organisms and stressing filter feeders. Micotopographical effects clearly visible 8 months post dredging and number and diversity of sessile fauna and flora reduced. May be a long term shift from K-selected species to R-selected species in response to dredging.	Firth of Clyde	Hall-Spencer J. (1995). The effects of scallop dredging on maerl beds in the Firth of Clyde. Porcupine Newsletter 6(1).

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 17 **Great northern diver** **Red throated diver** **Seabirds**	Gill nets	A broad overview of the effects of gill nets on seabirds including case studies. Worldwide 60 species of seabird reported as being caught in gill nets. In very few cases was it possible to estimate the level of mortality in specific fisheries but net mortality was implicated as a major contributed to large declines in certain populations. Great northern diver and red throated diver thought to be vulnerable. Average number of great northern divers caught per year 15 780% of great northern divers caught off Newfoundland entangled in salmon gill nets 20% in cod gill nets. Great northern divers caught in nets up to 50m deep. General principles associated with seabird mortality in gill nets: C species at greatest risk are predators which (a) pursue their prey underwater (b) aggregate in dense foraging groups. C daily catch rates can be very variable C greatest by-catch occurs during periods when prey occur in areas frequented by fisheries C magnitude of net mortality for many predators may be a function of prey abundance C net mortality decreases with distance from colonies of breeding seabirds vulnerable to entanglement C large kills can be caused by nets set at great depths (ie more than 100m) C net mesh size may be an important consideration in mortality rates.		Robins M. (1991) Synthetic gill nets and seabirds. Report to WWF and RSPB.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 18 **Estuary** **Mudflats and sandflats** **Shallow inlets and bays**	Hydraulic cockle dredging	Control and treatment type experimental investigation with pre and post dredge comparisons. Two spatially separated sites exposed to a single dredge with subsequent benthic sampling. Site A, Lavan Sands NW Wales 3m above chart datum substrate very fine sand, extensively rippled, compact and firm, well oxygenated sediment. Site B, Blackshaw Flats, Solway Firth 5m above chart datum well sorted very fine sand, extensively rippled, compact and firm, well oxygenated sediment. Two experimental regimes. Experiment 1: Effects of a single dredging activity. <u>Habitat effects</u> **-** Dredging had no significant impact on the measured sediment characteristics due to the small percentage of fine material and the high degree of sorting. <u>Species and community effects</u> **-** Rapid recovery of benthic infaunal communities as sediment exposed to regular disturbance from water movement **-** community already adapted to disturbance. *Hydrobia ulvae*, surface grazing gastropod, significantly affected by dredging. Experiment 2 at Lavan Sands 80 sampling stations over an area of 400x300m used to assess the effects of a 3 month licensed commercial dredging operation using pre and post dredging data. <u>Habitat effects</u> **-** No severe erosion of sediments occurred. <u>Species and community effects</u> **-** Impacts appear to be small and for the most part not statistically significant. Significant decrease in the population of tube dwelling polychaete *Pygospio elegans* whose tubes may be destroyed by dredging. *Lanice conchilega* has tough tubes apparently not greatly affected by the dredging operation. Also they can retract into tubes below the maximum depth disturbed by the dredge and can regrow head tentacles. Numbers of *Cerastoderma edule* and *Macoma balthica* reduced significantly resulting in a significant reduction in the total macrofaunal biomass (these molluscs contribute to about 70% of the biomass wet weight). Author concludes hydraulic cockle dredging unlikely to have a significant impact on non-target infaunal species at the site as the sediments are moderately mobile with a low silt content.	Lavan Sands, NW Wales Blackshaw Flats, Solway Firth	Moore J. (1991). Studies on the Impact of Hydraulic Cockle Dredging on Intertidal Sediment Flat Communities: Final Report

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 19 **Otter** **Grey seal** **Common sea** **Harbour porpoise** **Bottlenose dolphin**	Gill nets Longlines Creels Fyke nets Aquaculture	Comprehensive resume of recorded by-catches of marine mammals including dolphins, seals, porpoises and otters. Incidental catches of marine mammals by no means rare and are reported in most fisheries in Britain. Data is still too sparse to enable a robust estimate of marine mammal by-catch. Gill net fisheries likely to account for the majority of marine mammal by-catches. 130 grey seals from the Farne Islands and the Orkneys may drown in fishing gear every year. Young animals more vulnerable to fixed nets. Cetaceans and seals only very rarely affected by long-line fisheries, creel, potting or salmon nets. Otters may be significantly affected by creel and eel fyke nets and the latter may have been a significant factor in the decline of otters in East Anglia. Salmon farming may have a significant effect on seal populations locally, estimates in the region of 100 seals caught in anti-predator nets annually with a further 1,000 seals shot by fish-farm operators. The number of seals caught in anti-predator nets, fishing nets in general or shot by fish farm operators does not seem to have had a deleterious effect on seal stocks. Harbour porpoise most vulnerable to incidental catches. Possible solutions to conflicts with fishing discussed. Reflective knots at the intersection in netting may help prevent entanglement. Acoustic warning devices on nets may reduce the occurrence of entanglement. Certain nets and locations may precipitate large mammal catches these areas or methods may be avoided. Harbour porpoises more likely to be entangled during storms or at night, modification of fishing methods may reduce incidental by-catch. Comments on the use of a scheme whereby fishermen are asked to land incidentally caught marine mammals for pollution analysis proved to be a successful method of gaining more information on the numbers of animals incidentally caught as fishermen appear more willing to do this than provide information on a written basis especially as pollution has potential ramifications for fish stocks.		Northridge S. (1988). Marine Mammals and Fisheries: a study of conflicts with fishing gear in British waters. Report to Wildlife Link Seals Group.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 20 **Estuaries** **Mudflats and sandflats**	Shellfish aquaculture Suction dredging	Survey of intertidal benthic community and physical characteristics at a site of commercial clam cultivation on a shallow shelving mudflat during clam growth and post harvesting. Underlying sediment composed of London clay interspersed with shell debris and lignin deposits. Surface sediment of fine silt and sand with patches of clay. <u>Habitat effects</u> **-** During clam growth no significant difference in particle size, organic content or photosynthetic pigment between control and clam lay sites. Harvesting by suction dredging removed upper sediment layers exposing clay which is unsuitable for larval settlement. Seven months post harvesting sedimentation had nearly restored the sediment structure. <u>Species and community effects</u> **-** During clam growth no significant increase in faunal diversity under clam lay but density of benthic species individuals much greater. Community under clam lay significantly different from the control areas. Control area dominated by polychaete *Nephtys hombergii*, area under clam lay dominated by deposit feeding worms *Lanice concilega* and the bivalve *Mysella bidentata*. Nets may change hydrography reducing water flow and increasing sedimentation. This increases food supply and so may promote larval settlement. Adjacent areas may be influenced by commercial clam operation. Suction dredge harvesting had a profound effect on the community structure. Large amounts of sediment and associated animal community (particularly crustaceans and bivalves) removed. Seven months post harvesting density of individuals decreased significantly to the point where there was no difference between control and harvested sites, with *Neptys hombergii* responsible for the similarity between treatment and control. The effect of clam harvesting barely detectable after 7 months. Clam cultivation increases productivity as the netting reduces wave action and other disturbances. Authors conclude that clam cultivation does not have long-term effects on the environment or benthic community at the study site.	Whitstable, Kent	Kaiser M.J. Edwards D.B. and Spencer B.E. (1994). Infaunal community changes as a result of commercial clam cultivation and harvesting. Aquatic Living Resources, 9: 57-63. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 21 **Shallow marine inlets** **Estuaries** (Muddy gravel)	Clam dredge	Treatment and control type dredging experiment, 2 passes of a modified oyster dredge. Habitat effects **-** Sediment removed to a depth of between 15-20cm by dredging and gravel fraction reduced. Sediments may become more anoxic after dredging. Dredge tracks most likely to be filled with fine sediment in low energy conditions therefore discrete habitat variation will be created. Resuspended sediment may have serious survival implications for species unable to deal with heavy suspended sediment loads. Species and community effects **-** Due to the deep penetration of the dredge all fauna, with the exception of bivalves (eg *Abra tenuis, Cerastoderma edule* and *Mya arenaria*) were removed completely in the short term. It is likely that these organisms were dislodged and then redeposited by the dredge or that they migrated or were passively dispersed into the area from adjacent undredged areas. Annelids were most badly affected by the dredge with the exception of *Tubificoides benedeni* and a Phyllodocid. Abundance of bivalves was also greatly reduced but some found in some dredged samples (small specimens thought to have been disturbed by the dredge and re-deposited afterwards). No clear recovery of fauna evident over the 8 day period of study but opportunistic polychaetes (eg *Capitella capitata* and *Tubificoides benedeni*) likely to be early colonisers of disturbed mudflats along with the surviving bivalves. Authors suggest these will be followed by active polychaete species eg *Eteone longa* and more stable habitat species such as *Cirriformia tentaculata*. Continual disturbance will not favour stable habitat species, high biomass communities may occur but are unlikely to contain individuals of high biomass which may be exploited as a food source by birds.	Langstone Harbour	Southern Science (1992). An experimental study on the impact of clam dredging on soft sediment macro invertebrates. Report to English Nature.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 22 **Shallow bays and inlets** **Sandbanks**	Trawling	Laboratory based experiment investigating the behaviour of *Buccinium undatum* exposed to different prey items. <u>Species and Community effects</u> - Less mobile scavengers such as whelks may take several days to arrive at sites of trawl disturbance. Whelks are well suited to exploit fisheries discards as they are very responsive to chemosensory stimuli exuded from damaged or moribund animals. 98% of whelks caught in a beam trawl survive. Whelks are capable of exploiting a wide variety of prey due to their flexible feeding behaviour. In this experiment they ate *Liocarcinus depurator, Spatangus purpureus, Trisopterus minutus* but not *Pleuronectes platessa*. Where whelks are common they have an important capacity in utilising energy from dead or damaged animals. Whelks using this competitive advantage may exhibit local population increases and in areas of intense beam trawling, such as the southern North Sea, dead or moribund animals which result from these activities could make up a considerable proportion of the whelk diet.		Evans P.L. Kaiser M.J. and Hughes R.N. (1996). Behaviour and energetics of whelks, *Buccinium undatum* (L.), feeding on animals killed by beam trawling. Journal of Experimental Marine Biology and Ecology. 197: 51-62. [PR]
REF: 23 **Harbour porpoise**		Record of causes of death in 422 cetaceans of 12 species stranded on the coasts of England and Wales between August 1990 and September 1995 via post-mortem examination. Most frequent cause of death in harbour porpoises and common dolphins was entanglement in fishing gear. 38% of harbour porpoises and 80% of common dolphins diagnosed as being by-caught. The proportion of by-caught harbour porpoises increased from 1990 to 1995. Factors such as changes in fishing effort, technique or location or changes in the abundance or distribution of harbour may account for this. Probably an underestimate of the true incidence of by-catch in cetaceans. Estimates of the number of by-caught harbour porpoises cited as being between 328 and 552 by English fishing fleets on the Celtic shelf. The proportion of starved neonatal harbour porpoises higher than starved common dolphins may relate to the more coastal distribution of harbour porpoises. More coastal distribution of harbour porpoises may also increase their contact with co-factors such as pollutants making them more likely to die from species-specific pathogens than common dolphins. By-catch is a threat to both harbour porpoises and common dolphins around the coast of England and Wales. Of 7 *Tursiops truncatus* studied only one was determined as being by-caught.		Kirkwood J.K., Bennett P.M., Jepson P.D., Kuiken T., Simpson V.R. & Baker J.R. (1996). Entanglement and other causes of death in cetaceans stranded on the coasts of England and Wales.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 24 **Sand banks** **Shallow inlets and bays**	Beam trawling	Side scan sonar investigation into the effects of beam trawling in the southern part of the Danish North Sea. Habitat effects **-** Poorly preserved trawl marks were widely distributed in the study area except in one area of presumably coarse grained sediments where there were numerous extremely well-preserved beam trawl marks. The substrate appears to have altered from coarse grained sand or gravel to fine sand and coarse silt in the trawl marks as shallow scouring and smoothing from beam trawling created conditions favouring fine sand/coarse silt sediment filling the tracks. Effects of beam trawling on sediment may be long-term and in some areas may have resulted in a definitive change of the substrate with implications for the benthic community.	Southern North Sea	Leth J.O. & Kuijpers A. (1996). Effects on the seabed sediment from beam trawling in the North Sea. ICES 1996. Annual Science Conference. Mini-symposium: "Ecosystem Effects of Fisheries". ICES C.M. 1996/Mini 3.
REF: 25 **Sand banks** **Shallow inlets and bays**	Beam trawling	Experimental investigation into changes in sediment structure, in- and epifauna, mortality of by-catch and effects on predators caused by beam trawling with the application of twice-yearly fishing perturbations. Species and community effects **-** Trawling causes changes in the abundance of some in- and epifaunal species. Infaunal diversity reduced by 54%, epifaunal diversity not significantly altered. Mortality of animals retained in the cod-end studied by placing them in tanks. Results varied greatly between taxa. Mortality greatest for fish and animals with brittle skeletal structure such as sea urchins and swimming crabs, and very low for starfish, brittlestars and hermit crabs. Benthic species which are most likely to benefit from the increased scavenging opportunities brought about by trawling were starfish and hermit crabs.	Red Wharf Bay and Dulas Bay in Liverpool Bay	Kaiser M.J., Ramsay K & Spencer B.E. (1996). Short-term ecological effects of beam trawl disturbance in the Irish Sea. A review. ICES C.M. 1996/Mini 5.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 26 **Estuaries** **Shallow inlets and bays** **Sandflats and mudflats**	Clam digging	Laboratory experiments to see whether non-lethal burial or exposure on the sediment surface could alter the normal living depth of *Mya arenaria* in sand and mud. <u>Species and community effects</u> **-** After 2 weeks those buried under 1-15cm of medium fine sand were buried deeper than controls whereas clams exposed on the sand surface (and had subsequently reburrowed) were able to re-establish their normal living depths. Clams under 1-15cm of mud attained their normal living depth within two weeks but exposed clams reburrowed to abnormally shallow depths. The increased likelihood of predation at shallow sediment depths was compounded by the 60% lower reburrowing speed of exposed clams in mud when compared to sand. Conclusions were that negative impacts of clam digging on *M. arenaria* are not limited to removal of market-size clams and shell breakage of remaining ones. Exposure of prerecruits and depositions of tailings on clams adjacent to harvest sites may increase susceptibility of unharvested clams to predation, dessication or freezing. The effects depend on different substrate types. Mortality will be greater on clam flats having a mud substrate than of medium-fine sand. Management practice should reflect these differences. On sandflats there would be little to be gained from breaking up the clumps of soil turned over since tailing burial will probably not result in mortality. In muddy areas, reducing tailing piles is likely to enhance survival of both buried and exposed clams.	Laboratory	Emerson C.W., Grant J. & Rowell T.W. (1990). Indirect effects of clam digging on the viability of soft-shelled clams *Mya arenaria*. Netherlands Journal of Sea Research 27(1) 109-118. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 27 **Shallow inlets and bays** **Sandbanks**	Hydraulic dredging	Field experiment of impact of fishing for razor clams *Ensis* sp. by hydraulic dredging on the associated infaunal community, 7m depth. <u>Species and community effects</u> **-** Infaunal samples were examined at 1 and 40 days from fished and unfished plots. There were differences in mean number of species and individuals for control and fished sites 1 and 40 days later but only total numbers of individuals significantly lower. After 40 days no detectable difference. No statistically significant differences in the 10 most abundant species *Bathyporeia elegans, Siphonoecetes kroyeranus, Exogene hebes, Spio filicornis, Corophium crassicorne, Streptosyllis websteri, Cochlodesma praetenue, Nephtys cirrosa, Megalorupus agilis* and *Perioculodes longimanus* between treatments after either 1 or 40 days. Suction dredging for *Esnis* had profound immediate effects on benthic community structure with consistent reductions in the numbers of many macrofaunal species and the target species. However, despite the relatively large scale nature of the disturbance, these effects appear to persist for only a short period. After 40 days no detectable difference **-** visually or from macrobenthic community analysis, effects on long-lived bivalves could however be more serious, and action of the dredge is violent enough to often crack shells of adult *Arctica islandica*. Larger polychaetes and crustaceans are also often retained on the conveyer, crushed in the mechanism or fall off the end to fall at random on the seabed. No estimate was made of survivorship of these individuals but many scavenging hermit crabs were active immediately after dredging. Migration and passive translocation play a part in returning the abundance of species to pre-impact levels. Authors suggest that local population reductions due to dredging are only likely to persist in a habitat if one of two conditions are met: (a) macrobenthic populations themselves, or the sediments in which they live, are immobile or (b) the affected area is large relative to the remainder of the habitat such that dilution effect cannot occur. For most habitats where *Ensis* could be fished authors believe that neither of these conditions likely to hold. Current technology restricts this type of fishing to approximately 7m therefore likely to be strongly influenced by wind and tide-induced currents in these areas. Sediments are probably mobile and effects will be diluted rapidly. However they note there is little knowledge of the relative importance of the various processes which contribute to animal movement and whether certain habitats may be more susceptible to persistent damage than others. At most sites the authors believe there will be adequate areas to dilute effects but prior examination of potential fishery sites is warranted.	Loch Gairloch, Scotland	Hall S.J., Basford D.J. & Roberts M.R. (1990). The impact of hydraulic dredging for razor clams *Ensis* sp. on an infaunal community. Netherlands Journal of Sea Research 27: 119-125. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
		Target species removed in great numbers, long-lived bivalve species often damaged or killed and smaller-bodied infauna either displaced or killed. With the exception of large bivalves, it would appear that effects on macrofaunal community in general are not locally persistent, although in calmer seasons effects may persist for longer than observed here. Another consideration is that if *Ensis* and other large bivalves play an important role in structure of benthic communities, their removal would result in cascading effects over long time scales. But in the high levels of sediment mobility at the study site, this hypothesis was considered unlikely.		
REF: 28 **Shallow inlets and bays** **Sandbanks**	Beam and Otter trawls	Long term historical record (1945-1981) of by-catch from an area of the North Sea to the Northwest of the Netherlands at Zoological Station in Den Helder. <u>Species and community effects</u> **-** Bottom fisheries have a considerable effect on many by-catch species including demersal fish and invertebrates. Numbers of by-caught fish and invertebrates related to changes in fish gear and effort of bottom trawlers. Catchability of beam trawlers 10x higher than otter trawls. Model of bottom fisheries shows that bottom trawling has reduced the abundance of several demersal fish and invertebrates to very low levels within 35 years.	North Sea	Philippart C.J.M. (1996). Long-term impact of bottom fisheries on several bycatch species of demersal fish and benthic invertebrates in the southeastern North Sea. ICES C.M. 1996/Mini 6.
REF: 29 **Seabirds**	Fixed salmon nets	Investigations by the author into numbers of dead seabirds on the shore in early 1970s at Cruden Bay in NE Scotland in mid summer led to a conclusion that they must have been killed in some of the numerous local fixed salmon nets which were often seen holding dead birds. Most were auks which are known to be killed in fixed salmon nets on a considerable scale around the seabirds colonies on St. Abbs Head and Troup Head in the Moray Firth. Some shags also reported killed in nets set near a roost on the Summer Islands. Off the Scottish Wildlife Trust reserves at Longhaven and on the Dunbuy Rock to the south up to 17 bodies per net were recorded on the 12 or so occasions they were examined during the breeding season over the previous four years.	Cruden Bay, NE Scotland	Bourne W.R.P. (1989). New evidence for bird losses in fishing nets, Marine Pollution Bulletin. 10: 482. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 30 **Shallow inlets and bays** **Sandbanks**	Scallop dredges	Trials looking at effects of three types of trawling gear on bottom sediments. Shallow traces made by inshore and offshore scallop dredging could be distinguished from each other. Habitat effects - Scallop dredging observed to lift fine sediments into suspension, bury gravel below the sand surface, and overturn large rocks embedded in the sediment, appreciably roughening the bottom. The inshore Alberton dredge was inefficient, dumping its contents back on to the bottom at intervals. Trawl tracks were seen as grooves on the seafloor - considered to be made by otter trawl doors. Suspended sediment in dredge tracks reduced visibility from 4-8m to less than 2m within 20-30m of the track but dispersed within 10-15mins, coating the gravel in the vicinity of the track with a thin layer of fine silt and obscuring *Lithothamnion.* Offshore dredge - gravel fragments overturned. Depressions left by tow bar of the dredge. Gravel less frequent inside the track. Inshore dredge (Alberton) tracks left, gravel sparser inside and dislodged boulders commonly observed. Tooth marks over sandy bottom. Bottom type and hydrographic regime in the Bay probably allowed marks made by fishing gear to remain recognisable for a long time as tidal currents faster than 1km/hr were not encountered. Even a relatively minor fishery may therefore have a significant cumulative effect on bottom microtopography under these conditions. Scallop and otter tracks could be distinguished, scalloping contributing to an appreciable roughening of the bottom, lifting large boulders and overturning many of them, presumably leading to destruction of the epifauna on their upper surfaces. Under strong tidal flow author considers that intensive dredging will lead to erosion of sediment lifted into suspension by the dredge - this aspect needs more study. Species and community effects - Dredging caused appreciable lethal and sublethal damage to scallops left in the track. Damage greatest on rough bottom. Predatory fish and crabs were attracted to dredge tracks within 1hr, and fish were observed in the tracks at densities 3-30 times those observed outside the tracks. There was a pronounced and rapid aggregation of foraging fish - a natural response which also occurs in the absence of fishing operations.	Chaleur Bay, Gulf of St Lawrence	Caddy J.F. (1973). Underwater observations on tracks of dredges and trawls and some effects of dredging on a scallop ground. Journal of the Fisheries Research Board of Canada 30: 173-180. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 31 **Harbour porpoise**	Gill nets	Species and community effects - Study using reports of incidental catch of harbour porpoise. Most are killed in monafilament gill nets set for groundfish or pelagic species. Estimated total catch for the year in the area (based on notifications by fishermen) was 105±10.8 animals. The animals were entangled while nets on the bottom in water depths of 37-96m. They seem to catch certain size classes and not small or large animals. Factors other than fishing effort may also have effected the incidental catch rate of harbour porpoise. In one area it was disproportionately high, perhaps reflecting the high density of porpoises in the region. There were no changes in porpoise density in the region between 1980-86, but two significant changes in length frequencies (increase in length of calves and absence of large porpoises in the recent samples). These changes may be attributed to the fishery which has been operating for 10-15 years. The effects of sustained adult mortality in the gill-net fishery appear to have compressed the size and possibly the age structure of the population perhaps reducing the reproductive lifetime of females. Given the slow reproductive rate authors consider that these incidental catches seriously threaten the population as porpoises in Bay of Fundy and Gulf of Maine apparently form a relatively discrete population unit.	South-western Bay of Fundy, Canada	Read A.J. & Gaskin D.E. (1988). Incidental catch of Harbour Porpoises by gill nets. Journal of Wildlife Management 52: 517-523 [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 32 **Shallow inlets and bays**	Mussel dredging Bottom trawling	Habitat effects - Effects of mussel dredging and bottom trawling on particulate material, internal nutrient loads and oxygen balance were investigated. Sampling 0, 30 & 60 mins after fishing. Immediately after mussel dredging suspended particulate material increased significantly but 30 mins after the differences had decreased and, after 60 mins, had returned to the start level. Oxygen decreased significantly after mussel dredging and average ammonia content increased but large horizontal variation in the ammonia content prevented detailed interpretation of these increases. Changes in other nutrients were small. Changes in particulate matter and nutrients were also observed at some stations following low wind. Particulate matter and total phosphorus were markedly higher on windy days. Most dredging and trawling in the Limfjord takes place in summer when there is little wind, nutrients and oxygen consumption are low and temperature high. During these periods trawling and particularly dredging reduce the water quality by increasing internal nutrient loads, oxygen consumption and possibly phytoplankton primary production. Immediate increase in particulate matter, oxygen consumption and increase in nutrients particularly ammonia and silicate were a further effect of the fishing activities. Physical effects were scraping and pressure of gear the magnitude depending on depth of penetration, frequency of fishing and structure of sediment. Species and community effects - Trawling and dredging can be expected to cause a number of direct and indirect changes in the ecosystem - direct changes in fished populations and the benthos, but also changes in the nutrient level and oxygen budget in the water column. Phytoplankton primary production may increase if nutrients are the controlling factor. During summer when nutrients are generally low in the fjord mixing of sediments will have important consequences for the nutrient regime. It caused the deterioration of the water quality by increasing oxygen consumption and phytoplankton primary production. It was difficult to demarcate trawling and dredging effects versus wind induced effects at this site.	Limfjord, Denmark	Riemann B & Hoffman E. (1991). Ecological consequences of dredging and bottom trawling in the Limfjord, Denmark. Marine Ecology Progress Series 69: 171-178. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 33 **Shallow inlets and bays** **Sandbanks**	Scallop dredging	Observation of standard and spring-loaded dredges. <u>Habitat effects</u> **-** Bottom deposits settled about 20 mins after hauling. Short teeth of these dredges dug in up to ½ to ¾ of their length and generated a large mound of sediment in front of the toothed bar. Most was deposited around the sides of the dredge and at times completely filled the dredge opening, particularly when large stones or shells blocked some of the gaps between the teeth. Dredge tracks were distinct, ridges of sediment being deposited each side, but path of the spring-loaded dredge less obvious than standard dredge. <u>Species and community effects</u> **-** The dredges caused some damage to benthic organisms. Most hauls had a few crabs *Cancer pagarus*, and starfish eg *Marthasterias glacialis* broken up by the gear. The teeth also dug out several sub-surface animals including heart urchins *Spatangus purpureus* and the mollusc *Laevicardium crassum*. These and other organisms raked up by the teeth appeared to attract several fish and invertebrate predators including juvenile cod adult plaice and dogfish, whelks and hermit crabs.		Chapman C.J., Mason J. & Drinkwater J.A.M. (1977). Diving observations on the efficiency of dredges used in the Scottish fishery for the scallop, *Pecten maximus* (L). Scottish Fisheries Research No. 10 16pp.
REF: 34 **Harbour porpoise**	Gill nets	<u>Species effects</u> **-** Harbour porpoises are taken throughout their range and several populations are in decline, at least partly as a result of gill net entanglement. In the eastern North Atlantic substantial numbers are caught in gill nets in most areas. Highest known takes in Norway, Sweden and Denmark. UK also has substantial takes in gill nets as well as other fisheries. There are reports of harbour porpoise being caught in cod, salmon and whitefish gill nets off the Scottish coast, and in salmon drift nets and inshore set nets off NE England. Gill nets (which include set nets, drift nets and trammel nets) are considered to represent the single most important threat to porpoises as a group. Most porpoises have substantial problems with them. Harbour porpoise, for example, are found primarily in shallow waters, mostly nearshore which is the area where this form of fishing is generally practised.	North Atlantic	Jefferson F.A. & Currey B.E. (1994). Global review of porpoise. (*Cetacea: Phocoenidae*) mortality in gill nets. Biological Conservation 76: 167-183. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 35 **Harbour porpoise**	Gill nets	Species effects **-** Harbour porpoise are one of the more vulnerable marine mammals to incidental capture by commercial fishing gear and are particularly prone to entanglement. Nearshore habitats, small size and diet of commercially harvested fish contribute to the magnitude of the incidental and/or directed takes occurring through most of their range.	Global review	Polacheck T. (1989). Harbour porpoises and the gill net fishery. Oceanus 32: 63-70 [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 36 **Mudflats and sandflats** **Estuaries** **Waders**	Tractor towed cockle harvester	Investigated the use of tractor towed cockle harvester on invertebrate fauna. Smaller interstitial forms were not greatly affected in most cases significant reduction in species numbers occurred immediately after dredging with continued decline for at least two weeks subsequently. After that a few species showed signs of some recovery others did not, although seasonal trends were obviously important for several of the latter type. Effects at Site A (more tube dwelling and sedentary species) were obvious for longer than 3 months and the dredged area was still visible after 6 months. At Site B (more mobile fauna) natural winter weather disturbances resulted in changes of greater magnitude than those caused by dredging. Results suggested the importance of a stable environment, including surface microflora, for maintaining certain diverse community types and also revealed interesting patterns. Some types of benthic intertidal communities would be adversely affected by commercial tractor towed cockle harvesting. General conclusions from both this study and a 1990 study at Lavan sands are similar in that effects of dredge. 1. Result in a much decreased biomass of the target species, numerical reductions and likely decreased biomass of non-target species. 2. Are much more pronounced in areas with diverse communities and stable environmental conditions have some effects on certain types of sediment and can change sediment parameters at least in the short term. 3. Depend on the time of year the cockle bed is being exploited will be most severe if sufficient recovery time is not allowed. Results from this study did not agree with the conclusion that recolonisation takes place fully and quickly from nearby areas. Effects were obvious at Site A even at the end of the experiment. General effects on birds. Reductions in *Hydorbia ulvae* populations could affect shelduck, knot, dunlin and redshank. Disturbances to bivalve molluscs could affect oyster catcher, shelduck, knot, curlew and eider ducks, the latter however preferring *M. edulis*. Polychaetes are important in the diet of curlew, dunlin, bar tailed godwit and redshank although the latter prefer *Nereis* from the upper shore regions. Amphipods figure prominently as food for dunlin, curlew, oystercatcher, knot and shelduck.	Burry Inlet - Loughor Estuary (Llandhidrian sands)	Rostron D. (1993). The effects of tractor towed cockle dredging on the invertebrate fauna of Llandhidrian Sands, Burry Inlet. Subsea Survey. Report to Countryside Council for Wales.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 37 **Harbour porpoise** **Bottlenose dolphin**	Gill nets	Incidental capture of cetaceans in gill nets is geographically widespread and considered a severe problem. Most capture dolphins and porpoises although large cetaceans are also vulnerable to entanglement. Large incidental catches can occur in coastal gill net fisheries which can have a greater impact than oceanic fisheries because coastal cetaceans often have more restricted distributions than oceanic relatives. Several proposals to reduce impact are discussed.		Dawson S.M. (1991). Modifying gill nets to reduce entanglements of cetaceans. Marine Mammal Science 7(3): 274-282. [PR]
REF: 38 **Harbour porpoise** **Bottlenose dolphin**	Pelagic trawls Trammel-gill bottom nets	Both nets and trawls are involved in the incidental capture of dolphins however accurate estimates of by-catch cannot be made because of lack of relevant data. High opening pelagic trawls towed by pairs of boats and combined trammel-gill bottom nets tied together in a row about the continental shelf are perhaps the most likely cause of large dolphin by-catch.	French Atlantic coast	Charreire F. (1993). A report for Greenpeace on recent dolphin strandings along the French Atlantic coast.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 39 **Shallow inlets and bays** **Sandbanks**	Pelagic trawls Trammel-gill bottom nets	Five maerl beds surveyed in the upper parts of the Firth of Clyde. Some information on the impact on maerl habitats obtained from examination of catches during experimental dredge runs. Preliminary findings. Each ground was a focus of high infaunal diversity and biomass consisting primarily of *Phymatolithon calcareum*. Immediate effects a bow wave of fine particulates suspended ahead of the gear. Bobbins usually rolled along the surface but ploughed into the sediment by up to 4cm when the two-bar was skewed on impact with large boulder leaving trenches of crushed maerl. Cobbles and boulders up to a $1m^3$ were dislodged and overturned when hit by the tow bar or dredge mouths. Dredge teeth projected fully into the maerl deposits. Maerl flicked over dredge mouths creating a cloud of suspended sediment in the wake of the bar. Large macroalgae *L. sacaharina* torn up as dredge dragged through the sediment and large animals *Echinus, Echinocardium, Luidia, Mya, Ensis, Ascidella aspersa* were either mangled or entrained or flicked into the chain mail bags. Even highly motile elements were caught eg butterfish, plaice, *L. depuratur*. The dredging has major repercussions for the structure of maerl habitats and associated biota.	Firth of Clyde	Hall-Spencer, J. (1995). The effects of scallop dredging on maerl beds in the Firth of Clyde.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 40 **Shallow inlets and bays** **Reefs** **Sandbanks** (Mudstone reefs, cobble and bulder seabed, sandy areas with boulders and sandy substrates)	Scallop dredging	Single pass of full sized scallop dredge (12 spring-loaded dredges, deployed either side in groups of 6 attached to two beams) along 300m transects. Video recordings before and after and survival studies of specimens in laboratory for 14 days. <u>Habitat effects</u> **-** Scallop dredging can alter the substrate composition. Stones and boulders (up to 60cm in length) overturned, small boulders piled against larger boulders, fragments of mudstone reef broken off, sand waves in the dredge path completely obliterated, suspension followed by settlement of fine sediments disturbed by the dredge and displacement of substrate (apart from mudstone, loose rocks brought to the surface and shovelled off the deck once the catch had been sorted). Overall there was a markedly changed appearance the most striking being the covering of all boulders and rocks with a fine coating of sediment. Chipping and movement of cobbles and boulders has implications for the habitat of juvenile crabs, particularly *Cancer pagurus*, which appears to inhabit the areas of soft mudstone. Of the habitats studied, area of sand waves was probably the least vulnerable to scallop dredging in the long term. <u>Species and community effects</u> **-** Changes in species observed before and after dredging due to various factors; revealed by dredge as substrate overturned, dug out of substrate (eg *Pomatocerus triquiter, Pecten maximus*) or dislodged off the interstices eg *Maia squanado*; species hidden *Porifera*, destroyed *Pentapora foliacea*, injured or killed by action of dredge (adult crustaceans) and attracted by injured specimens in wake of the dredge *Pollachus* spp crustaceans. Survival of dredged specimens in laboratory tanks showed surprising resilience of juvenile *C. pagurus* and *Pholus dactylus* which remained in the honeycomb mudstone, sea squirts died rapidly compared to controls and starfish exhibited comparable survival between experiment and control. No clear cut evidence in the case of *P. foliacea* and *E. verrucosa* but these most likely to suffer from being displaced as unlikely to re-establish themselves so mortality of these species seems likely. Response of the whole system to dredging will depend on resettlement and growth of new stock and whether the substrate is suitable for this. The vulnerability of the system switching to another system would depend on importance of the species affected. If slower growing species with poor recruitment (eg *E. verrucosa* or slow growing but rapidly recruiting (eg *P. foliacea*) hold the system in its present form there is a high risk of complete change.	Lyme Bay (Beer Home Ground and Eastern Heads)	Sea Fish Industry Authority (1993) Benthic and ecosystem impacts of dredging for pectinids (reference 92/3506) Consultancy Report No.71

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 41 **Harbour porpoise** **Bottlenose dolphin** **Grey seal** **Common seal**	Fish farming, fisheries in general	Review paper Seals are still killed around the Scottish coast where they interact with fishing or fish farming interests but it is difficult to assess the impact. Probably localised and limited in extent, but could have a significant effect on some local populations. Seals and cetaceans may be caught accidentally in fishing gear and anti-predator nets around fish farms. Grey and common seals, harbour porpoises and common dolphins are the most commonly caught species in UK waters. Currently the assessment of the significance of the potential threats is hampered by lack of data on the nature of the threats and the dynamics of the populations concerned.	Scottish waters	Thompson P.M. (1992). The conservation of marine mammals in Scottish waters. Proceedings of the Royal Society of Edinburgh. 100B: 123-140 [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 42 **Shallow inlets and bays** **Sandbanks** (Mixed sediment chiefly sand and shell gravel with varying quantities of silt, shells, gravel, stones and cobbles)	Scallop dredging	Pre-dredging surface followed by qualitative and quantitative assessments (although not at the same stations), photographs and sediment samples. Habitat effects **-** Conspicuous tracks on the seabed about 4m wide. At each site a ridge of stones, shells and shell fragments approx. 15cm high and 30cm wide. Inside ridges shallow grooves formed by rubber bobbins at the ends of the towing beam. Examination of tubes of the anemone *Cerianthus lloydii* in the dredge paths suggested top 2-4cm had been removed. Passage of dredge created a thick sediment cloud the heaviest constituents of which settle out rapidly and close by. Fine sediments were carried away by the tide. Species and Community effects **-** Dredge bags contained shells and stones most of which supported sponges, hydroids, small anemones, tube-worms, barnacles, ascidians and bryozoans. Remains of several *P. folicacea* and large numbers of small crustaceans (chiefly *Pilumnus hirtellus*), molluscs (especially *Trivia* spp.) and juvenile echinoderms within the folds of the colonies. Also several sponges (mostly *Suberites* spp.) and a large number of epibenthic echinoderm species in the catch. Predators and tidal currents removed much evidence of killed or injured animals in the 24 hours after dredging but dead or damaged tubeworms, crabs, squat lobsters echinoderms and *P. foliacea* were found. Large numbers of *C. lloydii* present in dredge path. Broken tops of *l. conchilega* tubes were common in dredge paths but large numbers of intact tubes suggested that the worms had survived and rebuilt their tubes. Large mobile.	Skomer	Bullimore, B. (1985). An investigation into the effects of scallop dredging within the Skomer Marine Reserve. Skomer Marine Reserve Subtidal Monitoring Project. Report to the Nature Conservation Council.
		epifauna generally absent from dredge path except for occasional scavenging *A. rubens* although within 48hrs smaller mobile species such as hermit crabs were present. Counts of infauna in and immediately alongside dredge paths showed these species were unaffected by the level of dredging. Sessile species found during presurvey but not seen in dredge paths include “shell fauna”, *C. celata*, *Suberities* spp. *A. digitatum* and *P. foliacea*		

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 43 **Lagoons** **Harbour porpoise** **Bottlenose dolphin** **Grey seal** **Common seal**	Gill nets (including trammel nets and tangle nets)	Report on the nature and scale of European gill net fisheries and review of accidental catches of non-target species. Incidental catches reported for common dolphins, bottlenose dolphin, striped dolphin, harbour porpoise, common seal, grey seal, sharks (especially blue sharks), loggerhead turtles, guillemot, razorbill, shag and loon. Around the UK catches of grey seals in tangle net fisheries high in the Barra fishery and for Cornwall appeared to be higher than other areas. Catches of common dolphins often reported in southwest fisheries amounting to perhaps some hundreds per year. Bottlenose dolphins rarely recorded but porpoises fairly frequently found in gill net fisheries especially in the North Sea. Drift net fisheries catch most but most of these are released alive. Total drownings in gill nets throughout the country may be in high tens to low hundreds. Impact on porpoise population not known. Bird catches widely reported but little studied. Catches of non-target fish poorly known but crabs are taken in very large numbers. Regarding impact on marine mammals the study clarified importance of North Sea cod fishery and Atlantic hake fishery both already suspected of taking significant number of harbour porpoises and common dolphins respectively. With no populations studies on this species in Europe the impacts of these fisheries and the recently implemented tuna drift net fishery, remain speculative. There are apparently significant catches of birds in the salmon driftnet fisheries in Ireland and Denmark and catches in coastal and lagoon fisheries in Portugal and Italy. It has been estimated that breeding populations of guillemots at two sites in northern Norway have declined by 95% from the early 1960's to 1989 and that this decline could be explained entirely by gill net mortalities based on observed catch rates. Impacts on non-target fish poorly documented, but where examined a wide variety of species recorded. Probably most acutely seen in the swordfish driftnet fishery. May be an impact on benthic communities because of cumulative effect of exposure to netting (including lost netting) on certain seaweeds, seagrass or pedunculate invertebrate communities may be important but little investigated.	European Community waters	Northridge S. di Natale A., Kinze C., Lankester K., Ortiz de ZarateV. & Sequeira M. (1991). Gill net fisheries in the European Community and their impacts on the marine environment. MRAG Ltd. A report to the European Commission's Directorate General Environment.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 44 **Shallow inlets and bays** **Sandbanks** (Gravel sediment)	Scallop dredging Otter trawling	Habitat effects - small differences in sediment type between dredged and undredged sites with dredged sites having a slightly higher frequency of small pebbles, and the undredged sites having slightly more larger pebbles and cobbles. Species and community effects - Samples of benthic megafauna from disturbed and undisturbed sites showed that disturbed sites had lower density of organisms, biomass, and species diversity than undisturbed sites. Many of the species that were absent or less common in dredge sites were small, fragile polychaetes, shrimps and brittlestars. Most apparent difference was the lack of colonial, epifaunal taxa at the disturbed site. This study aimed to give a quantitative assessment of the impact using still photographs. Comparison of deep sites showed that *Filograna implexa* had a high percentage cover at the undredged site and no epifauna and few animals visible at the dredged site. Significant effect between depth and dredging for both *F. implexa* and plant-like animals with effect on percentage cover greater at the deep sites. For plant-like animals the effect was higher at the shallow sites. *Protula tubularia* was significantly more abundant at undredged than dredged sites. There were no differences in the proportion of photographic sampling cells with bryozoans in them, but dredged sites had a significantly higher proportion of cells with abundant bryozoans than undredged sites. *Spirorbis* was more abundant at the deep sites and was in higher frequencies at the dredged sites than undredged sites. Most likely explanation is that the emergent epifauna at undredged sites concealed encrusting bryozoans and *Spirorbis* from view. Depth had the greatest effect on the frequencies of non-colonial animals. Dredging had a lesser, but still significant effect on the frequencies of non-colonial species. Undredged sites had higher frequencies of almost all taxa except burrowing anemones, the earshell *Sinum perspectivum* and hermit crabs. Most of the non-colonial taxa seemed to be negatively affected by dredging but some seemed to profit from dredging. Burrowing anemones were more prevalent at dredged sites for example, perhaps because tentacles easily retracted to safety. Results consistent with the hypothesis that gravel habitats are very sensitive to physical disturbance by bottom fishing and the primary impact is the removal of emergent epifaunal taxa.	Georges Bank, Canada	Collie J.S., Escanero G.A. & Hunke L. (1996). Scallop dredging on Georges Bank: Photographic evaluation of effects on benthic epifauna. ICES CM. 1996/Mini: 9

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 45 **Shallow inlets and bays** **Estuaries** **Mudflats and sandflats** **Sandbanks** **Grey seal** **Common seal** **Harbour porpoise** **Bottlenose dolphin** **Seabirds**	Various	Review report describing direct effects of fishing. <u>Habitat effects</u> - all towed gears which exploit bottom-living species disturb the sediment and may therefore have an impact on the structure and processes at the seabed. Grain size distribution, sediment porosity and chemical exchange process are properties which may be affected. Another direct consequence is displacement of boulders which would otherwise be a surface for epifauna. A direct consequence of disturbance is an increase in suspended sediment load and the possibility of net transport of finer sediments. Resuspension may also influence uptake or release of contaminants, a shift in sediment-water exchange eg of nutrients. Reworking of sediments may result in burial of organic matter. Gears which disrupt the sediment most are beam trawls and shellfish dredges but method of rigging can have a profound effect on the level of disturbance. <u>Species and Community effects</u> - Box cores revealed extensive changes to infauna before and after trawling. Significant reduction in burrowing sea urchin and the density of tube-building polychaetes. Survival rates for infauna and epifauna caught in net of beam trawl were high for starfish, many molluscs and crabs but poor for *Arctica islandica*. Trawl-caught whelks and hermit crabs largely unaffected. These results suggested that a relatively high proportion of some benthic species can be killed in the path of a beam trawling. In relation to scallop dredging epibenthic mortalities can be marked. Effects on seabed and benthos depend on substrate type, hydrographic features and community structure as well as the design and operation characteristics of the gears. Seabirds have been killed in gill and other static nets, no comprehensive studies of entanglement in the North Sea but available evidence indicates that it is likely to occur for diving birds in areas with fixed net fisheries. Gill net fisheries in some places have had a high by-catch of diving birds. Seals may be caught in gill nets, fyke nets and fixed nets for salmon. Gill nets killed the most cetaceans, catch rates varying seasonally. Around the British Isles several species of small cetacean have been reported as incidental catches but in the North Sea reported by-catches of species other than harbour porpoise are rare. As well as catch, fishing operations cause incidental mortality of fish which escape from the gear. Gill nets, tangle nets and traps may continue to fish for some time after being lost of discarded. Length of time depends on factors such as current speed and fouling. On the bottom multifilament nets remain tangled, monofilament nets may, once clear of fish remains and crabs, disentangle, return to an upright position and resume fishing. Over time they build up an encrusting layer of marine organisms and become more visible to fish. Fragments of nets of all types may also entrap seabirds	North East Atlantic, North Sea, Irish Sea	ICES (1992) Report of the study group on ecosystem effects of fishing activities. ICES C.M. 1992/G:11. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
		Direct effects of fishing compared with the effects of other anthropogenic influences and natural processes also discussed, along with long-term effects of fishing activities. In the long term there may be changes in the feeding relationships of organisms, changes in the genetic makeup of populations and other changes such as in the habitat. The mix of direct and indirect effects makes it extremely difficult to establish causal relationships between the amount of fishing and observed long-term population changes. Long-term cascading changes in community structure may occur if 'keystone' populations are adversely affected by fishing, leading to marked changes in the pattern of predation and or competition. One general effect that has been suggested for benthic communities is that overall productivity may increase due to long-lived slow growing taxa being replaced by smaller faster growing taxa whose populations are better able to respond numerically to continued disturbance. Such shifts, it has been suggested, could lead to changes in other community parameters such as species diversity. However, not all levels of disturbance will necessarily result in lower community diversity. Current ecological theory supports the idea that intermediate levels of disturbance would result in an increase in diversity.		

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 46 **Shallow inlets and bays** **Sandbanks**	Beam trawling	Effects of 4m and 12m beam trawls investigated. Habitat effects **-** sole plate of 4m trawl exerted a force of about 2N/cm^2 at commercial trawling speeds. Trawl marks on coarse sand visible up to 52hrs after fishing. Species and community effects **-** Range of mortalities of discarded, non-target species due to capture and handling. High mortalities for undersized fish discarded, 50% or less for most crabs and molluscs and very little mortality (<10%) for starfish. Overall decrease of 0-85% from initial numbers for different mollusc species (solid-shelled or very small species such as *Chamelea gallina, Corbula gibba*, *Dosinia lupinus* and *Apporhais pespelicani* not affected. More vulnerable species such as *Abra alba*, *Mactra corallina, Ensis ensus, Arctica islandica* and *Turritella* communities had mortalities between 12-85%), 4-80% for crustaceans *Corystes cassivelaunus* and *Ebalia* spp. approx. 30%, *Eupagurus bernardus* showed size dependent mortality 15% for large animals and 74% for small animals; *Callinassa* spp. lived too deeply to be disturbed by beam trawling, 0-60% for annelids and 0-45% for echinoderms *A. rubens, A. irregularis, A. filiformis* and *O. texturata* little affected and *E. cordatum* too deeply buried to be harmed. Considering the high mortality of certain species and the fishing intensity, it can be expected that commercial beam trawling affects the structure and composition of the benthic community in the North Sea. Benthic animals damaged, dislodged or discarded by beam trawls may contribute significantly to the diet of scavengers whose populations may thus become enhanced.	North Sea	De Groot S.J. & Lindeboom H.J. (eds) (1994). Environmental impact of bottom gears on benthic fauna in relation to natural resources management and protection of the North Sea. Netherlands Institute for Sea Research. NIOZ-Rapport 1994-11, RIVO-DLO report CO26/94.
		Investigations into scavengers showed that dab, gurnard, dogfish and whiting increased intake of prey after fishing. Dab fed largely on bivalves *Arctica, Acanthocardium, Donax* and *Spisula* and crustaceans *Upogebia* and *Callianassa* the latter of which are not normally accessible to them. Gurnards and whiting fed on dislodged amphipods and whiting fed on the damaged burrowing heart urchin *Spatangus purpurreus*. Fish rapidly migrated into trawled areas to feed on animals damaged or disturbed by fishing.		

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 47 **Reefs** **Otter**	Lobster creels	Report of otter mortalities in lobster creels off S. Uist. Most were drowned foraging in depth of 2-5m of water. Greatest depth was 15m, 65% of known status were adult females 15% were juveniles, 10% sub-adult females and 10% adult males. The low number of males perhaps because fewer adult males in the favoured breeding area. Also because of their size the males may not be able to enter the parlour of the creel. Fish such as saithe, small cod and congers swim into the creels and are trapped and it is likely that the otters are attracted to this rather than the lobster bait. The incorporation of a parlour in these pots has greatly increased its ability for holding lobsters as well as otters. Does not appear to be as much a threat from crab creels as they are usually set on sandy bottom in deeper water further offshore rather than the favoured otter foraging areas.	Report of catches off coast of South Uist	Twelves J. (1983). Otter *Lutra lutra* mortality in lobster creels. Journal of Zoology, London. 201: 585-588. [PR]
REF: 48 **Estuaries** **Reefs** **Otter**	Eel fyke nets Pots	Accidental drowning of otters has occurred in crustacean and fish traps such as lobster pots, crab pots, and eel fyke nets in both freshwater and marine situations. Review of reports shows that this has taken place in parlour creels, single-compartment box creels, single compartment ‘inkwell’ creels and fyke nets. Work to prevent otter damage to fyke cod-ends suggests that in some cases they attack the nets from the outside and if severing the mesh proves impossible, move to the fyke entrance or directly to the entrance. Uncertain whether otters are attracted to crustacean traps by the bait or the catch -seems that both can occur. In the latter case this is because they tend to contain particularly favoured prey such as eels, crayfish and crabs. Estimates of times otters can submerge are for more than 3-4 mins, normal dive time is far shorter and they run out of time and drown. Sex and status of otters drowned in lobster creels off S. Uist mostly females. Adult males may be less active in the favoured breeding areas and may be unable to enter the parlour of the most widely-used creel. No data to support the view that those otters which drown are young and inexperienced. Some evidence to suggest that they escape more readily from single-compartment creels than double-chamber creels. Family parties are known to have drowned on five occasions. Juvenile casualties have involved animals towards the size where independence is reached, at about 10 months.	Report of catches off Devon coast, off the east coast of South Uist, Orkney, Skye, Shetland and west Sutherland	Jefferies D.J., Green J. & Green R. (1984). Commercial fish and crustacean traps: a serious cause of otter *Lutra lutra* (L.) mortality in Britain and Europe. Vincent Wildlife Trust, London. 31pp.
		Suggestions to alleviate the problem of drowning otters discussed in the paper. These are intermittent operation, size of net, depth, floating cod-ends, opaque covers for traps, excluders over fyke entrances; and ledges in box traps exposed to the air. Satisfactory, preventative measures for a given trap might vary, dependent upon local fishing conditions and the state of the regional otter population.		

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 49 **Estuaries** **Reefs** **Otter**	Eel fyke nets Creels	A major cause of mortality to otters has been accidental capture and drowning in fish and crustacean traps. Four types of guards for eel fyke nets were constructed and tested - square guard, ring guard, front net guard, grid guard. Effects on catches of eels (total weight, number and catch of saleable eels) were recorded. Techniques other than guards discussed but it was considered that the only safe and continually working otter protection device was a physical barrier at some point near the mouth of the fyke. The Steering Committee set up to look at the problem suggested authorities should consider and adopt most suitable designs for their situation and then consider ways of implementing and ensuring use. Otters investigate eel fyke nets because of the artificially concentrated prey in the cod end. They are unable to bite their way through modern multifilament nylon netting therefore the only way to get the prey is through the fyke entrance and down through the funnels. The time they can submerge is not sufficient in many cases for an otter to negotiate its way back to the entrance so it drowns. Between 1975-1984, 89 otters are known to have been caught in underwater traps (50, 33 and 6 in eel fyke nets, crustacean and fish nets). In the Solway verified data considered by an observer to be only 20-50% of the real total. Fish traps can be effective at reducing otter populations when set for a long period in a single locality.	Report of catches in the Solway	Vincent Wildlife Trust (1988). The effects of otter guards on the fishing efficiency of eel fyke nets. Vincent Wildlife Trust, London 47pp.
REF: 50 **Otter**	Monofilament net (discarded)	European otters have been caught and drowned in active gear such as wade nets off Pembroke, fyke nets in freshwater and estuaries and parlour creels set for lobsters. Chance encounters with cast-off fragments of “plastic” netting was not considered a cause of fatality. Otters may be attracted to explore such debris but their dexterity was thought to prevent fatalities. This now appears not to always be the case and could be an increasing problem for coastal otters. The paper describes condition of a dead otter found on the beach near Scarista on the Isle of Harris. It was emaciated and the cause of death strands of monofilament nylon which had become embedded into the flesh around the neck. It was a small section of fishing net (square aperture approximately 50mm).	Isle of Harris	Jefferies D.J., Johnson A., Green R. & Hanson H.M. (1988). Entanglement with monofilament nylon fishing net: a hazard to otters. Journal of the Otter Trust. 1988. p11-15. [PR]
		It seems likely that the otter was entangled at an early age (3-5 months) and as it grew the nylon became enclosed in tissues of the neck. Unknown how many are lost in this way and whether it is large enough to be a conservation problem and one of animal welfare. Needs monitoring. This case shows that even a small section of discarded net can be lethal therefore the solution is difficult.		

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 51 **Estuaries** **Reef** **Otter**	Fyke nets Creels	Further reports of otter deaths in fyke nets and creels. These include 2 males in fyke nets in the upper Ythan estuary after nets in the river for only 3 days, indicating the speed at which an eel fyke net will operate as an otter trap in a catchment with normally high otter density. Also reports the release of an otter from a fyke net providing an example of otter surviving capture when in shallow water if struggles bring the cod-end to the surface. Deaths in creels reported from a lobster creel in Scapa Flow, crab creel off Isle of Arran and prawn creel off Skye. Data confirm the potential of eel fyke to attract and kill otters living at very low density. Also appears to be considerable attraction when silver eels begin their seasonal migration - August/September on East Coast, October/November in Severn. This must be one of the last opportunities for otters to feed on eels in quantity before capture becomes too difficult until spring. Overall monthly distribution of all drownings in fykes, creels and fish traps shows a marked concentration in autumn and winter. Partly explained by seasonality of fishing but also when main food may be reduced for seasonal reasons. Four otter guard test results shows only a significant difference with the square guard but only approximately 17% reduction. This guard is used by the Danes as mandatory on fyke nets. They have been mandatory in some UK regions since the 1980's. Crustacean trap problem still unresolved and an issue on the rocky coasts of NW Scotland, the Northern and Western Isles.	Ythan Estuary, Scapa Flow, Isle of Arran and off Skye	Jefferies D.J. (1989). Further records of fyke net and creel deaths in British otters *Lutra lutra* with a discussion on the use of guards. Journal of the Otter Trust. 1989 p13-19. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 52 **Sandbanks** **Shallow inlets and bays**	Beam trawling	Review of data on penetration of depth of ticklers and chain arrays of beam trawls. <u>Habitat effects</u> **-** Under normal working conditions beam trawls influence only the top layers of the sea bed up to 30mm on muddy ground and up to 10mm on sandy ground. Summary of results to date suggest average penetration depth 4-7cm. The depth depends on the bottom type and structure of the ticklers and does not always penetrate as the gear moves over the seabed at speeds of 6-7 knots.		Groot S.J. de (1995). On the penetration of the beam trawl into the sea bed. ICES C.M. 1995/B:36
REF: 53 **Estuaries** **Reefs** **Shallow marine inlets and bays** **Sandbanks** **Seabirds**	Trammel nets and gill nets (discarded)	90m long gill net (100mm diameter mesh) and trammel net (100mm with 600mm diameter outer mesh) set by commercial fisherman and cut at one end to simulate net loss. Survey of catches by direct observation, still and video photography for the following 9 months. <u>Species and community effects</u> **-** Both nets caught large numbers of elasmobranchs which took about 3 weeks to decompose. Gadoids were eaten within 72hrs therefore not possible to tell how many were caught throughout the observation period and estimates were considered by authors to be conservative. Initially both nets caught more fishes than crustaceans but by 20 days crustacean catch was greater than fishes and was greatest 43 days after initial deployment. Catch per 24hr period declined with time and for fish was nearly zero at 70 days for gill net and 22 days for trammel net. Catch per 24hr for crustaceans remained higher than for fish for both nets throughout the study. Reduction of catch rate probably linked to reduction in net size and degree of entanglement. Overall catch over the 134 day experiment was 261 animals in the gill net and 292 in the trammel net. *Maja squinado* and *Scyliorhinus canicula* were the 2 species most commonly caught in both nets. Other species caught were lobster, brown crab, swimming crab, Nurse hound and Smooth hound. All the crustaceans caught known to scavenge carrion. Other scavengers also aggregated to feed on the animals in the nets included *A. rubens, M. glacialis, O. fragilis* (in large swarms) and *E. esculentus*. Three shags were also caught. When nets retrieved (3 months after last survey) 2 spider crabs, previously marked were still alive after more than 102 days in the net. Towards the end of the experiment the free end of the nets began to roll up reducing the total length of net. Authors conclude that total catch of animals during life of a net may be considerable as in the present study but will depend on local fauna, habitat type and environmental conditions at the site.	St Brides Bay, Southwest Wales	Kaiser M.J., Bullimore B., Newman P., Lock K. & Gilbert S. (1996). Catches in ‹ghost fishing' set nets. Marine Ecology Progress Series. 145: 11-16. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 54 **Shallow bays and inlets**	Mussel dredging	Experimental work *in situ* and in laboratory to evaluate the importance of the upwelling of sediment during dredging and, in particular, the amount of sediment particles, nutrients and oxygen consuming substances released during dredging as these factors can effect macrophyte and phytoplankton growth as well as affecting fish and bivalves. <u>Habitat effects</u> **-** Preliminary results suggest a minimum flux of $2km^2$, corresponding to about 0.9cm penetration of the gear. The release of particles, nutrients and oxygen-consuming substances seems to have little effect on the overall environmental conditions in the fjord. Where 10-15 boats dredge for several days, authors note that this will alter the local concentrations of nutrients and suspended matter directly, but the effect would probably only be visible or significant, during the dredging operations. Total annual release of suspended particles shown to be relatively unimportant compared with total annual wind-induced resuspension and release of nutrients compared to load from land. <u>Species and community effects</u> **-** the effects are probably much more severe on the ecosystem by changing the bottom flora and fauna which may in turn affect water quality. If natural bottom community cannot be established the areas will be characterised by low biodiversity and by opportunistic species dominated by young individuals of small sizes. Overall environmental effects of this disturbance in Limfjorden is not fully understood.	Limfjorden, Denmark	Dyekjaer S.M. Jensen J.K. & Hoffman E. Mussel dredging and effects on the marine environment. ICES C.M. 1995/E:13 ref.K.
REF: 55 **Seabirds**	Discards and offal from several fisheries	Data from a study of scavenging seabirds in the North Sea and review of literature on quantities of discards. Fishery waste from North Sea fishery is important to seabirds. The sources evaluated here are demersal trawlers and seiners catching gadoids, pelagic trawlers and seiners, and beam trawlers. Authors estimate quantity available amounts to around 62,800t offal, 262,200t roundfish, 299,300t flatfish, 15,000t elasmobranchs and 149,700t benthic invertebrates per year. Beam trawls have the highest rates of discards of fishing fleets in the area. Discard fraction is dominated by flatfish which are less favoured by seabirds potentially supported by fishery waste in the North Sea estimated to be roughly 5.9 million individuals in an average scavenger community. Discards and offal may easily support all scavenging seabirds in southern and southeastern sub-regions of the North Sea for example but only half in the northwest region.	North Sea	Garthe S, Camphuysen K.C.J. & Furness R.W. (1996). Amounts of discards by commercial fisheries and their significance as food for seabirds in the North sea. Marine Ecology Progress Series. 136:1-11. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 56 **Shallow inlets and bays** **Sandbanks**	Beam trawling	Distribution of fishing effort by 25 Dutch commercial beam trawlers analysed and show that in 8 of the most heavily fished rectangles in the North Sea, 10% of surface area trawled less than once in 5 years, 33% less than once in a year. The surface area of the seabed trawled more than 10 times a year estimated at 3%. Authors note two key parameters to be considered in relation to the impact of beam trawling on benthic fauna; depth of penetration of the beam trawl in relation to sediment type, and spatial distribution of beam trawl effort. They note that the areas of intensive beam trawling have been trawled intensively for several years and still provide profitable fishing grounds and comment that without ample benthic food for plaice and sole, these fishing grounds would have lost their profitability for fishing. However a further comment is that it is not unlikely that the benthic community in intensively trawled areas shifted towards a dominance of highly productive opportunistic species.	Southern North Sea	Rijnsdorp A.D., Buijs A.M., Storbeck F. & Visser (1996). Micro-scale distribution of beam trawl effort in the southern North Sea between 1993 and 1996 in relation to the trawling frequency of the sea bed and the impact on benthic organisms. ICES C.M. 1996/Mini 11.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 57 **Shallow inlets and bays** **Sandbanks**	Scallop dredging	Update on studies relating to areas closed to fishing. Two described here. Other studies reported are trawling experiment on the Grand Banks, North Sea Plaice Box, Loch Gareloch (Scotland) and Gullmar Fjord (Sweden). Comparison of community structure in areas of high and low scallop dredging on northern Georges Bank shows undredged sites had higher densities of shallow burrowing and epibenthic species, more abundant *Modiolus modiolus* and more abundant small fish. Hard-shelled molluscs were equally abundant at dredged and undredged sites as well as scavenger species suggesting that scavenger abundance was not food limited. No consistent differences in mean size and weight of species between dredged and undredged sites. Many polychaete species were only abundant at the undredged sites because of the complex habitat there. Habitat complexity was higher at the undredged sites due to present of *Filograna implexa*, bushy bryozoans and hydroids. Closed area (from 1989) of scallop ground off Port Erin, Isle of Man is being used to assess environmental impact of scallop dredging. Benthic community and physical habitat has been compared with adjacent areas since 1994 and two plots within the closed area experimentally dredged at 2 month intervals. Results to date show differences in the epifaunal communities including greater species consistently more abundant in undredged areas. Further analysis shows this was due to absence of dredging and not variations in sediment or depth. Overall higher densities of shallow burrowing and epibenthic species at the undredged sites but particular species noted for their vulnerability to dredging eg *A. digitatum*, *Anseropoda placenta*, *Luidia sarsi*, *Cellaria fistulosa* and *E. esculentus*. There was no evidence of longer-lived benthic species at undredged sites but this was not surprising due to relatively short time since effective closure of the area. Scavenger species were common at both dredged and undredged sites with *A. rubens* consistently more abundant on the dredged sites. Ratio of polychaetes to molluscs was lower at the dredged sites and may be due to greater habitat complexity in the closed area although authors also note that infaunal bivalves were probably not adequately sampled.	Northern Georges Bank, NW Atlantic Port Erin, Isle of Man	ICES (1996) Report of the Working Group on Ecosystem effects of fishing activities. ICES C.M. 1996/Assess/ Env:1. Ref: G. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 58 **Shallow inlets and bays** **Sandbanks**	Beam trawling	Review of impacts of bottom trawling <u>Habitat effects</u> **-** Effect of trawls will be influenced by substrate. Visibility of markings depend on substrate and currents and depth of penetration up to 30mm on muddy ground and 10mm on sandy ground. <u>Species and community effects</u> **-** Some groups of animals eg hydrozoans, echinoderms (eg heart urchins) suffer heavy damage by trawling, others escape relatively easily (eg gastropods, hermit crabs). Author speculates that it is not unlikely that in the long-term a shift in species and numbers may occur as has been found in the German Wadden Sea where polychaetes are on the increase and molluscs and crustaceans in decline but that this is unlikely to have a negative effect on fish stocks. Large quantities of benthic animals become available as food source for fishes. Temporary covering due to sand movement is not exceptional and they will survive, and a shift in species distribution from one group or groups of animals to another cannot be ruled out in the long-term. Author comments that as this shift is, in principle, reversible it constitutes no major threat to benthic life.	North Sea	Groot S.J. de (1984). The Impact of bottom trawling on benthic fauna of the North Sea. Ocean Management 9:177-190. [PR]
REF: 59 **Grey seal** **Common seal** **Harbour porpoise** **Diving seabirds**	Aquaculture	Survey into the effects of predator control measures around aquaculture facilities. Grey seals, common seals, cormorants, shag and mink were the most prevalent predators with most of the fish farms surveyed suffering losses to some or all of them. Eider duck and, on some occasions oyster catchers are known to feed on shellfish farms. Predator control measures can be detrimental to all these species which can get tangled and drown in predator nets. Tangling in fish farm nets, mostly top nets and predator nets, was reported from 68% of the 47 sites visited. The animals reported caught were seals, herons, cormorants, shags but also gulls, eider duck, black guillemot, great northern diver, gannet, dolphins (unspecified), harbour porpoise and even a basking shark. Seals, herons, cormorants and shags have also been shot by fish farm operators to protect the stock. The main impacts of predator control around fish farms are disturbance, displacement and killing both directly and indirectly. More detailed information is needed to assess the significance to local populations but author suggests that it is likely to be acute given the concentration of destructive control measures around individual farms.	Scotland	Ross A. (1988). Controlling nature's predators on fish farms. Marine Conservation Society, Ross-on-Wye. 96pp.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 60 **Sturgeon**	General effects of fishing	Life history of 24 species of sturgeon summarised with details of the three different life histories depending on whether the adults remain in fresh water, move into brackish water or finally move into the sea. Sturgeons are of economic importance as stocks are exploited. Accidental catches in trawls and nets sometimes happen at sea (eg juveniles caught when trawling for clupeid fishes in the Black Sea) but it occurs especially at the mouths of large rivers when fishing for other species. Other impacts, physical obstacles for migrating fish and physical impacts on spawning and nursery areas are also described together with possible mitigating measures. The need to develop techniques for artificially rearing of sturgeon is proposed.	Europe	Rochard E., Castlenaud & Lepage M. (1990). Sturgeons (Pisces: Acipenseridae); threats and prospects. Journal of Fish Biology. 37 (Supplement A); 123-132. [PR]
REF: 61 **Sturgeon** **Lampern** **Sea Lamprey** **Allis Shad** **Twaite Shad**	General effects	A review of site based information on these species, life history, distribution, habitat, reproductive biology and sources of threat. Together with recommendations to better assess and implement actions to help with the conservation of each species.	UK	Potts G.W. & Swaby S.E. (1993). Marine Fishes on the EC Habitats and Species Directive.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 62 **Estuaries** **Shallow inlets and bays** **Mudflats and sandflats** **Seabirds**	Mechanised cockle fisheries	Review. Environmental effects fall into several broad categories the most obvious being (a) direct impacts, mainly on the benthic biotopes and on the discarded undersize by-catch (b) indirect interactions with predators and scavengers, including shorebirds, (c) ancillary disturbance from the vessels and vehicles, including effects at the shore access points. <u>Habitat effects</u> **-** Hydraulic dredge tracks can be seen at low tide days or weeks later, persistence depending on the stability of the sediment surface and the prevailing tide or wave conditions. On areas of cohesive sediment the tracks appeared to act as lines from which erosion of the surface layer spread out therefore appearing to accelerate the erosion phase of a natural cycle of cohesion of the surface sediment by worm tube mats. Where dredging has been carried out in a sheltered area with eel grass (Auchencairn Bay) breaking the sward allowed erosion that produced clearly visible grooves down the shore. Long-term effects on benthic diatoms on and in the surface of intertidal flats were considered unlikely. <u>Species and community effects</u> **-** Shell breakage occurs with overall damage rates to cockles and *Macoma baltica* in screen rejects from hydraulic dredgers 12.6% and 5.3% respectively. In experimental plots where damage rates from tractor dredging were determined these were 9.3% in an area of muddy sand and 8.2% in a sandy area but only impinged directly on about 80-85% of the area of the plots. Dredged areas often had a lot more dead shell scattered on the surface, an effect which can persist for several months whereas in undisturbed beds most dead shell is normally under the surface which can create a shell layer limiting the depth to which small drainage channels can normally erode into a cockle flat. Observation on other species include the tendency for some motile species, like the amphipod *Bathyporeia sarsi* to temporarily leave disturbed areas, lugworms producing normal casts in dredge tracks as soon as the tide falls, tubes of the sand mason worm *L. conchilega* still standing, apparently to nearly their full extent in the hydraulic dredge tracks. Results from a study of tractor dredging in the Burry Inlet recorded declines in other invertebrates (particularly *H. ulvae*, *P. elegans* and *N. hombergi*), the greatest fall being 14 days after dredging for the less mobile species in the muddy areas, and increases in some species *Urothoe* sp., *M. balthica*, *A. tenuis*. Localised additional bird activity has	Various UK sites	Rees E.S. (*in press*). Environmental effects of mechanised cockle fisheries: a review of research data. A report commissioned by the Ministry of Agriculture Fisheries and Food.

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
		also been reported in some areas following dredging. In a study on the Solway Firth it was concluded that because natural changes are very large the fishery may not have a significant effect on bird numbers unless a high proportion of the cockles are harvested. On sandy areas the effect on most invertebrate populations was considered to be causing some thinning of stocks rather than persistent patchy defaunation. In muddier, more cohesive sediments tracts may persist for months. Persistent hydraulic dredging has in some cases been reported to have changed the sediment structure which may have medium term consequences for deposit feeding benthic species. The most undesirable effects are where the surface is bound by swards of eel-grasses.		
Natura 2000 Habitats & Species	**Fishing Technique**	**Effects**	**Location**	**Reference**

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 63 **Shorebirds**	Intertidal Shellfisheries	Report develops a predictive model to explore the effect of different shellfishery management options on the mortality rates of the migratory shorebirds that feed on shellfish on intertidal wintering grounds in Europe. Effects incorporated include disturbance and reduction of abundance of the shellfish stocks. Application to the Exe estuary was successful in predicting levels of oystercatcher winter mortality in previous years. Main conclusions were: ! Given a number of conditions it is possible to exploit shellfish stocks without increasing the winter mortality of shorebirds. ! Effects of a given intensity of shellfishing depends crucially on local conditions of the climate and the general abundance of food. ! Methods of shellfishing which disturb birds can be significantly more damaging to the bird's chances of survival. ! Numbers of birds using alternative food sources is an early warning that a change in shellfishery practice is beginning to have an effect on the birds. ! Key factor in determining the impact is the proportion of the shellfish stock that is affected ! Cumulative effects of small increases in shorebird morality in winter can over a period of years greatly affect stable population size. ! As fishing effort increases, shorebird mortality may be hardly affected initially but then may suddenly increase dramatically once a threshold level of fishing effort has been reached.	Model tested on Exe estuary	Stillman *et al*., (1996) Models of Shellfish Populations and Shorebirds: Final Report. Institute of Terrestrial Ecology Report to the Commission of the European Communities, Directorate-General for Fisheries.
REF: 64 **Estuaries** Shallow inlets and Bays Mudflats and Sandflats Shorebirds	Bivalve mariculture	Reviews current knowledge of environmental modification or conflicts with other species at seed collection, seed nursery and on-growing, and harvesting stages of the cultivation process. Seed collection - subtidal dredging for seed mussels likely to be confined to relatively small areas of seabed because they occur in dense aggregations in discrete areas. UK licensed areas from unstable beds which are likely to be lost anyway. Non-target species probably adapted to large-scale natural disturbance so likely to recolonise rapidly but in extensive heavily exploited fisheries, such as the Wadden Sea, the entire mussel stock was removed in 1990/1 resulting in increased mortalities for eider duck and reduced breeding success for oyster catchers. May be some effects associated with intertidal collection (trampling, disturbance of foraging birds and removal of winter food source). Few impacts likely from spat collectors, continuous relaying of cultch leads to habitat modification which may increase diversity. There are also risks of introduction of alien species. Ongrowing - effect depends on habitat, type and scale of cultivation. Introduced structures effect local hydrography and provide a settlement surface, high densities increases local oxygen demand and		Kaiser *et al*., (1998) Environmental impacts of bivalve mariculture. J.Shellfish Res. 17(1):59-66. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
		elevates input of organic matter however beds used to be extensive and they fulfil an important role in the retention of phosphorus and nitrogen. May be eutrophication beneath mussel lines if not enough tidal flow to disperse particulate matter. Decreases in abundance of macrofauna and increases in meiofauna beneath oyster trestles been measured. In the USA insecticide is sprayed on intertidal areas and ground may be harrowed prior to cultivation. Addition of gravel or shell, formation of mussel mud anduse of protective netting induces localised changes in benthic community composition. Small-scale culture seems to have only very limited effects on local benthic communities. Cultivation sites may conflict with bird feeding or roosting sites but probably only problematic if cultivation areas cover significant part of the feeding grounds. Harvesting - restriction harvesting to early winter could ameliorate site restoration if main mechanism for recolonisation is by larval settlement. Suction dredging or mechanical rakinking affects the habitats. Recolonisation rates likely to differ between habitat types. Management considerations in light of the reported effects are discussed and potential beneficial effects mentioned such as the proposal that integrated fish/bivalve mariculture systems can ameliorate undesiratal impacc ts of nutrient rich effluents from fish farmining, or for restoration of enclosed, polluted water masses.		
REF: 65 **Shallow inlets and bays** **Sandbanks**	Various	Starfish and decapod Crustacea are among the most important megaepibenthic scavengers that aggregate in areas of fishing activity but recent work indicates that scavengers are far more selective than presumed previously. They avoid carrion that is phylogenetically similar and may avoid carrion that attracts potential predators. The authors suggest that additional food resources arising from fishing activities are distributed unequally between sympatric populations of hermit crabs as a consequence of differences in their competitive abilities. This may provide a mechanism whereby fishing activities could lead to changes in the structure of crustacean scavenger populations. This type of effect has been well document for seabirds where fisheries-generated offal and discards have been linked to the increase in populations of larger scavenging seabird species.		Kaiser, M.J., Ramsay, K & Hughes, R.N. (1998) Can fisheries influence interspecific competition in sympatric populations of hermit crabs? J.Natural History 32:521-531. [PR]
REF: 66	Beam trawling	Experimental beam trawling trials to investigate effects on megafauna immediately after fishing and 6 months later on two seabed types - mobile megaripple structures and stable uniform sediment. Control and fished areas were sampled.	Area off north east coast of Anglesey,	Kaiser et al., (1998) Changes in megafaunal benthic communities in

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
Shallow inlets and bays **Sandbanks**		Short term changes (within ca. 24hrs) were recorded in the megafaunal community in stable sediments but not in the mobile sediments. There were decreases in the relatively slow moving megafauna eg *Aphrodita aculeata*, *Macropodia deflexa* and *Asterias rubens*. Some mobile species (eg. *Pagurus bernhardus* and *Ophiura ophiura* increased in the trawled area and are known to migrate into areas of fishing disturbance. There were also increases in some relatively sessile species eg. *Mya truncata* in the trawled areas but not statistically significant. The effects on the megafaunal community were not uniform, even though the fished areas were completely swept by the gear at least once. Six months later, seasonal changes had occurred in both communities and the effects of the trawling disturbance were no longer evident. No significant change in biomass of hydroids and *Alcyonium digitatum* recorded immediately after fishing although these organisms were the largest proportion of the biomass of beam trawl catches at the study site. Repeated and more intense trawling effort is likely to have a greater effect on these organisms.	Liverpool Bay.	different habitats after trawling disturbance. ICES J.Mar.Sci. 55:353-361. [PR]
REF: 67 **Shallow inlets and bays** **Sandbanks**	Bottom trawling	Author develops a conceptual model of gear impacts across gradients of habitat complexity and levels of fishing effort. Habitats are grouped into 8 general categories and scored according to their complexity. The conceptual model shows the response of the range of seafloor habitat types to increases in fishing effort scored from 0 to 4. It shows a range of changes in habitat complexity based on the effects of fishing grear and predicts reductions in the complexity provided by bedforms from direct smoothing of gear.		Auster, P.J. (1998) A conceptual model of the impacts of fishing gear on the integrity of fish habitats. Cons.Biol. 12(6): 1198-1203. [PR]
REF: 68 **Shallow inlets and bays** **Sandbanks**	Otter trawling	Comparison of two fishing areas over a three year period, one of restricted fishing with light levels of trawling and the other with high levels of trawling. Results indicate that intensive trawling significantly decreased habitat heterogeneity. All the epifaunal invertebrates counted were less abundant in the heavily trawled area. No differences were found in the number of infaunal crustacean species but there were more polychaete species in the lightly trawled area every year, implying that high levels of trawling can reduce biodiversity. This also suggests that high-intensity trawling favours opportunistic species. High numbers of ophiuroids and the amphinomid polychaete *Chloeia pinnata* in the highly trawled area may be because they can pass through net mesh unscathed and then benefit from feeding on those organisms that the net crushes or kills. *C.pinnata* was also found to be the most common	Monterey Bay, USA	Engel, J. & Kvitek, R. (1998) Effects of otter trawling on benthic community in Monterey Bay National Marine Sanctuary. Cons.Biol.12(6):1204-214. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
		invertebrate in the diet of several commercially important flatfish species in both areas suggesting that certain prey species and commercially important fish may be enhanced by some level of trawling disturbance.		

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 69 **Shallow inlets and bays** **Sandbanks**	Otter trawls	Three year study into the effects of otter trawling on a sandy-bottom ecosystem of the Grand Banks. Sediment samples, acoustic measurements and video surveys undertaken. Habitat effects Statistical analysis of seven size fractions gave no evidence that trawling had any immediate effect on sediment grain size. Sidescan sonar showed the persistence of door tracks was variable from several months to a year. Acoustic data suggest that repeated trawling did not affect sediment texture but increased surface relief or roughness. Small-scale biogenic sediment structure down to 4.5cm also changed. Video surveys showed clear differences in the appearance of the seabed. After trawling hummocks were removed or less pronounced, organic floc was either absent or less abundant and mottled appearance of the seabed less pronounced. Sediment grain size data suggest that there may be natural inter-annual changes that are more pronounced than those caused by the experimental trawling. Species effects. Video imagery showed organisms and shell has organised into linear features in the trawled areas. At times high concentrations of *Strongylocentrotus pallidus* were visible and seemed to be scavenging on dead snow crabs. Biological effects have still to be examined.	Grand Banks	Schwinghamer *et al.*, (1998) Effects of experimental otter trawling on surficial sediment properties of a sandy-bottom ecosystem on the Grand Banks of Newfoundland. Cons.Biol 12(6): 1215-1222. [PR]
REF: 71 **Shallow inlets and bays** **Sandbanks**	Bottom trawling	Effects of mobile fishing gear at three sites on a variety of bottom types in the Gulf of Maine were investigated. Habitat complexity was reduced by direct removal of biogenic and sedimentary structures and the organisms that create structure eg. reduction of an extensive sponge community to the occasional small colony on large boulders, absence of previously widely distributed ascidian, reduced density of shrimp, dispersal of shell deposits by mobile gear. Authors discuss how this reduction in complexity may lead to increased predation on juveniles of harvested species and ultimately recruitment to harvestable stock especially in the northeast USA, where fish assemblages are part of a system where predation mortality on postlarval and juvenile fishes has a major effect on year-class strength.	Gulf of Maine	Auster *et al.*, (1996) The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (northwest Atlantic): implications for conservation of fish populations. Reviews in Fish.Sci. 4(2): 185-202.
REF: 72 **Shallow inlets and bays**	Beam trawling	Analysis of bycatch of 7 fish and 10 invertebrate species taken in otter and beam trawls in an areas north west of the Netherlands which were registered annually between 1945 and 1983. A fisheries catchability model is developed using this data. For species with reliable field data the model results on long-term trends in abundance were in agreement with observations eg. considerable decrease in abundance of Roker and Common skate off Dutch coast between 1951 and 1960. Model also suggests that decline of landings of greater weever in early 1960s often considered to be due to severe winter	Northwest Netherlands	Philippart, C. (1996) Long-term impact of bottom fisheries on several bycatch species of demersal fish and benthic invertebrates in the

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
Sandbanks		and/or introduction of beam trawlers should also be attributed to effects of otter trawling. Most differences could be related to changes in gear and fishing effort with otter trawlers catching relatively more fish than invertebrates and beam trawlers catchability ten times higher than that of otters for all species considered. Model estimates suggest that bottom fisheries had a considerable impact on the abundance of several bycatch species even before the Second World War.		southeastern North Sea. ICES Annual Science Conference.
REF: 73 **Shallow inlets and bays** **Estuaries**	Aquaculture	Two year study of macrofaunal succession and sedimentary biogeochemical parameters of seabed after intensive fish farming discontinued at 3 sites. All sites had low numbers of taxa at the beginning of the survey which increased in the two years but one site remained impoverished. The increase showed large fluctuations in one case which the authors attribute to a secondary input of organic material to the site which was considered to have set back recovery by at least 6 months. This points to the sensitivity of recovering sediments to additional stress. Improvements in terms of increased numbers of species and increased redox potential were recorded together with decreases in organic carbon, nitrogen and pore-water ammonia.	Loch Fyne & Loch Sunart	Nickell, T.*D et al.,* (1998) The recovery of the seabed after the cessation of fish farming: benthos and biogeochemistry. CM 1998/V:1
REF: 74 **Shallow inlets and bays** **Sandbanks**	Trawling	Study of the effects of extensive and repeated trawl disturbance over 18 months followed by 18 months recovery in an area which has been closed to fishing for over 25 years. Reference and treatment areas sampled. <u>Habitat effects</u>. The relative differences in roughness between the treatment and reference areas increased during the disturbance programme and declined during the recovery period. The sediment in both areas was poorly sorted fine silt and trawling disturbance did not appear to have any effect on the sediment characteristics but trenches were left in the sediment by the trawl doors. Differences in organic carbon levels were not thought to be ecologically significant. More than 18 months was required before the physical characteristics of the sites became indistinguishable. <u>Species & community effects</u>. Changes over time in abundance of individuals occurred at both sites but a treatment effect was also observed. Species numbers were greater at the treatment site after 16 months and remained so throughout the monitored recovery period. Numbers of some individuals were also significantly greater at the treatment site after 10 months disturbance (eg. *Chaetozone setosa* and *Caulleriella zetlandica*) only returning to similar numbers after 18 months recovery. Others declined in density (*Scolopolos armiger* and *Nephtys cirrosa*). There were no detectable effects on infaunal biomass. Community effects extended beyond the 18 month recovery period	Loch Gareloch	Tuck I.D., *et al.,* (1998) Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch . Mar.Ecol.Prog.Ser. 162:227-242. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
		studied. Such recovery times suggest that even fishing during a restricted period of the year may be sufficient to maintain a community in an altered state.		

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 75 Shallow inlets and bays Sandbanks	Water jet dredges.	Experimental dredging in sandy areas swept by strong tidal flow with a paucity of epifauna but openings of numerous larger infaunal animals such as various bivalve species.Tests conducted using single fishing events rather than repeat fishing. <u>Habitat effects</u>. Trenches up to 2m wide and 0.15 deep at centre were observed. These started to fill after 5 days and were no-longer visible after 11 weeks but sediment in the tracks remained fluidised under a thin crust of firm sediment. Long term physical effects are less well understood and may be exacerbated by repeated fishing of the same area. <u>Species and community effects</u>. Immediate reduction in number of species, individuals and biomass in fished tracks but measures of diversity showed no effects. Abundance of polychaetes reduce and of amphipods increase. Crab species moved into the region to scavenge of material disturbed by the dredge. The results suggest biological effects are only short term. No effects were recorded after 11 weeks. Species likely to be damaged (eg.heart urchins and large bivalves) were rare in the samples but present in dredge catches where damage was noted. Most of the animals in the sediments are adapted to a mobile environment so other than being removed or displaced they were not thought to be greatly affected by the dredging. On the basis of this work difficult to comment on areas with more obvious and diverse epifauna. Authors conclude there is little difference between the biological impact of water jet dredges and suction dredging although the latter may have a greater physical effect and fish less selectively.	Western Isles	Fisheries Research Services (1998) A Study of the effects of water jet dredging for razor clams and a stock survey of the target species in some Western Isles populations. Marine Laboratory, Aberdeen Report No. 8/98.
REF: 76 **Shallow inlets and bays** **Sandbanks**	Bottom trawling and dredging.	Review paper. Authors suggest that effects of bottom trawling are the marine equivalent of forest clearcutting, acting as a major threat to biological diversity and economic sustainability, and occurring at a rate two orders of magnitude higher than forest loss worldwide. Reasons include reduction in structural complexity of benthic communities, alternation of biogeochemical cycles, and slow recovery after disturbance. The effects can be large and long-lasting on benthic communities as well as young stages of some commercially important fishes although other species benefit when structural complexity is reduced. Recent experimental studies on trawling and dredging impacts on benthic communities are tabulated. The paper describes the extent and severity of the activity noting that advances in fishing technology have virtually eliminated de facto refuges from trawling, and that frequency of trawling is orders of magnitude higher than other severe seabed disturbances. It calls for the establishment of refuges free		Watling, L. & Norse, E.A. (1998) Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. Cons.Biol. 12(6):1180-1197. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
		of mobile fishing gear, modification of fishing methods and a precautionary approach to management.		
REF: 77 **Shallow inlets and bays** **Estuaries** **Mudflats and sandflats** **Reefs** **Sandbanks** **Seabirds**	Various	Review paper describing direct and indirect effects of fishing gears on benthic fauna and habitat, fish community structure and trophic interactions. Effects on habitats and benthic communities most readily identified and last longest in those areas that experience infrequent natural disturbance. Initial effects can be dramatic, additional effects more difficult to detect. Authors concluded that once an ecosystem enters the fished state, diversity, structure and fish production tend to remain relatively stable across a wide range of fishing intensities. Fishing has accelerated and magnified natural declines in abundance of many forage fishes and this has led to reduced reproductive success and abundance in birds and marine mammals. Dramatic and apparently compensatory shifts in the biomass of different species in many fished ecosystems are considered to often be driven by environmental change rather than indirect effects of fishing. When predator or prey fill a key role, fishing can have dramatic indirect effects on community structure Authors conclude that many marine ecosystems are overfished and that better management is needed. Population-based management, management which minimises the direct and indirect effects of fishing and the case for marine reserves as an adjunct to other management methods are discussed.		Jennings, S. & Kaiser, M.J. (1998) The effects of fishing on marine ecosystems. Adv.Mar.Biol. 34:201-352. [PR]
REF: 78 **Shallow inlets and bays** **Sandbanks**	Bottom trawling	Report on the results of international research project investigating the effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystem. Provides an overview of the effects of bottom trawling on marine communities with chapters on physical impact, direct mortality due to trawling, scavenger response to trawling, comparison of undisturbed and disturbed areas and long term trends in demersal fish and benthic invertebrates. Recommendations are made for future studies including approaches to management and fishing methods. For more conclusive evidence on the long-term effects of beam trawling on benthic ecosystem authors call for study of relatively large areas closed to fisheries for many years.		Lindeboom, H.J & de Groot, S.J. (Eds) (1998) The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems. RIVO-DLO Report C003/98
REF: 79	Suction dredging	Comparative study of dredged and undredged sites to investigate effects of suction dredging on razor clam. Undredged site was characterised by an absence of small razor clams, contained the largest individuals, and a higher density of razor clams. At the dredged site the population had changed considerable in the 7 years of spasmodic dredging. The most notable differences were the absence of	Orphir Bay and Bay of Ireland, Orkney Islands	Robinson, R.F. & Robinson, C.A. (1998) The direct and indirect effects of suction dredging

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
Shallow inlets and bays **Sandbanks**		a middle size range of clams and a decline in the number of large razor clams. Shells from the dredged site hand considerably more disturbance marks/damage to the outer shell layer than at the control site with 70% showing the highest level ie. Deep clefts in the outer shell layer embedded with sand grains. Observations of the reburying of razor clams collected by airlift and subsequently released onto the surface of the sediment suggested that they are highly vulnerable to attack from predatory crabs and will experience a high level of mortality after removal.		on a razor clam *(Ensis arcuatus)* population. ICES J.Mar.Sci 55:970-977. [PR]
REF: 80	Gill net	Survey of lost gill net over a three year period using submersible. Known ghost net sites at depths between 30m and 127m on a variety of seabed types, surveyed quantitatively by transects. 700m long ghost net on Stellwagen Bank in a boulder field grading to silt-clay substrate was visited on two occasions. Species caught include dogfish, bluefish, lobster, spider crab and edible crab. Hagfish were often seen preying on the dogfish and bluefish. A 470m long ghost net surveyed for two consecutive years had dogfish as the most predominate vertebrate catch. Cancer crabs were the most common invertebrate catch. Codfish were not seen in the ghost gillnet, nor were there identifiable remains of cod at the base of the net.	Gulf of Maine	Cooper, R.A. (1988) Manned submersible and ROV assessment of ghost gillnets on Jeffries and Stellwagen banks, Gulf of Maine. NOAA Undersea Research Programme Research Report 88-4.
REF: 81 **Harbour porpoise** **Bottlenose dolphin**	Gill net	Assessment of cetacean by-catch in the Irish and UK set gill net fisheries for hake in the Celtic Sea over 19 months based on observer programme. Marine mammal by-catch during the sampled trips was 43 porpoises and 4 common dolphins. One porpoise was in a tangle net the rest in the hake nets. No relationships were recorded between by-catch rate and water depth and no significant differences between hake nets with double or single footropes. There were significantly higher by-catch rates during neap tides but no correlation with sea state during net hauling or with hake landings. Observations consistent with porpoise entanglement occurring while net is one the bottom. By-catch rate was 7.7 porpoises per 10,000 km/hr of net immersion. Authors conclude that although they cannot accurately quantify the impact of the set gill net fishery in the Celtic Sea on harbour porpoises, there is a serious cause for concern about the ability of the populations to which these animals belong to sustain an annual by-catch of the magnitude indicated by their study.	Celtic Sea	Tregenza N.J.C., (1997) Harbour porpoise (*Phocoena phocoena* L.) by-catch in set gillnets in the Celtic Sea. ICES Journal of Marine Science 54:896-904. [PR]
REF: 82	Aquaculture	Symposium report with papers dealing with the physical environment, input of nutrients and chemicals, benthic enrichment, interactions between sea trout and other fish species, seabirds and mammals and aquaculture, the use of wrasse, the consequences of nitrogen enrichment and the	Principally Scottish sea lochs	Black, K.D. (Ed) (1996) Aquaculture and sea lochs. Scottish Association for

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
Shallow inlets and bays **Estuaries** **Mudflats and sandflats** **Sandbanks**		possible effects of escapees on wild fish.		Marine Science.
REF: 83 **Shallow inlets and bays** **Estuaries** **Mudflats and sandflats** **Sandbanks**	Aquaculture	Review of environmental issues associated with different types of aquaculture conducted around the world. Describes different systems of aquaculture then covers environmental impact of the facilities (eg. mussel cages and floating cage farming), and of the use of chemicals including antibiotics. Sections on waste minimisation, wastewater treatment systems and environmental management systems for aquaculture.		Midlen, A. & Redding, T. (1998) Environmental Management for Aquaculture. 223ppChapman & Hall. London
REF: 84 **Reefs** **Shallow inlets and bays** **Sandbanks**	Potting	Experimental study on catches and mortality and 10 simulated lost traps, left in place for 1 year. During this time 169 crabs (*Cancer magister*) were caught, nearly all males, and about half died. This despite 'escape ports' to allow crabs under the legal minimum to escape. Study revealed that the traps continue to attract crabs long after initial bait has gone, and that catch rates were as high after 1 year as 2 weeks after the start of the study. Questionnaire survey of crab fishermen in Fraser River estuary led to estimates of an annual trap loss rate of 11% leading to estimate that loss to ghost fishing might be equivalent in weight to 7% of report catch in the Fraser River District.	British Columbia	Breen, P.A. (1987) Mortality of Dungeness crabs caught by lost traps in the Fraser River Estuary, British Columbia. N.Am.J.Fish.Mnt.7:429-435. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 85 **Shallow inlets and bays** **Sandbanks**	Scallop dredging	Scallops (*Argopecten irradians*) are found in commercially valuable quantities almost exclusively in eelgrass meadows (*Zostera marina*) in North Carolina. Experimental dredging studies on hard sand and a soft mud compared to an area of no dredging showed a significantly reduced level of eelgrass biomass and shoot number on both hard and soft seabed. The seagrass was more susceptible to damage (all shoots removed) in the latter case whereas on hard seabed about 15% of the eelgrass per core remained. The dredges were pulled by hand rather than boat as sometimes done by commercial workers so excluded any effects of propeller scour. Authors conclude that intensive scallop dredging has the potential for immediate as well as long-term reduction of eelgrass nursery habitat. This was based on observation of biological damage which reduces surfaces for attachment for early stage juvenile scallops and other invertebrates.	North Carolina, USA	Fonseca, M.S., *et al (*1984) Impact of scallop harvesting on eelgrass (*Zostera marina)* meadows:implications for management. N.Am.J.Fish.Mnt. 4:286-293. [PR]
REF: 86 **Shallow inlets and bays** **Sandbanks**	Scallop dredging	Review of study investigating disturbance by scallop dredging from large (fishing grounds) to small-scale (experimental plots) around the Isle of Man. Dredging disturbs and may be a factor in structuring benthic communities on gravelly sea bed. Community composition is related to the intensity of commercial dredging effort and effects may differ from that of bottom fishing on other soft sediments due to extreme patchiness of animal distribution, greater abundance of epifauna and to the combined effect of the heavy, toothed scallop gear and the stones caught in the dredges. [Details from abstract only - full paper in press]	Isle of Man	Bradshaw, C. *et al.*, (in press) Effects of scallop dredging on gravelly seabed communities. In:Kaiser, M.J. & de Groot, S.J. (eds). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Fishing News Books
REF: 87 **Shallow inlets and bays** **Sandbanks**	Scallop dredging	Comparison of historic (1946-1951) and recent data on benthos in locations some of which have been subject to heavy scallop dredging over the intervening years, some to little dredging. Changes apparent regardless of intensity of dredging. In heavily dredged areas there was extreme physical disturbance, increased polychaete:mollusc ratio, loss of some fragile species and an increase in the predominance of scavenger/predator species. Changes in lightly dredged areas included loss of a number of species including some potentially fragile tube-dwellers. Reasons for these changes not apparent. [Details from abstract only - full paper in press]		Hill, A.S. *et al*., (*in press*). Changes in Irish Sea benthos: possible effects of forty years of dredging. Estuarine Coastal & Shelf Science. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 88 **Shallow inlets and bays** **Sandbanks**	Scallop dredging	Experimental dredging at two subtidal sandflats (depth around 24m) to identify short-term impacts on macrobenthic communities. Comparison with adjacent reference plots. Habitat effects Natural surface features broken down (eg.emergent tubes, sediment ripples) and teeth on dredge created grooves 2-3cm deep. Species and Community effects. Density of common macrofauna decreased at dredged sites and some significant differences still apparent after 3 months. At both sites more than 50% of the common taxa showed significant effects. Differences in recovery process likely to relate to differences in initial community composition and to differences in environmental characteristics. Authors consider the effects recorded were conservative as commercial fishermen work over much larger areas and repeatedly dredge the same area in any one fishing trip.	Mercury Bay, New Zealand	Thrush S.F. *et al.*, (1995) The impact of habitat disturbance by scallop dredging on marine benthic communities; what can be predicted from the results of experiments? Mar.Ecol.Prog. Ser. 129:141-150. [PR]
REF: 89 **Estuaries** **Mudflats and sandflats** **Shallow inlets and bays**	Aquaculture	Changes in sediment composition and benthic community structure under cultures studied over 3 years in a narrow sound, 13-15m deep with generally weak currents.. Habitat effects. Faecal material and mussels drop to the seabed. As a consequence a layer of sediment was found to increase at a rate of 10cm/yr. This resulted in the production of H_2S in the uppermost layers. Small grain size, high organic content and a negative Redox potential recorded under the cultures and changed with distance from the culture. Species and community effects. Benthic fauna initially dominated by *Nucula nitiosa* (numerically), *Echinocardium cordatum* and *Ophiura* spp (biomass). After 6-15 months these disappeared and were replaced by opportunistic polychaetes (*Capitella capitata*, *Scolelepis fuliginosa* and *Microphthalmus sczelkowii*). Anaerobic sediments and mass occurrence of opportunistic polychaetes localised 5-20m around the cultures. After harvesting only limited recovery was observed after 6 months.	Sweden	Mattson, J. & Linden, O. (1983) Benthic macrofauna succession under mussels, *Mytilus edulis*, cultured on hanging long-lines. Sarsia 68:97-102. [PR]
REF: 90 **Sandbanks**	Shrimp trawling	Review paper on by-catch associated with shrimp fisheries. Shrimps tend to live in areas with a great diversity and abundance of other invertebrates and fishes. Many of these caught in trawls. Paper reviews estimates of by-catch, associated mortality of species caught and impacts on ecosystems also discussed. Authors note that there is limited detailed information currently available on this issue.		Andrew, N.L. & Pepperell, J.G. (1992) The by-catch of shrimp trawl fisheries. Oceanogr.Mar.Biol.Annu. Rev. 30:527-565. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 91 **Sandbanks** **Seabirds**	Shrimp trawling	Investigation into the potential impact of a policy of immediately discarding all by-catch from shrimp fisheries in the North Frisian Wadden Sea. Clearance rate of discards estimated by feeding crabs and shrimps in aquaria. Traps baited with discards used to examine fate in sublittoral and take by birds assessed using combination of counts, photography and video recording. Underwater video revealed grey seals feeding on discarded fish. Authors conclude that 1988 seabird population in the area would have easily been capable of clearing the discards of moribund roundfish. Harbour seals which were most likely to benefit from flatfish discards.		Berghahn, R. (1990) On the potential impact of shrimping on trophic relationships in the Waden Sea. In: Trophic Relationships in the Marine Environment. Proc.24th Europ.Mar.Biol.Symp. Barnes, M. & Gibson, R.N. (Eds). [PR]
REF: 92 **Shallow inlets and bays** **Estuaries** **Mudflats and sandflats**	Aquaculture	Study on ecological effects of Manila clam cultivation at the end of the cultivation phase (for all stages see Reference 64) Habitat effects. Organic enrichment in net covered area. Short term sedimentation rates were up to 4 times higher in netted plots than control areas. The increase was localised. Increased organic matter, percentage fines and phaeopigment in the sediment and reduced water flow on the netted plots is likely to have had a major influence on the changes in abundance of some infauna species. Species and community effects. Netting encouraged settlement of green macro-algae and in turn *Littorina littorea.* In the first 6 months fauna dominated by opportunistic species P.elegans. After 1 year the stabilising effect of netting and sedimentation led to establishment of species such as *Ampharete acutifrons* and *Tubificoides benedii.* Authors consider biotic and abiotic changes are relatively benign compared to other forms of marine culture.	River Exe	Spencer, B.E. *et al*., (1997) Ecological effects of intertidal Manila clam cultivation: observations at the end of the cultivation phase. J.Appl.Ecol. 34:444-452. [PR]
REF: 93 **Sandbanks**	Cockle dredging	Three year study into impact and recovery of habitat and marine benthic communities from suction and tractor dredging to harvest cockles. Suction dredging had a statistically significant effect on infauna leading to up to a 30% reduction in number of species and 50% reduction in number of individuals. These effects were not seen with tractor dredging. Authors suggest this may be due to experimental design and different times of year	Auchencairn Bay, Solway Firth	Hall, S.J. & Harding, M.J.C. (1997) Physical disturbance and marine benthic communities: the effects of mechanical harvesting of cockles on

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
Shallow inlets and bays **Estuaries** **Mudflats and sandflats**		in which the experiments were done. By day 56 much of the difference between area where suction dredging was used compared to control site was lost but some effects remained.		non-target benthic infauna. J.App.Ecol. 34:497-517. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 94 **Sandbanks** **Shallow inlets and bays**	Trawling	Simulation in test tank of effects of otter trawl door on infaunal bivalves when moving across a relatively dense, level, sandy seabed. Six species of bivalve were placed in the test bed in typical life positions. Habitat effects. A mound of sediment in front of the door formed a single rounded berm with adjacent shallow U-shaped depression which represented the scour furrow. Species effects. All bivalves within the scour path at the sediment/water interface were displaced but only 5% sustained major damage. Shallow burrowing bivalves in the scour path were redistributed and concentrated along the berm. Exposure on the seabed would make them vulnerable to predation. Increased sediment stress was recorded to depths occupied by deep burrowers but in this experiment the transient elevated stress levels were considered to be of insufficient magnitude to cause shell damage. Possible behavioural or physiological effects on the bivalves unknown.		Gilkinson, K. *et al*., (1998) Impacts of trawl door scouring on infaunal bivalves: results of a physical trawl door model/dense sand interaction. J.Exp.Mar.Biol. & Ecol. 224:291-312. [PR]
REF: 95 **Shallow inlets and bays** **Mudflats and sandflats** **Estuaries** **Sandbanks** **Reefs**	Various	Review of fishing effects on habitat. Common themes to emerge included immediate effects on species composition and diversity and reduction in habitat complexity. Recovery variable depending on habitat type, life history of component species and natural disturbance regime. Authors call for work to predict outcomes of particular management regimes and discuss use of conceptual models to do this as predictive numerical modelling not currently possible. Disturbance theory used to provide the framework for predicting effects of habitat change. Authors call for adaptive and precautionary management practices until empirical data become available for validating model predictions.		Auster, P. J. & Langton, R.W. (*in press*). The effects of fishing on fish habitat. Am.Fish.Soc Symp. [PR]

Natura 2000 Habitats & Species	Fishing Technique	Effects	Locations	Reference
REF: 96 **Shallow inlets and bays** **Mudflats and sandflats Estuaries**	Mariculture	Papers from working group meeting. Sections on fallowing strategies in coastal cage farming and associate research needs, minimum separation distances between cage farming sites, on coastal management and mariculture and on escapes.		ICES (1998) Report of the working group on environmental interactions of mariculture. ICES CM 1998/F:2. Ref:ACFM+ACME+E
REF: 97 **Shallow inlets and bays** **Mudflats and sandflats** **Estuaries**	Mariculture	Experimental study to investigate changes in benthic communities and sediment composition associated with clam cultivation. Trials with four treatments, clams with net covers, net covers only, control plots without clams or net covers and control plats without clams, net covers or human activity. Sediment of the trial area was a stable muddy sand. Netting and the green alga growing on it caused an increase in sedimentation rate, and slight increase in proporation of silt. Number of worm species increased substantially benearth netted plots irrespective of whether clams were present. Increase occurred within 6 months of placement and still present 2.5 years after seeding when clams were harvested. Harvesting by hand raking, followed by suction dredge. Suction dredge increased sediment load in the water which dispersed to near background levels within 40m of the device. A trench about 10cm deep was left by the harvester which took about 3-4 months to fill. Hand raking caused a reduction of 50% in abundance and diversity of species and suction dredging, a reduction of 80-90%. Regeneration of species diversity and abundance, after harvesting in the winter was completed by the following summer.		Exe estuary MAFF (1997) Clam cultivation:localised environmental effects. Results of an experiment in the River Exe, Devon (1991-95). Directorate of Fisheries Research, Conwy.