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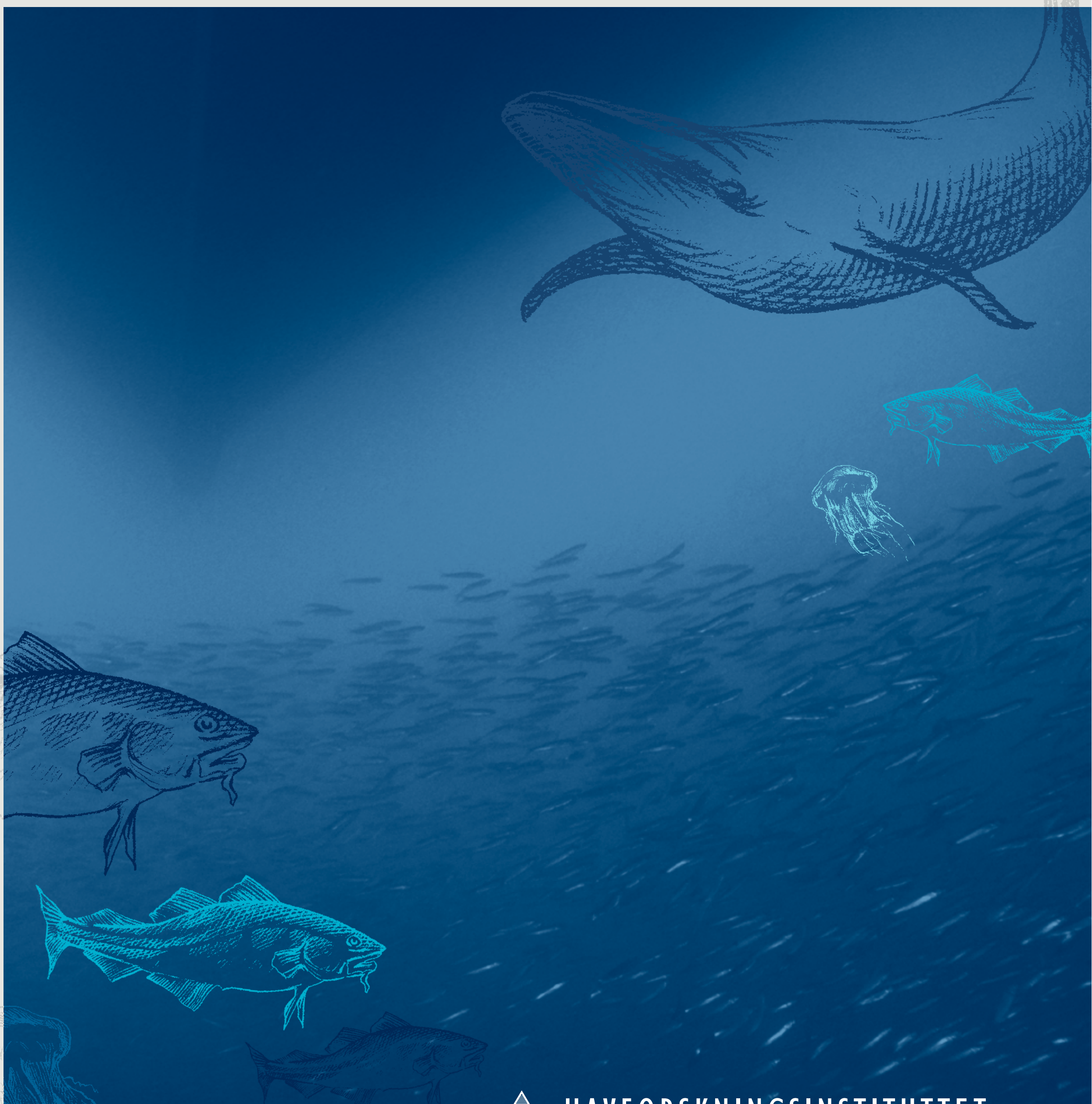
By Lene Buhl-Mortensen, Asgeir Aglen, Michael Breen, Pål Buhl-Mortensen, Arne Ervik, Vivian Husa, Svein Løkkeborg, Ingolf Røttingen and Hans Hagen Stockhausen



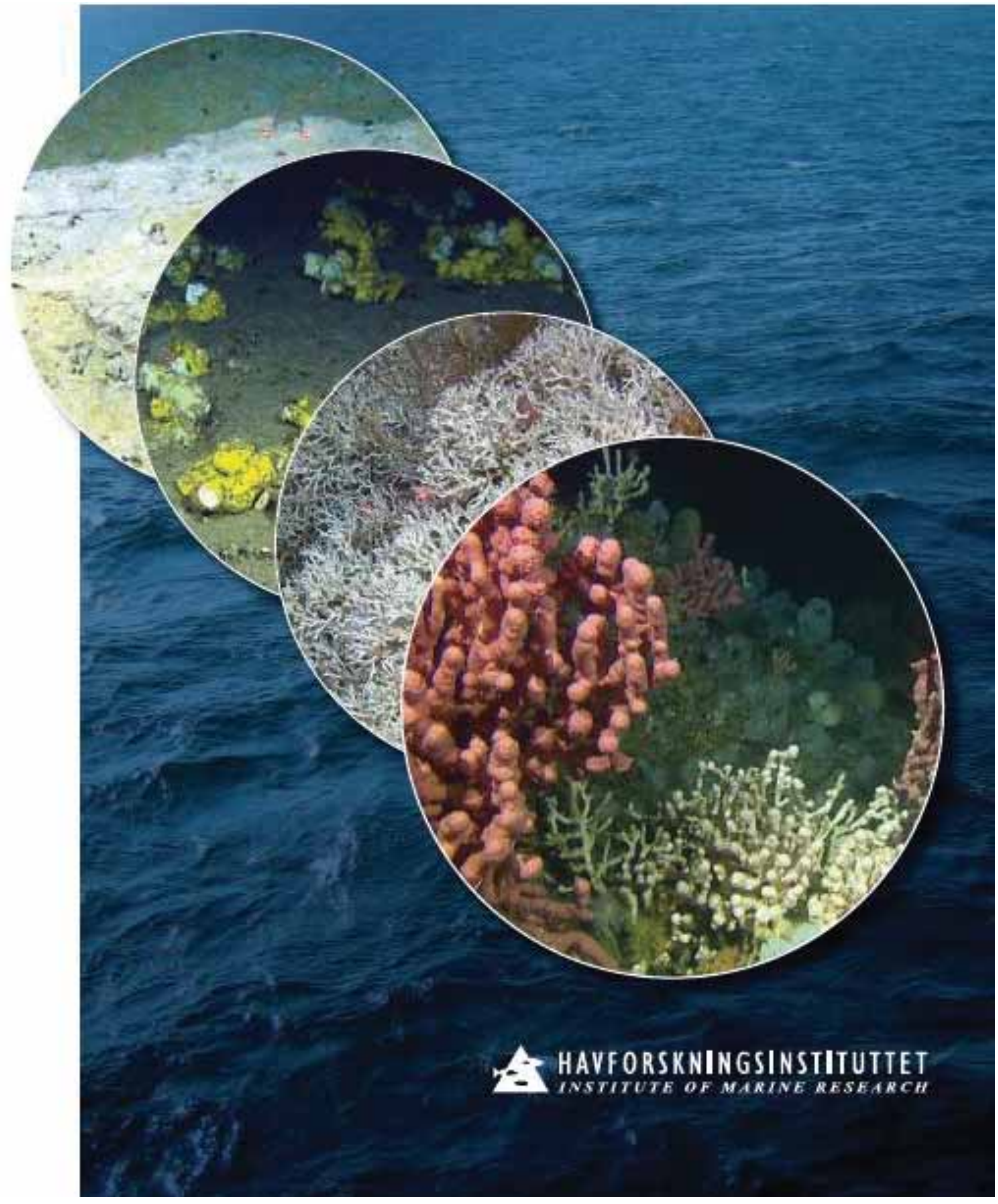
HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH

Impacts of fisheries and aquaculture on sediments and benthic fauna: suggestions for new management approaches

Produced by The Institute of Marine Research's internal committee
on the effects of fishing and aquaculture on sediments and seabed habitats

By Lene Buhl-Mortensen, Asgeir Aglen, Michael Breen, Pål Buhl-Mortensen, Arne Ervik,
Vivian Husa, Svein Løkkeborg, Ingolf Røttingen and Hans Hagen Stockhausen

Bergen, January 2013



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Summary (Norwegian):
Rapporten gir en beskrivelse av fiskeredskaper brukt i norske fiskerier som berører bunn. Berørte områder og grad av eksponering beskrives i rapporten. Bunntrål etter fisk og reker er den redskapstypen som har størst effekt på bunnsubstrater, habitater og bunndyr.

Summary (English): The report describes the fishing gears that contact the seabed used in Norway, and also details the geographical areas affected. The report describes how modifying fishing gears can reduce the impact on seabed habitats, and suggests actions to be taken to reduce the effects of trawling on sediments and benthic fauna.

Emneord (norsk):	Subject heading (English):
Bunntråling, havbruk, fiskeriaktivitet, fiskerieffekter, følsomme habitater, koraller, svamper, sedimentforstyrrelse, nye fiskeredskaper.	Bottom trawling, fishery activity, effects of fisheries, sensitive habitats, corals, sponges, sediment disturbance, new fishing gears

Contents

Summary

The background to this report is the Ministry of Fisheries and Coastal Affairs' letter of allocation to The Institute of Marine Research for 2012, in which the ministry made the following requests: "*The Institute shall investigate the impacts of fisheries and aquaculture on coral reefs and other seabed habitats, and help to assess what additional monitoring and action is required in light of its findings*" and "*In 2012, The Institute of Marine Research shall present an assessment of the effects and impacts of bottom trawls and other fishing gears with contact have on different substrates and benthic habitats.*" The purpose of this report is to comply with the request of the Ministry.

The report describes the fishing gears with contact that are in use in Norwegian fisheries. Affected areas and levels of exposure are presented. Bottom trawl used for fish and shrimp is the gear that has the biggest impact on bottom substrates, habitats and benthic fauna. The current design and use of this gear results in sediment displacement and smothering. On some sediment types they leave marks and trenches, which can result in local accumulations of organisms and changes in topography. Bottom trawls can also crush, remove or displace large benthic fauna. This report presents modified fishing techniques that can contribute to a reduction in impact and outlines measures to reduce the impact of trawling on sediments and benthic fauna.

Benthic organisms play an important role in marine ecosystems. They decompose organic material that has settled on the sea floor and thus ensure that nutrients can be transported back (via upwelling) to the upper waters and used for phytoplankton production. Many benthic organisms have pelagic larvae that form part of the zooplankton which is an important source of food for many species, including fish larvae. On the, benthic fauna is part of the diet of demersal fish. Large species such as corals and sponges hosts a number of associated species, including fish, and therefore play an important role in marine food webs and biodiversity. Current knowledge suggests that large, long-lived organisms such as corals and sponges will disappear from areas that are regularly trawled, and that the benthic community in those areas will become dominated by fast-growing, short-lived species. In particular erect organisms taller than twenty centimetres are at risk. New results from the MAREANO programme show that the density and diversity of large benthic species is generally lower in areas with long-term, heavy trawling activity. These results are based a comparison of past fishing activity and occurrence of benthic fauna for the same area the causal relationship is not direct.

Little research has been done on the recovery rate for large benthic organisms, but the available studies suggest that organisms such as sponges, corals and sea pens may need anything from decades up to centuries to recover from trawling, depending on their growth rates. Few studies have documented the long-term effects of trawling, and little is known about its impacts on the productivity and resilience of ecosystems.

Particles from aquaculture can also change the sedimentation environment and lead to smudging of long-lived filter feeders such as sponges and corals. Currently we know little about how this benthic fauna is affected, whereas impacts on smaller organisms close to fish farms are well documented.
This report proposes nine actions to be taken, either related to the internal activities and priorities of The Institute of Marine Research, or to the fisheries management collaboration with the Directorate of Fisheries and Ministry of Fisheries and Coastal Affairs.

1 Background to the report

In the Ministry of Fisheries and Coastal Affairs' letter of allocation to The Institute of Marine Research for 2012, it sets out the following tasks:

– *The Institute shall investigate the impacts of fisheries and aquaculture on coral reefs and other seabed habitats, and help to assess what additional monitoring and action is required in light of its findings".*
– *In 2012, The Institute of Marine Research shall present an assessment of the effects and impacts of bottom trawls and other fishing gears that contact the seabed on different substrates and seabed habitats.*

The Institute of Marine Research believes that it is important to develop a better understanding of the impacts of fisheries and aquaculture on coral reefs and other seabed habitats. The intention of the Marine Resource Act is to move the focus away from activities such as fishing and hunting, and instead concentrate on the overall management and exploitation of living marine resources (ecosystem-based management). This should make it possible to stop or limit the exploitation of wild marine resources if it is having a negative impact on whole marine ecosystems, or on parts of them.

The management plans for the Barents Sea and Norwegian Sea specifically mention coral reefs and seabed habitats, and the goals state that (anthropological) damage to marine habitats considered threatened or vulnerable should be avoided. The updated management plan for the Barents Sea and waters off Lofoten (Meld. St. 10 (2010–2011) Section 6.4.1) confirms the observation of damage to coral reefs, sponges and sea pens caused by trawling. This issue is also receiving growing attention at an international level, and both ICES and NEAFC have raised it on their agendas.

In order to shed light on the above topic, on 13/04/2012 The Institute of Marine Research set up an internal group with the following mandate (also see Annex 1):

– *The group shall prepare a report for the Ministry of Fisheries and Coastal Affairs, presenting the effects and impacts of bottom trawls and other fishing gears that contact the seabed on different substrates and on coral reefs and other seabed habitats.*
– *The group shall assess how information from MAREANO and any other relevant programmes can be used for this purpose in the future.*
– *The group shall look at the impacts of aquaculture on seabed habitats and fisheries.*
– *The group shall propose measures to prevent harm to vulnerable and valuable seabed habitats*

Members of the group:

A. Aglen
M. Breen
P. Buhl-Mortensen
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A. Ervik
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2 A review of the known impacts of fishing on marine ecosystems

The impacts of fishing can become apparent at varying points in space and time. The direct impacts of fishing start with the immediate effect on individual organisms (biotic effects) and on the substrate of the seabed (abiotic effects). Over time, these direct impacts can lead to changes in the biological community beyond the areas exposed to trawling, and can potentially result in long-term changes at the ecosystem level (Kaiser et al. 2002). Research has mainly focused on the specific, direct effects of fishing, such as benthic impacts (Jennings and Kaiser 1998, Hall 1999, Kaiser et al. 2002), unintended mortality (ICES 2005; Suuronen 2005), bycatches and discards (Hall et al. 2000, Kelleher 2005, Harrington et al. 2006, Davies 2009), and ghost fishing (Breen 1990, Brown et al. 2005, Macfayden et al. 2009). An increasing number of studies show that these direct effects have an impact on the wider marine ecosystem, for instance through changes to the community structure (Kaiser et al. 2002, Worm et al. 2006, Pauly et al. 2002), changes to food chains (Pauly 1998), and reductions in biodiversity (Worm et al. 2006).

2.1 Direct biotic impacts

The impact of fishing activities on benthic fauna depends on the fishing gear, sediment type and vulnerability of the organism. When exposed to fishing gear, there are four possible outcomes for benthic fauna, fish and other organisms: avoid being caught and survive; be caught and become part of the catch; be returned dead (discards); or be caught and die in lost or abandoned fishing gears.

Landed catch: species of commercial value are more likely to be caught than species of little or no commercial value, as the fishing gear will have been developed specially to catch them. Moreover, if caught, they are likely to be retained as part of the catch that is landed. This also includes illegal, unreported and unregulated fishing, which can undermine the sustainable management of fisheries by underestimating the fishing pressure (ICES 2005).

Bycatch/discards: some undersized individuals are also caught by fishing gears, and these are often referred to as the bycatch (Hall et al. 2000, Davies et al. 2009). Bycatches can include species of high ecological or charismatic value, but may also be without any commercial value whatsoever. Fish that are discarded are exposed to a number of stress factors that reduce their chances of survival: physical damage; decompression; asphyxia; exposure to UV light and extreme temperature changes (Davies 2002).

Escapees: in an attempt to reduce the bycatch in certain fisheries, significant resources have been invested in modifications to fishing gear that allow unwanted organisms to escape – particularly undersized individuals of commercially important species, and species of high ecological or charismatic value (Hall et al. 2000, Davies et al. 2009). Such measures reduce the probability of discards suffering injuries or stress-induced death, but it has been shown that not all organisms survive their escape from some of the selection devices used in commercial fisheries (Suuronen 2005, Breen et al. 2007, Ingolfsson et al. 2007).

Ghost fishing: some fishing gears continue to catch fish even if they have been lost or abandoned. This is particularly the case for passive gears like gill nets, pots/fyke nets and hook gears. When they come into contact with these gears, organisms will either be caught and die in the gear, or escape. Individuals that escape may survive, but the survival rate will depend on the extent to which they are injured, and the impact of the capture process on their behaviour (Breen 1990, Brown et al. 2005, Macfayden et al. 2009).

2.2 Impacts of fishing at the ecosystem level

The direct biotic and abiotic impacts can lead to considerable mortality amongst benthic fauna, fish and other organisms, as well as altering the habitats where they live. Little is known about the extent to which the combined impact of these effects can cause changes to ecosystems over the longer term. The complexity of the interaction between interlinked effects, and some of the principles at work, are shown in Figure 2.1. These interlinked effects can be difficult to assess and to separate from other influences on the system.

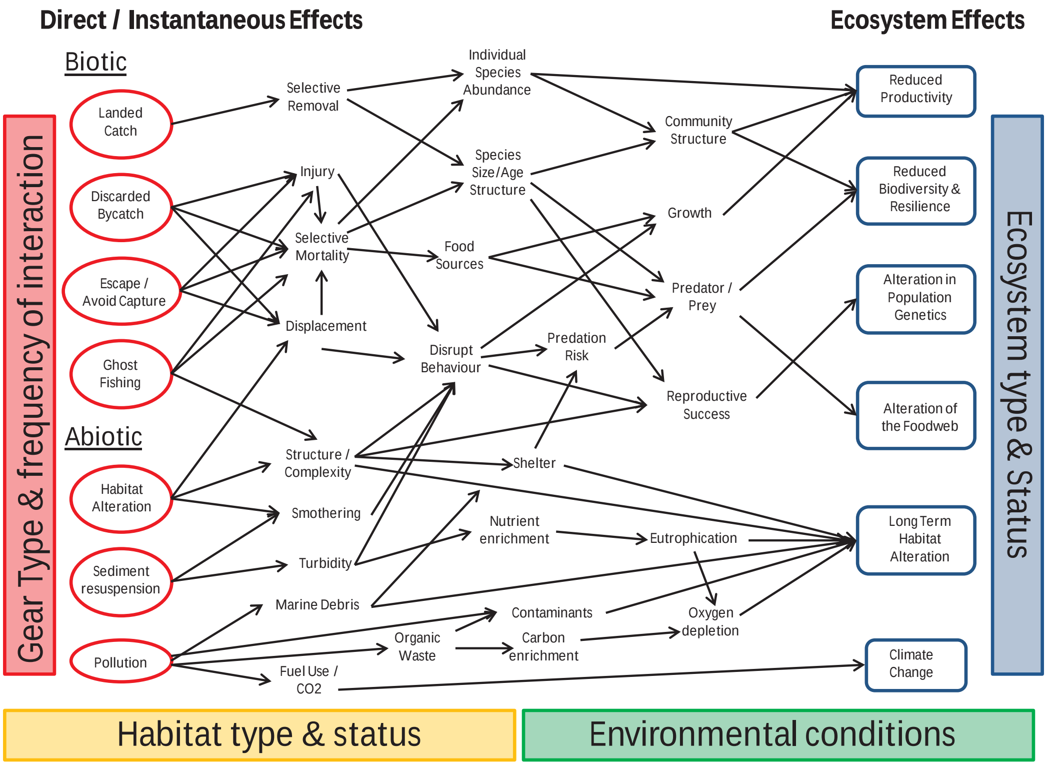

Figure 2.1. A schematic representation of the potential key direct/immediate biotic and abiotic impacts of fisheries, and of the intermediate mechanisms that link them to indirect impacts observed at the ecosystem level.

Removal and relocation of biomass/bycatches and discards: Removing biomass from ecosystems by fishing can reduce their production capacity, particularly if one or more species are being overexploited (Heino og Enberg 2008). In mixed stock fisheries, a sustainable mortality rate for highly productive species may be unsustainably high for less productive species, such as skates (Brander 1981, Walker and Hislop 1998, Stevens et al. 2000, Jennings and Revill 2007). Selective harvesting of organisms based on their commercial value or catchability may significantly change the structure of the community in the affected areas (Kaiser et al. 2002). Selection pressure for particular anatomical (e.g. size) and reproductive (e.g. early sexual maturity) characteristics can also lead to genetic changes in the harvested populations (Law 2000, Heino and Godø 2002, Heino and Dieckmann 2008). Other important sources of organic pollution from fishing are waste from processing, and dead or dying organisms that have been discarded or have escaped. This can lead to significant local accumulation of organic waste, and can cause carbon flux between different ecosystems. One example of this is the release of unwanted catches from pelagic purse seines, a single instance of which can lead to hundreds of tonnes of dead pelagic fish being deposited on a limited area of the seabed (Huse and Vold 2010, Tenningen et al. 2012).

These dead and dying organisms represent a new food source, which can attract scavengers and predators into the area (Kaiser and Spencer 1996, Groenewold and Fonds 2000), thus further altering the structure of the community. These changes in community structures and predator/prey relationships can ultimately have an impact on the food webs in the ecosystems (Kaiser et al. 2002, Jennings and Revill 2007).

Unintended mortality caused by fishing activities both has a negative impact on the natural resources themselves, and makes it more difficult to manage them (Hall et al. 2000; Harrington et al. 2006). However, in some ecosystems positive side effects have been observed, with the productivity of some species increasing (Zhou 2008, Zhou et al. 2010, Garcia et al. 2012). In these cases, the dead and dying organisms discarded by fishing vessels represent a food source for some species (Rijnsdorp and van Beek 1991, Groenewold and Fonds 2000), including ones that are targeted by commercial fisheries, such as shrimp (Zhou 2008). In other cases, lower numbers of some predators can reduce the predation pressure on vulnerable species, which may again include ones that are commercially targeted (Gribble 2003, Zhou 2008).

2.3 An ecosystem-based approach to fisheries management

There is now international recognition of the need to develop an integrated, ecosystem-based approach to the management of marine resources, including fisheries (Garcia et al. 2003, Pikitch et al. 2004, Link 2002, ICES 2006, Francis et al. 2007, Hilborn 2011). In Norway, several regions (Barents Sea/Lofoten, Norwegian Sea) are covered by integrated, ecosystem-based management plans (Olsen et al. 2009, Ottersen et al. 2011), and similar plans are being developed for the North Sea/Skagerrak. These plans treat the impacts of fishing on ecosystems in the same way as those of various other human activities – the oil and gas industry and shipping are the most obvious examples, but also mining, tourism, leisure, etc. They provide an overriding framework, and are designed to ensure that these various activities are managed and administered in a way that keeps overall pressure on the marine ecosystems at a sustainable level. Thus, resource exploitation is balanced against environmental protection, in order to safeguard human health, productivity, food safety and the whole marine ecosystem.

3 The ecological role of benthic fauna

Benthic-pelagic coupling: Benthic fauna play a vital role in recycling and returning sedimented organic material that has been produced in the water column above them. Upwelling allows inorganic nutrients released near the seabed to be returned to the upper, productive layers of the sea, where they can again play an important role in primary production. Many benthic species are also in the food chains of fish and other organisms that spend part of the day, or parts of their lives, near the sea bottom. For instance, the diets of cod and haddock include shrimp, amphipods, echinodermata and bristleworms. Some groups of benthic fauna – particularly crustaceans – play an important role in benthic-pelagic coupling by swimming up to higher layers of the water column during the night, where they find nutrients and are in turn hunted by fish and krill. The larvae of the vast majority of benthic fauna live in the upper water layers, where they constitute a significant proportion of the zooplankton. Here they provide an important source of food for animals that feed on plankton, including fish and fish larvae.

Production stabilisation: In marine ecosystems in the far north, productivity varies a great deal over the course of the year, which leads to strong pulses of organic material ending up on the sea floor. These pulses, which represent the main food source for benthic fauna, are converted into benthic biomass. This biomass acts as a store of energy and nutrients, dampening the effect of the large annual fluctuations in productivity higher up the water column, and hence stabilising the availability of nutrients in the marine ecosystem.

3.1 Classification of benthic communities and habitats

At the moment, habitats are best defined for the bigger, more obvious and vulnerable habitat-forming organisms and communities, whereas areas of the without obvious characteristic features are only defined in general and rough terms. Examples of vulnerable habitats include coral reefs, coral forests, sponge communities, sea-pen bottoms, eelgrasses and kelp forests.

One of the tasks of the MAREANO project is to map marine habitats, and a map of vulnerable habitats is shown in Figure 3.1. Changes in the distribution of these vulnerable and threatened habitats are used by OSPAR as an indicator of ecosystem health, but they are not yet well defined. Data from MAREANO provides useful information about the normal densities of key species in these habitats, which is essential information if we are to monitor changes in conditions (Buhl-Mortensen et al. 2010, Bobbe 2012).

The OSPAR Commission (2008) has defined 16 marine habitats as threatened and/or in decline. Four of them are characterised by the presence of sessile megafauna, and are relatively common in Norwegian waters. Some of these habitats are defined so vaguely that in the MAREANO programme it has been decided to split two of them (Deep-Sea sponge aggregations and Coral gardens) into sub-groups. In addition, MAREANO has established a new category for deep-sea *Umbellula* (sea pens). Not all of the habitats listed by OSPAR are threatened and/or in decline everywhere, but well-documented threats exist in all of OSPAR's sub-regions (Hall-Spencer and Stehfest, 2009, Christiansen, 2010a,b, Curd, 2010). The MAREANO programme has chosen to designate these habitats as vulnerable, as they are not exposed to a local, identified threat everywhere. The key species in these habitats are large and fragile sessile organisms that in many cases have a long lifespan and grow slowly (Hall-Spencer and Stehfest, 2009, Christiansen, 2010a,b, Curd, 2010).

In order to document the distribution of habitats in all areas of the sea bottom, the MAREANO programme has developed a method by which locations are classified using multivariate statistics based on the composition of species in samples. Full-coverage maps showing habitats can be modelled based on the relationships between the distribution of communities of organisms and environmental conditions.

This process of classifying and mapping habitats is carried out in collaboration with the project *Naturtyper i Norge* ("Habitats in Norway", abbrev. *NiN*), which is being run by The Norwegian Biodiversity Information Centre, and aims to develop a comprehensive system for classifying the sea floor. The idea is that this system will be more appropriate and comprehensive for Norwegian waters than existing systems such as EUNIS (EUropean Nature Information System) or the habitats defined by the Norwegian Directorate for Nature Management.

To date, deep-water habitats (in the aphotic zone) are not covered in much detail by *NiN*. MAREANO is therefore mapping habitats at a more detailed level than *NiN* does at its lowest level (nature system level) (http://www.artsdatabanken.no/NIN_hovedtyper_og _grunntyper _ Drj8E.pdf.file). The lowest level of MAREANO represents biotopes/habitats. Examples of these biotopes can be found in the MAREANO mapping service (www.mareano.no) for the areas Eggakanten, Tromsøflaket and Nordland VII/Troms II.

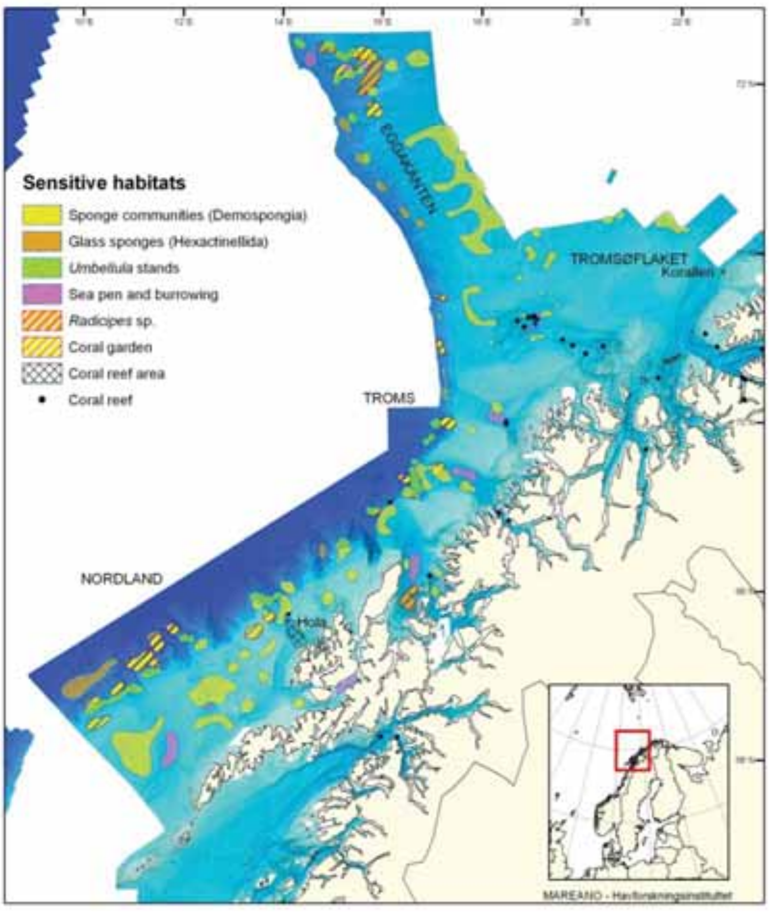

Figure 3.1. Distribution of sensitive habitats documented by MAREANO.

3.2 Habitat formation

Large benthic organisms create habitats for other species living on or near the sea floor. The most significant ones are corals (sea pens, sea fans and stony corals) and sponges, due to their size, their spatial complexity and the age of the habitats they offer. It has been shown that these groups of animals provide homes for a variety of associated species, including fish, and that they therefore play an important role in the marine food web and in maintaining marine biodiversity (an overview can be found in Buhl-Mortensen et al. 2010a). On certain sediment types, smaller species of benthic fauna also form important habitats. In deep-water areas with relatively uniform, soft bottoms, the tubes of bristleworms and the stems of sea feathers offer a firm substrate, which is slightly raised from the sea floor. Here organisms find it easier to attach themselves, and have better access to nutrients, than in the surrounding area.

3.3 Sponges

Sponges can be divided into three classes: glass sponges (Hexactinellida), calcareous sponges (Calcarea) and horny sponges (Demospongiae). The last of these groups includes most species. Sponges create a complex living environment for many species. They can offer a hard substrate, protection against predators and increased access to nutrients (Wulff 2006). Most of the species associated with sponges live inside the sponge's canal system, and live off plankton and particles that are not used by the sponge. Sponges have a fairly simple structure, with many canals, and this is thought to promote close association with other organisms. The spicules of dead sponges can provide a substrate for other organisms (Bett and Rice 1992).

Glass sponges: These sponges, which have a silica skeleton, are common in deep waters, but they are also found in relatively shallow areas (Conway et al. 2005). At a depth of 1000–1300 m off Ireland, there are dense colonies of *Pheronema carpenteri* (1.5 m^{-2}). In Norwegian waters, *Caulophacus arcticus* (the "chanterelle" sponge) is the most common species. Where it is found, there is a greater density of benthic fauna (Bett and Rice 1992). Sponge spicules cover around a third of the sea floor in areas with sponge communities, forming a suitable substrate for many species of horny sponges.

Horny sponges: This is the class of sponges with by far the most species. Their skeletons are made of "spongin" fibres and silica spicules. They come in a variety of shapes: some form carpets on rocks, while others have branched stems that stand upright in the water. In general they are large, with a diverse associated fauna, and they have been described as "veritable living hotels" (Klitgaard 1995). The most common species in Norwegian waters are in the genera *Geodia*, *Aplysilla/Hexadilla*, *Stryphnus* and *Isop* (Figure 3.2). The distribution of sponges in the area mapped by MAREANO is shown in Figure 3.3.

Klitgaard (1995) reported on the associated fauna for eleven species in the Geodidae family found at depths of 157-780 m off the Faroe Islands. Of 411 individuals, 80% had associated fauna, most of which were observed on the outside of the sponge. In the many videos taken as part of MAREANO, redfish and brittle stars are often seen on *Phakellia* and *Axinella* sponges. It is also common to find a squat lobster (*Munida*) buried under a *Geodia* sponge.

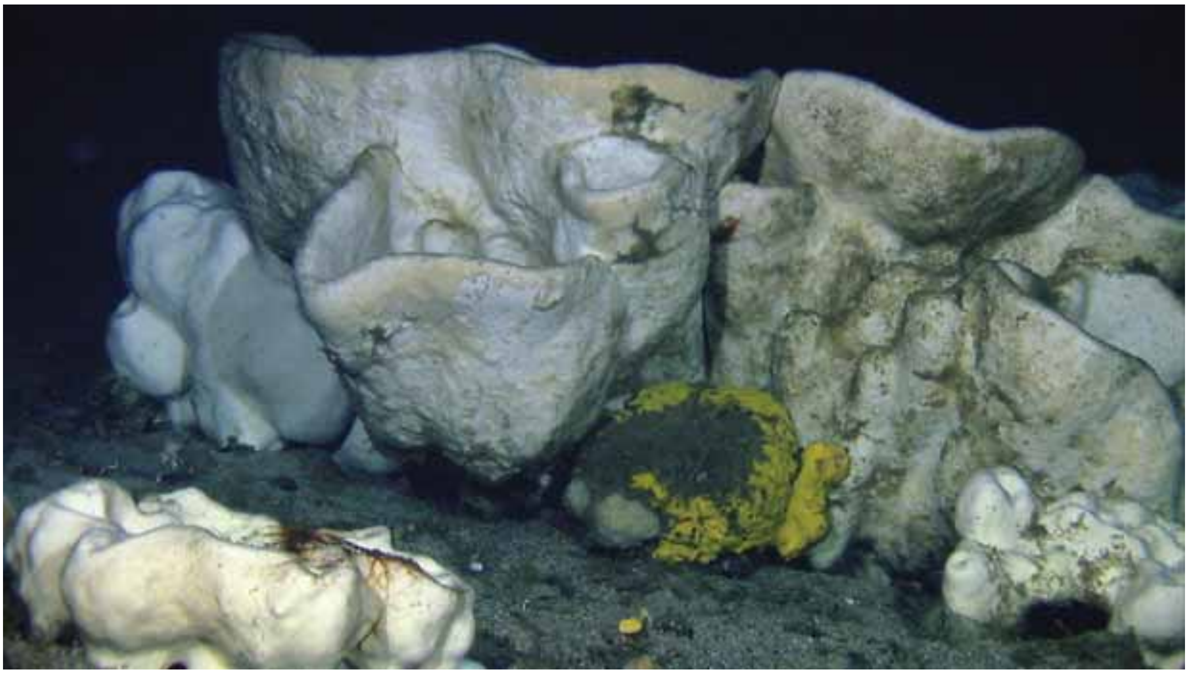

Figure 3.2. Photo from MAREANO of the sponges *Geodia* sp and *Aplysilla* sp (yellow).

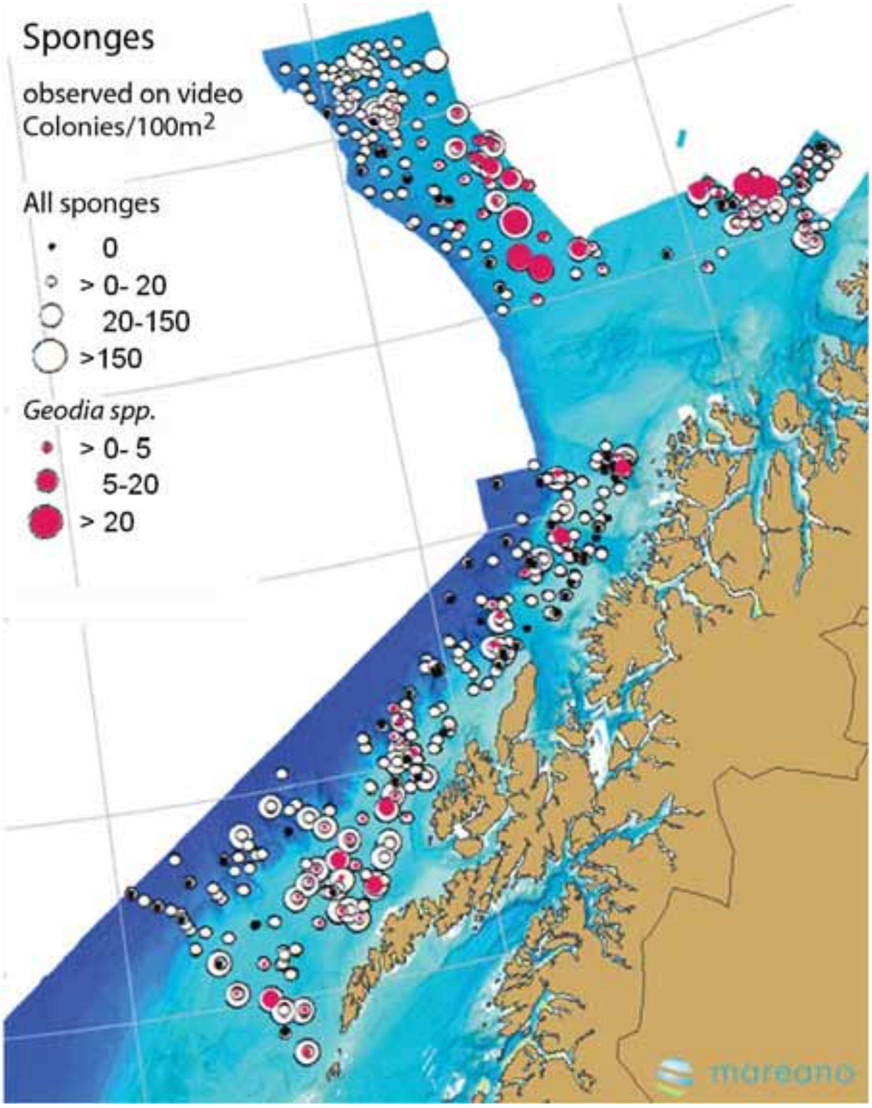

Figure 3.3. Distribution of sponges observed on videos taken by the MAREANO project.

3.4 Corals

Cold-water corals live in many parts of the world, and are most commonly found at depths of 200-1500 m (Mortensen et al. 2006). However, there are very shallow reefs (40 m) in Norway, New Zealand, Chile and British Columbia, and the depth distribution depends on the characteristics of the water (salinity and temperature) rather than on the depth *per se*. Typically, these corals offer habitats extending from decimetres to metres above the surrounding seabed, and they are found on mixed sediments in areas with relatively strong currents. They contain a variety of micro-habitats with different currents, food sources and substrates (Buhl-Mortensen and Mortensen 2004a, 2004b, 2005). Most corals have a tree-like morphology, with branches stretching up into the strong currents above the relatively still waters in the transition layer near the seabed. Their architecture is complex, and they offer habitats of varying ages. Protected hollows inside colonies and reefs are frequently rich in organic sediment, whereas the outer branches offer strong currents and low sedimentation.

Horny corals: Horny corals offer habitats both on individual colonies and between colonies in places where they are found in dense communities. The density of colonies is typically greater for small species than for larger ones (Mortensen and Buhl-Mortensen 2004). Most horny corals are found on hard bottoms, and the most common species in Norway are *Paragogia arborea*, *Primnoa recedaformis* and *Paramuricea placomus* (Figure 3.4). Some common species are also found on soft bottoms; these include *Isidella lofotensis* and *Radicipes gracilis,* which attach themselves to soft bottoms using root-like organs. *P. arborea* and *P. resedaeformis* are home to a rich variety of fauna (Buhl-Mortensen & Mortensen 2004a, 2004b, 2005). There is a greater diversity of species associated with cold-water horny corals than tropical corals.

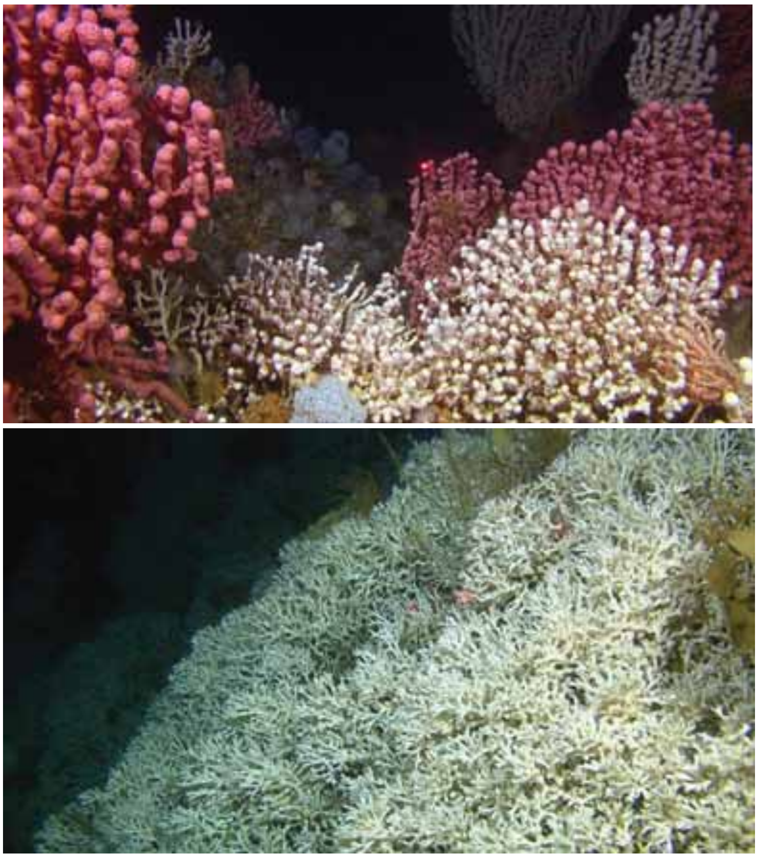

Figure 3.4. Photo from MAREANO of the red horny coral P*aragorgia arborea* (top), and the reef-building stony coral *Lophelia pertusa* (bottom).

Reef-building stony corals: Reef-building stony corals can only establish themselves on a hard bottom, whether it be made of shells or small stones. Once a colony has been established, it provides a new, hard substrate for further colonisation. Colonies that have lived in one location for centuries cover the sea floor with fragments of coral skeletons as they grow, die and fragment (Mortensen et al. 2001 discusses the growth rates and ages of coral reefs). This kind of area is known as a reef. In Norway, the only coral that builds reefs is *Lophelia pertusa* (Figure 3.4). These reefs are typically circular or oblong, with a maximum length of around 1000 m. It is thought that there are 6000 *Lophelia* reefs on the Norwegian continental shelf (Mortensen et al. 2001). Many of them are several hundred metres long, and they occur in groups (reef complexes) up to 35 km long (the Røst reef) (Fosså et al. 2005). In spite of that, they cover less than 0.1 per cent of the total area within the depth range where they are found. Normally the reefs consist of vertical zones, with live corals on top and increasingly broken-down skeletal fragments as you head towards the bottom of the reef (Mortensen et al. 1995). Three habitats can be observed when you cross a reef: a coral gravel zone consisting of small pieces of skeleton; then a coral block zone dominated by blocks of coral skeleton; and finally the living part of the reef. Four different habitats can be found in living reefs: (1) living coral tissue, (2) dead coral covered in detritus, (3) in pores within coral skeletons and (4) the areas between the branches of coral. There is great biodiversity associated with *Lophelia* reefs (Reed et al. 1982, Reed and Mikkelsen 1987; Jensen and Frederiksen 1992, Rogers 1999, Mortensen and Fosså 2006), although the associated fauna is not generally host-specific. The greatest diversity of species has been documented in the coral block zone (Jensen and Frederiksen 1992, Mortensen and Fosså 2006), as the skeleton is exposed, and there is greater three-dimensional complexity than in coral gravel.

Leather corals: Leather corals are found on many sediment types, including consolidated clay. Leather corals, and particularly cauliflower corals (*Nephtheidae*), are found in a wide variety of locations and depths (Mortensen et al. 2006, 2008). Their colonies are quite small (<30 cm), but they can be found in great densities (>500 colonies/100 m^2) (Mortensen et al. 2006). They are generally more widely distributed than horny corals. Only a few species are associated with this group of corals. Brittle stars have been reported living in association with cauliflower corals, and it appears that the early life stages of the gorgon's head brittle star can be found in these corals (Mortensen 1927, Fedotov 1924). In comparison with horny corals and reef-building corals, leather corals offer an unstable substrate, which is not very suitable for sessile species.

Sea pens: Sea pens can reach a height of 0.1-0.2 m above the seabed. They offer protection against predators and a raised position for filtering particles from the moving water. They appear to have few associated species, but there have not been many studies. The biggest species found in Norwegian waters is *Umbellula encrinus*, which can reach a height of more than two metres (Figure 3.5). One example of a close relationship is the one that exists between the tall sea pen (*Funiculina quadrangularis*) and the brittle star *Asteronyx loveni*, which has been observed both off Scotland and Norway (Hughes 1998, MAREANO).

Shrimp have also often been observed on *Pennatula* (MAREANO). The nudibranch *Armina loveni* predates on the slender sea pen (*Virgularia mirabilis*), and the Stegocephalidae family of amphipods also feeds on sea pens. Many slender sea pens lack the top part of the colony, which is thought to be because fish eat them. Anemones have also frequently been observed at the top of sea pens.

Figure 3.5. Photos from MAREANO of the sea pen *Umbellula encrinus* (left) and of *Funiculina quadrangularis* with the brittle star *Asteronyx loveni*.

Close-up of the horny coral *Anthelia borealis in a coral reef.*

4 Fishing gears used in Norwegian fisheries

In this part of the report, we will describe the types of fishing gear currently used by Norwegian and foreign vessels in Norwegian fisheries. The first section describes the fishing gears, looking at how they work, their contact with the seabed and potential impacts on sediments and benthic fauna. The next section summarises the number of vessels and total catch landed per type of gear. It is mainly bottom trawling for fish and shrimp that is relevant in terms of having an impact on sediments and benthic fauna, and the subsequent section describes which areas of the Norwegian sector are exposed to these gear types, as well as the degree of exposure. The final section describes ongoing and future technological developments that will help to reduce the impact of trawling on sediments.

4.1 Description of the fishing gears used in Norwegian fisheries that contact the seabed

There follows a general description of the most widely used fishing gears in Norwegian fisheries that contact the seabed. A detailed description of the design, capture method and operation of the various fisheries is given by von Brandt (1984) and Karlsen et al. (2001).

Bottom trawls: Bottom trawls are essentially conical nets that are dragged along the sea floor. The trawl net is held open using trawl floats, ground gear and trawl doors (Figure 4.1). The trawl doors that are used by the biggest vessels can each weigh up to 5-6 tonnes. The trawl is dragged along the bottom at a speed of between two knots (shrimp trawling) and five knots (fish trawling). The trawl doors are connected to the net by sweeps made of steel wire or chain. These can be 30-150 m long. Under the net there is the ground gear, which is designed to protect the net against wear, and to help it across rough terrain. There are various designs of ground gears, as shown in Figure 4.2. In traditional bottom trawling, the trawl doors, sweeps and ground gear all come into contact with the ground during trawling. Depending on the length of the sweeps, the width of seabed affected by a single bottom trawl can vary between 40 and 200 m. Assuming a speed of four knots, and a width of 100 m at the trawl doors, this equates to 740,800 m^2 of affected seabed for each hour of trawling. In modern bottom trawling, multi-rig trawling is also used, which involves two or three trawls being tied together so that they can be dragged side by side (Figure 4.3). Twin rig trawling involves the use of two trawl doors, two trawls and a weight located between the middle warp (towing cable) and the sweeps going to each of the trawls. The weight is approximately 30 per cent heavier than the trawl doors. Twin rigs are mostly used for shrimp trawling, and to some extent for cod trawling. Triple rigs, which consist of three trawls, two trawl doors and two weights, are also used for shrimp trawling. A third type of bottom trawling is pair trawling, where two vessels drag a single trawl (Figure 4.4). In that case there are no trawl doors, but there may be weights at the transition between the warps and sweeps.

Danish and Scottish seines: A Danish seine consists of a conical net with wings, rather like a trawl. What is special about a Danish seine is that the net is laid out in a triangle on the seabed using very long ropes that are hauled in by an anchored vessel. A variation on the Danish seine is the Scottish seine, which involves a vessel using its own power to maintain a virtually constant position while towing in the ropes. The technique is illustrated in Figure 4.5. The rope length on each side can vary between 1,000 and 2,500 m. As the two ropes are hauled in the net gradually closes, and towards the end of the haul it moves forwards in the same way as a trawl.

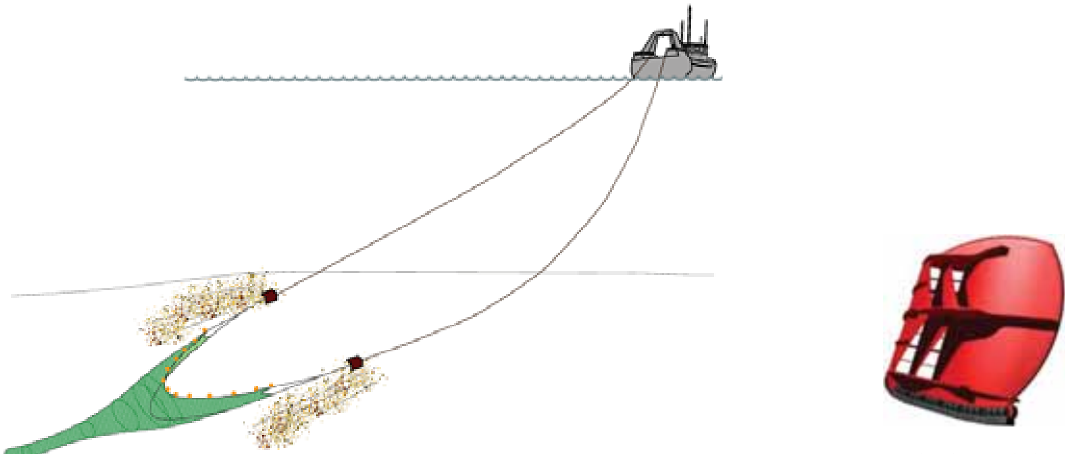

Figure 4.1. Illustration of bottom trawling using a single trawl.

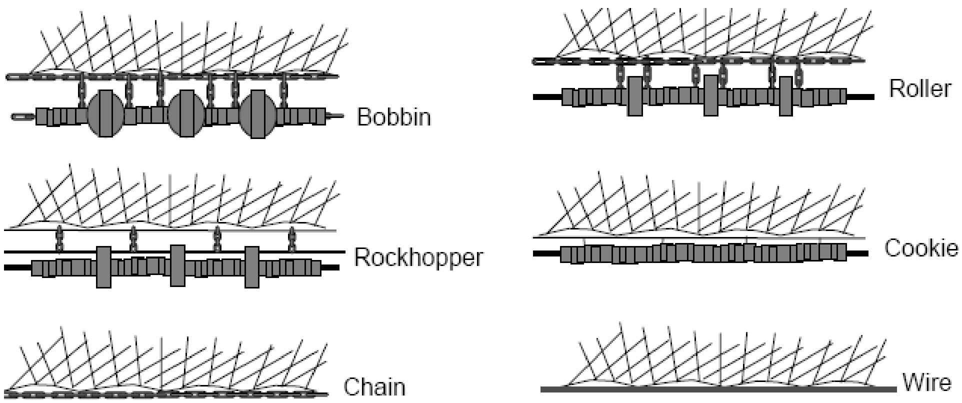

Figure 4.2. Examples of ground gear designs for bottom trawling.

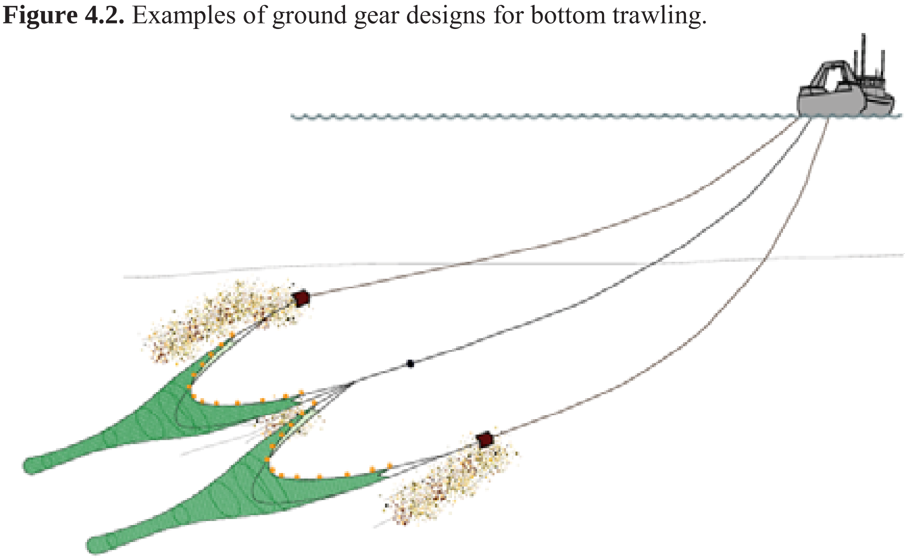

Figure 4.3. Bottom trawling using two trawls (twin rig trawling).

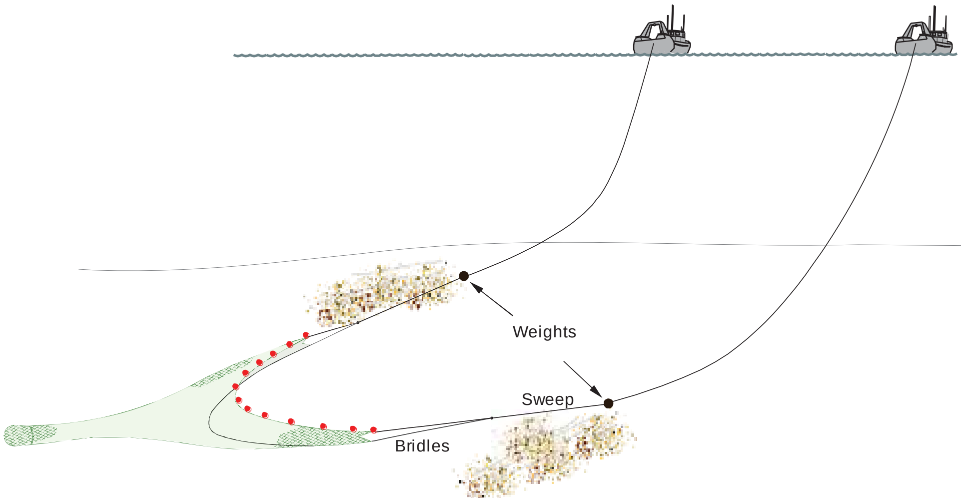

Figure 4.4. Pair trawling with a bottom trawl.

Danish and Scottish seines have lighter ground gear than trawls. They involve "shooting" the net at schools of fish. The area of seabed affected mainly depends on the length of the ropes used and the sea depth, and is therefore much smaller than the area affected by trawling (Figure 4.5). The biggest impact is from the ropes, when they are pulled together in the first phase of the operation. Since this kind of fishing is dependent on the ropes not getting caught on obstacles during the herding phase, there are clear limitations on the sediment types where it can be used. No studies have been done to document the physical impact of Danish and Scottish seining on seabed habitats. The potential effects are probably much smaller than for bottom trawling, since there are no trawl doors, the ground gear is lighter and the seine is not dragged long distances. However, the ropes may have a physical impact similar to that of the sweeps of a trawl.

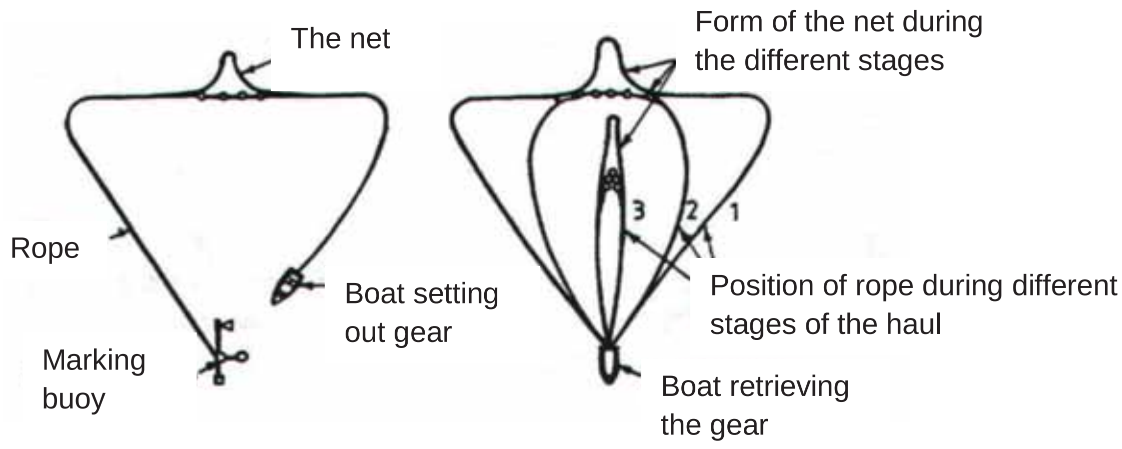

Figure 4.5. Sketch showing the principles of Scottish seining.

Pelagic trawl: This fishing gear is mainly used when targeting pelagic species (e.g herring, mackerel, capelin, blue whiting). The trawl is towed through the pelagic zone, and does not come into contact with the seabed. Under current regulations, pelagic (midwater) trawling is defined as trawling where no parts of the fishing gear contact the seabed. However, pelagic trawling is also increasingly being used to catch codfishes during the periods when they swim up from the sea floor. Pelagic trawling has been particularly successful in the saithe fishery, where it is often used in such a way that parts of the trawl come into contact with the seabed.

Demersal longline: Demersal longlines are set on the sea floor, and have a grapnel at either end. The grapnel, the line itself and the hooks lie on the ground during fishing. With the exception of the grapnel, which is heavy, this gear won't affect the seabed, as the line, hooks and bait are of low density. However, the hooks may catch on benthic species, so sponges and corals are sometimes torn loose when the line is hauled in. The line can only affect a narrow strip of the seabed, so it has a small footprint. Longlines are often set parallel to one another at a distance of around half a nautical mile.

Semi-pelagic longline: This method is a hybrid between a pelagic and a demersal longline. The line is raised off the seabed using floats, and the hooks do not come into contact with benthic organisms. Semi-pelagic longlines have a grapnel at each end, and are anchored to the sea floor using stones roughly every 100 metres. This type of longline therefore only potentially affects the seabed in small, scattered locations.

Gill nets: Gill nets are set along the sea bed. At the top they have a float line to keep the top of the net up, and at the bottom they have a lead line or iron rings to keep the bottom of the net on the ground. Like longlines, gill nets only come into contact with a narrow strip of the seabed. In strong currents, the bottom of the net itself may also be pushed onto the ground. When they are hauled in, the nets can tear loose benthic organisms that have become entangled in the net. Another problem, which is a serious issue in some areas, is "ghost fishing". This happens when nets that are lost for one reason or another remain on the seabed and continue to catch fish, and in some cases also damage the sea floor. The Norwegian Directorate of Fisheries puts a significant amount of resources into clearing up lost nets, which is important both in terms of protecting habitats and fish stocks.

Pots: Pots are cages used to trap fish and crustaceans that are lured into them by bait. In Norwegian fisheries, pots are mainly used to target crustaceans (brown crab, king crab, lobster) and to a lesser extent when targeting codfishes (tusk, ling, cod). The normal size of a cod pot is 1.0 x 1.5 m, which is also the size of the seabed area that the gear comes into contact with. Raised pots have also been developed, which are held up by floats, in order to avoid taking a king crab bycatch. Cod pots are set 30-50 m apart.

4.2 Fleet structure, landed catches and catch value

This section describes the structure of the fleet that operates in Norwegian waters, as well as the volume and value of the landed catch in each fishing gear segment. Table 4.1 shows the approximate distribution of vessels by fishing gear type in 2011, based on the Electronic Reporting System (ERS). It should be noted that many vessels use several fishing gears, and the type of gear/code can therefore change from report to report, depending on which gear has been used. The summary in Table 4.1 shows reported shrimp catches under shrimp trawlers, even if those vessels have also landed fish. Beam trawls are only used to a very limited extent in the North Sea/Skagerrak, so they have been included in the bottom trawl category. It would be possible to use this data to categorise the catches more precisely, but it would require a more detailed analysis.

Table 4.1. Distribution of vessels by fishing gear type in Norway in 2011, based on data from the Electronic Reporting System (ERS) provided by the Directorate of Fisheries.

Fishing gear type	Fishing gear code (Directorate of Fisheries)	Number of vessels
Purse seine	10 & 11	195
Pelagic trawl	53 & 54	56
Hooks and lines, pelagic	31, 33 & 34	27
Gill nets	20 & 22	109
Hooks and lines, demersal	30 & 32	91
Pots	42	9
Bottom trawling, fish	51	70
Bottom trawling, shrimp/langoustine	55	87
Danish and Scottish seines	61	175
TOTAL		**819**

The shrimp/lobster trawl category almost entirely relates to trawling for the shrimp species *Pandalus borealis*, but other species in the *Pandalus* genus and the Norway lobster or langoustine (*Nephrops*) are also included in this group. Langoustine trawling is only done on a very small scale, and only in parts of the North Sea/Skagerrak, but all shrimp and langoustine species have been included in the same category here, due to some incorrect classifications in the catch logs.

The total volume of the catch landed in the Norwegian economic zone increased each year over the period 2005-2010, but then fell slightly in 2011 (Figure 4.6). In spite of the lower volume, the value of the catch was highest in 2011 (Figure 4.7).

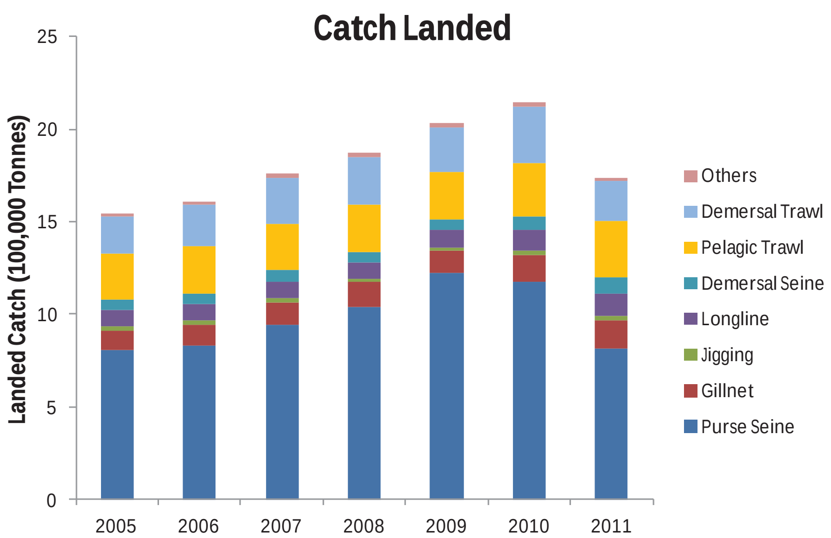

Figure 4.6. Total landed catch (in 100,000 tonnes round weight) by fishing gear type in the Norwegian economic zone over the period 2005-2011; data from the Directorate of Fisheries (2012).

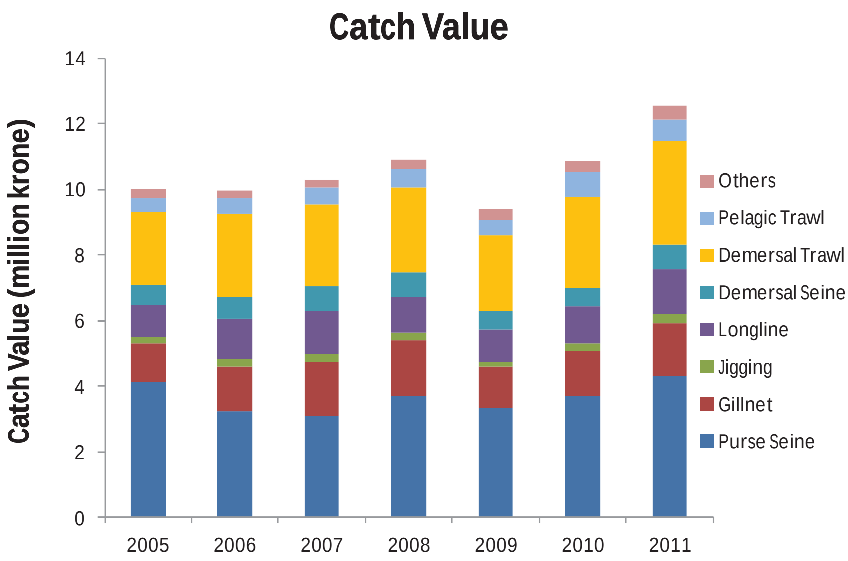

Figure 4.7. Total catch value (in NOK billion) by fishing gear type in the Norwegian economic zone over the period 2005-2011; data from the Directorate of Fisheries (2012).

4.3 Areas exposed to trawling and trawling intensity

In this section we present estimates of the size of the area affected by bottom trawls and shrimp trawls, as well as maps showing the areas exposed to bottom trawling, and the trawling intensity.

The estimates of trawling intensity and maps have been calculated using ERS data for 2011. The data includes all Norwegian and foreign vessels above 15 m that used bottom trawls in the Norwegian economic zone (NOR) or fisheries protection zone (XSV). In the ERS regulations, the duration of the capture operation is defined as the period from when the trawl is shot until the gear is back on deck, and is therefore a slight overestimate of the time that the gear is in physical contact with the seabed. In order to map where trawling took place, including which areas were exposed, and the trawling intensity in those areas, the GPS coordinates for shooting and hauling in the ERS data were analysed and plotted in a Geographic Information System (GIS).

Each data point was allocated to the relevant geographic cell (5 x 5 km). The towing distances were calculated as straight lines between the recorded initial (shoot) and final (haul) positions. The trawl intensity was calculated for each cell as the distance per area (km/km^2).

Figure 4.8 shows the geographic distribution of bottom trawling carried out by Norwegian and foreign vessels in Norwegian waters in 2011. Bottom trawls are mainly used to target cod, haddock and saithe, whereas shrimp trawls almost exclusively target the shrimp species *Pandalus borealis*. Overall, there is a lot of trawling in large parts of the North Sea, from the Dogger Bank and the German Bight in the south to Tampen in the north. Large areas of medium to high trawling intensity can be found in Skagerrak and the northern part of the North Sea. The highest intensity area stretches from Skagerrak along the Norwegian Trench to north of Shetland. There are some other areas exposed to high trawling intensity: off Møre, Haltenbanken, Sklinnabanken and the banks and outer continental shelf off Nordland. However, large parts of the waters closest to the coast of western Norway are unaffected by trawling. Medium to high intensity areas stretch north from Vesterålsbankene up to the banks off Troms and Tromsøflaket. There is also a belt of relatively high trawling intensity in the banks off Finnmark. The map shows that there is medium to high trawling intensity in the area around Bear Island and in the northern parts of the Barents Sea. There is also trawling by Svalbard and in the area around Jan Mayen, including some high intensity areas. However, large parts of the central and eastern Barents Sea are not exposed to trawling.

Based on the data shown in Figure 4.8, the total seabed area exposed to bottom trawling is estimated to be 607,683 km^2, or 25.1% of the Norwegian exclusive economic zone (2,419,182 km^2 in total). The average trawling intensity within this area was 1.7 km/km^2, which assuming an average door spread of 100 m equates to an average affected area of 0.17 km^2/km^2 within the relevant cells. The true area may be somewhat higher, however, due to changes of course while trawling, e.g. trawling in an arc, in which case the towing distance is longer than the distance between the initial and final positions. This error is partly compensated by the fact that the gear will not have been in contact with the seabed throughout the period recorded by the ERS.

4.4 Modification of fishing techniques in order to reduce the impact on sediments

Research and technological developments can help to reduce the impact of trawling on sediments and benthic fauna in a variety of ways. Below we set out five different measures that could help to significantly reduce the overall impact on seabed habitats in comparison with the current situation:

1. Going over to more pelagic trawling
2. Reducing the area affected during trawling
3. Reducing the pressure exerted by trawl components on the seabed
4. Increasing trawling efficiency
5. Improving our knowledge of sediment types, so that trawling can be avoided in particularly vulnerable areas.

Pelagic trawling: Norwegian trawling is currently a mixture of pelagic (midwater) trawling and bottom trawling. Some species of fish, like blue whiting, are mainly caught using pelagic trawls, so the fishery has no impact on the seabed. Several other species of fish can also be found in the pelagic zone, so they can be caught using pelagic trawls and purse seines. This is true of pelagic species such as herring, mackerel and particularly capelin, which is traditionally caught using seine gears. Codfishes such as cod, haddock and saithe can be found both near the seabed and in the pelagic zone. Traditionally they have primarily been targeted with bottom trawls (with a single or twin rig). However, in the 1970s commercial fishers caught codfishes in the Barents Sea with pelagic trawls. This was banned in 1979, as too many small fish were caught, and due to the difficulty of handling excessively large catches, often resulting in a lot of discards. Over the past five years, on a trial basis and to some extent commercially, pelagic trawls have been used to catch codfishes. In the case of saithe, this technique has proved superior to traditional bottom trawling. In the Barents Sea, pelagic trawls have achieved good individual catches in trials, but cod and haddock are only available to pelagic trawling for a very limited period, both in terms of season and time of day. However, the trials show that pelagic trawls can be effective during certain periods, which means that trawlers equipped with pelagic trawls could take part of their quota using a trawl that doesn't contact the seabed. If pelagic trawling were permitted, and the relevant trawlers were equipped with the right gear, then it would be possible to catch a large proportion of the codfish quotas using trawls that don't touch the seabed at all.

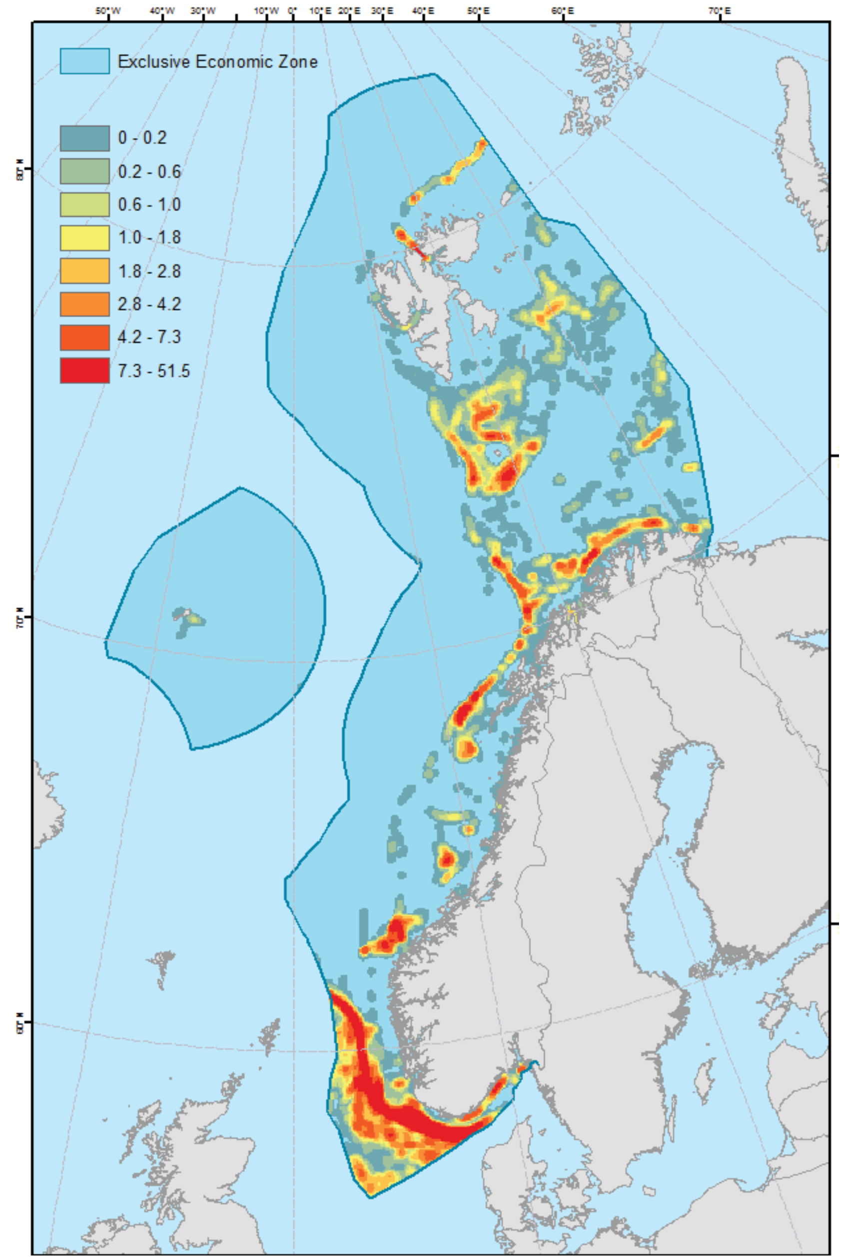

Figure 4.8. Trawling intensity in Norwegian waters (Norwegian and foreign vessels) in 2011, plotted on 5x5 km cells. The scale indicates the trawling intensity in towing distance by area (km/km^2), split into 8 intensity categories (quantiles). The total area trawled is 607,683 km^2, with an average trawling intensity of 0.17 km^2/km^2 in the affected cells. Blue represents areas not exposed to trawling.

Reducing the area affected during trawling: A standard bottom trawl affects, to varying degrees, a width equivalent to the distance between the trawl doors. For twin-rig trawls that width is 250-300 m, while for single trawls it is approximately 100 m. Apart from the trawl doors and roller clumps (weights), the ground gear, which comes into direct contact with the seabed, is the part of the trawl that has most impact on the bottom, and it runs for approximately 30 per cent of the fishing width of a conventional bottom trawl. The sweeps, which are lines that run between the net and the trawl door/roller clumps (approximately 70 per cent of the fishing width), are the part of the trawl that has least impact on the seabed. The most effective way of reducing the area affected by trawling would be to raise the trawl doors off the ground and to ensure a clearance between the ground and the sweeps from the trawl doors to the wings of the net. New technology in this area is being developed at SFI-CRISP (www.imr.no/crisp). This measure would eliminate the direct impact of the trawl doors, as well as reducing the affected area considerably – by 2/3, it is estimated. It would also lead to a significant reduction in fuel consumption during trawling. Several trawlers have already started using techniques that raise the trawl doors off the seabed, even in shrimp trawling, where it is essential for the ground gear to be in contact with the seabed. Two of the main challenges with this approach are uncertainty about whether the ground gear will have sufficient contact with the ground, and doubts about whether the sweeps can effectively herd the fish towards the mouth of the net if they are not in contact with the seabed. As a result, weights are normally attached 40-50 m behind the trawl doors, in order to ensure that the sweeps remain in contact with the seabed (Valdemarsen et al. 2007) (Figure 4.11), reducing the benefit of using pelagic rigging for the trawl doors.

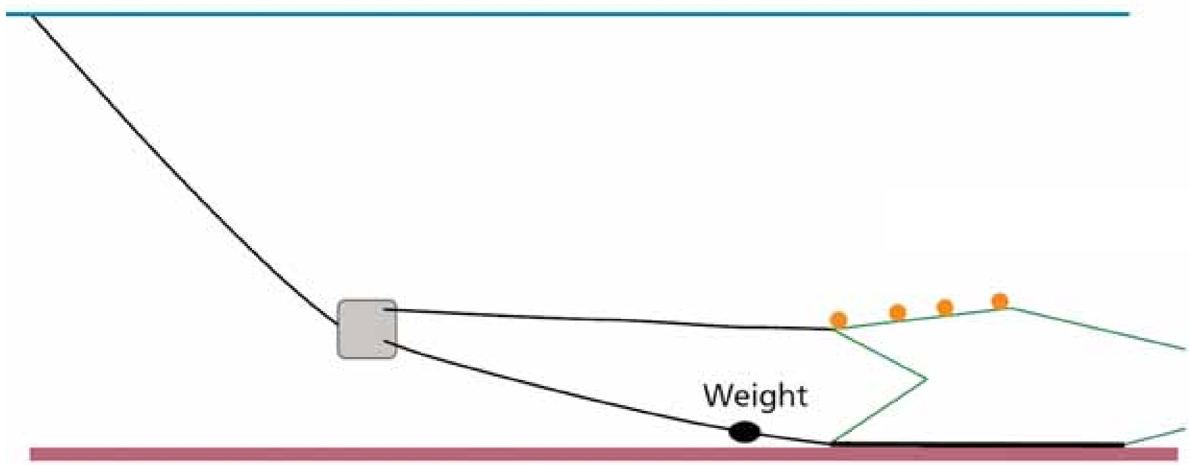

Figure 4.11. Pelagic rigging of trawl doors for bottom trawling (from Valdemarsen et al. 2007).

To allow the technique of raising the trawl doors and sweeps above the seabed to work optimally, and gain wider acceptance than today, it will be important to develop instruments to monitor contact with the seabed at the wing tips. It would also be a great advantage if the trawl doors on each side could be adjusted vertically to ensure that the trawl's contact with the seabed is the same on both sides. Another important prerequisite for the technique to be useful in practice, is that sweeps raised above the seabed must herd fish in the same way as if they are dragged along the bottom. If that can be achieved, then this technique, which is often referred to as semi-pelagic trawling, can play an important role in reducing the impact of trawling on the sea floor.

Reducing the pressure exerted by trawl components on the seabed: If the trawl doors and sweeps are raised off the sea floor as described above, we are left with the challenge of reducing the impact of the ground gear. Today, the rockhopper is the dominant ground gear in all bottom trawling (see Figure 4.2). In order to ensure good contact with the seabed, rockhopper gear is very heavy. It would probably be possible to reduce the weight of this type of ground gear without any impact on fishing efficiency. Instruments for monitoring contact with the seabed would be a useful tool for ensuring that efficiency is maintained. Another potential approach is to develop ground gear types that have less impact. In fisheries where it turns out that fishing efficiency depends on the sweeps remaining in contact with the ground, another option is to install bobbins on the sweeps. This would raise the sweeps 5-10 cm off the ground between the bobbin discs. This technique has been evaluated, and is for instance used for bottom trawling in Alaska (Rose 2006).

Increasing fishing efficiency: One good way of reducing the impact on the seabed is undoubtedly to spend less time catching the allocated quota. This can be achieved by developing better trawls and trawling techniques, including the development of new trawl instrumentation. The work being done at CRISP aims to solve several of these challenges (www.imr.no/crisp).

Improving our knowledge of sediment types, so that trawling can be avoided in "vulnerable" areas: Trawling is an active form of fishing, and the distribution of fish stocks largely determines where trawling takes place. For bottom trawling, there is often a connection between the sediment type and fish density. Modern trawlers are equipped with instruments that allow them to position their fishing gear accurately in relation to fish densities and sediment types. If the position of particularly vulnerable areas of the seabed is precisely defined, then it is perfectly possible to avoid contact with them during fishing. This would require these areas to be identified and marked on electronic fishing maps, and restrictions to be placed on trawling there.

5 Effects of fishing on sediments

The physical interaction of fishing gear with the surroundings depends on the type of gear and the ecosystem. This report looks at the effects of active gears that come into direct contact with sediments, and the focus is therefore on bottom trawls. Bottom trawling can alter the topography of the sea floor (abiotic effects), for instance by leaving marks in sediments or by levelling structures. Moreover, moving significant quantities of sediments can bury and asphyxiate other organisms. These physical interactions can also reduce the complexity of a habitat, but removing small-scale structures on the surface of the sediments, or by breaking up coral structures that provide shelter to, and are a source of food for, other organisms.

The physical interaction between the trawl and the seabed depends on the sediment type and on which part of the trawl is in contact with the bottom. In Section 4.1 we saw that trawls, in their simplest form, have three main components that come into contact with the sea floor: the ground gear, sweeps (and associated components) and trawl doors. Based on our assumptions about the size of a trawl (summarised in Section 4.1), the potential area affected by each component has been calculated, and this is summarised in Figure 5.1.

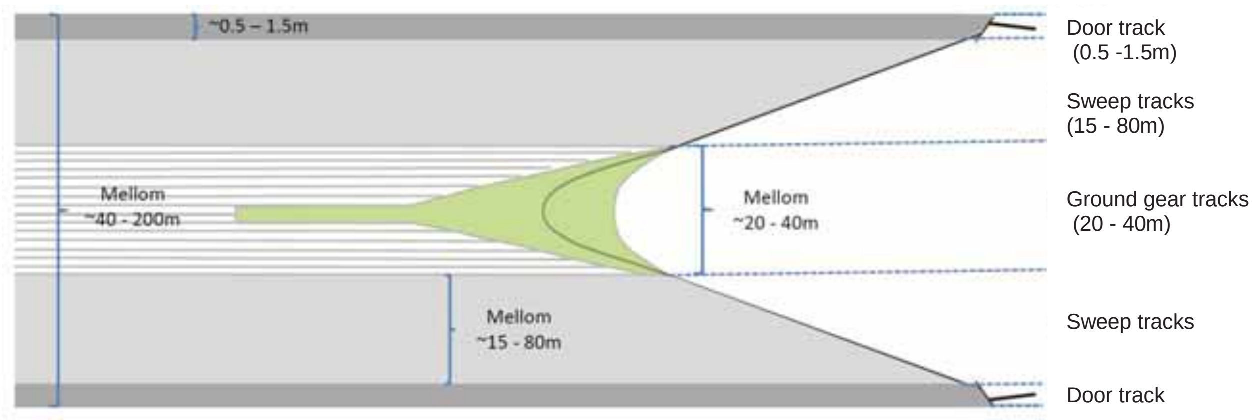

Figure 5.1. Area potentially affected by a trawl and its components

5.1 Documentation of the physical impact on seabed substrates

Studies have been performed in Norway and Scotland, as part of the DEGREE project, to measure the dimensions of the marks left by these components on the sea floor (DEGREE 2010) (figures 5.2-5.4). In Scotland divers compared areas of the seabed (with different substrates) before and after the trawl had passed. Photos of examples of the marks left by each component are shown for mud and sand bottoms in Figure 5.5. By using laser scanning techniques, the divers were able to obtain exact measurements of the sea bottom topography before and after trawling (see e.g. Figure 5.6).

Figure 5.2. Marks created by the door of a rockhopper trawl in soft mud in Varangerfjorden. The distance between the red laser lights is 10 cm (from DEGREE 2010).

Figure 5.3. Marks created by a sweep chain in soft mud in Varangerfjorden. You can see small heaps of mud spread across the chain tracks. The distance between the red laser lights is 10 cm (from DEGREE 2010).

Figure 5.4. Marks created by the ground gear of a rockhopper trawl in soft mud in Varangerfjorden. The distance between the red laser lights is 10 cm (from DEGREE 2010).

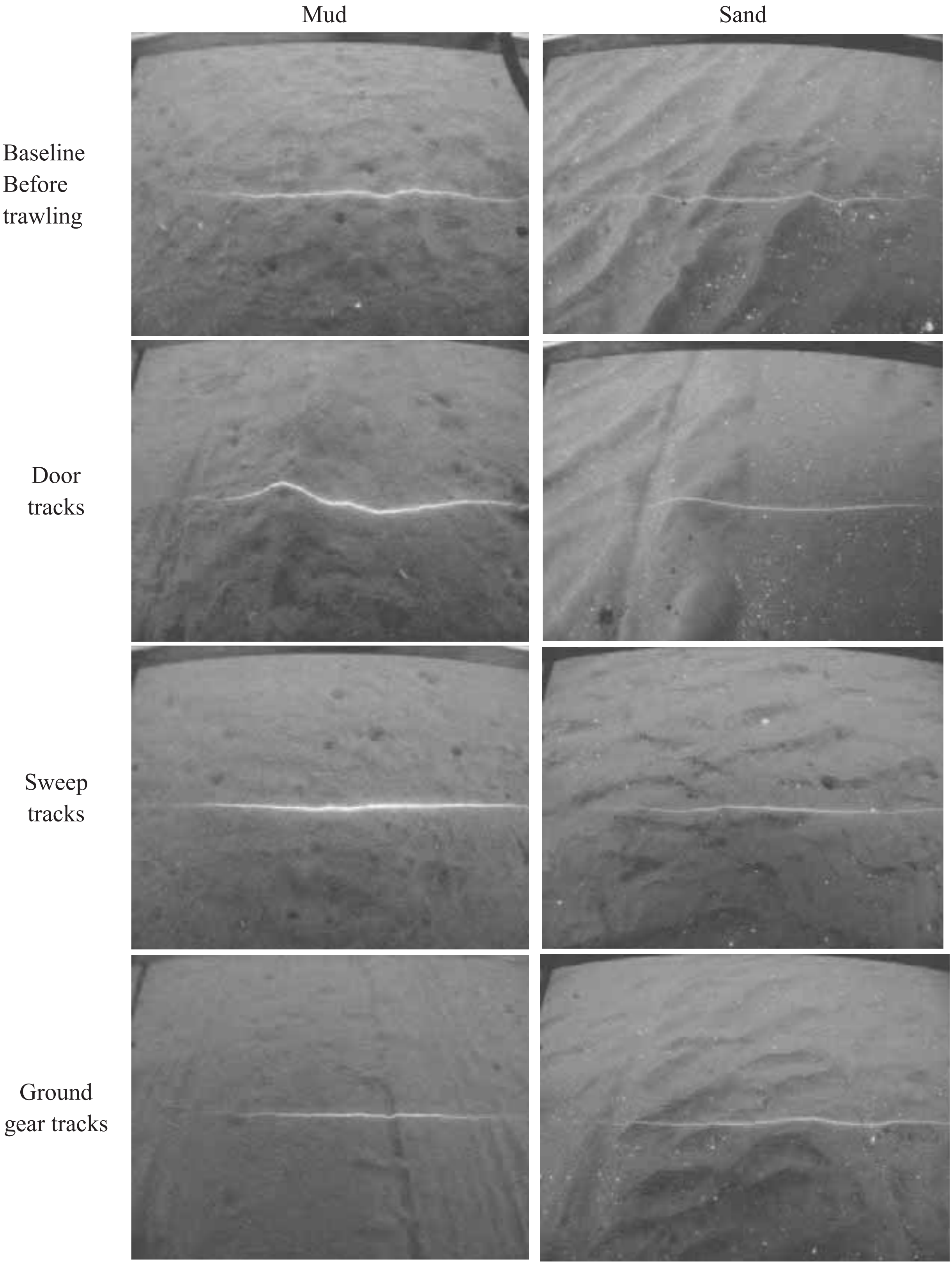

Figure 5.5. Photos of sediments before and after contact with various components of the trawl in mud and sand. Each photo also shows a laser profile from DEGREE 2010.

Based on the photos it was possible to calculate what proportion of its path each trawl component affected, and the depth of the marks they left in the substrate (Table 5.1). In terms of the proportion of the path affected, there was no doubt that the trawl doors had the biggest impact, although the path was relatively narrow (~0.5-1.5 m). The trawl doors dug up a trench/furrow that was up to 20 cm deep in Norway (10 cm in Scotland), and transferred large amounts of sediments onto either side of their path. The furrow was not always continuous, as the trawl doors sometimes floated up off the bottom, depending on the topography and sea state. The ground gear affected only a relatively small proportion of its path (up to 12% in sand and 20% in mud), but due to its width (~20-40 m), it left a bigger mark than the trawl doors (~2-4 m in sand; ~4-8 m in mud). The sweeps represented the biggest proportion of the trawl path, but they appeared to have little impact on mud bottoms. On sand there is more contact due to waves in the sand, but the impact is limited to the top two centimetres of sediment. However, it is important to remember that this component can destroy any structures that rise up more than a few centimetres above the surrounding sea floor.

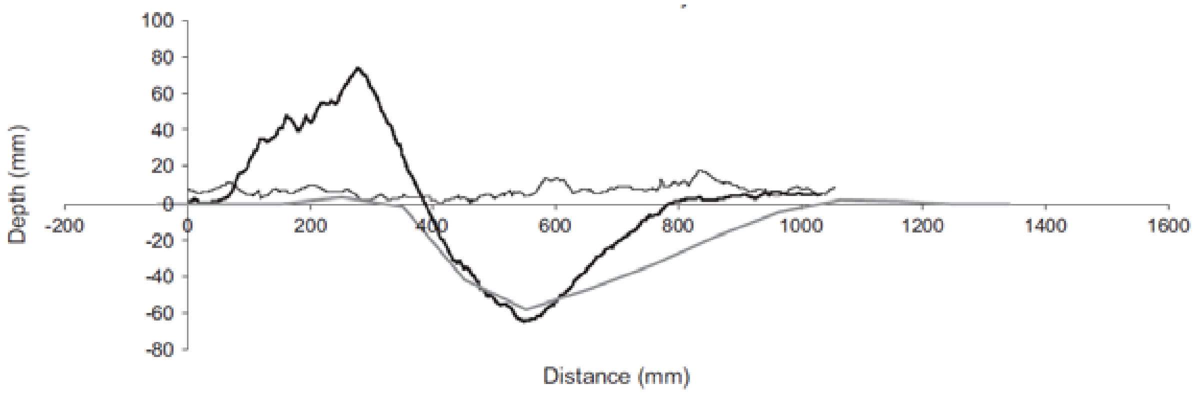

Figure 5.6. Laser readings before (dotted line) and after (solid black line) contact with a trawl door in muddy sand, compared with the predictions of a classic FE model of plasticity (solid grey line) (from O'Neill et al. 2010).

Table 5.1. The proportion of sediments at various depths affected by trawl doors, sweeps and ground gear during trawling trials on sand and mud sediments. None of the components penetrated more than 10 cm into the various habitat types.

		Proportion of sediments affected	
Trawl component	**Depth (cm)**	**Mud**	**Sand**
Door tracks	0-2	0.91	0.2
	2-5	0.30	0.01
	5-10	0.05	0
Sweep tracks	0-2	0	0.19
	2-5	0	0
	5-10	0	0
Ground gear tracks	0-2	0.2	0.12
	2-5	0.2	0
	5-10	0.2	0

5.2 Documentation of physical impacts from MAREANO

The MAREANO project has mapped the number of trawl marks observed per 100 metres of seabed documented with video. Examples of trawl marks are shown in Figure 5.7.

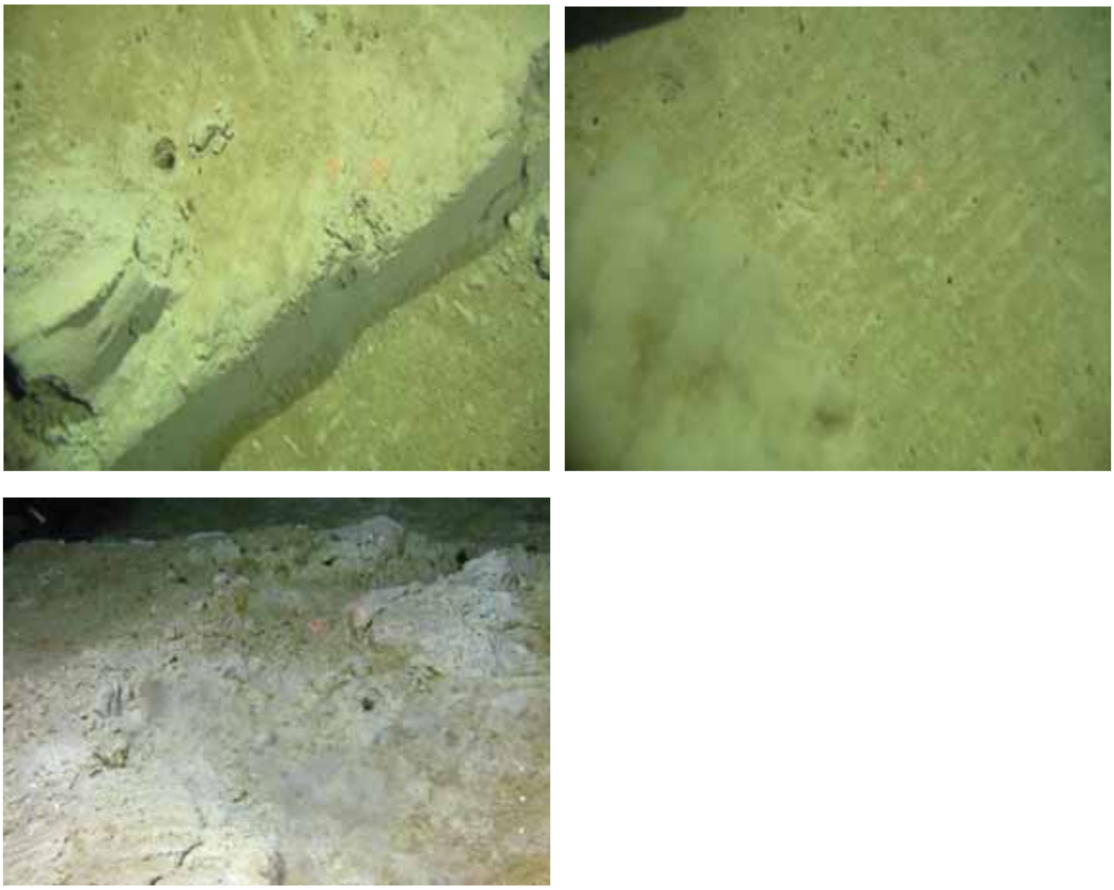

Figure 5.7. Physical impact of otter trawl on seabed as observed by video. **A** Cuts in the sediment caused by trawl door. **B** Marks caused by the chain on the trawl's footrope. **C** Sediment churned up by trawl. The red laser points show a 10 cm scale.

The distribution of trawl marks in the area mapped by MAREANO is shown in Figure 5.8. On average, 2.3 marks per 100 m of video observation were observed in Eggakanten, with a peak value of 11 per 100 m. Meanwhile, in Tromsøflaket the average was 4.2 per 100 m, with a peak of 10 per 100 m. In the Nordland VII zone, the maximum number of observed marks was 4.9 per 100 m, It is not uncommon to find a trawl mark every 25 metres, and in some areas they are as dense as every ten metres. Preliminary results of comparing the prevalence of trawl marks with the distribution of fishing activity based on satellite tracking data suggest that marks are more likely to be left on soft, clay-rich substrates. Figure 5.9 shows the distribution of trawl marks by sea depth. The plots indicate that there is high trawling activity at two different depth ranges. The two peaks in trawl mark density reflect different fisheries. The peak at depths of 100-400 m represents fisheries for various types of white fish, whereas the peak of 600-700 m relates to the Greenland halibut fishery.

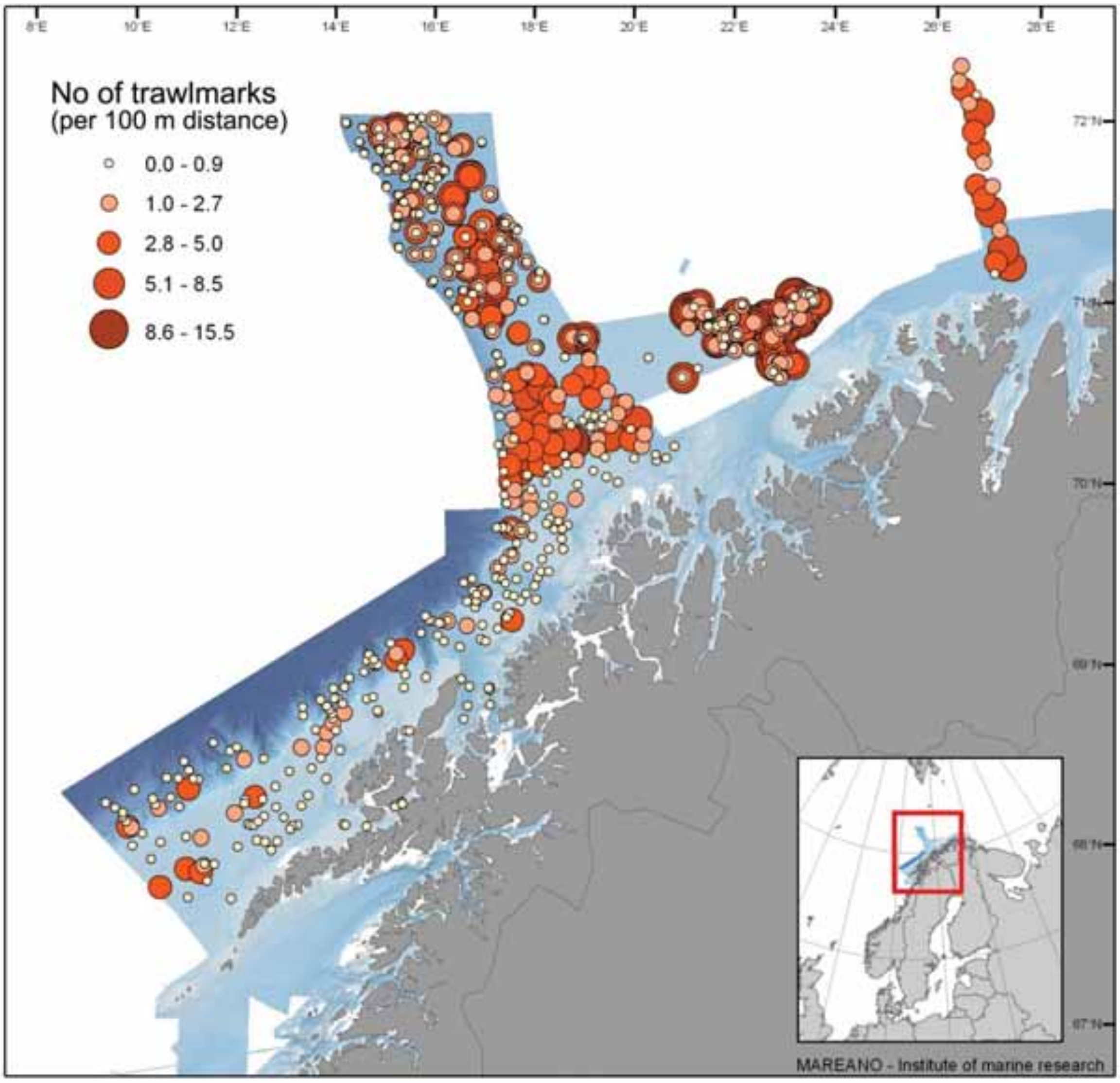

Figure 5.8. Density of observed trawl marks per 100 m stretch of video observation in areas mapped by MAREANO.

5.3 Disturbance of sediment particles from seabed substrates

Physical contact can also alter the substrate and water column through the resuspension of sediments. The DEGREE project (DEGREE 2010) described the quantity and composition of particles churned up from the sea floor in the wake of trawls, and particularly trawl doors, based on diver observations (Figure 5.10). Techniques are now being developed to help us describe these particle clouds in greater detail using multibeam echo sounding (O'Neill et al., in prep) (Figure 5.11).

Another issue is that the resuspension process can release nutrients (Duplisea et al 2002) and pollutants (Olive 1993) into the water column, and release anoxic layers of sediments, which can in turn increase biological oxygen consumption (Reimann and Hoffman 1991). Through these kinds of processes, the physical impact of fishing can to some extent affect natural bio-geochemical processes by restructuring sediments (Kaiser et al 2002).

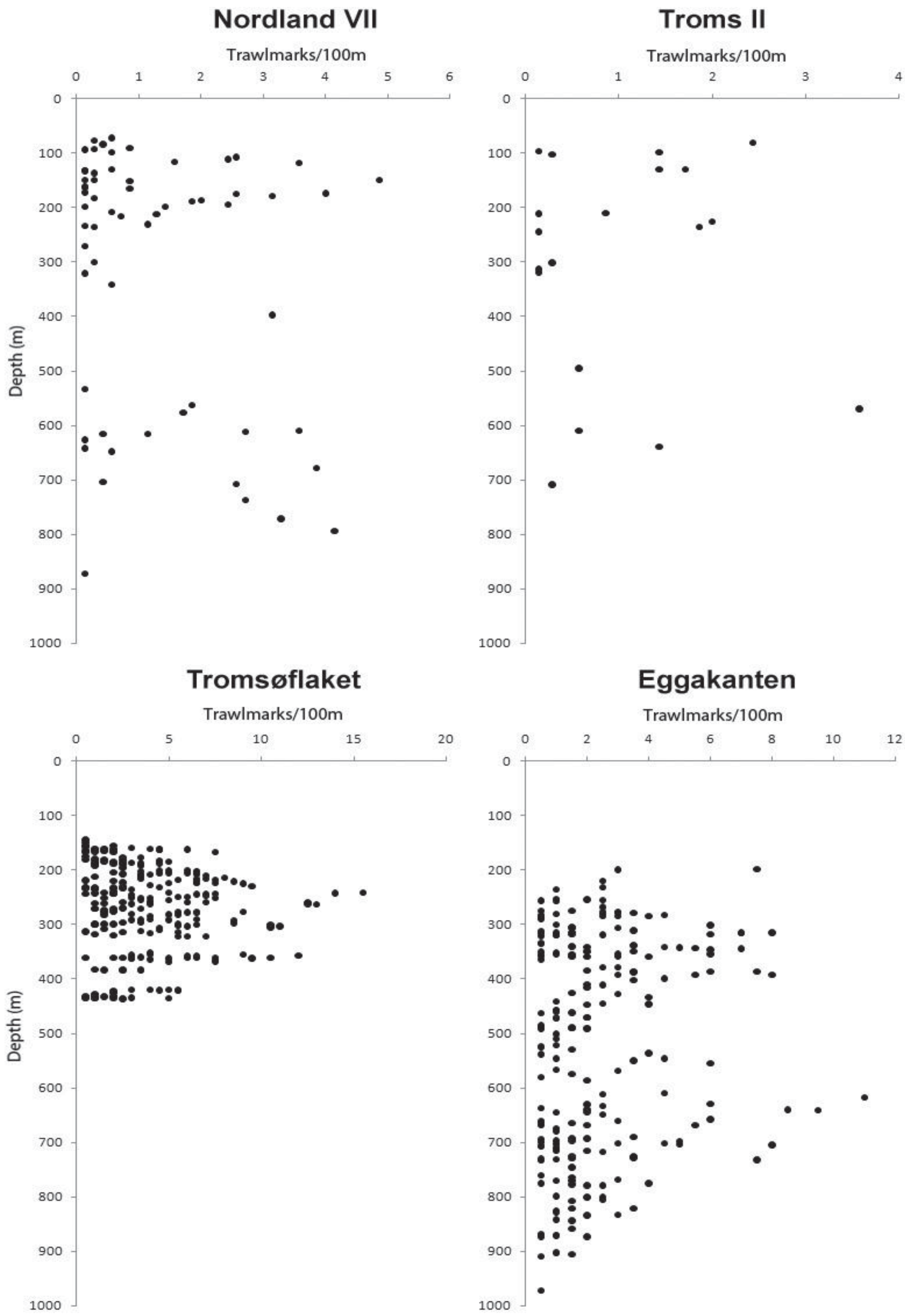

Figure 5.9. Density of observed trawl marks per 100 m stretch of video observation in four different areas mapped by MAREANO.

Figure 5.10. The cloud of sand behind the trawl shows how it can churn up sediment particles (from Breen 2004).

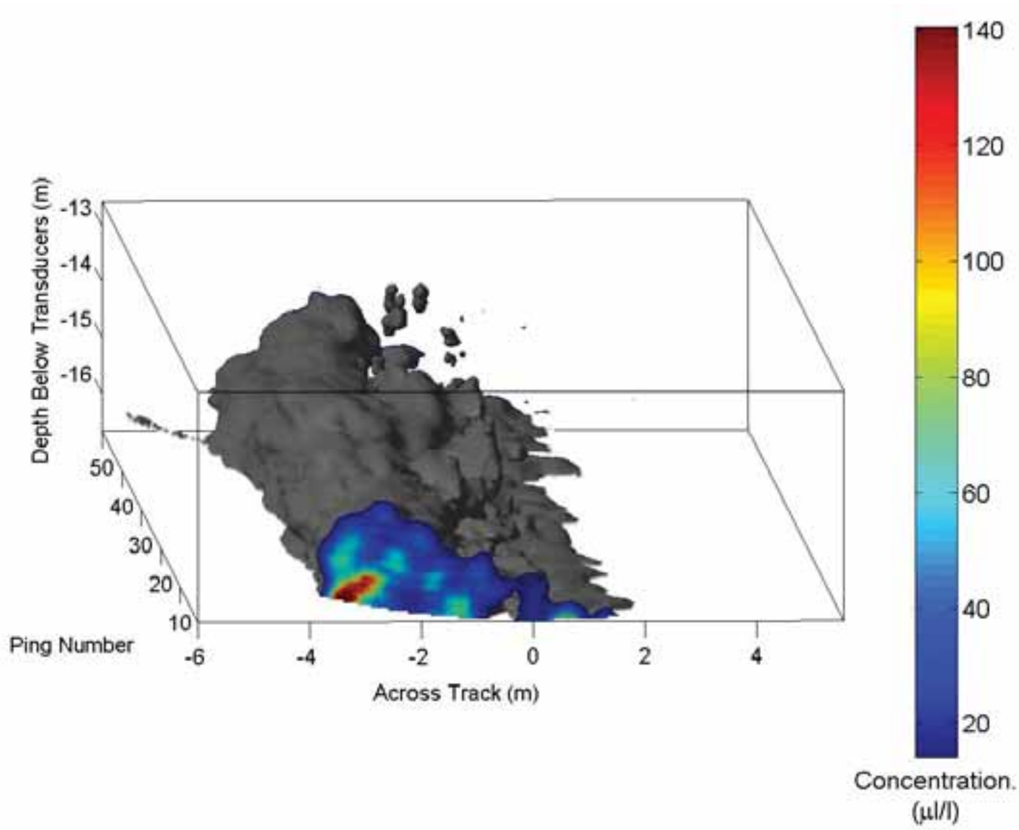

Figure 5.11. 3D model of the sediment cloud in the wake of a trawl door based on multibeam echo sounding using the Reson 7125 (from O’Neill et al., in prep).

6 Effects of fishing on benthic communities and habitats

Fishing can have a variety of effects on marine ecosystems, depending on where the fishing takes place. Fisheries management authorities have focused particularly on damage to seabed habitats caused by the use of bottom trawls. The updated management plan for the marine environment in the Barents Sea and waters off Lofoten (Meld. St. 10 (2010-2011)) states that damage caused by dragged gears has been observed.

6.1 General knowledge about impacts on benthic communities and habitats

There are few studies that document the long-term impacts of ongoing bottom trawling on large benthic fauna. It is important to study the long-term effects if we want to understand the changes caused by bottom trawling at the ecosystem level (Hinz et al. 2009). However, long-term effects on benthic communities and ecosystems are hard to document. Nevertheless, our current knowledge suggests that ongoing trawling can lead to fundamental changes to benthic communities, which can in turn alter food chains and energy flows at the ecosystem level (Hinz et al. 2009).

Published studies show that long-lived, habitat-forming benthic fauna is particularly sensitive to bottom trawling (Sainsbury et al. 1997, Desprez 2000, Moran and Stephensen 2000, Pitcher et al. 2000, Sarda et al. 2000, Wassenberg et al. 2002).

We currently have little quantitative information about the recovery process. Studies suggest that for benthic fauna that live buried in sediments (infauna) the recovery process might take 18 months (Tuck et al. 1998), while for epibenthos such as Mollusca, Crustacea, Annelida and Echinodermata, the recovery time might be 1-3 years (Sarda et al. 2000, Desprez 2000). Sessile megafauna make take anything from years to decades to recover. Indirect studies by Pitcher (2000) and Sainsbury et al. (1997) show that large sponges may need more than 15 years to re-establish themselves. One study of changes to megafauna on seamounts found that ten years after trawling ceased there was still no sign that the affected sponges and corals were recovering (Williams et al. 2010). These large benthic organisms create habitats that are rich in benthic fauna and fish (Buhl-Mortensen et al. 2010a).

6.2 Results from experimental trawling off Bear Island

In Norwegian waters, there have been few controlled experiments to study the direct impact of bottom trawling on benthic habitats and organisms. A study was performed at a depth of 85-100 m in the fisheries protection zone around Bear Island (Kutti et al. 2005). The sediment there was dominated by shellfish remains and fine sediments (silt, sand, gravel). The protection zone around Bear Island has been closed to trawling since 1978, so it is highly suited for a controlled trawling experiment where you want to make a comparison with an unaffected control area. For the experiment, trawling was carried out in two different areas. One was exposed to intensive trawling (700% coverage: ten trawls (140 m door width) within a 200 m wide area that was trawled seven times on average), and one to moderate trawling (230% coverage: ten trawls within a 600 m wide area). Side-scan sonar and video observations were used to examine the physical effects of trawling within a limited area. The observations revealed very obvious marks created by the trawl doors, which had dug 10 cm deep and 20 cm wide furrows with 10 cm high ridges on either side (Humborstad et al. 2004). The ground gear (rockhopper), meanwhile, left smaller furrows. Observations carried out five months later found that the physical traces had disappeared. The acoustic seabed classification system RoxAnn was used to investigate physical changes to the seabed sediments. The conclusion was that intensive trawling left the sediments softer, and slightly increased the unevenness of the substrate, while no changes were found in the area exposed to moderate trawling.

The biological effects on the area exposed to intensive trawling were investigated by taking samples of benthic organisms before and immediately after trawling. Epibenthos samples were taken using a sledge, and the composition of fauna in these samples were compared with equivalent samples taken in an unaffected area. The main impact of the trawling was the resuspension of surface sediments, which left previously buried shells (bivalves) exposed on the surface of the sea floor. No change was found in the number of species or numerical biodiversity, but measured in terms of biomass, biodiversity increased as a result of trawling. Almost none of the species in the samples had been killed or injured by trawling. The study concluded that trawling did not cause major changes to the benthic community in this habitat type.

6.3 Results from experimental trawling in the Scottish part of the DEGREE project

The DEGREE project in Scotland uses divers to examine the immediate physical impacts (described in Section 5.1) and biological impacts of trawling on seabed habitats (DEGREE 2010). In order to assess biological impacts, the divers took baseline samples from an area of the sea floor before trawling, and a series of samples from the same area after the trawl had passed. The aim was to take post-trawling samples from within the tracks left by the various trawl components (as described in Section 5), as well as baseline samples from outside the identified path of the trawl. Both the total quantity (number of individuals per core sample) and species diversity (number of species per core sample) were significantly lower in the trawl door track than in the baseline samples, but this was not the case for the sweep or ground gear tracks (figures 6.1 and 6.2). This was true of both sand and mud sediments. On muddy bottoms, the following species exhibited the biggest differences in the number of individuals: the brittle stars *Amphiura filiformis* and juvenile *Ophiuroidea spp.*, the echinodermata *Pholoe baltica*, the amphipod *Ampelisca tenuicornis* and the mollusc *Mysella bidentata*. Meanwhile, on muddy bottoms the following species exhibited the biggest differences: the amphipods *Bathyporeia spp., Perioculodes longimanus* and *Megaluropus agilis*, a *Nemertea spp.*, the echinodermata *Spiophanes bombyx, Magelona filiformis, Aricidea minuta* and *Peresiella clymenoides*, the mollusc *Cochlodesma praetenu*, a juvenile *Nephtys spp.* and *Phoronis spp.* Based on observations of the various trawl components' physical impacts (see Section 5.1) and the known distributions of common species in mud and sand sediments, the study also calculated the mortality risk posed by the various components for each species (for further details see DEGREE 2010).

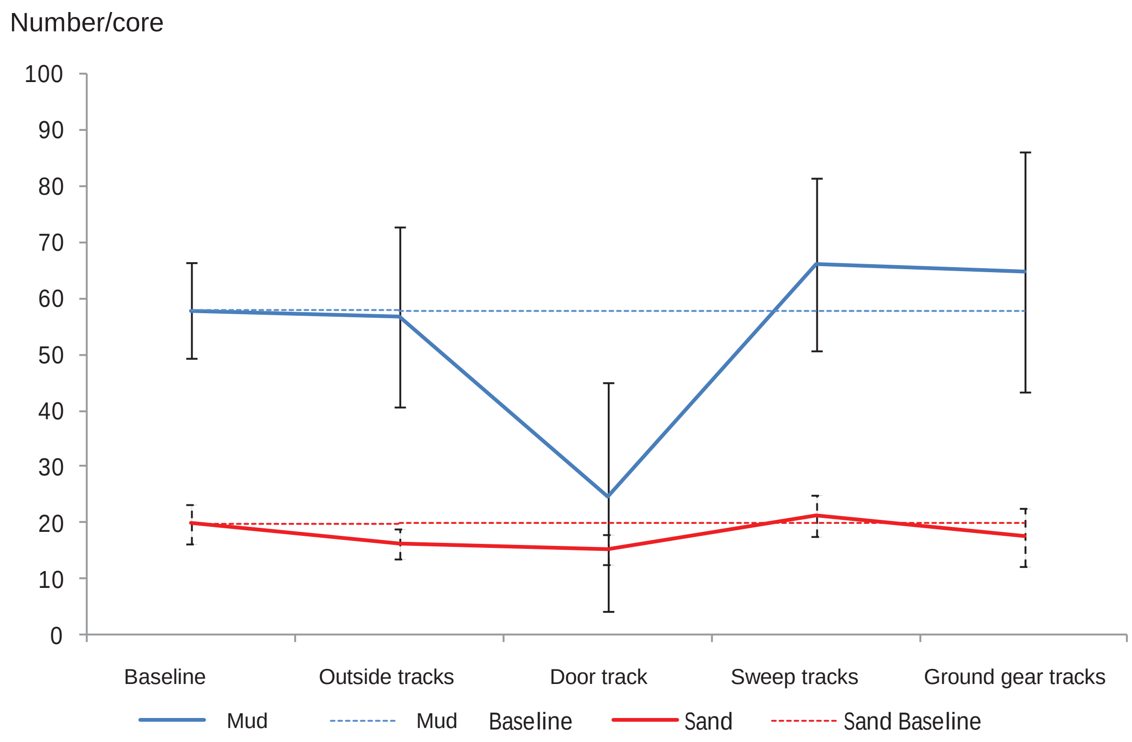

Figure 6.1. Total quantity of benthic fauna (number of individuals per core sample) in the baseline, outside the trawl path and in the various zones of the trawl path.

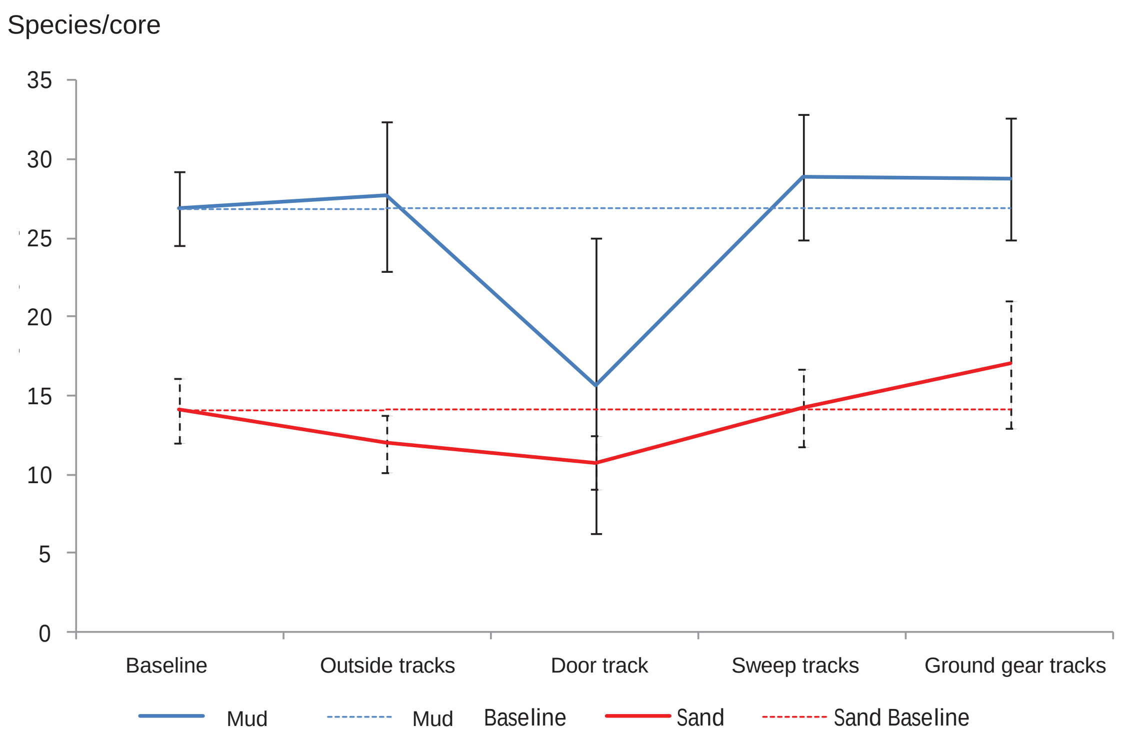

Figure 6.2. Species diversity (number of species per core sample) in the baseline, outside the trawl path and in the various zones of the trawl path.

6.4 Long-term impacts on large benthic species, results from MAREANO

The results from the MAREANO project are useful for analysing the effects of bottom trawling on seabed habitats. Some of this material, which consists of more than 1,000 (700 metre long) video transects documenting large and long-lived benthic species, as well as samples from approximately 250 stations, is now being classified and prepared for scientific publications. This will be an important resource for the future management of Norwegian waters. Each year, the MAREANO project documents vulnerable habitats such as sponge communities and coral reefs. In some areas they are heavily affected by trawling, and it is not unusual to find abandoned fishing gear on coral reefs (Figure 6.3).

In the most intensively trawled areas, such as Tromsøflaket, the large sponges *Geodia* and *Steletta* are often concentrated in the trawl paths, covered in sediments (Figure 6.4). We do not have detailed observations of how bottom trawling affects sponges, but their unnatural distribution in Tromsøflaket suggests that they are dragged by the trawl for a short distance before being left behind in rows behind the trawl doors, or being dumped in heaps when the trawl jumps.

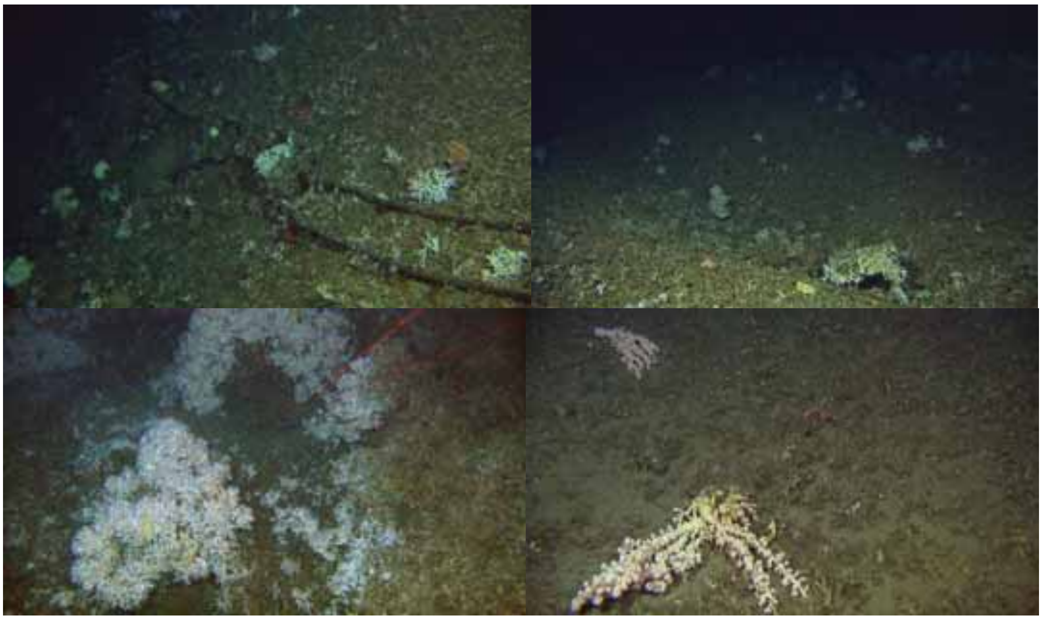

Figure 6.3. Examples of the impacts of fisheries on the Korallen reef, northwest of Sørøya.

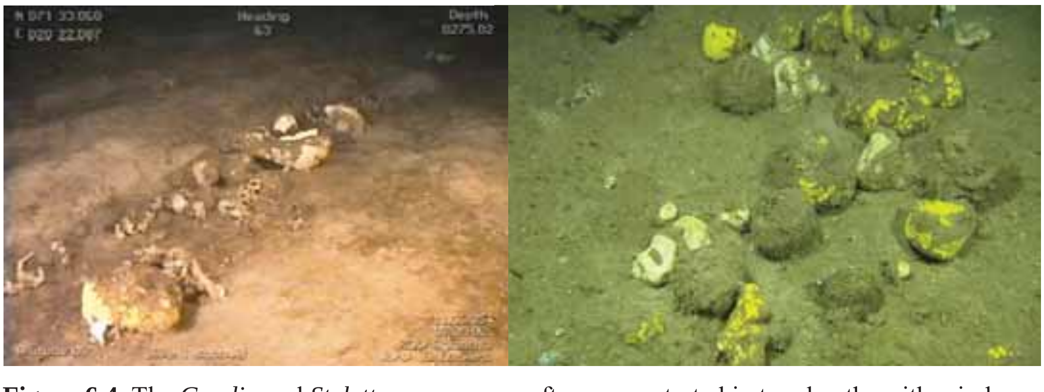

Figure 6.4. The *Geodia* and *Steletta* sponges are often concentrated in trawl paths, either in long rows or in heaps.

Until recently, we knew little about the distribution of sensitive habitats (sponges, reefs, coral forests) in Norwegian waters, but video mapping has given us useful new information about these benthic communities (Buhl-Mortensen et al. 2010b). The figure below shows the distribution of these vulnerable habitats based on information from MAREANO (Figure 6.5).

By comparing the distribution of vulnerable habitats (Figure 6.5) with the distribution of trawling activities (Figure 6.6), it is possible to identify potential areas of conflict. Moreover, it will be possible to use new information about the distribution of large benthic species to study the chronic effects of trawling, by comparing those data with past trawling activity.

MAREANO results relating to the distribution of benthic communities and habitats have made it possible for the Norwegian Directorate for Nature Management to develop a model for valuing and locating important and vulnerable habitats (http://www.havmiljo.no/). In the EU project "Monitoring and Evaluation of Spatially Managed Areas", data from MAREANO have been compared with information about human activities (fisheries, petroleum-related activities and shipping) in order to develop tools for identifying areas of conflict and the level of impact.

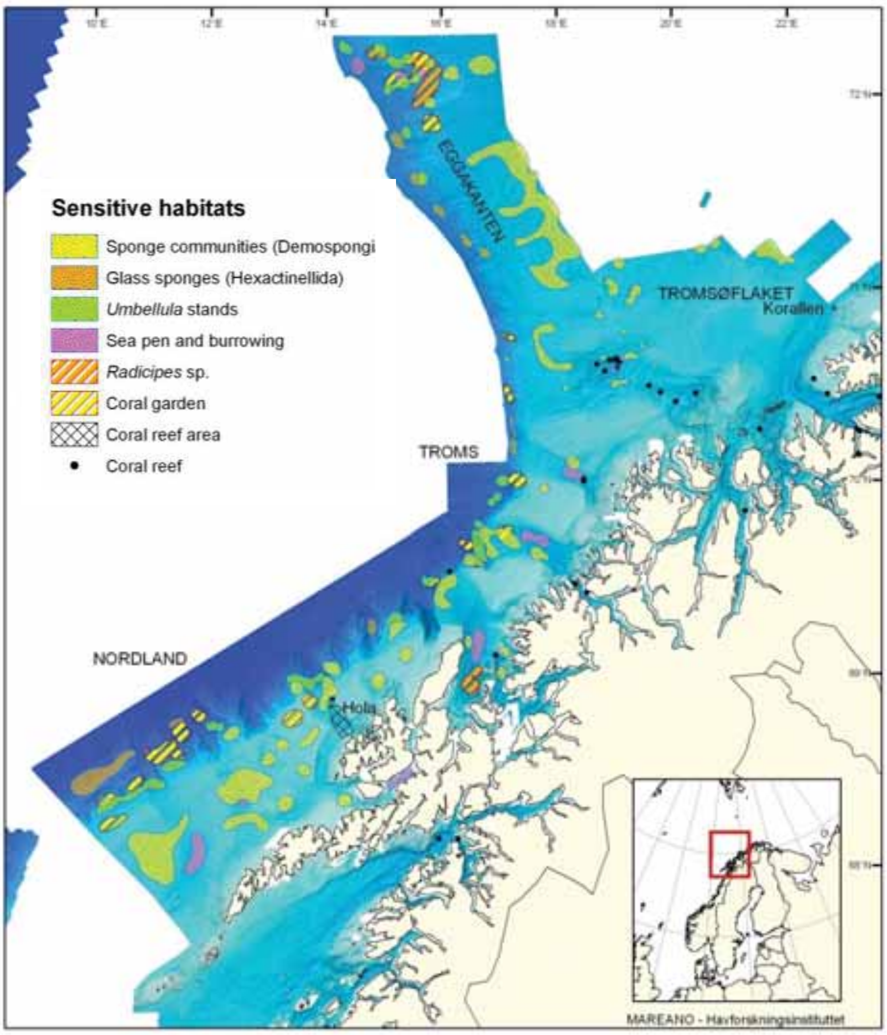

Figure 6.5. Distribution of vulnerable habitats documented by MAREANO.

The MAREANO project has started analysing the effects of bottom trawling, using satellite tracking data (VMS data) supplied by the Directorate of Fisheries as a quantitative index of trawling activity (Figure 6.6). Preliminary results indicate that the density of individuals is lower, and there are fewer taxa, in areas exposed to intensive trawling activity. These preliminary results also suggest that it is particularly sessile sponges such as *Phakellia, Axinella, Hymedesmia* and *Craniella* that are under-represented in these areas (Figure 6.7 shows examples of some of the sponges). However, a few species that are scavengers appear to be more common in areas exposed to intensive trawling. There were no coral reefs present in the areas studied. The caveat should be made that these are preliminary results, and no direct causal relationship has been documented between trawling and the low numbers of these species.

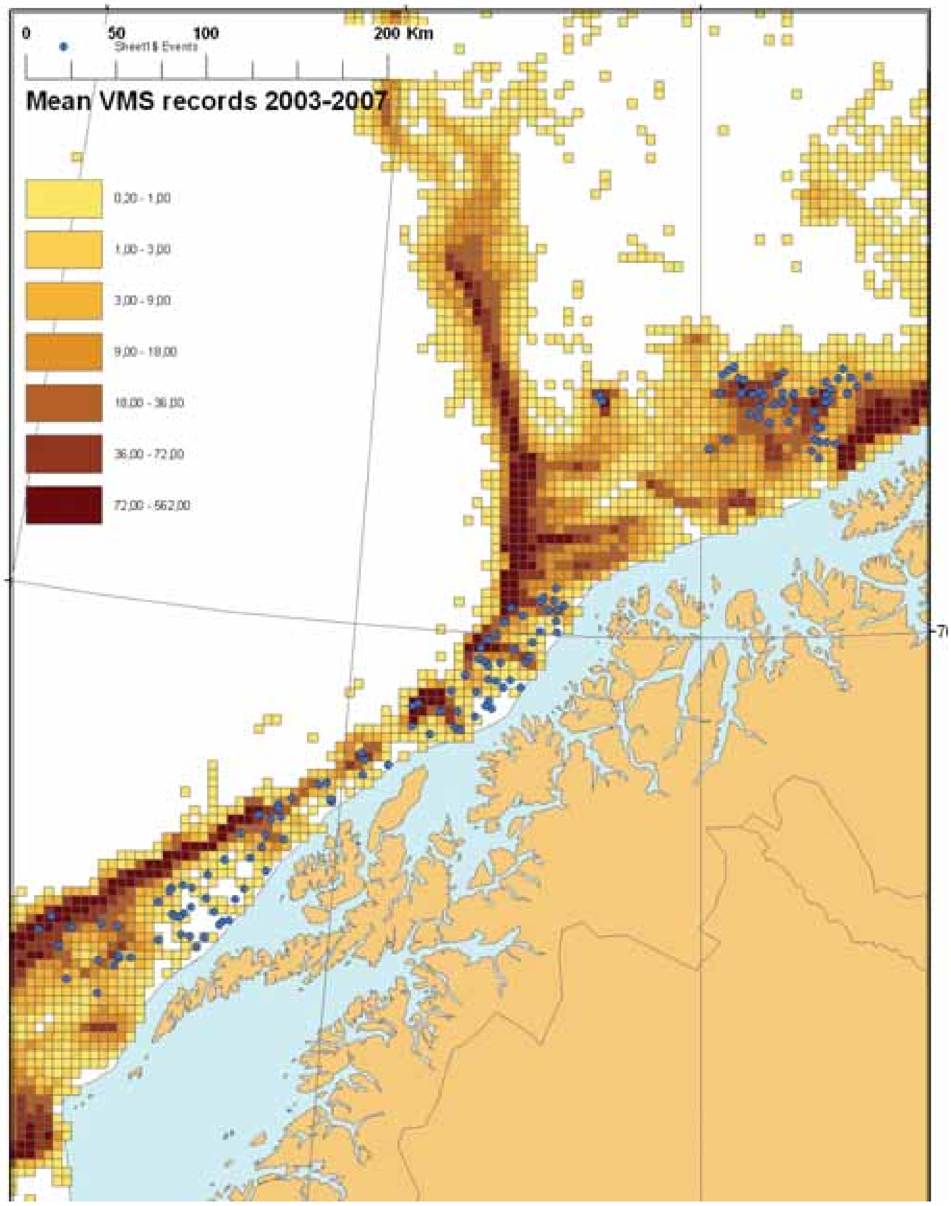

Figure 6.6. Average annual trawling activity based on satellite tracking (VMS data) for a five-year period (2003-2007). The colour codes represent activity level categories: 0.2-1, 1-3, 3-9, 9-18, 18-36, 36-72 and > 72 trawlers recorded per year within 5x5 km grid squares. The blue spots represent places where MAREANO video observations have been used to analyse the impacts of trawling.

Figure 6.7. Stills from a video of relatively spread out sponges in areas with intensive trawling activity.

6.5 Effects of bottom trawling on coral reefs

It is well documented that bottom trawling is very harmful to cold-water reefs (Mortensen 1998, Fosså et al. 2002), and the MAREANO project is regularly documenting new coral reefs, many of which show signs of having been damaged by bottom trawling. It is clear that the coral reefs furthest out to sea have been more exposed to bottom trawling than the ones nearer the coast. The impact on reefs in fjords and near the coast is therefore lower. For instance, the reef at Stjernsund showed no signs of damage from fisheries, and at a reef that was mapped by MAREANO in Andfjorden in 2008 (http://www.mareano.no/nyheter/ nyheter2008/andfjordens perle), damage was only observed in a limited area. Here it was shown that saithe nets were to blame for the damage. These nets easily get tangled up in the corals, and when a tangled net is drawn in, it can fill up with corals, which means that it scrapes its way through the colonies. The reef in Andfjorden showed signs of this having happened, the results of which are similar to the damage that can be caused by parts of a trawl.

6.6 Monitoring damaged coral reefs; results of the Hermione project

As part of the EU project Hermione (Hotspot Ecosystem Research and Man's Impact on European Seas), The Institute of Marine Research studied the faunal composition and colony sizes of *Lophelia* reefs that had been exposed to varying degrees of bottom trawling over a four-year period. It based its study on 66 video transects from fifteen reefs in the counties of Troms and Finnmark. These had been filmed by Campod in 2006, 2007, 2009 and 2010. The fifteen coral reefs studied were in five areas: Lopphavet, west of Sørøya, Korallen, Stjernsund, and a small reef to the north of Korallen (Figure 6.8).

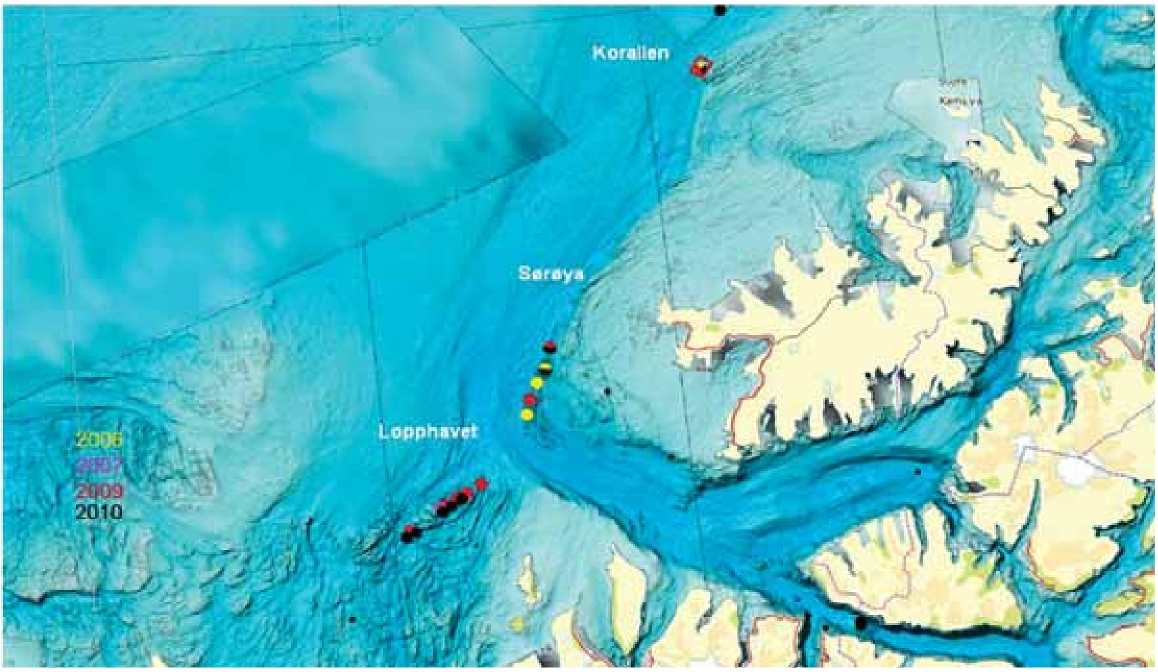

Figure 6.8 The three main areas that were studied in The Institute of Marine Research´s contribution to Hermione. The location in Stjernsund is marked with a black spot on the lower right-hand side of the map.

The biggest reef studied is located in the small reef area called "Korallen", and is approximately 1.2 km long and around 30 m high. The reef is in a good state, with large areas almost entirely covered with living *Lophelia pertusa*. The highest biodiversity can be found in the zone with dead coral blocks.

The impact of habitat destruction: It is clear that the coral reefs furthest out to sea have been more exposed to bottom trawling than the ones nearer the coast. This is apparent both from VMS data and the video observations carried out as part of the study (figures 6.6 and 6.9). Judging by the type of trawl gear that was observed on the sea bottom, and the size of the regenerated colonies, and taking into account the growth rate of *Lophelia*, it is probable that the damage observed on the Korallen reef area is more than ten years old. Korallen was protected against bottom trawling in 2009, but as long ago as 1999 a general ban was introduced on trawling over known coral reefs in Norway. On an expedition in 2010, a completely dead coral reef was found to the north of Korallen. The seabed was made up of crushed coral fragments (Figure 6.9), and there was a lot of abandoned towing cable in the area. There were no signs of regeneration.

Scope of the damage: The impact on reefs in fjords and near the coast is lower than on the ones further out to sea. The reef at Stjernsund showed no signs of damage from fisheries. At Lopphavet and west of Sørøya, 0.6 and 1.6% respectively of the reef´s area was affected. At Korallen the proportion of damaged coral seabed was higher, with 5.9% of the area destroyed. The scope of the damage varied locally from reef to reef, with between 0 and 76% of the seabed having been destroyed. The most obvious impact of the fishing gear was that coral colonies had been crushed and moved. In several places no large coral fragments were observed, and instead there was an even cover of small (<10 cm), living fragments. Broken and overturned colonies of bubblegum coral (*Paragorgia arborea*) were also observed. These areas were interpreted as having been recently trawled, as the small coral fragments were still alive. Other places were much less affected, and intact colonies were observed between small damaged areas with clear trawl marks. The coral colonies in the affected areas (both *Lophelia* and *Paragorgia*), were around half as high as the ones in the intact areas (Figure 6.10).

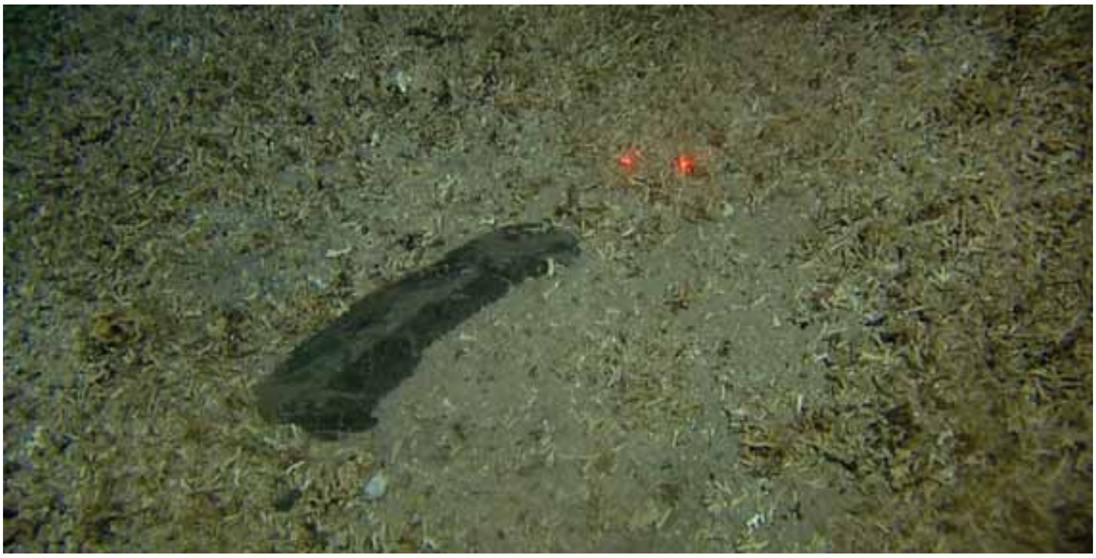

Figure 6.9. Coral reef completely destroyed by trawling north of Korallen.

Impacts on biodiversity: Comparing the biodiversity of intact and affected coral locations revealed a clear difference in the case of habitats dominated by dead coral blocks and coral gravel, whereas the differences were less obvious for living coral habitats. Here the number of species was 7-8 for both categories, whereas for dead coral blocks the number was twice as high (10.6 per picture) at the intact locations as at the affected ones (5.0 per picture). This may possibly be due to the fact that there are no living coral habitats that have been badly affected by trawling. Badly affected areas are transformed into coral gravel, which means that any living coral habitats will only have been lightly affected.

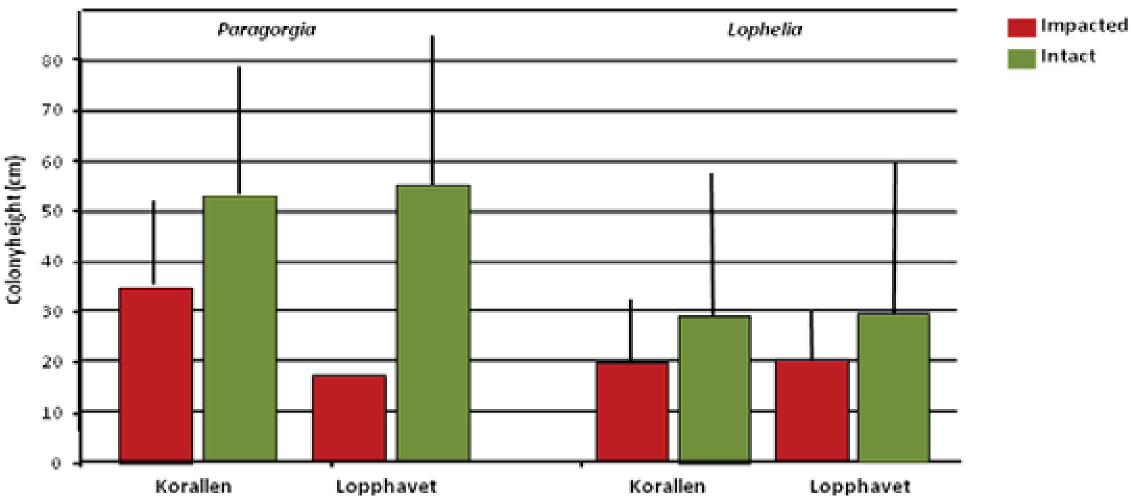

Figure 6.10. Height of coral colonies at affected and intact coral locations at Korallen and Lopphavet. The vertical error bars indicate the standard deviations.

Impact on relative distribution of organisms: In general, the number of individuals per unit area was higher in affected coral locations than intact ones. In most cases, the high density of organisms was due to the anemone *Protanthea simplex* and unidentified brittle stars. For most species physical contact reduces density, but a few opportunistic species can make use of newly liberated areas, or feed on injured or exposed organisms.

The average density of fish was higher in the intact coral habitats than in the damaged ones (Table 6.1). In total, nine fish species were recorded in the analysed photos. Four of them were not observed at all in the affected coral habitats. The biggest difference was observed for the *Sebastes viviparus*, which had a density of 15.5 individuals in intact coral habitats, compared with only 2.8 in damaged habitats. The one clear exception to this rule was the saithe, which was twice as common in damaged habitats as intact ones.

Table 6.1. Average fish density (individuals per 10 m^2) observed in intact and damaged coral habitats.

Species	Injured	Intact
Atlantic wolffish	0.0	0.3
Tusk	1.1	3.4
Yarrel’s blenny	0.0	0.3
Cod	0.0	0.3
Ling	1.7	0.3
Saithe	14.2	7.1
Golden redfish	0.6	0.3
Beaked redfish	7.4	11.5
Norway redfish	2.8	15.5
Moustache sculpin	0.0	0.3
Number of species	6	10
Average density	27.8	39.5

Regeneration of damaged coral habitats: There are several indications that the damage to Korallen was caused prior to 1999. Most of the broken *Paragorgia* colonies were dead, and a “carpet” of almost uniformly-sized *Lophelia* was observed in several locations where trawl marks were still visible. Figure 6.9 shows an example of a coral seabed with what might be regenerated coral. The other typical feature of these locations was the presence of low *Paragorgia colonies.*

Figure 6.11. Example of coral seabed with what might be regenerated *Lophelia pertusa*.

7 How do fish farms affect seabed habitats

The emissions from fish farms include both dissolved and particulate substances. Of the dissolved substances, the inorganic nutrients nitrogen and phosphorous have received most attention. They increase algae growth and can lead to eutrophication, while organic particles affect the bottom, and can lead to poor environmental conditions. In addition, medication and pollutants can enter the marine food web via fish feed and faeces.

7.1 Emissions from fish farms and their spread in the environment

In 2011, the Ministry of Fisheries and Coastal Affairs and Ministry of the Environment appointed an expert group to investigate eutrophication along the Norwegian coast, with a particular focus on the Boknafjord and the Hardangerfjord (Anon 2011). The group estimated nitrogen and phosphorous emissions from aquaculture using three different methods: a model developed by Yngvar Olsen, NTNU; the Ancylus model developed by Stigebrandt, University of Gothenburg; and the TEOTIL model developed by NIVA (Table 7.1).

Table 7.1. Comparison of three methods (the Ancylus, Teotil and Olsen models) for estimating emissions of nitrogen and phosphorous from fish farms in the Hardangerfjord (including Stokksundet and Langenuen). All figures are stated in tonnes (modified from Anon 2011).

Model	Fish production	Dissolved nitrogen	Particulate nitrogen	Total nitrogen	Dissolved phosphorous	Particulate phosphorous	Total phosphorous
Hardangerfjorden							
Ancylus	74,764	770	1,756	2,526	127	280	407
TEOTIL[1]	74,764			2,868			532
“Olsen”	74,764	2,484	923	3407	270	420	690

[1] Here we only have a figure for fish production, so a feed factor has been assumed. 1.15 has been chosen as a representative figure. Based on data collected by the Directorate of Environment, the fish feed has been assumed to contain 5.91% N and 1.01% P.

The total estimated emissions from salmon production vary depending on which method that is used. This is due to differences in their assumptions and input data. TEOTIL is based on a mass balance between nitrogen and phosphorous levels in feed, compared with the levels in the fish produced (fish that have been harvested or die during on-growing). This model does not calculate the fraction of dissolved compounds. There is a big difference in the proportion of dissolved compounds estimated by the “Olsen method” and the Ancylus model, due to variations in the way nutrient assimilation and feed waste are calculated. Bergheim & Braaten (2007) argue that the Ancylus model is the most realistic one for estimating emissions from fish farms. Based on a salmon production of 1,060,000 tonnes in 2011 (Directorate of Fisheries), total emissions of nitrogen and phosphorous from salmon farming in Norway would be 34,000 and 9,750 tonnes calculated by the Ancylus model, and somewhat higher for the other models. That means that the aquaculture industry is responsible for the biggest contribution to anthropogenic emissions of inorganic nutrients and organic substances to Norwegian coastal waters. Aure and Skjoldal (2003) estimated that the total annual transport of nitrogen in the top 50 m of the water column in the stretch of coast from Lista to Stad was of the order of 2,000,000 tonnes, while it was around 2,500,000 tonnes for the stretch Stad-Leka. Compared to natural sources of nutrients the contribution from fish farming is thus relatively small.

The emissions from fish farms include both dissolved substances and particles. Dissolved compounds released from farms spread with the currents in the upper water layers around the farms, and are diluted relatively quickly (Figure 7.1, Sanderson et al. 2008, IMR unpublished data). The dispersion of particles from fish farms depends on the depth, current velocity and the sinking rate of the individual particle. Studies show that the majority of faecal particles have a relatively high sinking rate, which means that over 60% sink faster than 5 cm/s, while approximately 10% sink slower than 1 cm/s (Figure 7.2). At locations with weak currents (<5 cm/s), most of the organic material will be deposited under or close to the farm (Valdemarsen et al. 2012), while at locations with strong currents (>10 cm/s) there will be less organic material under the farm, as the particles will be spread over a greater area (Bannister et al. in prep). There is large variation in water depth and current velocities along the Norwegian coast and in the fjords, which means great variation in dispersion of organic material from on-growing fish farms as well in the benthic impact.

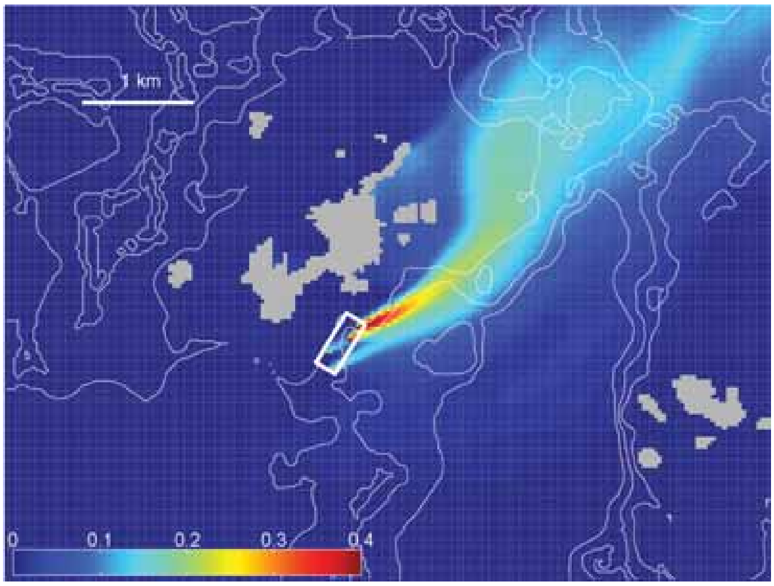

Figure 7.1. Modelled spread of ammonium (nitrogen) from fish farms (Ole Jacob Broch, SINTEF). Values are stated in µM.

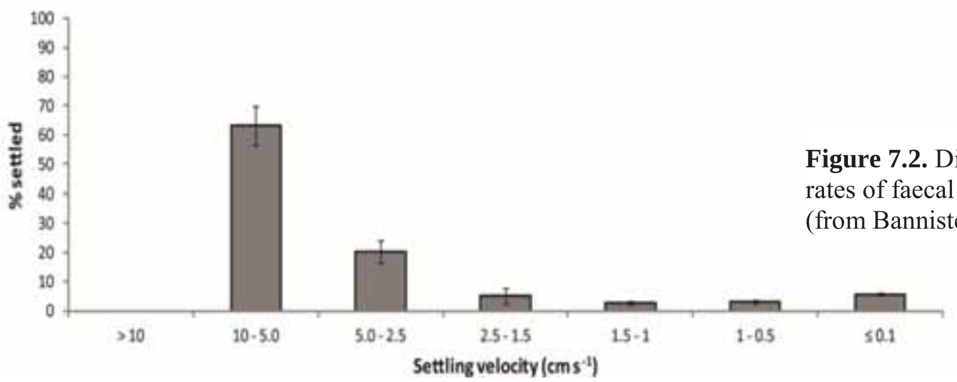

Figure 7.2. Distribution of sinking rates of faecal particles from salmon (from Bannister et al., in prep).

The variation in particle dispersion means that one gets different sedimentation and influence areas, or impact zones, around the farms (Figure 7.3). The greatest impact occurs under and immediately around the farm, and falls with increasing distance from the fish cages. In some cases it is possible to trace waste several kilometres downstream from farms, but most particles normally settle on the seabed less than 500 m from the cages.

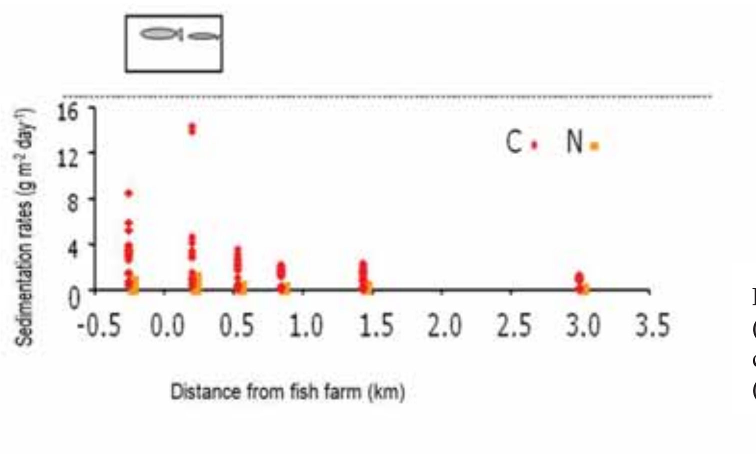

Figure 7.3. Sedimentation rates of carbon (C) and nitrogen (N) over one production cycle at varying distances from a fish farm (Kutti et al. 2007a).

7.2 Impacts on benthic communities

The impacts on soft-bottom communities near fish farms are well documented. In Norway, Kutti et al. (2007b) investigated the impact gradients around a fish farm at a deep site over one production cycle. They found a zone with few species close to the farm, with large numbers of a few opportunistic species, while the benthic community at intermediate distance was stimulated and had a higher diversity of species than the reference station (Figure 7.4). At the reference station 3 km away, the benthic community was unaffected. This is the normal pattern for local organic enrichment (Pearson and Rosenberg 1978), which has been confirmed by several studies of fish farms. Where a large proportion of the particles are deposited on the seabed close to the farm, the oxygen consumption might be so high is so high that oxygen depletion occurs in the sediments, causing the fauna community to collapse. Such anoxic sediments produce gas, leading to bubbles that might transport materials and pathogens from the sediments up to the fish cages. It is now mandatory to monitor the benthic impact of fish farms, in accordance with Norwegian Standard 9410 (Anon 2007) or an equivalent international standard.

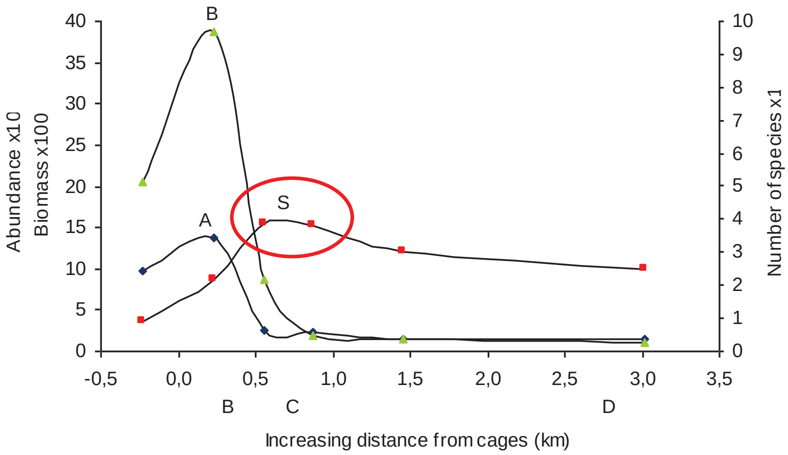

Figure 7.4. Biomass of benthic fauna (B), number of individuals (A) and number of species (S) at varying distances from a fish farm (Kutti et al. 2007b).

Recent studies (Hansen et al. 2011) show that sessile fauna at deep hard-bottom habitats (100-200 m) are sensitive to sedimentation of organic materials from farms. Sessile organisms such as sponges and Cnidarians and Echinoderms were absent from a radius of at least 75 metres around the farm, and the benthic communities were totally dominated by opportunistic bristle worms. Work is being done to determine how big an area can be affected in deep hard-bottom habitats, and to decide how best to monitor the impact.

There is a growing concern how emissions of inorganic nutrients and organic materials from fish farms affect valuable habitats (coral reefs, coral forests, sponges, seagrass meadows, maerl beds, etc.), but so far relatively few studies have been done. Studies of the effects of emissions from aquaculture on coral reefs in tropical and sub-tropical areas show a clear negative impact on the growth, survival and reproduction (Huang et al. 2011, Villanueva et al. 2006, Bongiorni et al. 2003). In Norway we know little about the presence and distribution of vulnerable habitats in areas where aquaculture takes place (fjords and coastal areas) (Buhl-Mortensen and Buhl-Mortensen, 2013), and we also lack knowledge about the effects of emissions from fish farms in such habitats (Tangen og Fossen 2012).

The negative impacts on benthic habitats of increased sedimentation from various other sources are well documented. A number of studies from temperate and tropical waters have found changes in the structure, biodiversity and recruitment of vulnerable sessile fauna (Fabricius 2005, Bannister et al. 2010). Organic waste from fish farms is thought to have a larger impact than inorganic particles, since organic waste consumes oxygen as it is broken down (Weber et al. 2012; 2006).

7.3 Impacts on shallow seabed habitats

Habitats in the shallow areas around fish farms can be affected by both dissolved inorganic nutrients and fine suspended particles that settle at the sea floor. This is the case both in the littoral zone and if the farms are located in a shallow shell sand areas or kelp banks. Measurements around the farms show that inorganic nutrients and particles are rapidly diluted as one gets further away, and are not normally traceable beyond a 500 metre radius (Sanderson m.fl. 2008, IMR unpublished data). Studies of local impacts on hard-bottom habitats in the coastal zone have revealed that emissions have low impact in dynamic environments, but that they can have an impact in more enclosed areas, particularly if the farm is close to the shore (Hansen et al. 2011). In such areas there might be seagrass meadows, which are an important habitat for juvenile fish (particularly coastal cod). The negative impacts of small organic particles on seagrass have been documented in the Mediterranean, where they have been found to slow growth rates and reduce the presence of seagrass in a radius of up to 400 m around farms (Diaz-Almela et al. 2008, Duarte et al. 2008). Experiences from the Mediterranean are not necessarily transferable to Norwegian conditions, where farms are normally located in water too deep for seagrass meadows, but we need more knowledge on the impacts on these important habitats.

It has been demonstrated that emissions from fish farming have a negative impact on maerl beds in Spain (Aquado-Gimènez and Ruiz-Fernàndez 2012, Sanz-Lazaro et al. 2011) and in Scotland (Hall-Spencer 2006). These habitats consist of loose-lying coralline algae, which are generally found in inlets with strong currents, and are particularly common in northern Norway. Maerl beds are known to have high biodiversity, and are protected in many parts of the world. In terms of the impacts on other important species that are found in shallow areas, including scallops and lobster, we are not aware of any studies that discuss the potential effects.

In the past, spawning grounds for cod along the Norwegian coast were identified by interviewing fishermen, but currently data from a National habitat mapping project are gradually becoming available, and stored in a public database (Directorate of Fisheries, Norwegian Directorate for Nature Management). The authorities thus have more information available when planning expansion or establishing new fish farms. However, there is little data on how cod spawning grounds and spawning grounds of other species are affected by the presence of fish farms. Past studies have looked at whether fish farms affect the behaviour of sexually mature cod when it enters the fjord. In laboratory experiments cod avoided water from salmon tanks (Sæther et al. 2006), but no similar impact could be demonstrated in the field (Bjørn et al. 2007, Svåsand et al. 2004).

Additionally there can be indirect impacts on vulnerable or valuable seabed habitats from pollutants in faeces or waste feed. So far we know little about the long-term effects of low concentrations of such substances on benthic fauna. Emissions of in-feed medicines, such as delousing agents, may affect animals with chitin shells, such as shrimps, crabs and lobsters (IMR, unpublished data). Copper from antifouling agents and other xenobiotica can accumulate in the sediments around fish farms (Figure 7.5). Copper can affect the reproduction of fauna (Bielmyer et al. 2010, Reichelt-Bruschett and Harrison 2000, Johnston and Keough 2000) as well as flora (Andersson and Kautsky 1996, Chung and Brinkhaus 1986).

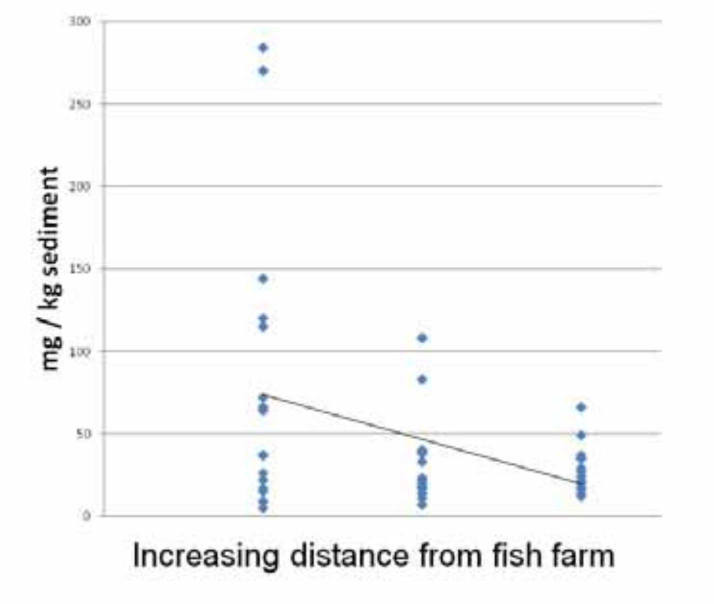

Figure 7.5. Copper concentration around a fish farm measured using a MOM C survey as defined in NS 9410. The Norwegian Pollution Control Authority (now Klif) defined concentrations of under 35 mg/kg as low, while values in the range 35-150 were considered moderate. Concentrations in the range 150-700 mg/kg were considered high (source: Hordaland County Governor).

8 Recommended actions

It has been shown that human activity, and in particular the use of bottom trawls, has a direct impact on sediments and on benthic fauna in certain habitat types. This has been documented in published articles referred to in management documents. Section 6.4.1 of the updated management plan for the Barents Sea and waters off Lofoten (Meld. St. 10 (2010–2011)) confirms the observation of damage to coral reefs, sponges and sea pens caused by trawling, and states that the aim of avoiding damage to threatened or vulnerable marine habitats has not been met.

The fisheries management authorities should carefully consider measures to limit the damage to, and negative impacts on, ecosystems from fishing. The Institute of Marine Research will be able to help assess potential new measures to protect coral reefs and other seabed habitats in view of new information. Below the committee outlines nine measures that should be taken. However, the committee would like to point out that this is a constantly changing field, both in Norway and internationally. The proposed measures should therefore be seen as stages in a process, to be revised and expanded as required.

Action 1: Introduce trawling techniques with a lower impact on the seabed

Current bottom trawling practice and certain other fishing techniques can have a harmful impact on sediments. The committee wants to outline the following measures that could help to reduce those impacts:

- Changes to rules and regulations to promote a gradual transition to fishing gear types and fishing methods with a lower impact on sediments.
- Improvements to existing fishing technologies and techniques in order to reduce the impact on the seabed.

Action 2: Report observations made by the fishing fleet in a format that allows further analysis

Both the new Norwegian bottom trawling regulations and a NEAFC rule state that in the event of hitting corals or sponges, fishing vessels should stop fishing, move two nautical miles away from the area and report the type and quantity of coral/sponge. The committee believes that the reports of the fishing fleet on benthic organisms in their catches will be an important source of data to help with managing seabed habitats. Moreover, it is important for this data to be available in a format that allows further analysis.

The committee believes that these reports should be included in the electronic reporting system, which requires resources to set up, and that the data should be presented in a way that allows further analysis (cf. letter from the Ministry of Fisheries and Coastal Affairs of 26 March 2012, and the response from the Directorate of Fisheries/IMR of 11 June 2012; see annexes 2 and 3).

Action 3: Produce a handbook for classifying sponges and corals

A handbook (with illustrations/photos) of relevant benthic fauna/groups of benthic fauna should be produced, to help the fishing fleet classify these creatures in its electronic reporting. The Institute of Marine Research has started work on producing identification guides (code lists and species identification sheets) for sponges and corals. This work is being done in collaboration with the Directorate of Fisheries, and the final product is intended for use on fishing vessels over 15 m (12 m in Skagerrak). This measure will help to improve the quality of future reporting by the fishing fleet. The level of taxonomic identification required for reporting must be realistic. The identification guides will be made available through the catch log on the Directorate of Fisheries' website.

Action 4: Mapping coral communities

In the management plans for the Barents Sea and Norwegian Sea, mapping coral communities is listed as a very important priority. Moreover, the Marine Resource Act of 2009 forbids trawling on known coral communities. Meanwhile, our knowledge about the distribution of corals and other habitats in Norwegian waters is growing. The Institute of Marine Research has worked with the Directorate of Fisheries to get quality-controlled data on coral communities included on sea charts. The current status of this project is that a list of coral reefs to be included on sea charts has been sent to the Norwegian Hydrographic Service, with the Ministry of Fisheries and Coastal Affairs being in charge of what happens next. The committee recommends that the completion of this project be prioritised.

Action 5: Activities to reduce the impact of aquaculture on corals and other seabed habitats

There is a need to develop a standard for monitoring of important habitats in areas close to fish farms. In the past, there have been no strict rules on mapping the existing types of habitats in an area before establishing a new fish farm.

The committee proposes that such mapping should be a prerequisite for approval to establish a new location or expand an existing one. It also believes that methods for the mapping process should be developed. Here it will be possible to draw on experiences from MAREANO and the project to map Norwegian marine habitats.

Action 6: Improve the "Fisheries table"

As part of the implementation of the Marine Resource Act, the "Fisheries table" was introduced as a tool to help with prioritisation, and to provide a summary of the impacts of the various fishing gears on ecosystems. This is a very useful starting point for assessing how to monitor and prioritise measures as part of a practical approach to ecosystem-based management. The Directorate of Fisheries and The Institute of Marine Research should also consider whether the table can be improved and be made more useful.

The committee proposes the following measures as possible improvements:

- Including information such as the fishing time/affected area, extent and catch/bycatch.
- Include confidences (e.g. with categories such as "no underlying data", "anecdotal information", "scientific experiment")
- Add relevant variables (columns) to the table
- Establish a weighting system for the relative importance of the variables, so that a reasonable balance can be achieved between various factors
- Formalise the process for updating the fisheries table, for instance by introducing an annual review by representatives of the industry, scientific community and management authorities

Action 7: Assess reference areas to help study of fishing impacts

The committee believes that reference areas are an important tool for mapping fishing impacts on sediments and seabed habitats. The committee suggests that the following actions be considered:

- Protect some untouched habitats (where there has been little or no bottom trawling to date)
- Compare areas where bottom trawling does and doesn't take place (with the same sediment types)
- Study the effect of stopping bottom trawling in areas with intensive trawling activity
- Study the effect of increasing trawling activity in areas with little or no activity
- Introduce protected areas (MPAs, trawl-free zones or other forms of protection) in order to protect particularly vulnerable areas

Action 8: Awareness about newly ice-free areas in the Arctic that may become exposed to fishing activity

The new areas that become available for fisheries in the Arctic as the ice retreats are in principle untouched by fisheries. The committee believes that it will be useful to initiate research in these areas, in order to provide advice on the use of fishing gears and impose any local restrictions.

Action 9: Establish a multi-disciplinary group

The committee proposes setting up a group with multi-disciplinary expertise, which can help to monitor the current situation and advise on the introduction of new measures. The committee believes that the following areas of expertise should be represented: seabed habitats, fisheries research and fishing gear technology.

This group should study reports sent by fishing vessels when they hit vulnerable habitats, as well as data from research vessels, hired fishing vessels, MAREANO and the reference fleet. Based on its assessments, the group should advise on new measures to reduce the negative impacts of fishing on benthic organisms.

9 Knowledge requirements

Within the field that deals with monitoring and new measures to prevent damage to seabed habitats caused by fisheries and aquaculture, there is a need for greater knowledge within a number of areas. For example, the committee would like to highlight the fact that the Ministry of Fisheries and Coastal Affairs wants a distinction to be made between significant negative impacts and impacts defined as insignificant in relation to the continuation of fishing (letter from the ministry of 26 March 2012, see annex 2).

With our current levels of knowledge, it is hard to define "*significant negative impact*". Consequently, it is also hard to define impacts that are "*insignificant in relation to the continuation of fishing*".

In order to comply with the Ministry of Fisheries and Coastal Affairs' wishes, knowledge is needed in the following areas:

- the degree of direct harm caused by the fishery
- the ability of the affected species to recover, and how quickly they can do so
- how rare/unique the affected species are
- the importance of affected species in terms of maintaining a sustainable ecosystem
- the long-term impacts of the fishery on marine ecosystems

Reef-building stony corals take a long time to recover (centuries), and they are highly vulnerable to bottom trawling. Leather corals, sea pens and sponges have so far not received as much attention as coral reefs, and we know less about their vulnerability, both in terms of their ability to regenerate and how rare they are.

Some of these species probably take a long time to recover, and new data (MAREANO, etc.) will eventually allow us to determine how rare/unique many of these species actually are. We can get a better idea of the species' recovery times through long-term monitoring of suitable reference areas. It may also be possible to carry out aquarium-based experiments for some species.

We currently know little about the sensitivities and tolerance levels of valuable habitats such as corals and sponges in relation to emissions from fish farms. Based on past experience of impacts on soft and hard bottoms, we know that emissions can have a fatal impact on the immediate vicinity of the farm. We lack knowledge in the following fields:

- the size of the required buffer zone around the farm in order to prevent permanent damage to particularly important habitats.
- how medications and other foreign bodies can enter food chains and affect species at an individual or population level.

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11 Annexes

Annex 1. Background to the report.

Annex 2. Letter from the Ministry of Fisheries and Coastal Affairs to the Directorate of Fisheries and The Institute of Marine Research regarding regulating the use of fishing gear that contacts the seabed in the Norwegian Exclusive Economic Zone.

Annex 3. Reply from the Directorate of Fisheries to the letter in Annex 2.

Annex 4. Fisheries table for ecosystem-based management developed by the Directorate of Fisheries.

Annex 1

Background

The Ministry of Fisheries and Coastal Affairs' letter of allocation to The Institute of Marine Research states as follows:

4.1 Advice on resource management, page 7: *The Institute shall investigate the impacts of fisheries and aquaculture on coral reefs and other seabed habitats, and help to assess what additional monitoring and action is required in light of its findings*

4.1.3 Tasks related to advice on resource management in 2012, page 9: *"In 2012, The Institute of Marine Research shall present an assessment of the effects and impacts of bottom trawls and other fishing gears that contact the seabed on various substrates and seabed habitats"*

In 61/2012, the management group made the following resolution: "In 2012, IMR shall present an assessment of the effects and impacts of bottom trawls and other fishing gears that contact the seabed on various substrates and seabed habitats." Our expertise is spread across a number of programmes and research groups, and they can bring different approaches/points of view to bear on this new type of advice.

On 13 April 2012, Director of Research Harald Loeng established a group to write a report to the Ministry of Fisheries and Coastal Affairs in response to the letter of allocation.

Mandate

The group shall prepare a report for the Ministry of Fisheries and Coastal Affairs, presenting the effects and impacts of bottom trawls and other fishing gears that contact the seabed on different substrates and on coral reefs and other seabed habitats.

The group shall assess how information from MAREANO and any other relevant programmes can be used for this purpose in the future.

The group shall look at the effects of aquaculture on seabed habitats and fisheries.
The group shall propose measures to prevent harm to vulnerable and valuable seabed habitats

The group shall base its report on existing knowledge, and no new research shall be done. If the group discovers gaps in our knowledge and proposes mitigating measures, cost estimates shall be obtained.

Members of the group:

A. Aglen
M. Breen
L. Buhl-Mortensen (leader)
P. Buhl-Mortensen
A. Ervik
V. Husa
S. Løkkeborg
I. Røttingen
H. Stockhausen

Apart from the group's members, the following people have also contributed to the report:
B.E. Axelsen, K. Skaar, J.W. Valdemarsen and Genoveva Gonzalez-Mirelis

Annex 2

DET KONGELIGE
FISKERI- OG KYSTDEPARTEMENT

HAVFORSKNINGSINSTITUTTET
DATO: 27.03.12
SAKSNR. 09/910
J.NR.
ARKIVNR.: 008
SAKSBEH.:

Fiskeridirektoratet
Havforskningsinstituttet

Deres ref	Vår ref	Dato
	201100622- /ENG	26 MARS 2012

Oppfølging av regulering av fiske med bunnredskap i NØS, fiskerisonen ved Jan Mayen og fiskevernsonen ved Svalbard

Fiskeri- og kystdepartementet viser til forskrift 1. juli 2011 om regulering av fiske med bunnredskap i Norges økonomiske sone, fiskerisonen rundt Jan Mayen og i fiskevernsonen ved Svalbard, som trådte i kraft 1. september 2011. Forskriften svarer blant annet på oppfordringen i FNs fiskeriresolusjon fra 2006 (UNGA 61/105) om å beskytte sårbare marine økosystemer mot ødeleggende fiskemetoder, herunder skadelig bunnfiske i nasjonale farvann.

Departementet viser videre til tildelingsbrevene for 2012, hvor det fremgår at Fiskeridirektoratet og Havforskningsinstituttet skal utvikle og implementere et system for oppfølging og vurdering av sårbare bunnhabitater.

Det nye regelverket innebærer blant annet at fiskefartøy skal rapportere treff av koraller og svamp, og gjennom denne rapporteringen kan det fremkomme ny kunnskap om forekomster. Innrapporterte sammenstøt må imidlertid følges opp, både ved at informasjonen registreres og systematiseres, samt ved en faglig vurdering av om ny kunnskap fordrer iverksettelse av eventuelt nye tiltak. Det vil i denne sammenheng være flere kilder til informasjon enn det som rapporteres fra fiskefartøy, blant annet data fra MAREANO og andre forskningsresultater. Det er viktig at denne informasjonen underlegges en enhetlig vurdering med tanke på eventuell reguleringsmessig oppfølging.

Når det gjelder påvirkning fra fiskeri må det skilles mellom signifikant ugunstig påvirkning og påvirkning som defineres som ubetydelig i tilfelle fortsatt fiske.

Postadresse	Kontoradresse	Telefon *	Telefaks	Saksbehandler
Postboks 8118 Dep	Grubbegata 1	22 24 90 90	22 24 95 85	Elisabeth N. Gabrielsen, 22 24 64 74
0032 Oslo	Org. nr.: 972 417 815	Nett: fkd.dep.no		postmottak@fkd.dep.no

FKD vil med dette be Fiskeridirektoratet, i samarbeid med HI, om å utvikle og implementere et system for vurdering og oppfølging av tilgjengelig informasjon om sårbare bunnhabitater. Eventuelle forslag til nye reguleringer skal utarbeides av Fiskeridirektoratet. Direktoratet bes også om å kartlegge informasjonsbehovet for at fiskerne skal kunne etterleve det nye regelverket korrekt.

Departementet ber om at et forslag til organisering i tråd med denne bestillingen oversendes FKD innen 15. juni 2012.

Med hilsen

Vidar Landmark
ekspedisjonssjef

Sverre Johansen
avdelingsdirektør

FISKERIDIREKTORATET
Ressursavdelingen

Fiskeri- og kystdepartementet
Boks 8118 Dep

0032 OSLO

Saksbehandler: Gunnstein Bakke
Telefon: 99105452
Seksjon: Utviklingsseksjonen
Vår referanse: 09/2629
Deres referanse:
Vår dato: 11.06.2012
Deres dato:

Att:

OPPFØLGING AV REGULERING AV FISKE MED BUNNREDSKAP I NØS, FISKERISONEN VED JAN MAYEN OG FISKEVERNSONEN VED SVALBARD

Innledning
I likelydene brev av 26. mars 2012 til Havforskningsinstituttet og Fiskeridirektoratet ba Fiskeri- og kystdepartementet om at det ble utviklet og implementert et system for vurdering og oppfølgning av tilgjengelig informasjon om sårbare bunnhabitater. Svaret er utformet i samarbeid med Havforskningsinstituttet som dermed ikke sender eget svar.

Systemet må bygge på de vanlige prinsippene som benyttes i fiskeriforvaltningen. Det vil i denne sammenhengen innebære at oppgaveløsningen deles i tre faser. Den første fasen er datainnsamling. Andre fase er vurdering av innsamlede data og identifikasjon av mulige risikofaktorer og konsekvenser. Tredje fase er håndtering av identifisert risiko.

Første fase, datainnsamling
I første fase har både Havforskningsinstituttet og Fiskeridirektoratet roller.

For Fiskeridirektoratets del vil arbeidet i første fase bestå i å samle inn de rapportene som skal sendes fra fiskefartøy ved sammenstøt med sårbare habitater, jf. forskrift om regulering av fiske med bunnredskap. I tillegg skal opplysninger om sårbare habitater som måtte komme fra andre kilder tas vare på. Alle opplysningene skal formidles til Havforskningsinstituttet.

Rapporter fra fiskefartøy må kunne opprettes og sendes på samme måte som andre pliktige rapporter fra fartøyene. Det nye systemet for elektronisk rapportering kan med en viss arbeidsinnsats i direktoratet tilpasses. Tilpasningen og selve rapporteringen vil trolig kunne skje uten ekstra kostnader for flåten. Dette kan oppnås ved å integrere rapportene i de som allerede sendes om hvert enkelt hal som er utført i løpet av døgnet. Fiskeridirektoratet vil iverksette nødvendige tiltak for å få dette gjennomført.

Det er behov for å formidle betydelig mer informasjon til flåten om bunnfiskeforskriften og pliktene ved sammenstøt ved sårbare habitater. Arbeidet med å gjennomføre de nødvendige endringene i systemet for elektronisk rapportering vil gi en svært god anledning til å formidle nødvendig informasjon gjennom direkte kommunikasjon til næringsorganisasjonene og på våre nettsider. Havforskningsinstituttet har kunnskap om både korall- og svampartene og vil kunne formidle denne dersom det skulle vise seg å bli nødvendig.

Postadresse: Postboks 185 - Sentrum 5804 BERGEN
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Internett: www.fiskeridir.no

Havforskningsinstituttet sin rolle i første fase handler også om datainnsamling og er av praktiske årsaker beskrevet i teksten nedenfor der andre fase behandles.

Andre fase, vurdering av data og identifikasjon av risikofaktorer og konsekvenser
Havforskningsinstituttet vil være alene om å utføre oppgavene med å vurdere de innsamlede data og identifisere mulige risikofaktorer og konsekvenser, det vil si oppgavene i andre fase.

I tildelingsbrevet til Havforskningsinstituttet framgår det i pkt 4.1 at instituttet skal utvikle kunnskap om påvirkning på korallrev og andre bunnhabitater som følge av fiskeri og havbruk, og delta i arbeidet med å vurdere oppfølging og nye tiltak som følge av ny kunnskap om forekomster. I tillegg vises det til pkt 4.1.1 hvor det står at instituttet skal levere en vurdering i 2012 av hvilken effekt og påvirkning bunntrål og andre redskaper som berører bunnen har på ulike substrater og bunnhabitater.

For å følge opp tildelingsbrevet sine intensjoner er det nedsatt et internt utvalg ved Havforskningsinstituttet som skal levere en rapport innen 15. oktober 2012. Rapporten skal inneholde forslag til innsamling av relevante data og behandlingen av dem. Grunnlagsdata for å vurdere effekt og påvirkning redskaper har på ulike substrater og bunnhabitater vil hentes fra:

1. Forskningsfartøytokt
2. MARENO
3. Referanseflåten
4. Rapporter fra fiskefartøy

Havforskningsinstituttet mener at det er viktig at data og opplysninger fra fiskeflåten skal foreligge på et format som muliggjør viderebehandling. Fiskeridirektoratets forslag til innsamling og formidling av data gjennom det nye systemet for elektronisk rapportering vil gjøre viderebehandling mulig på en mest mulig effektiv måte. Instituttet støtter derfor dette arbeidet.

Tredje fase, håndtering av identifisert risiko
Fiskeridirektoratet vil i systemet ha hovedansvaret for den tredje fase.

Bestands- og fiskeritabellene er utviklet for å få en oversikt over problemstillinger knyttet til alle bestander og fiskerier som er aktuelle for norsk forvaltning. I fiskeritabellen er bunnpåvirkninger tatt inn og Fiskeridirektoratet har foreslått for Reguleringsmøtet at vurderinger av tiltak for å redusere belastninger på bunnhabitat blir videreført som en av de prioriterte oppgavene i 2013.

De vurderingene og tilrådninger som Havforskningsinstituttet kommer med etter sitt arbeid i andre fase vil være retningsgivende i tabellarbeidet hvert år. Det må arbeides for at instituttets leveranser er tilpasset tidsmessig til arbeidet med tabellene.

Oppsummering
Dette systemet vil integrere alt arbeid knyttet til sårbare habitater i de ordinære arbeidsprosessene. Dette gir en god integrering av dette arbeidet med de eksisterende oppgavene. Det synliggjør også at dette arbeidet er en sentral del av fiskeriforvaltningen.

Som nevnt ovenfor skal det utføres videre arbeid både ved Havforskningsinstituttet som skal være ferdig innen utgangen av november og i Fiskeridirektoratet før systemet kan beskrives i detalj og implementeres fullt ut.

Med hilsen

Anne Kjos Veim
seksjonssjef

Gunnstein Bakke
seniorrådgiver

FISKERI					ARTSSELEKTIVITET								
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Redskap	Målart(er)	Fangstområde	Nasjonalitet	Redskaps spesifiskasjoner	Truede fisk og skalldyr	Ikke truede fisk og skalldyr	Sjø-patte dyr	Sjøfugl	Størrelses selektivitet	Utkast-problem	Bi-dødelighet	Bunn-påvirkning	Merknader/ Utfordringer
Bunntrål	Torsk, sei, hyse etc.	I og II	B	130 mm nord 64°N, 120 mm sør 64°N. Spilavst. 50/55 mm.	2	1	1	1	2	3	2	4	
Bunntrål	Sei	IIIa og IV	N	120 mm	2	2	1	1	2	2	2	3	
Bunntrål	Blandingsfiske	IIIa og IV	N	120 mm. Tillatt med 70 mm i IIIa dersom kvadratmaske.	4	3	1	1	4	3	2	3	
Bunntrål	Blandingsfiske	IIIa og IV	U	120 mm	4	5	1	1	4	5	2	3	
Bunntrål	Øyepål	IIa, IV	B	16 mm Spilavst. 40 mm	2	3	1	1	4	1	2	3	
Bunntrål	Kolmule	IIa, IV	B	16 mm Spilavst. 40 mm	2	2	1	1	2	1	2	3	Sorteringsrist.
Bunntrål	Tobis	IVa,b	B	<16 mm	2	2	1	1	3	1	2	2	
Bunntrål	Flatfisk	IIIa og IV	U	120 mm	0	0	1	1	0	5	2	3	
Bunntrål	Vassild	IIa	N	16 mm	1	0	1	1	0	0	2	4	
Bunntrål	Reke	I og II	B	35 mm Spilavst. 19mm	3	3	1	1	3	3	2	4	
Bunntrål	Reke	IIIa og IV	B	35 mm Ikke rist	3	5	1	1	5	4	2	4	
Bunntrål	Reke	NAFO og Grønland		35 mm. Spilavst. 22 mm	3	3	1	1	3	3	2	4	
Flytetrål	Makrell	IIa og IVa,b, VIa og IIIa	B	16 mm	1	3	1	1	2	1	2	1	
Flytetrål	Hestmakrell	II a, IVa og VIa	B	16 mm	1	3	1	1	2	1	2	1	
Flytetrål	Nvg-sild	I, IIa, IVa	B	16 mm	2	3	1	1	2	2	2	1	
Flytetrål	Nordsjøsild	IVa og IVb	B	16 mm	1	3	1	1	2	1	2	1	
Flytetrål	Lodde Barentshavet	I og II	B	16 mm	2	3	1	1	2	1	2	1	
Flytetrål	Uer												
Flytetrål	Kolmule	IIa, IVa, Vb, VI, VIIb,c	B	35 mm	2	2	1	1	2	1	2	1	
Flytetrål	Vassild	IIa	N	16 mm	0	0	1	1	0	1	2	1	
Flytetrål	Krill	CCMLAR	N		1	1	1	1	1	1	2	1	
Taretrål	Stortare	IIa, IV	N		1	2	1	1	1	1	1	3	
Not	Makrell	IIa og IVa,b, VIa og IIIa	B		1	2	1	1	2	1	3	1	
Not	Hestmakrell	IIa, IVa	B		1	3	1	1	2	1	3	1	
Not	Nvg-sild	I, IIa, IVa	B		2	2	1	1	2	1	3	1	
Not	Nordsjøsild	IVa og IVb	B		1	2	1	1	2	1	3	1	
Not	Lodde Barentshavet	I og II	B		2	2	1	1	2	1	3	1	
Not	Lodde IM, IØS, GRL	IIa, Va, XIV	B		1	1	1	1	2	1	2	1	
Not	Havbrisling	IVb	B		1	2	1	1	2	1	2	1	
Not	Kystbrisling	IIa, IIIa, IV	N		2	2	1	1	2	1	2	1	
Not	Sei	I og IIa	N		3	3	1	1	3	2	1	1	

FISKERI					ARTSSELEKTIVITET								
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Redskap	Målart(er)	Fangstområde	Nasjonalitet	Redskaps spesifiskasjoner	Truede fisk og skalldyr	Ikke truede fisk og skalldyr	Sjø-patte dyr	Sjøfugl	Størrelses selektivitet	Utkast-problem	Bi-dødelighet	Bunn-påvirkning	Merknader/ Utfordringer
Not	Sei	IIIa og IV	N		3	2	1	1	3	1	1	1	
Notfiske med lys	Makrell, brisling, sild	Innenfor grunnlinjen	N		0	0	1	1	0	0	0	1	
Snurrevad	Torsk, sei, hyse	I og IIa	N	120 mm 62°-64°N, 135 mm nord for 64°N, 125 mm kvadrat hele området nord 62°N	3	1	1	1	3	2	2	3	
Snurrevad	Blandingsfiske	IVa og IIIa	N	120 mm sør for 62°N	4	1	1	1	3	2	2	3	
Snurrevad	Blandingsfiske	IVa og IIIa	U	120 mm sør for 62°N	4	3	1	1	3	5	2	3	
Garn	Torsk, sei, hyse	I og IIa	N	156 mm (torsk)	3	1	2	2	2	2	2	2	
Garn	Blåkveite	I og IIa	N		1	1	2	1	1	2	4	2	
Garn	Uer	I og IIa	N	120 mm	1	1	2	1	2	2	3	2	
Garn	Breiflabb	Alle	N	360 mm	3	1	2	1	2	2	2	2	
Garn	Kveite	Alle	N	470 mm	1	1	2	1	1	2	2	2	
Garn	Rognkjeks		N	267 mm	1	3	2	3	1	1	2	2	
Garn	Blandingsfiske	IVa, IIIa	N	148 mm utvalgte arter (torsk, hyse, sei, rødspette, lange, lyr, lysing) utenfor 4 nm	3	1	2	2	2	2	2	2	Minste maskestørrelse 126 mm i bunngarn fra 1.1.2012
Garn	Blandingsfiske	IVa, IIIa	U		3	3	2	2	2	5	2	2	Minste maskestørrelse 126 mm i bunngarn fra 1.1.2012
Fløytline	Hyse	I og IIa	N		2	1	1	4	4	4	2	2	
Line	Torsk, hyse	Nord 62°N utenfor 12 mil	B		3	1	1	3	3	2	2	2	
Line	Torsk, hyse	Nord 62°N innenfor 12 mil	N		3	1	1	3	3	3	2	2	
Line	Lange, brosme	IIa, IV, V, VI, VII	N		3	1	1	3	2	2	2	2	
Line	Blåkveite	II	N		2	1	1	3	2	2	2	2	
Line	Kveite	IIa	N		1	1	1	1	0	2	2	2	
Annen krok-redskap	Torsk, hyse m.m.	I, IIa	N		3	1	1	1	2	2	1	1	
Annen krok-redskap	Makrell	IIa, IIIa, IVa	N		1	1	1	1	2	1	1	1	
Ruser	Torsk	IIa, IIIa, IVa	N		1	1	1	1	2	1	1	2	
Ruser	Leppefisker	IIa, IIIa, IVa	N		1	1	1	1	2	1	1	2	Forbud mot å fange ål
Teiner	Hummer		N	Fluktåpning 60 mm	1	1	1	1	2	1	1	2	
Teiner	Taskekrabbe		N	Fluktåpning 80 mm	1	1	1	1	2	1	1	2	
Teiner	Kongekrabbe		N		1	1	1	1	2	1	1	2	
Teiner	Leppefisker	IIa, IIIa, IVa	N		1	1	1	1	2	1	1	2	

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