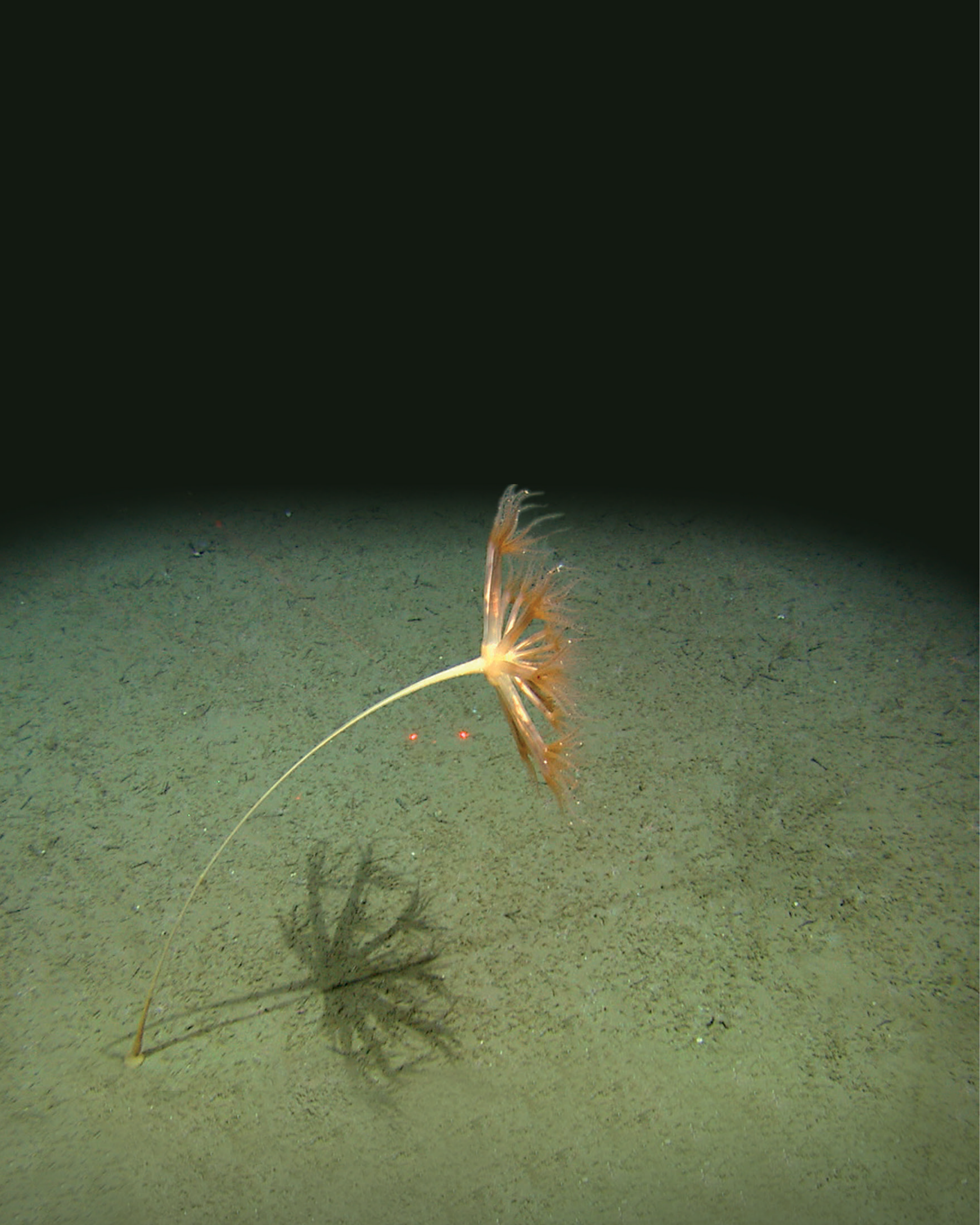

ENVIRONMENTAL THREATS – POLLUTION AND PHYSICAL IMPACT

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10.1 POLLUTION

The sea off Lofoten, the southern Barents Sea and the Norwegian Sea off Central Norway are rich in marine resources and, in the latter years, these areas have received renewed attention as potential oil and gas provinces. Documentation and monitoring of the environmental status in these areas is important and is carried out through a range of programmes that in total cover all aspects, from seabed to air masses. The MAREANO programme has focused on the environmental condition of the seabed and has mapped the occurrence of environmental contaminants in the sediments.

We have studied surface and core samples from Finnmark, Tromsøflaket, the continental shelf off Troms and the shelf and shelf slope down to 2700m depth off Lofoten and Vesterålen, Røstbanken and Mørebankene. In total, 113 sediment core samples have been taken in these areas (Figure 1). Previously, surface samples have been taken from large areas of the Barents Sea. Most of the surface samples and all of the core samples have been collected in marine valleys and depressions such as Ingøydjupet off Tromsøflaket and Malangsdjupet off Troms as well as from marine trenches on the continental slope off Lofoten. These depressions act as traps for fine-grained sediments, as layer upon layer sink to the bottom, and these sediments tend to accumulate contaminants. Based upon experience, such areas are good for mapping contaminants, as the sediments act as an environmental archive showing how contaminants have accumulated over decades, centuries and – in some cases – millennia. Environmental contaminants – both heavy metals and organic substances – generally bind to fine-grained sediments rich in organic carbon (such as organic remnants of algae and organic material from land) rather than coarser sediments. Hence, the sediments in the depressions will reveal whether contaminants are transported and deposited with the sediments, and places where this happens can be used for future environmental monitoring.

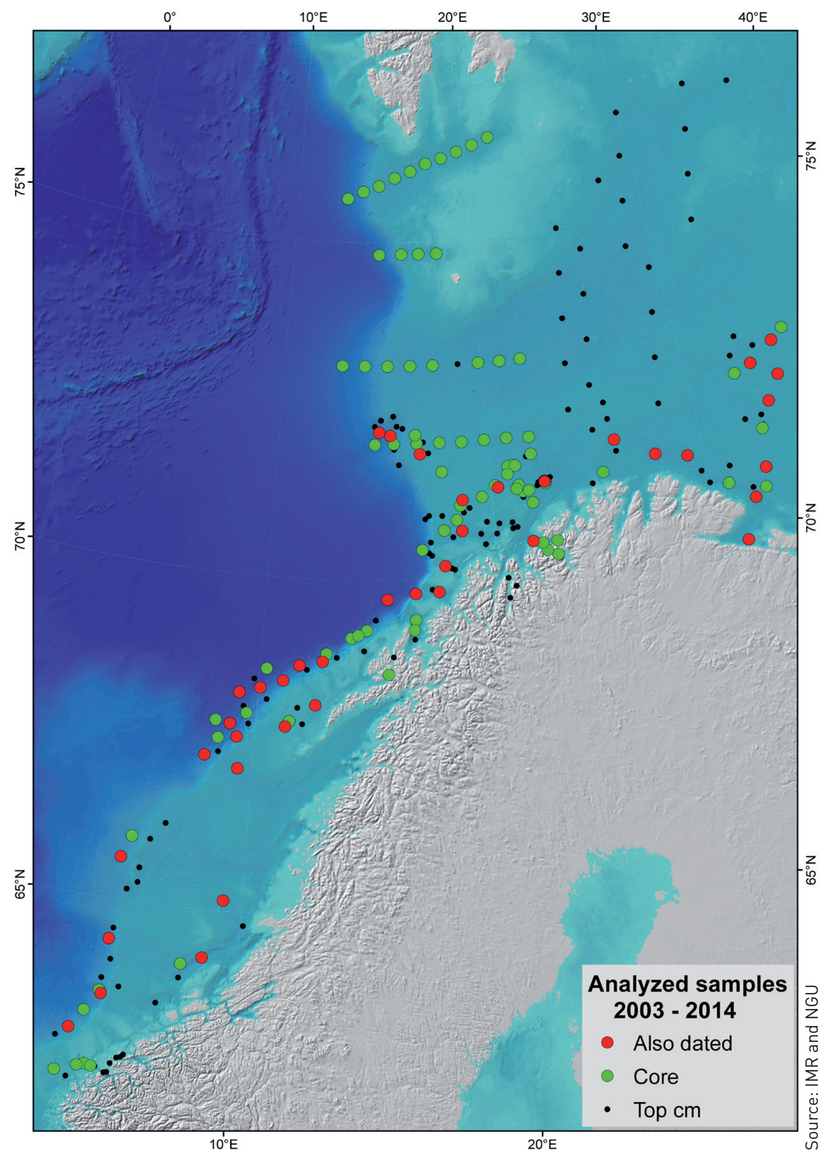


Figure 1. Environmental sampling in the Barents Sea and the Norwegian Sea

One overall objective for the Management Plan is that emissions and influx into the Barents Sea, the areas off Lofoten and the Norwegian Sea should not pose any threat to health or nature's ability to produce and regenerate. With this in mind, we have carried out analyses of a range of heavy metals such as lead, cadmium, copper, chromium, mercury, nickel and zinc, as well as the trace element arsenic, and of organic contaminants such as tributyltin (TBT), polycyclic aromatic hydrocarbons (PAH), total hydrocarbon content (THC) and brominated flame retardants (PBDE) in sediments. In addition, the content of barium is analysed and reported in order to have background levels in case of emissions of baryte ($BaSO_4$), which is used in the drilling mud when drilling exploration and production wells.

The objective with regards to Health and environmentally hazardous chemicals and radioactive substances is as follows:

The environmental concentrations of hazardous and radioactive substances should not exceed the background levels for naturally occurring substances and should be close to zero for man-made synthetic substances. Releases and inputs of hazardous or radioactive substances from activity in the area should not cause these levels to be exceeded.

We have been able to trace human impact and discover naturally high levels of both heavy metals and organic pollutants (THC, PAH) by analysis of contaminants both in surface and core sediments. Organic contaminants such as TBT and PBDE do not occur naturally but are solely man-made compounds.

10.1.1. Sources and Characteristics of Studied Environmental Pollutants

Environmental pollutants in sediments can come from natural (geological) sources and processes, or as a result of human activity. As far as metals are concerned, there is a range of well-known human sources. Lead is released into the atmosphere by the combustion of leaded petrol. This source has been reduced since leaded petrol was banned in most Western countries in the 1970'ies. Other sources include metal production, emissions from coal power plants and leaded paint, which has been banned for many decades. Mercury is primarily released into the atmosphere through coal combustion and to a lesser extent from metal production and waste combustion. Cadmium comes from waste incineration and metal production, as well as zinc ore and concrete production. Similarly to mercury, arsenic is released during coal combustion and metal production. Copper, nickel and zinc are released during the processing of metal-containing ore, such as the copper and nickel production in north-western Russia. Copper is used as a detergent for algal growth on fish farming facilities.

PAH (polycyclic aromatic hydrocarbons) may have varying chemical-physical properties depending on their structure (Figure 2). In the marine environment, PAH are generally absorbed by marine organisms or buried in fine-grained sediments. PAH remain in the sediments for long periods of time and we can study trends in influx of PAH by analysing deeper layers of the sediments. Many PAH compounds, such as benzo[a]pyrene, are toxic and carcinogenic to organisms.

PAH may come from various sources, both natural and anthropogenic. Crude oil and other fossil fuels contain PAH, mostly the lighter compounds such as naphtalene, phenanthrene, dibenzothiophene, generally with hydrocarbon side chains. Total levels of these compounds, abbreviated NPD, are indicators for oil contamination/presence. In this case, we say that the PAH have a petrogenic origin. Another important source of PAH is various combustion processes, such as forest

Sediment sampling

Sediment core samples have been taken from 101 sampling stations with a multi or box corer, mainly from areas with fine-grained sediments consisting of silt and clay. Sediments with a high content of fine-grained material are shown in image A from the Campod photo rig used by MAREANO for documenting the seabed. The sampling gear ensures preservation of the sediment surface and core (B) as well as minimal disturbance of the sediments. Reliable results are important for the environmental analysis of heavy metals and organic compounds in the sediments. The surface sample (C) represents the current environmental status. The sediment cores vary between 20cm and 50cm in length and represent the past 100–200 years of sedimentation, depending on core length and sedimentation rate. 1cm samples are taken from the sediment cores (D) for chemical analyses for heavy metals, grain size, organic carbon, inorganic main and trace elements, as well as organic substances (TBT, THC, PAH and PBDE).

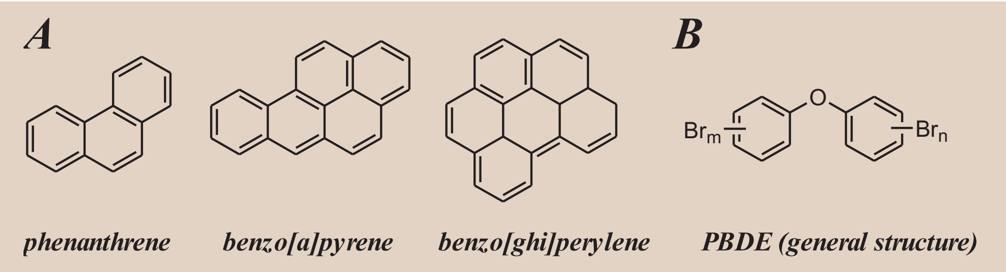


Figure 2. Examples of organic environmental pollutants discussed. A: polycyclic aromatic hydrocarbons (PAH). B: Polybrominated diphenyl ethers (PBDE), 0<m≤5, 0<n≤5.

fires, volcanoes, heating, exhaust from combustion engines and other traffic. These are sources of pyrogenic PAH. Among these, the largest and most thermostable PAH molecules dominate, such as benzo[a]pyrene. The most important of these are on the "PAH16 list" used by the authorities to estimate PAH contamination. The third large source is biomaterial (plants, fungi) for biogenic PAH. High levels of perylene indicate biomaterial as a source.

THC stands for Total Hydrocarbon Content. In sediments, it provides a general indication of hydrocarbon levels, including PAH, monoaromatic hydrocarbons, alkanes and cycloalkanes. Elevated THC levels in an area may indicate oil emissions.

Brominated flame retardants like PBDE (polybrominated diphenyl ethers) are persistent, bio-accumulative and potentially harmful mass-produced chemicals that do not exist naturally in the environment. Of the 209 theoretically possible variations of PBDE, 26 compounds are analysed by MAREANO in surface sediments.

10.1.2. Current Contamination Status

Concentrations of heavy metals and arsenic are generally low in the surface sediments of the studied areas and are thus not a threat to the marine ecosystem. At some sampling stations, the levels of lead and nickel are slightly higher than 30mg/kg (all concentrations in sediments are given based on dry weight sediment), which corresponds to the Norwegian Environment Agency's Class II (Good) for fjord and coastal sediments. An increase in lead levels in the sediments over the past decades is the reason why some sampling stations fall into the Environment Agency's Class II.

There are very low concentrations of hydrocarbons (both PAH and THC) in the studied areas. In the southwestern part of the Barents Sea, at Tromsøflaket, the concentrations are less than 250µg/kg for total levels of all studied PAH and less than 10mg/kg for THC. The Environment Agency has developed status classes for PAH16 in marine sediments to estimate contamination levels in fjords and coastal areas. If we adopt this classification for the open sea – not forgetting that levels in the open sea may be explained by the occurrence of natural sources – all samples from this area fall into the Environment Agency's Class I (Background), i.e. less than 300µg/kg.

The levels of hydrocarbons are also low in the Norwegian Sea off Lofoten and Vesterålen, although, on average, slightly higher than observed levels at Tromsøflaket. Further south in the Norwegian Sea, at Mørebankene, the hydrocarbon levels are low. Total PAH levels in the upper sediment layer are less than 500µg/kg on the shelf and up to 2500µg/kg on the slope down towards 2000m depth, while THC levels are less than 25mg/kg. According to the Environment Agency's classification for PAH16, the sediments are in Class I (Background) or Class II (Good, 300–2000µg/kg).

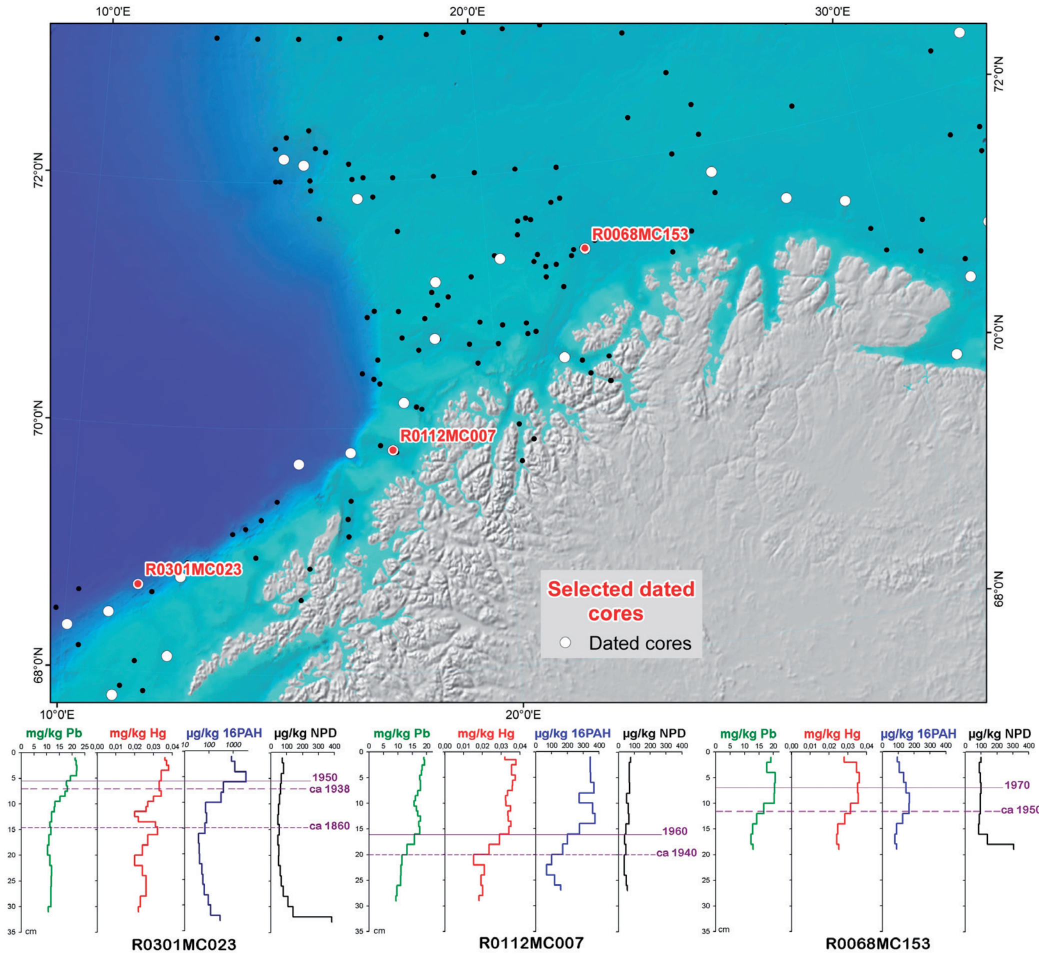


Figure 3. Lead, mercury, 16PAH and NPD concentrations from three sediment core samples in the MAREANO area. The years given for the three samples are based on lead-210 dating.

10.1.3. Contamination Development over the Past Centuries

Chromium, copper, nickel and zinc concentrations are generally low and vary little in the core samples. Low and constant concentrations indicate that these heavy metals are at a natural background level, including today in the surface sediments. Lead and mercury are the exceptions, as both these heavy metals increase from low background levels to higher levels in the upper part of most analysed sediment cores. But even though the increases of both lead and mercury levels are significant, they are still within the Environment Agency's Class I (Background) for fjord and coastal sediments. The historic development of lead, mercury, PAH16 and NPD is exemplified by sediment core samples from three different areas including 2 continental shelf locations at Ingøydjupet in the Barents Sea and Malangsdjupet and a location at the continental slope off Lofoten (Figure 3). The lower concentrations at the bottom of the core samples correspond to natural background levels for both heavy metals. Higher up in the cores, both lead and mercury levels increase. The procedure for dating cores is described in Basic Facts 2.

The results of lead-210 dating and cesium-137 analyses of two of the three dated cores, R112 and R068 (figure 3), show that levels of both mercury and lead have increased over the past 70–80 years, while the core from the continental slope, R301, shows an increase that started just after 1860. The background levels for mercury at the bottom of the three core samples are similar: about 0.02mg/kg, while the increased levels reach a maximum of 0.030–0.038mg/kg at the top of the sediment cores. The comparable changes in concentrations in the three sediment cores indicate changes that have a wide geographical distribution. Long distance transportation of both mercury and lead from industrial emissions is probably the reason why the content of individual pollutants has increased towards the current status.

The hydrocarbon levels are generally low, but in some places we have observed a clear increase in hydrocarbons of a certain kind, either petrogenic or pyrogenic. In sediment cores from Tromsøflaket, the increase is due to petrogenic PAH; for example, at station R68, which is close to the Goliat oil field. This is not clearly apparent in surface sediments where levels are low. However, in deeper sediments there is a clear trend of elevated NPD levels in a number of the analysed sediment cores (see figure 3, station R68). The trend is different for PAH16, which shows no increases in the deeper sediments. The increase of NPD occurs in sediments which date back to the 19^{th} century or earlier and indicates a natural petrogenic contribution to the PAH levels in these locations. Thus, in the area around station R68, particular features on the seafloor – so-called pockmarks – indicate that gas or fluids have seeped up to the surface. Hydrocarbon seeps from deeper geological formations may occur in these pockmarks.

Depth profiles of the NPD content in sediment cores from the Norwegian Sea off Lofoten and Vesterålen are generally different from those observed in samples from Tromsøflaket. NPD levels in this area are low throughout the cores and show no clear sign of increase in neither deeper nor upper layers (see Figure 3, stations R112 and R301). This indicates that there is no significant natural petrogenic contribution to the PAH composition.

We frequently observe an increase in PAH16 levels in the upper layers of the studied sediment cores. The PAH16 levels level out or start diminishing close to the surface. In the dated sediment cores (Figure 3), this increase peaks around the 1950'ies and levels out or starts diminishing after the 1960'ies. Even if this trend in some places is relatively weak after correcting for total deposition of organic carbon, it is a common trend many places in the world, including northern Norway, and can be explained by increased emissions of pyrogenic PAH into the environment from the increasing industrial activity since the mid-1800s. From the 1960'ies, the use of coal has diminished in Western Europe, which probably explains the levelling out of PAH in the top layers. These trends have been observed even in the open sea in remote Arctic regions, despite low total levels, and are due to long-distance transportation: PAH binds to organic particles and can be carried over long distances by both air and ocean currents and end up in sediments hundreds of kilometres from the source.

PAH16 levels are notably higher in the sediment cores from the Norwegian Sea off Lofoten and Vesterålen than at Tromsøflaket. Some places, the PAH16 levels increase quite rapidly in newer sediment layers before diminishing in the surface sediments. For instance, the levels in the sediment core from station R301 (Figure 3) are in the Environment Agency's Class III (Moderately polluted) at 4–5cm core depth (which, according to the core dating, corresponds to the 1960'ies). A possible explanation for this is that there is more long-distance deposition of pyrogenic PAH (i.e. combustion-related PAH) in this area, which is further south and closer to the coast than Tromsøflaket.

Very low concentrations of PBDE were found in surface sediments – less than 10µg/kg dry weight for the total of all 26 PBDEs. This indicates that no point source of PBDE emissions can be indentified in the area. The existing concentrations have probably been transported from distant sources.

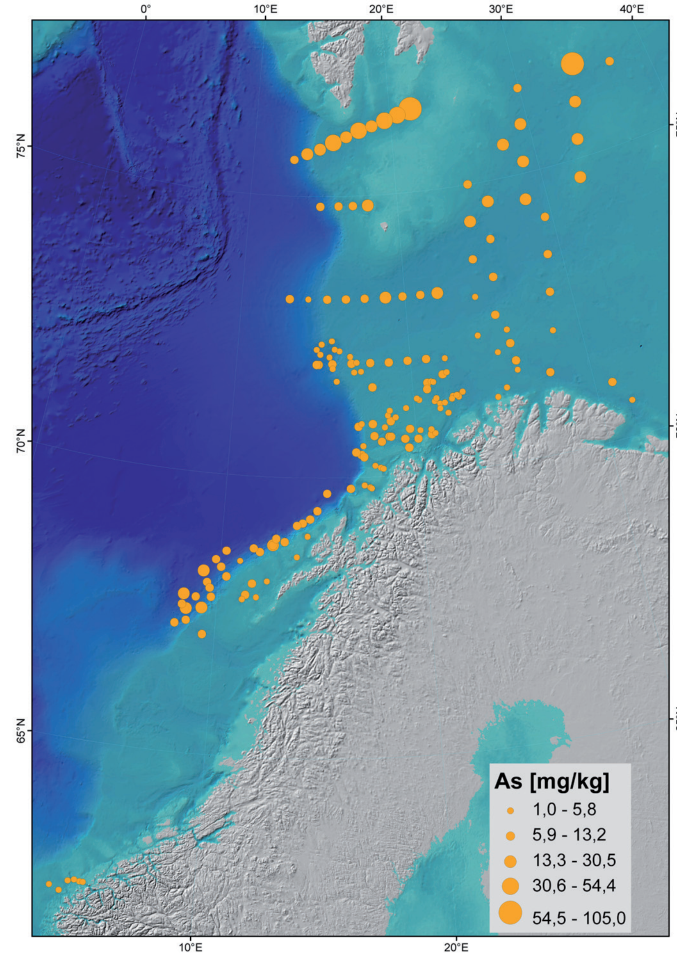
basic facts 2

Lead dating and cesium-137 analyses in sediment cores – an archive of sedimentation over the past 100–150 years

Lead-210 (^{210}Pb) and cesium-137 (^{137}Cs) are radioactive isotopes of the two elements lead (Pb) and cesium (Cs). Cesium-137 does not occur naturally. It originates from events such as the nuclear weapons tests in the 1950s and 1960s, the Chernobyl disaster in 1986 and recycling of spent nuclear fuel (such as from the Sellafield plant in the UK, which releases radioactive waste into the Irish Sea). Lead-210 is part of the natural radioactive uranium-radium series and is used for lead-210 dating.

Sediment cores serve as an archive for sediment deposits over a certain time period. The sediment cores sampled by MAREANO are cut into 1cm-thick samples. Measurements of lead-210 are used to determine the age of each sample from the surface and down the core. This method is appropriate for dating up to 150 years back in time, which is sufficient for documenting human effects from industrial activity. Lead-210 dating can suggest at what point anthropogenic concentrations of substances such as lead and mercury started elevating from natural background levels.

The levels of ^{137}Cs in the samples from a sediment core can peak at certain years or time periods. There are three kinds of events in particular that can cause ^{137}Cs peaks in sediment cores: The nuclear weapons testing in the 1950'ies and 1960'ies, the emissions from Sellafield in the 1970'ies and the Chernobyl disaster in 1986. These ^{137}Cs peaks can contribute to confirming/correcting the lead-210 dating.



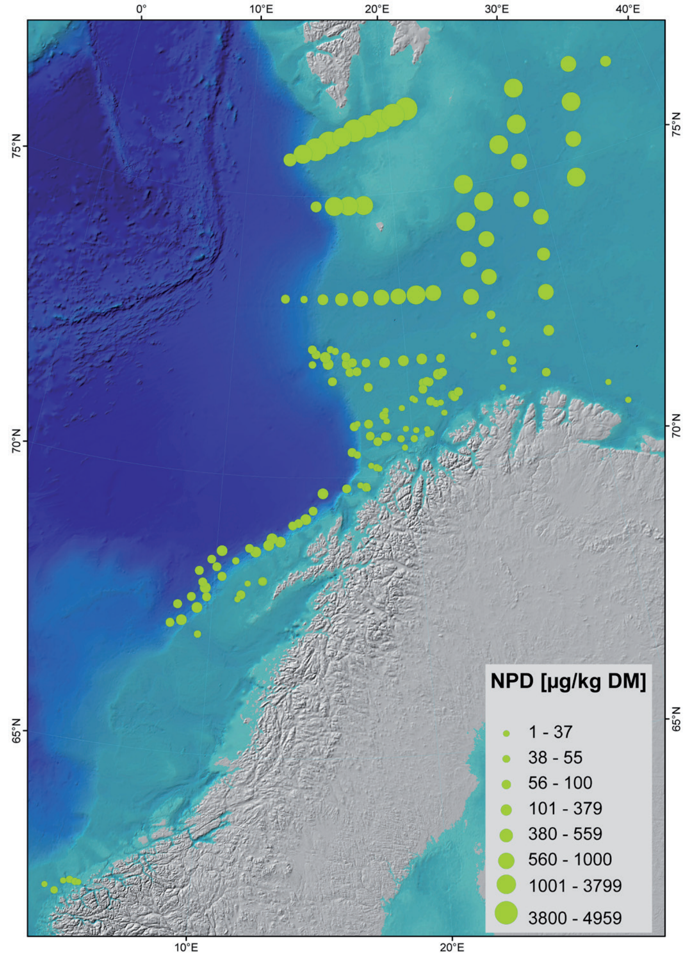


Figure 4.Arsenic concentrations in surface sediments in parts of the Norwegian Sea and the Barents Sea.

Figure 5. NPD concentrations in surface sediments in parts of the Norwegian Sea and the Barents Sea.

10.1.4. Biological Effects

No studies of heavy metal or organic contaminants in bottom fauna has been carried out in MAREANO. However, the generally low concentrations of the analysed substances in surface sediments suggest no biological effects on bottom fauna.

10.1.5. Environmental Status in the Barents Sea – Regional Variations

Heavy metal and arsenic concentrations are generally low in surface sediments and thus pose no obvious threat to the marine ecosystem. However, certain substances are an exception. A comparison between arsenic levels in the surface sediments in the Lofoten–Finnmark area and the central Barents Sea, show large geographical variations (Figure 4). In Storfjordrenna south of Svalbard and one station further northeast in the Barents Sea, the arsenic concentrations are far higher than further south, with concentrations up to 105mg arsenic/kg sediment. According to the Environment Agency's classification system for fjord and coastal sediments, the arsenic samples from Storfjordrenna are in Class II (Good)–Class III (Moderately polluted), while the levels in the Lofoten–Finnmark area are in Class I (Background). However, the arsenic levels in Storfjordrenna do not come from pollution, but from erosion of Svalbard sedimentary rocks containing naturally high concentrations of arsenic. Thus, arsenic shows how nature's own contribution can vary considerably within a large region such as the Barents Sea depending on the sources for the sediments.

There are large geographical variations in PAH composition and levels in the Barents Sea, and a notable difference between various areas. This has mostly natural causes, and no strong human influence can be demonstrated, neither for the whole of the Barents Sea nor at a regional scale. In the Barents Sea, total levels of PAH vary from under 50µg/kg up to more than 6000µg/kg, and levels of THC vary from 1mg/kg up to 70mg/kg. For certain PAH compounds, the spread in levels is even greater and stretches over 5 orders of magnitude.

While large areas of the Barents Sea show very low levels of PAH and THC, we have found notably higher levels in some places. The highest levels of both PAH and THC are found close to Svalbard. This is an area with large reserves of coal and other sedimentary rock units containing fossil hydrocarbons and thus petrogenic PAH and NPD. Previous studies have shown that the main source of PAH in marine sediments from this area is erosion of carbonaceous sedimentary rocks. Thus, the PAH compounds in the area are characteristically petrogenic, and NPD levels are high (Figure 5). PAH16 levels are also relatively high due to the total PAH concentration in the sediments. The Environment Agency's classification system is not applicable to this area, since the PAH levels have natural sources and are not caused by human activity. THC levels

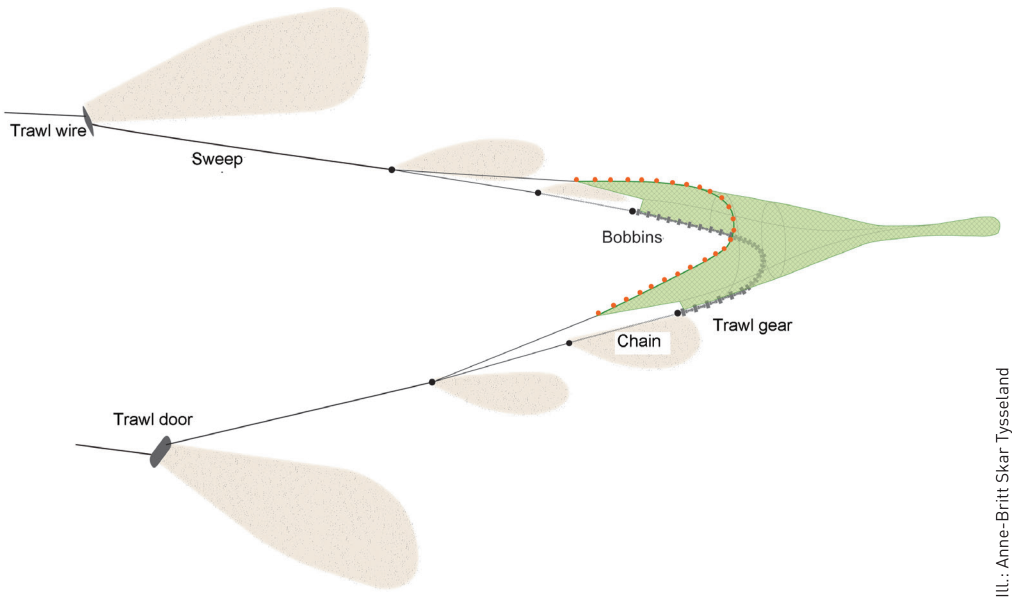


Figure 6. Otter trawl catches fish and shrimp on the seabed, just above the seabed, or several metres above. Trawl doors keep the trawl open and creates a "cloud" of sediment scaring fish and shrimps into the opening of the net. The bottom of the trawl can have heavy weights to keep it on the seabed, and a "rockhopper" gear of round rubber plates may prevent the trawl to get stuck in rock or coral. Furthermore, a chain in from of the ground gear can bring the fish and shrimp up from the seabed.

in sediments from various areas of the Barents Sea follow the same pattern as the PAH, with the highest levels around Svalbard. This is also due to erosion of carbonaceous sedimentary rock transported out to sea.

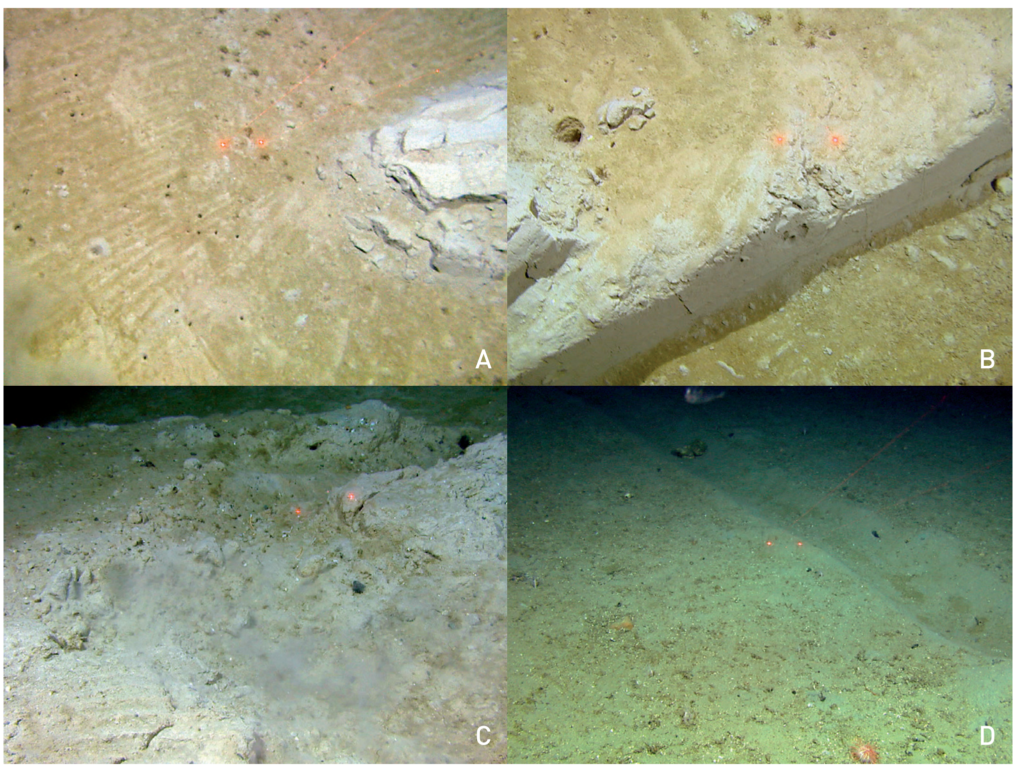


Figure 7. Examples of tracks after trawl on the seabed. A. Tracks after chains in front of the trawl. B. Cut or furrow after trawl door. C. Overturned sediments. D. Rounded track probably created by round "bobbin" ball on a trawl. Images A-C were taken at Tromsøflaket, 2006 while D was taken at MAREANO's spring cruise 2008.

10.2. EFFECTS OF FISHERIES

Every year an area equivalent to half of the world's continental shelves is trawled at depth shallower than 200 meters. The trawling activities are not evenly distributed because trawlers often pursue the same fishing localities years after years. In the North Sea where fishing intensity is high the seafloor is trawled more than 10 times per year.

The physical effect of fishing gears on the seafloor depends on the bottom type, gear weight, trawling speed, and gear design (figure 6 shows a common trawl with its different parts). Trawl doors can make 30-40 cm deep furrows depending on the weight of the doors (from 100 kg to several tonnes) and softness of the sediment. Trawl marks are deeper in mud than in sandy sediment and can last from months to years depending on type of bottom and strength of bottom currents. Thus there is not necessary a direct relation between observed marks from trawling and fishing intensity in an area.

Numerous studies of the effects of trawls and shell dredges on bottom communities have been undertaken. However, it has proven hard to quantify the impact of high levels of fishing pressure on marine ecosystems. Some general patterns have emerged. Frequent trawling of soft sediments will change the composition of bottom fauna from large and longer lived organisms to smaller and fast reproducing organisms. The most vulnerable organisms are those that reach up above the seafloor such as corals, sponges, and sea pens. With intensified trawling over large areas this type of bottom fauna will disappear. Due to their size and structure they are habitat providers for a wide range of other organisms and are thus the local foundation for high species richness that will disappear. Other organisms benefits from the turning over of sediments and crushing of organisms due to trawling. These are scavengers and opportunistic species that quickly can colonise an area and benefit from new resources available. The squat lobster (*Munida sarsi*) which is very common at "Tromsøflaket" (see chapter 4.2) is one of the scavengers that can benefit from frequent bottom trawling. This implies that seafloor that has for a long period in time has experienced trawling or turnover due to other gears is depowered with regards to a range of species and that biodiversity and productivity is likely to decrease. Nevertheless, the immediate response to trawling in a limited area can

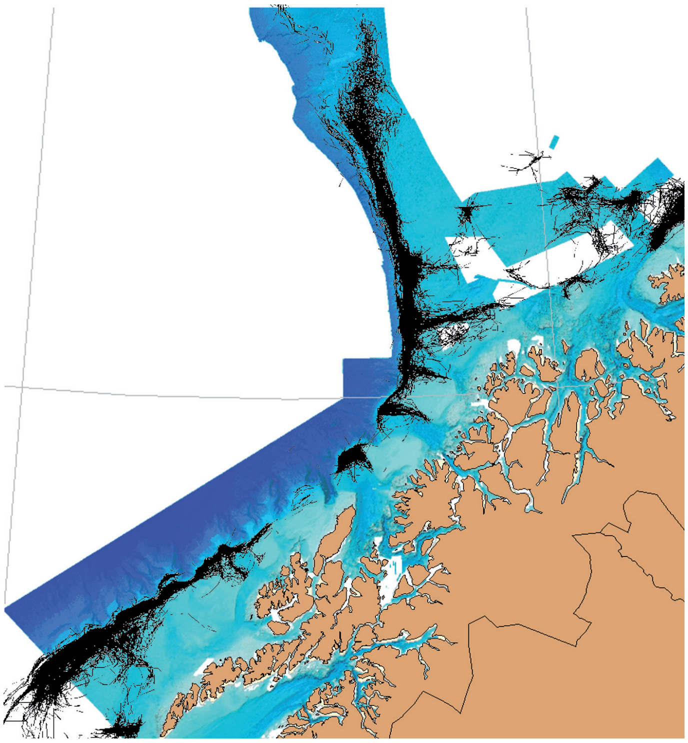


Figure 8. Satellite tracking data (VMS-data) give a good indication of the trawling intensity and where it takes place. This map is based on VMS data from 2005 and reflects very well the traditional trawling areas. Details may vary somewhat from year to year, and depending on bottom type and current patterns this activity leaves tracks that can be observed for several years after the trawling occurred.

be the introduction of species that benefits from the disturbance and a short time increase in species richness.

The seafloor mapping by video recording conducted by Institute of Marine Research as part of the MAREANO-programme is in addition to documenting bottom fauna communities and species richness also recording effects of fisheries. These are mainly: tracks or marks from fishing gears; bottom organisms that are dislocated, turned over or crushed; or lost gear. The video-records reveal marks from different parts of the trawl (figure 7). These are quantified in numbers per distance or area inspected.

Many places where MAREANO has mapped have high trawling intensities. This is indicated by satellite monitoring of vessel activities (VMS-data) that shows the activity of boats in different areas. Figure 8 shows the vessels that are engaged in trawling in 2005 in the areas Troms II and Nordland VII.

In what follows we will present selected results from the MAREANO mapping that is related to effects of fisheries.

10.2.1. Effects on the seafloor

In many of the mapped areas we find clear trawl marks. It is particular the trawl doors that make deep cuts and trenches in the sediment. The depth depends on bottom conditions, sediment types and near bottom currents. The trenches that have been observed varies in depth from a few centimetres to more than half a meter deep furrows (se figure 7 and 9).

The fishing intensity at Tromsøflaket can be characterised as high (figure 10) and damage to the habitat is documented to a reliatively large extent trough MAREANOs mapping. In many places the distance between furrows from trawl doors is short, and marks from trawling are observed at around 90% of the video records. On average 42 trawl tracks were observed every kilometer filmed seabed. This corresponds to one track per 25 m distance and in some places tracks were observed every ten meters.

At Eggakanten, SW off Bjørnøya, trawlmarks were observed at 51 of 75 investigated locations (figure 11). The highest density was 50 trawl marks along 700 meter recorded seabed. The distribution of trawlmarks at different depths indicate that they are caused by two different fisheries. A peak in trawl mark density at

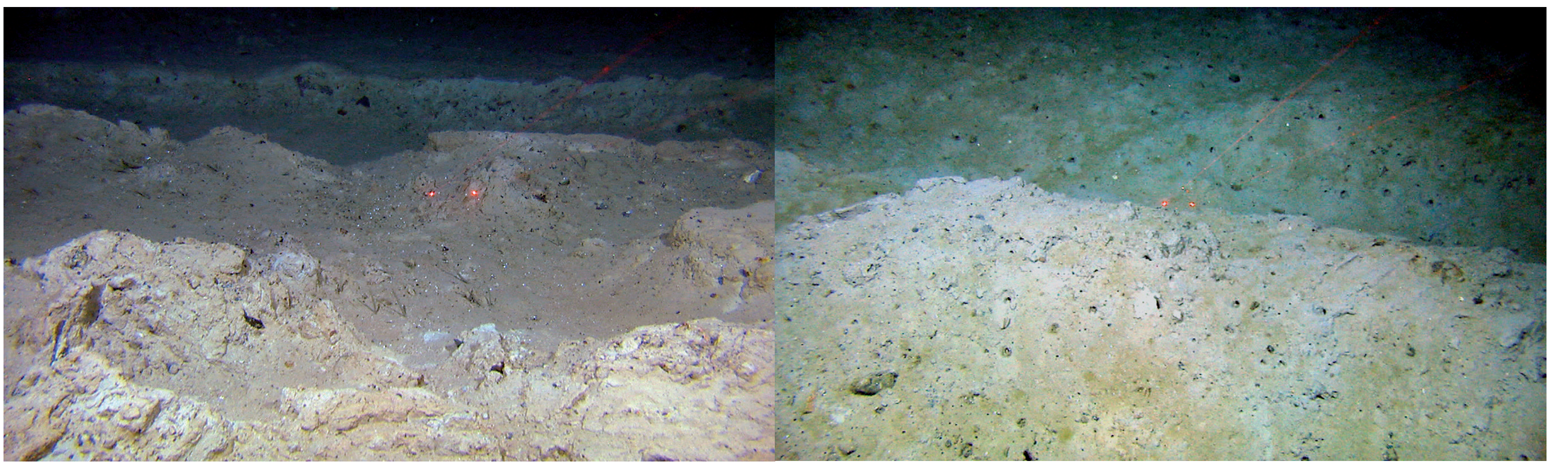


Figure 9. Big marks after trawling on gravelly sand bottom in deep water. The pictures are from 555 m depth in the "Eggakanten" area (A) and from 796 m depth on the slope off "Nordland" (B). Red dots from laser beams indicate a scale of 10 cm.

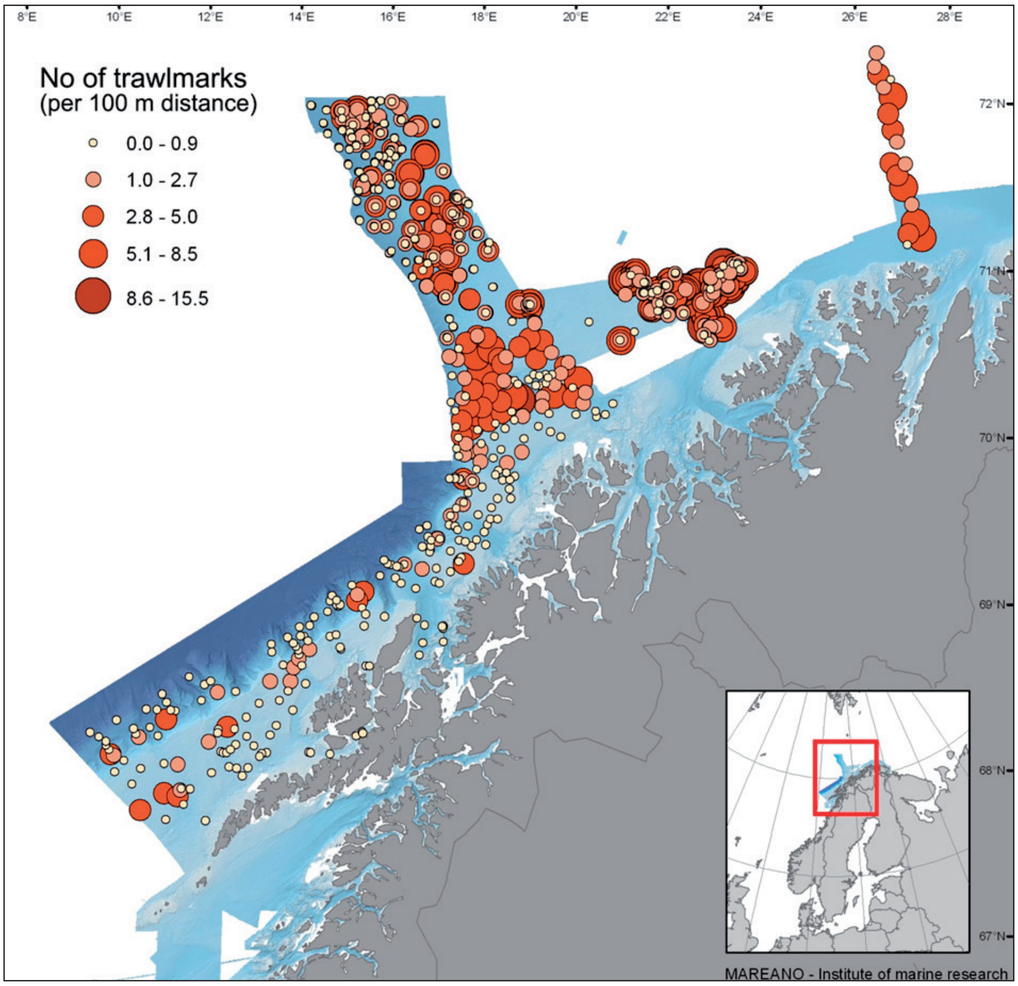


Figure 10. Density of trawl marks observed on the seafloor in the area mapped by MAREANO.

300-400 meters depth can be related to trawling for white fish, while another peak deeper at 600-700 meters are caused by fishing for Greenland Halibut.

Traces after trawling are common on the shelf in areas with high trawling activity, while they are less common in the deep. Therefore it was surprising when MAREANO found a field with lots of trawl marks at 830 meters depth at a plateau on the slope off Nordland. It is likely to be Greenland Halibut that is targeted at this depth. The fishers using this area must know the seabed very well to avoid damaging the gear in the steeper bottoms around the plateau. This plateau is not larger than it just fits for one trawl haul with a typical length.

Video surveys in Nordland VII showed that trawlmarks occurred at 40% of all video transects. Similar to Eggakanten, the trawl marks in Nordland VII were mainly distributed within two depth intervals (figure 11). The highest density occurred at the continental shelf with a maksimum density of 4.9 trawl marks per 100 m recorded seabed. Deeper, at around 600-700 m, higher densities were observed, likely caused by fishing for Greenland Halibut.

10.2.2. Effects on benthos

During the analysis of video recorded megabenthos, organisms with signs of damage (tilting, breakage or displacement) are also recorded. This is a useful material for assessing the effects of trawling on benthos and is an indicator of fishing effects.

Coral reefs, coral trees and sponges are vulnerable to fisheries with bottom gear. The outer part of the shelf off mid- Norway, close to the shelf break is the area where bottom trawling has made greatest damage to coral reefs (see chapter 7). This fishery has been active for many years in this area, and damage to reefs has accumulated. Especially at depths above 300 m there are frequent occurrences of reefs that have been completely decimated. The coral reef structures have been reduced in height from almost 20 m to almost nothing. Coral colonies that previously were up to a couple of metres in size have been fragmented to pieces of rubble, less than 10 cm in size. These damages represent great local biodiversity loss, and have also changed the local bottom topography, with possible implications for altered environments. This could imply less favorable hydrodynamic conditions for filter feeders and less suitable sites for settlement of corals that could restore the destructed reefs. In contrast to the damages to the stone coral *Lophelia* (figure 12) the damages to “coral gardens” formed by coral trees (horny corals) are hard to detect, partly because colonies are more disparate than *Lophelia*. Thus signs of trawling impact are harder to detect than on reefs. Another reason for this is that the skeletons of the coral trees or sea fans decompose faster or can be transported away by bottom currents than the heavier, solid skeletons of *Lophelia*. Many places along the eastern coast of Finnmark damaged coral gardens have been reported.

On Tromsøflaket sponges were found to aggregate in the bottom of trawl furrows (figure 13). They were observed to be covered with more sediment than usual and some specimens were rotting and covered with bacteria. Thus fishery in this area clearly is a threat to the ecological function and biodiversity of local sponge ecosystems. The trawl may directly have moved the sponges together in the furrows or they have been transported there by strong bottom currents. Seemingly, the sponges can survive for some time in the trawl furrows but they probably die slowly and the tracks are will be filled with mud and sponge spicules. Signs of trawling damage will probably not last for long because the sponges die and disintegrate after being crushed by the trawl. It is not known how well sponges can sustain fragmentation.

Areas of high sponge densities and trawling activity are partly overlapping. The highest trawling activity appears to be connected to gravelly sand bottoms. On these bottom types *Stylocordyla borealis*, *Mycale lingua* and many other small sponge species are very common. These areas are on the outskirts of Tromsøflaket, at the border to local depressions (depth of ca 200-300 meters) with softer sediments where the large habitat forming sponges *Geodia* spp. and *Aplysilla sulfurea* dominate.

In the trawling areas at around 1000 meters depth on the continental slope outside Nordland VII the large and palm tree like sea pen *Umbellula encrinus* was recorded. Most of the specimens observed earlier have varied in height from 1.5 to 2.5 meters, but here, in the trawling area all were small specimen of 40-60 centimetres in height (figure 14). This indicates that these small specimens have re-colonised the area after trawling and it would be interesting to know when this area was last trawled. With this knowledge at hand we could estimate the growth rate for *Umbellula*. The trawl marks were not new, indicated by their rounded edges. However, they are probably not very old either since the bottom current is relatively strong here. Trawling in deep waters has not taken place very long (it requires large boats and heavy gear). The observations of re-generating deep seapen habitats indicate that vulnerable organisms are impacted by trawling even at great depths.

The horny coral *Radicipe*s sp. (Pigtail coral) appears to be threatened by trawling. In 2009 MAREANO recorded a dense population of this coral at around 700 meters depth in the ”Bjørnøyaraset” slide area (northern part of ”Eggakanten”). This is the first observation of this coral off Norway. This group of corals are common further to the south in the North Atlantic ocean. In”Bjørnøyaraset” *Radicipes* occurs in dense stands of more than two colonies per square meter. It forms a special kind of coral garden. OSPAR (Oslo-Paris convention) has defined coral garden as a threatened and declining habitat. Radicipes sp. in”Bjørnøyaraset” is a rare species forming coral gardens known only from this place in Norwegian waters. In the same area bottom trawling also occurs (figure 15).

10.2.3. Lost fishing gear

It is common to observe trawl wire, net, ropes and other artefacts from fishers in some areas. Particularly in canyons or local depressions lost gear is often recorded where it can get stuck in rocks, outcrops or coral reefs. In coral reefs, recovery of gear may damage the reefs. At the ”Steinavær” coral reef in Andfjorden and on the ”Malangen” reef north of ”Malangsgrunnen” lost nets and cuts through the reefs was

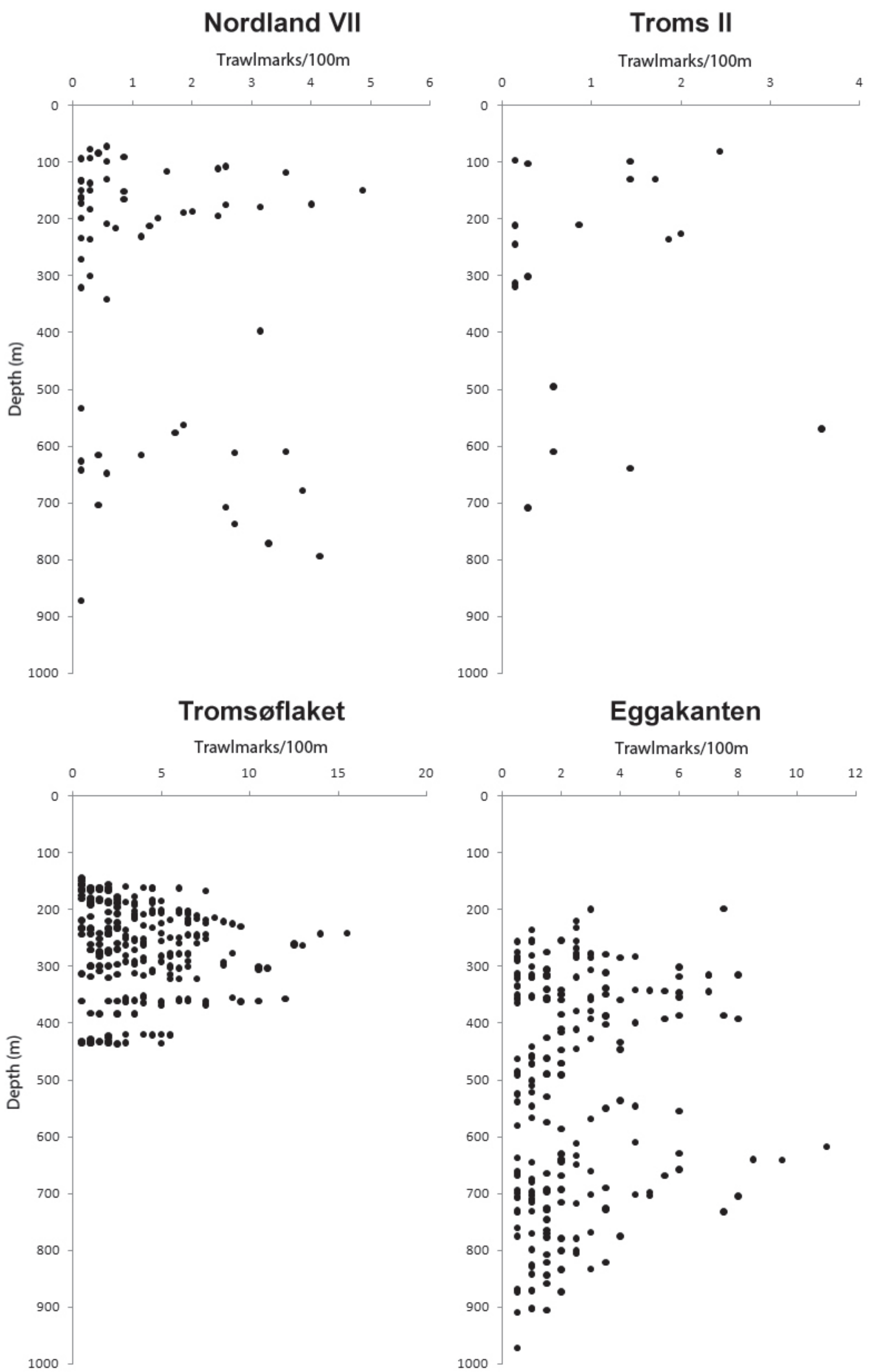


Figure 11. The two highs in the depth distribution of trawlmarks mirrors fisheries of white fish and the shelf and Greenland halibut at larger depths. It is clear that the number of trawl marks are much higher on the ”Tromsøflaket” and ”Eggakanten” than in ”Troms III” and Nordland VII.

Figure 12. Damaged coral reef on the continental shelf nortwest of Vestvågøy. The reef, which is not larger than 50-100 meters in extension, had deep tracks after trawl doors. Pieces of coral skeleton are mixed with mud and no live corals were observed.

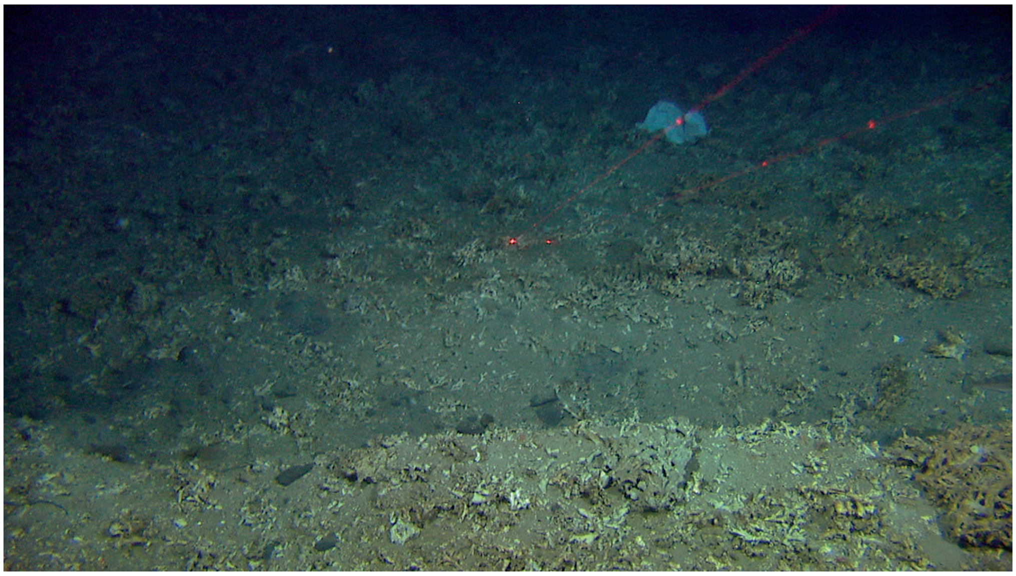


Figure 13. Sponges in the bottom of a trawl mark at Eggakanten (311 m depth). The sponges here are *Stryphnus ponderosus* and *Aplysilla sulfurea* (bright yellow). We also see fragments of another sponge, *Phakellia* sp. on a sponge that is disintegrating. The picture was taken on sandy mud during MAREANO's autumn cruise 2009 in the southeastern part of "Eggakanten", on the boarder of "Tromsøflaket".

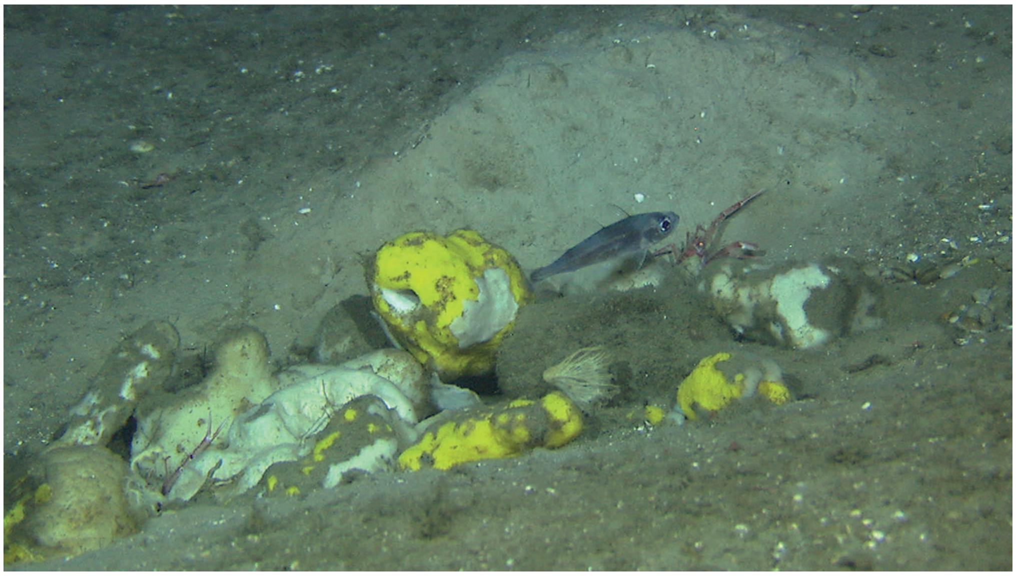
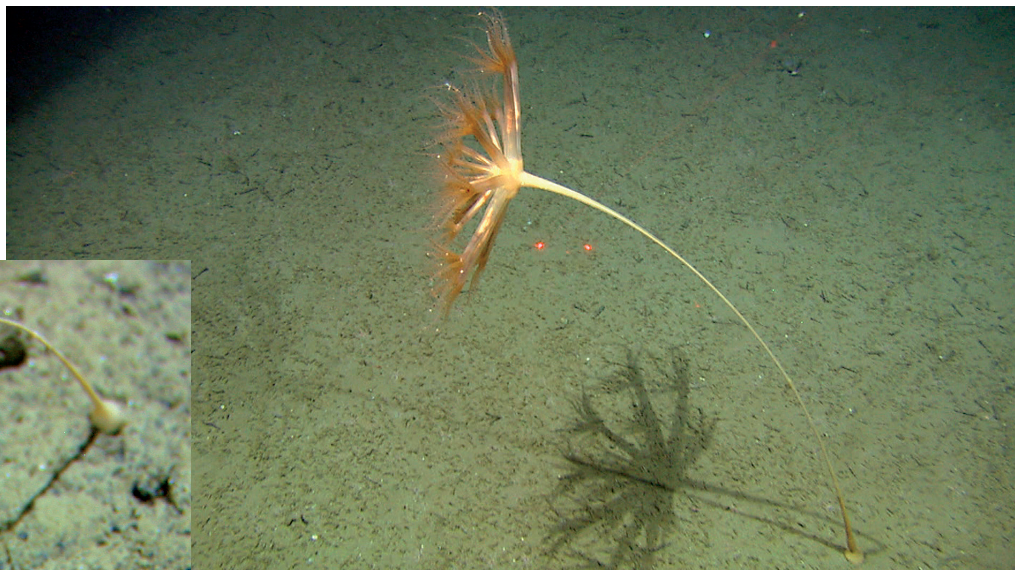
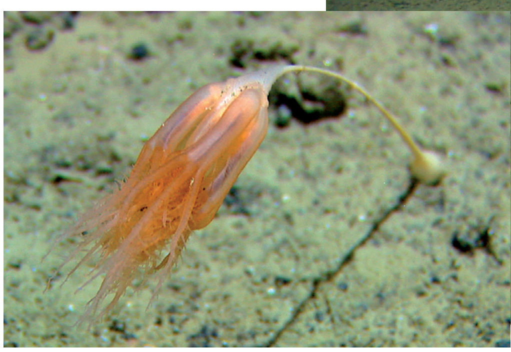


Figure 14.The prominent sea pen *Umbellula encrinus* rise like a palm tree with its crown of polyps 1.5 – 2 meter over the seabed. It feeds on passing particles and zooplankton which it captures with tentacles on the polyps.



Under: Small, presumably young *Umbellula* are an unusual sight, here one is observed in a trawled area on the slope off "Nordland".



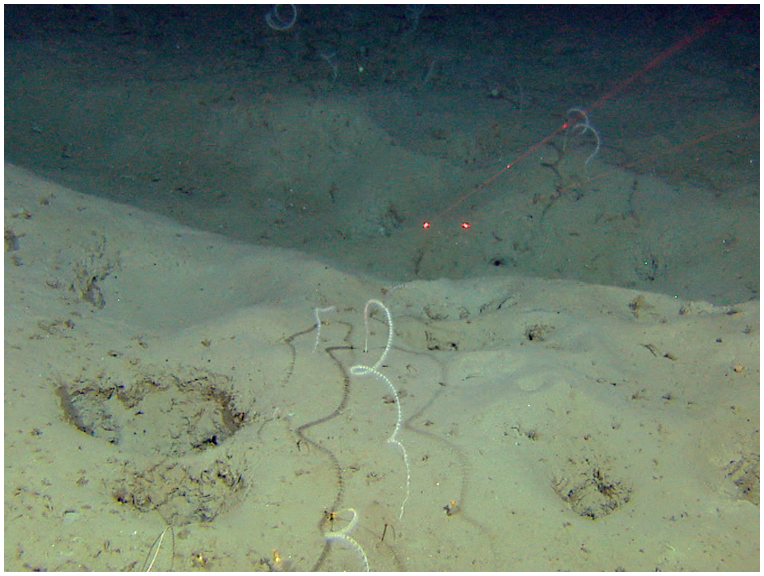


Figure 15. The pigtail coral *Radicipes gracilis* in a heavily trawled area on "Eggakanten".

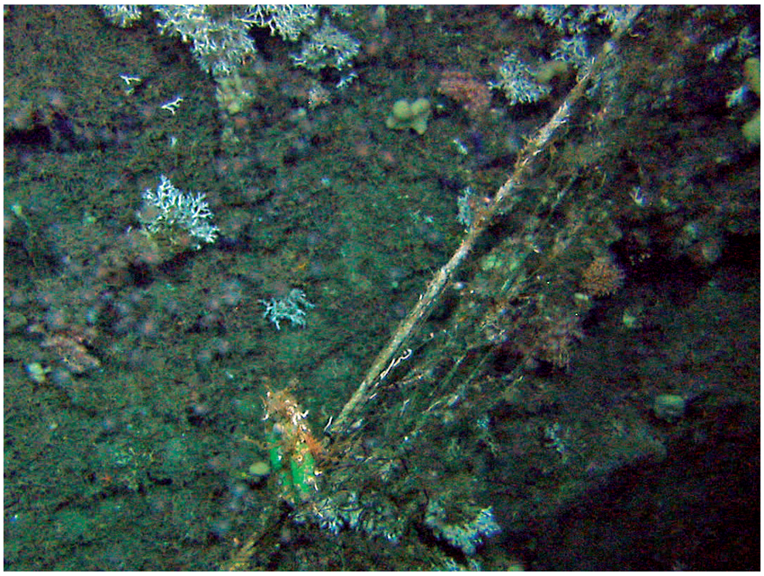


Figure 16. Lost gill net for catching saithe at the Steinavær reef in Andfjorden. The net must have been left for some years since it was fouled by hydroids and other fauna. The picture was taken at 211 m depth during MAREANO's autumn cruise 2008, in a period of bad weather, not allowing mapping at open sea.

recorded, likely resulting from dragging net and entangled corals over the reef (figures 16 og 17). It is known that damaged fishing gear have been dumped at sea. Trawl wire found in a pile on the seabed is a sign of this (figure 18). Nets that are allowed to stay at the seafloor will continue to collect fish until they are decomposed or are overgrown by fouling organisms and collapse. The fishing conducted by lost nets is called "ghost fishing" and is a problem because of the fish mortality it creates which fisheries management has a problem to assess.

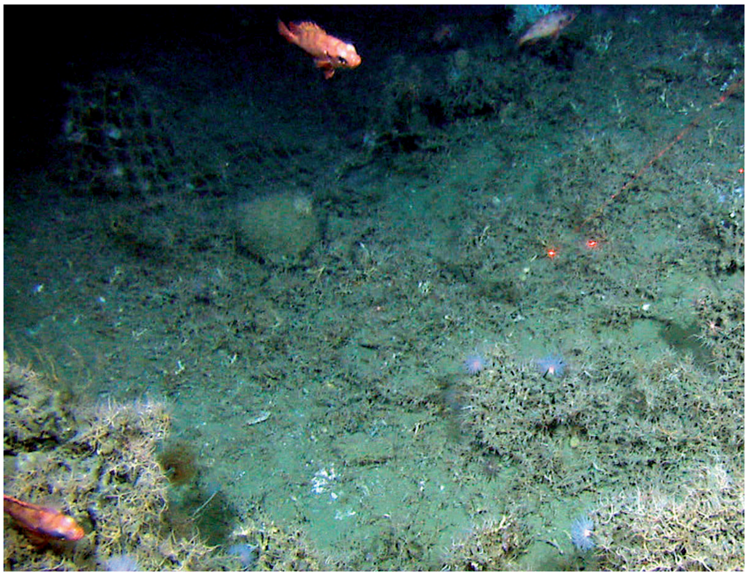


Figure 17. At the Malangen reef we found gillnet torn to pieces (the arrow indicates the location of the net). Overgrown coral fragments are found in the middle of the picture. It is not possible to tell whether these are signs of trawl impact or old fragments created by natural processes. The red-fish (*Sebastes* sp.) is very common on the coral reefs

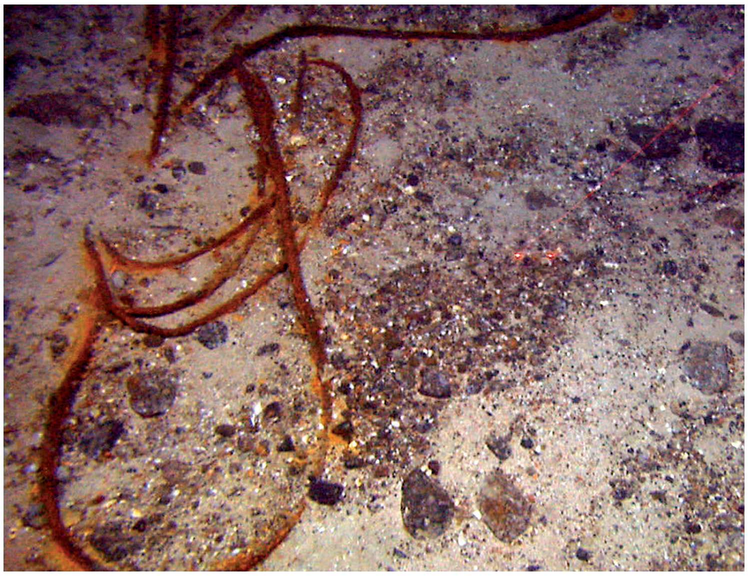


Figure 18. Lost or dumped trawl wire at 181 m depth on the continental shelf at "Langenesgrunnen" in the "Nordland VII" area.