INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

Kartverket

GEOLOGICAL SURVEY OF NORWAY
- NGU -

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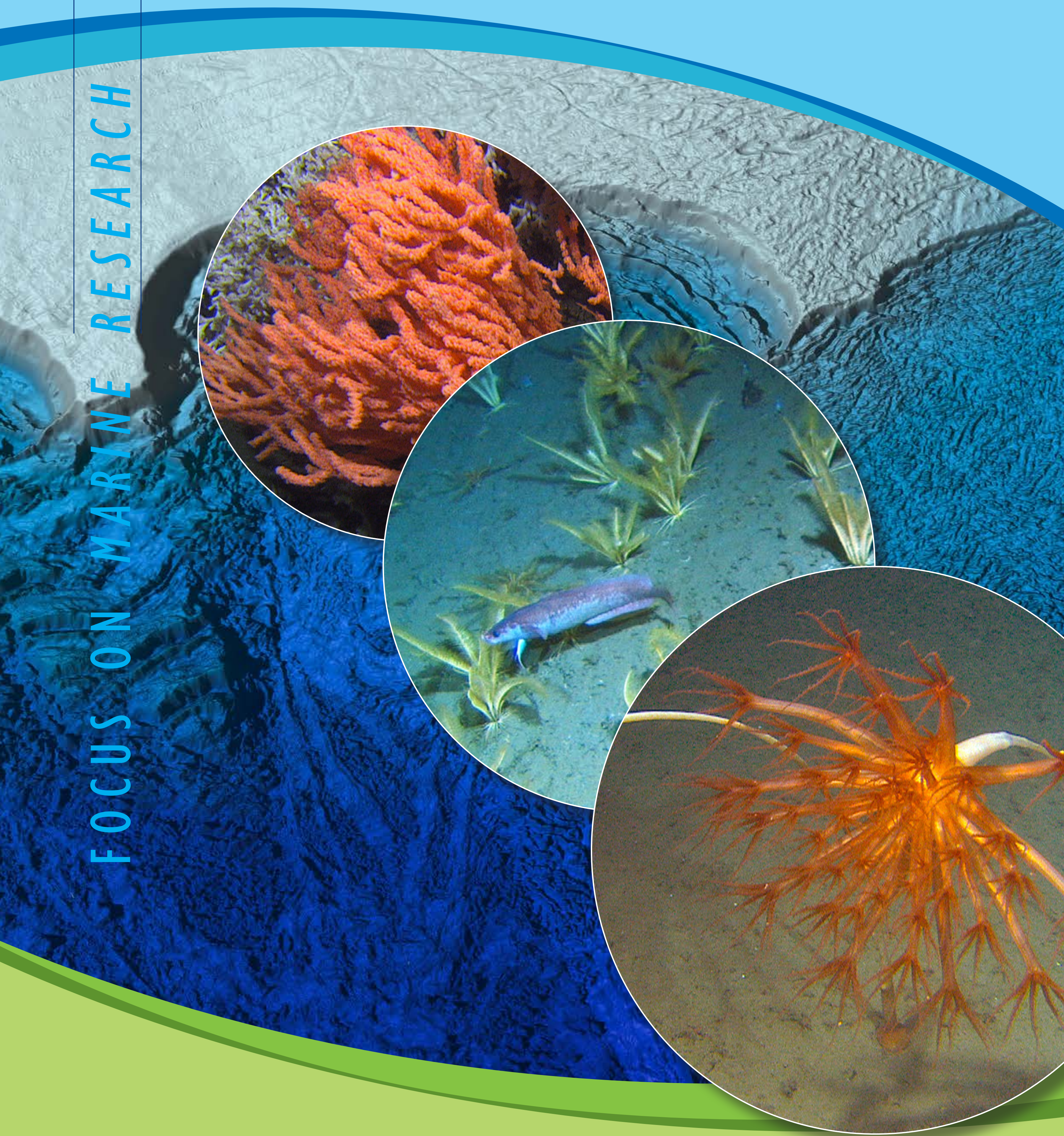
FOCUS ON MARINE RESEARCH



mareano

collecting marine knowledge

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MAPPING THE SEABED

Over the past ten years, the MAREANO programme has mapped large areas of the Barents Sea and Norwegian Sea. We now know that the seabed has large underwater plains, deep troughs and high mountains. It is also rich in fauna, some of which is totally unique. This brochure presents some of our findings from the past few years.

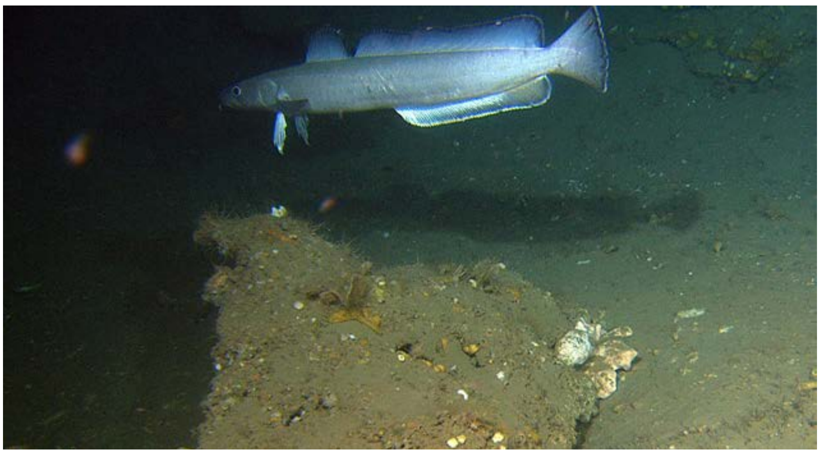
What is MAREANO?

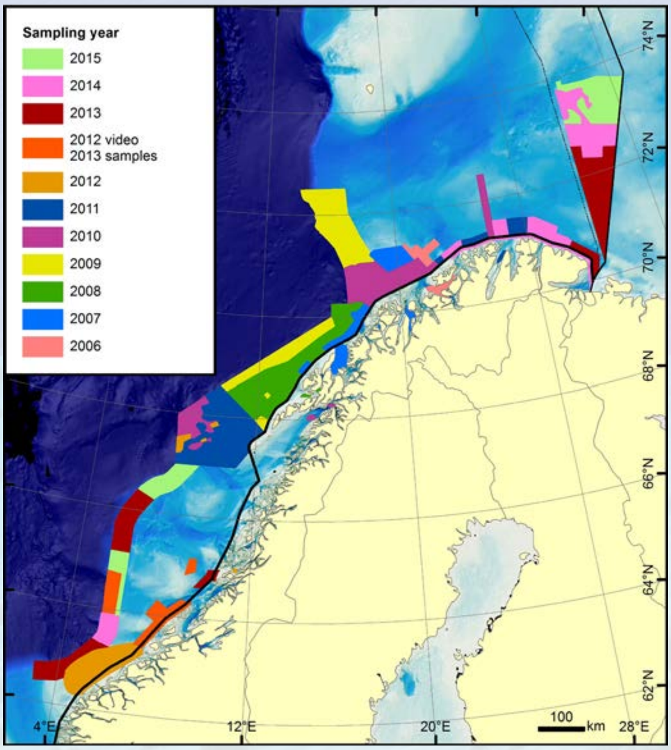
MAREANO is a national programme to map the seabed in Norwegian waters. The programme is inter-disciplinary, including the fields of hydrography, geology, biology, oceanography and chemistry. The programme’s steering group is drawn from five ministries, while responsibility for its implementation lies with a group of representatives from directorates, with mapping conducted by the Institute of Marine Research, the Norwegian Mapping Authority Hydrographic Service and the Geological Survey of Norway.

The MAREANO programme is helping to build up our knowledge and understanding of the seabed environment in Norwegian waters. The terrain, bottom sediments, fauna and chemical conditions are surveyed and the results compiled into a format that is useful to the relevant management authorities and industry. Maps are produced showing the terrain, sediment types, species distributions, biotopes, vulnerable species and pollution. Over 175 000 square kilometres of the sea floor have so far been mapped. The results are available at www.mareano.no.

The aim is to improve our understanding of the sea floor, and thereby support the sustainable management of Norwegian waters. The knowledge built up through the MAREANO programme is used in many different contexts. It has provided important input to the management plan for the Barents Sea and the waters off Lofoten, the management plan for the Norwegian Sea, and updates to these plans.

Information from MAREANO is also passed on to several international bodies and databases such as OSPAR and EMODnet.

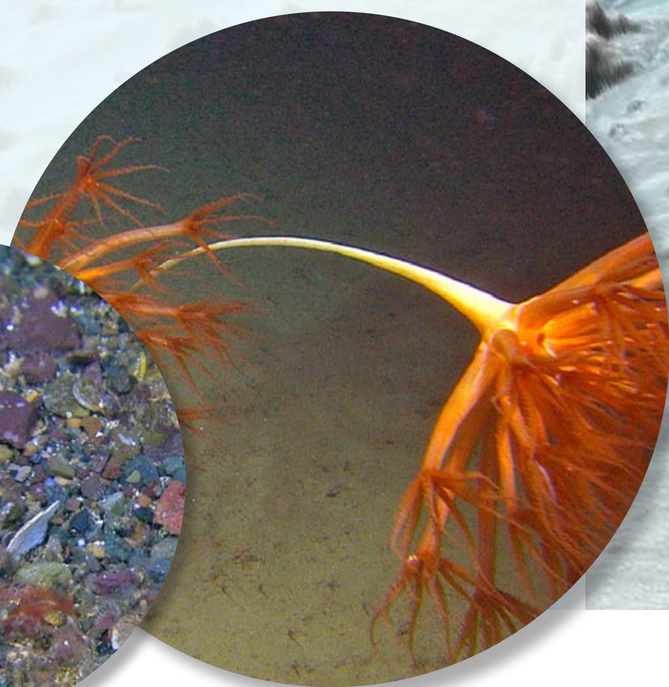




Over the period 2005-2015, the MAREANO programme has given priority to mapping particularly valuable and vulnerable areas as defined by the management plans for the Barents Sea and Norwegian Sea. The figure shows when the field surveys of the various areas were completed.

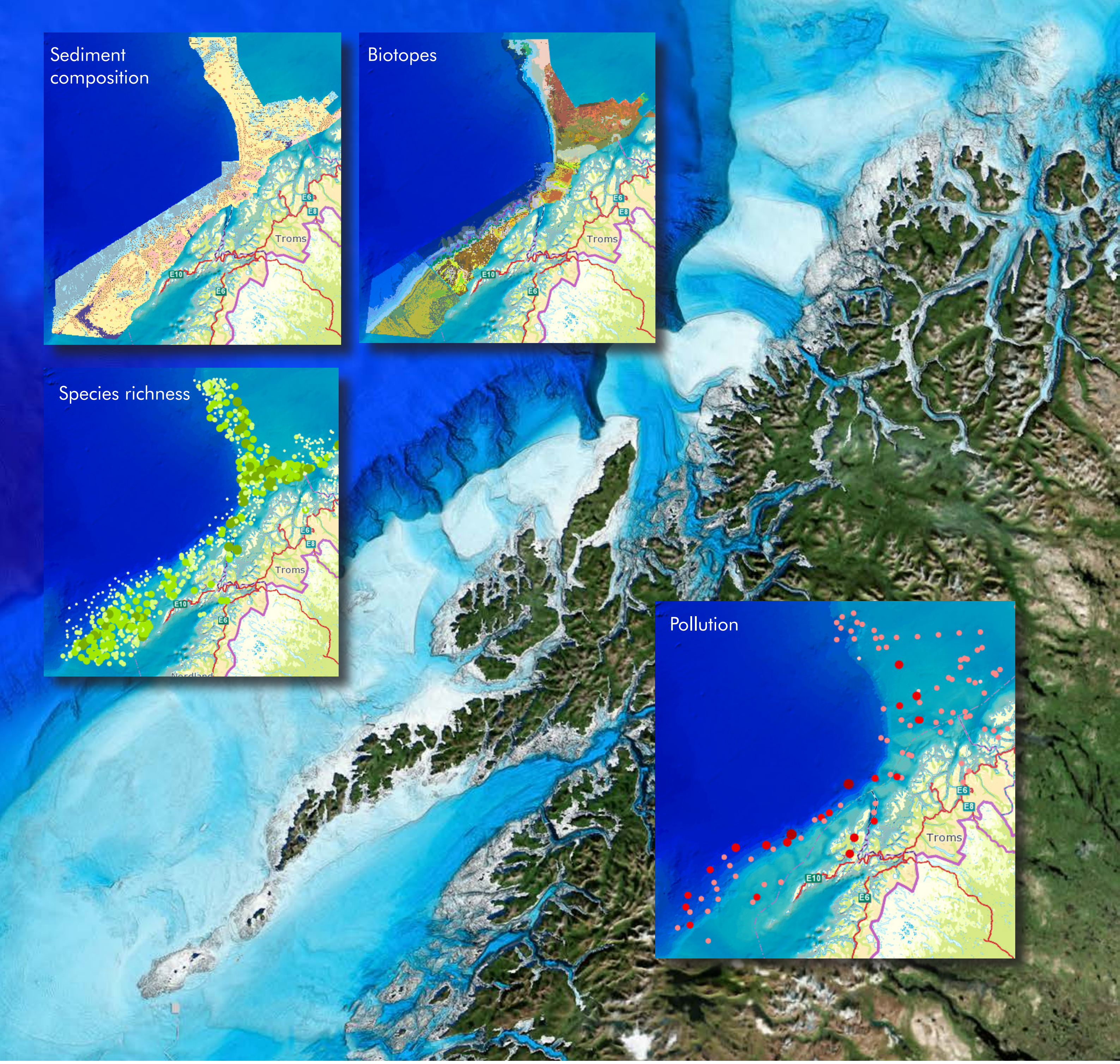
On MAREANO cruises over the period 2005–2015 we have:

- collected data from an area of approximately 175 000 km², equivalent to half of equivalent to half of Norway's land area;
- collected data from depths of between 20 and 2 900 metres, from off the baseline out to the cold and deep waters of the Norwegian Sea and the Barents Sea;
- spent five years at sea: three and a half years of vessel time has been spent mapping the terrain and bottom types using advanced echo sounders; the rest of the time has been spent acquiring geological, biological and chemical samples;
- recorded 2 000 hours of videos; these cover 1 400 kilometres of the sea bed;
- acquired samples from 290 stations in the Barents and Norwegian seas;
- acquired approximately 850 core samples of the bottom sediments to study their chemical composition and reveal any environmental pollutants; the best samples are analysed, and the remainder are frozen for possible future use;
- used 4 000 buckets and jars to store animals for analysis; these are stored at the University Museum of Bergen;
- discovered around 20 new species, around 10 of which have been scientifically described so far.



AREAS COVERED BY MAREANO FROM 2005 TO 2010

From the start of the project in 2005 until the end of 2010, MAREANO focused on Northern Norway, mapping areas from the Lofoten Islands to the southwest Barents Sea. The MAREANO programme has produced bathymetry, geological and biological maps, and has analysed the chemical substances in the seabed sediments. The results have been included in the revised management plan for the Barents Sea and the waters off Lofoten. Some of the maps produced are shown below.

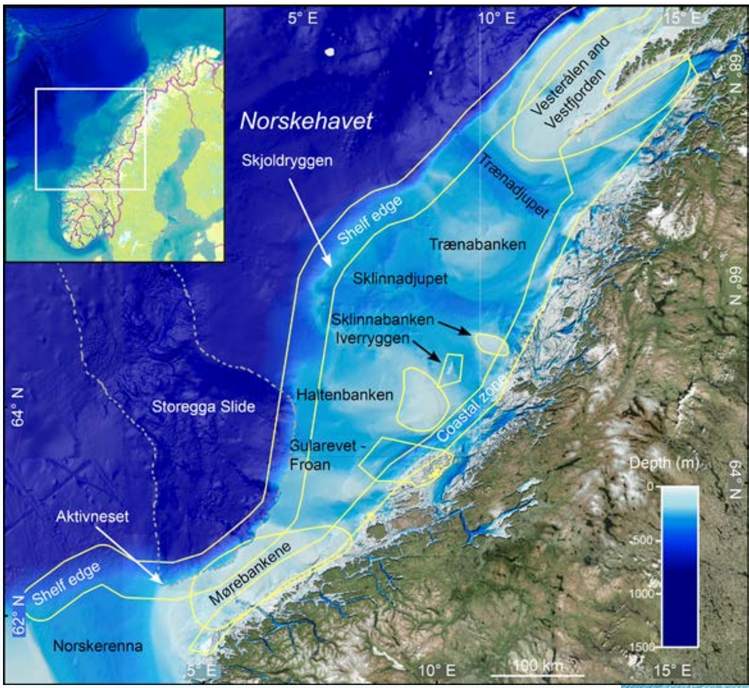


MID-NORWEGIAN SHELF

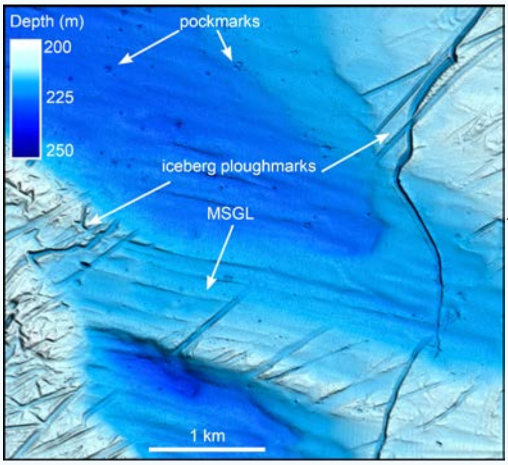
The landscape of the continental shelf off Mid-Norway consists of shallow banks and marine valleys (troughs), eroded by glaciers during the last ice age. The great variation in the terrain, water depth and bottom type results in lots of different biotopes. The waters off Mid-Norway are famous for their rich fishing banks and spawning grounds. The Mørebankene area is a major fishing ground and also hosts the largest and most important spring-spawning herring spawning grounds in Norwegian waters. The seabed sediments on the banks vary greatly, ranging from silty clay to gravel, cobbles and boulders. In the shallowest areas near the coast, the bedrock protrudes.

Shaped by the Ice Age

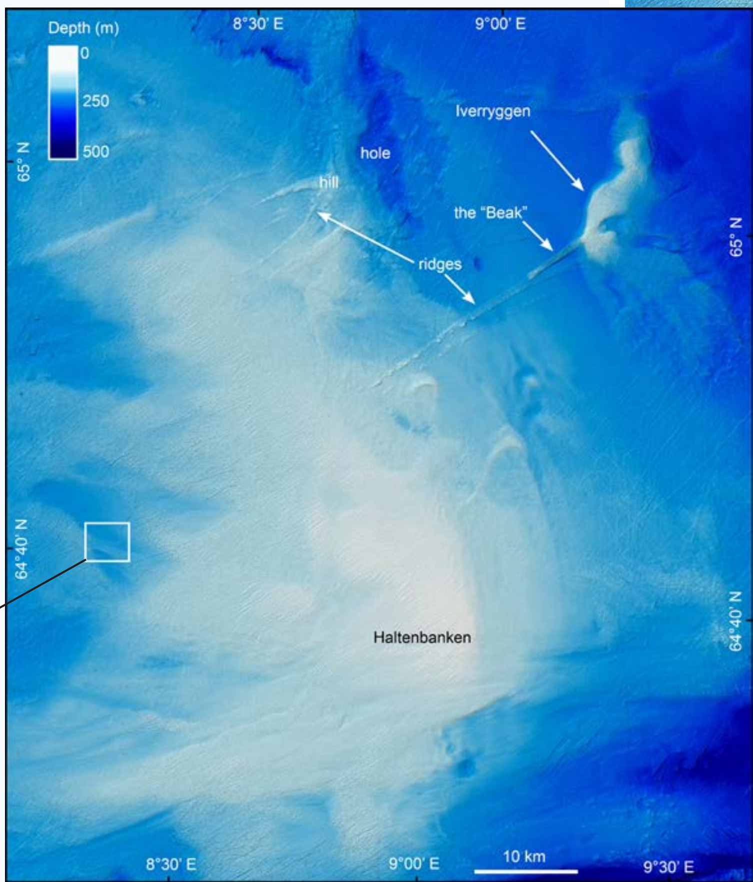
Off Mid-Norway, the continental shelf was shaped by the movements of glaciers. On their way out to the shelf edge, the base of the glaciers ploughed down into the sediments, leaving deep



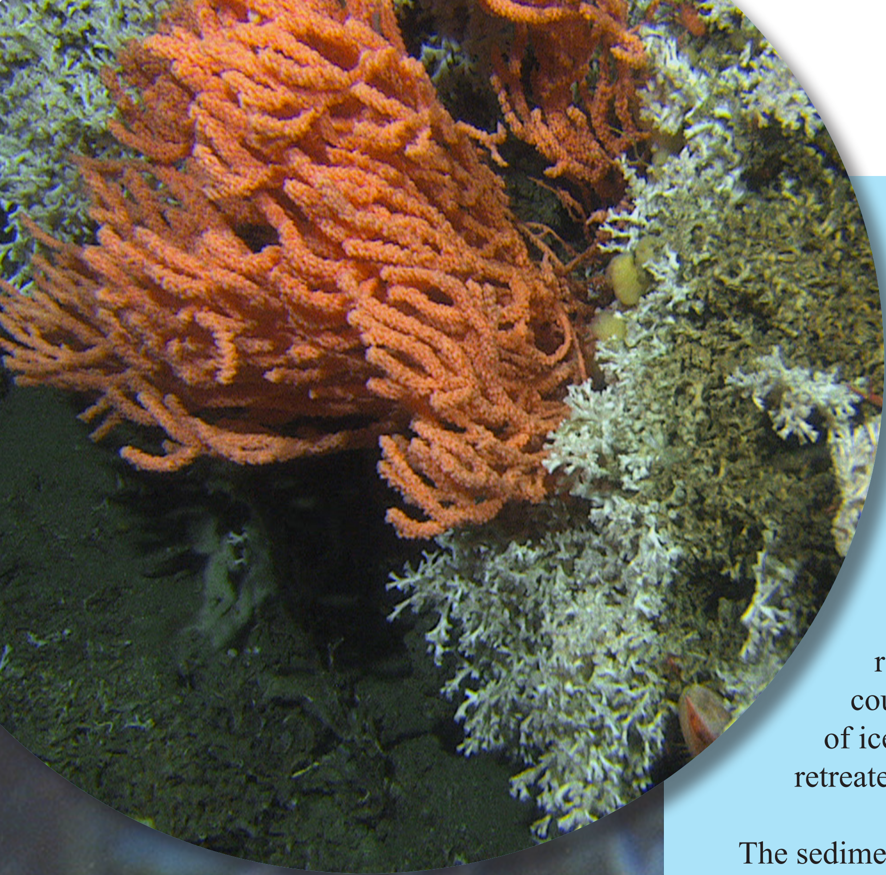
Selection of priority areas for MAREANO. The yellow lines indicate the outlines of particularly valuable and vulnerable areas as defined by the management plans.



The furrows, ridges and iceberg ploughmarks are a reminder of the ice that once covered the continental shelf off Mid-Norway. Pockmarks occur in soft sediments, where gas or liquid have seeped out of the sea floor.



On the continental shelf, the sea floor has been shaped by glaciers. Haltenbanken and Iverryggen are good examples of this. Smaller ridges and other submarine landforms complete the picture. Note the "beak" that runs south-west from Iverryggen. The small square indicates the area shown in the figure to the left.



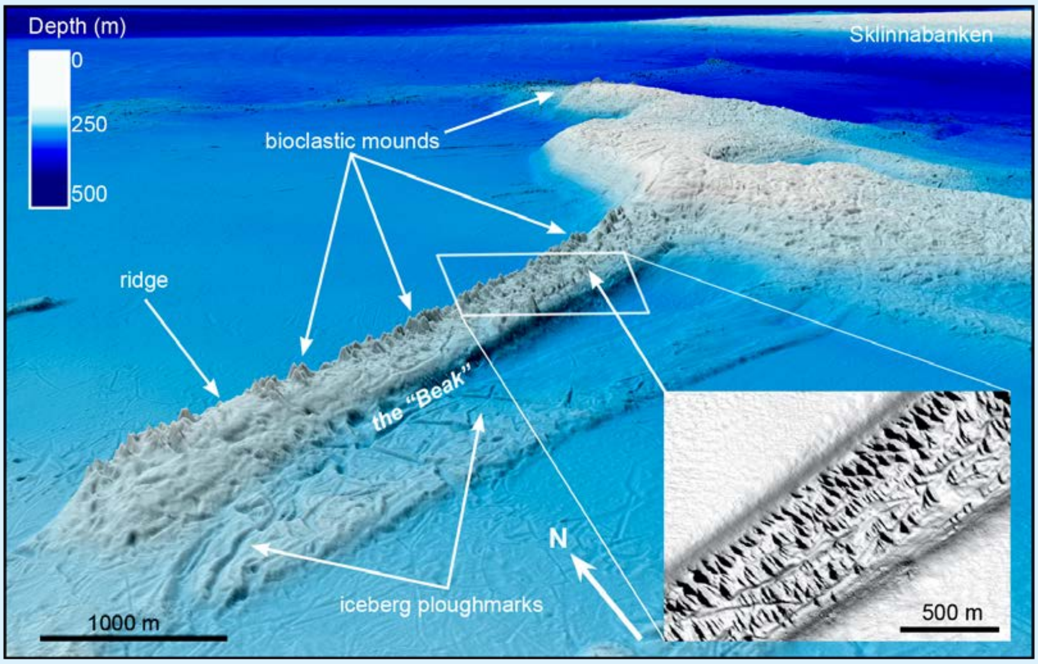
tracks. These glacial lineations are still clearly visible, even though more than 10 000 years have passed since glaciers covered the Norwegian Sea, and they give the sea bed its present striated appearance, particularly in the troughs. The glaciers also pushed and transported the seabed sediments, creating numerous ridges. Iverryggen is an example of one such ridge. On the seabed there are also countless ploughmarks left by the keels of icebergs that were released as the ice retreated.

The sediment composition on Iverryggen is highly varied, ranging from sandy mud to gravel, cobbles and boulders. Some of the sediments have a biological origin, such as numerous mounds of coral sediments. These mounds of bioclastic sediments are often covered by living coral reefs.

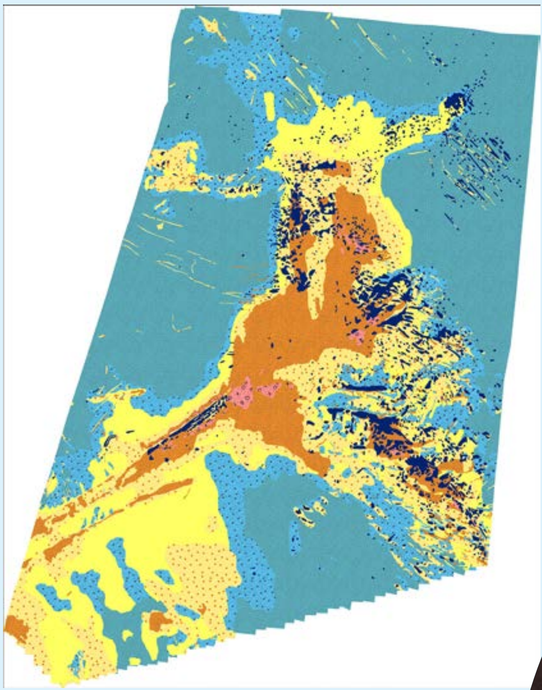
Life at the shelf break – dependent on the currents

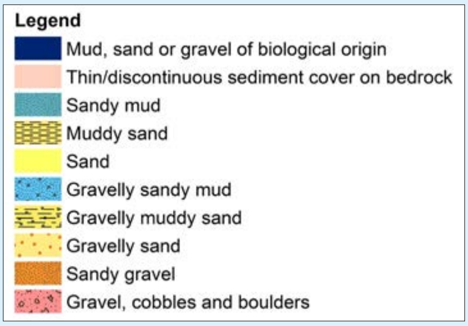
Hundreds of coral reefs have already been documented by the MAREANO programme, but new ones are still being found. The Pearl Chain Reef was discovered in autumn 2015 on the Skjoldryggen terminal moraine; it consists of several small reefs strung out like pearls on a string along the edge of an iceberg ploughmark. The reef is home to everything from fish to tiny worms seeking shelter from their predators and enjoying the good supply of nutrients. On the top and sides of underwater ridges, banks and the shelf break, the ocean currents can be particularly strong due to the influence of the terrain, and this is often reflected in the animals that live there.

The cold-water coral *Lophelia pertusa* is known to build large reefs in the seas off Norway, and it is also an important species in the Pearl Chain Reef. The orange coral in the top picture is bubblegum coral. If you look carefully, you can see both squat lobsters and file shells hiding amongst the corals. The picture to the left shows a close-up of *Lophelia pertusa*, which can reach up to 1 cm in diameter. You can just detect the tentacles at the end of each polyp.



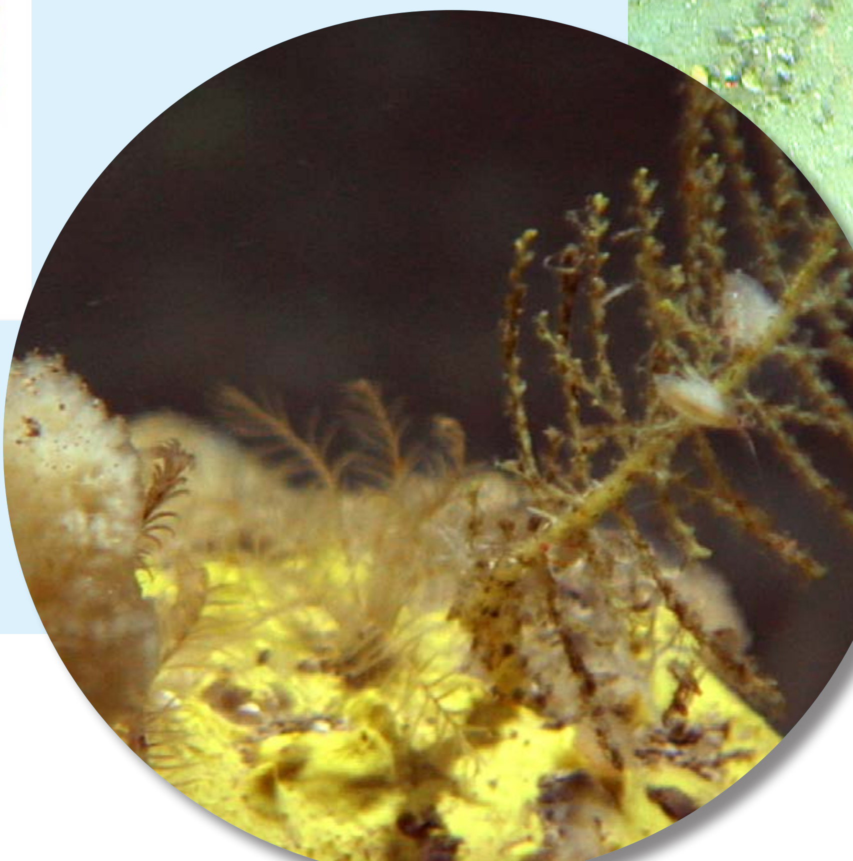
Iverryggen, which is famous for its many coral reefs, is a Marine Protected Area. On the ridge in the foreground – the "beak" – hundreds of mounds of bioclastic sediments are visible. A video survey was done of two of the mounds, which confirmed the presence of living corals.

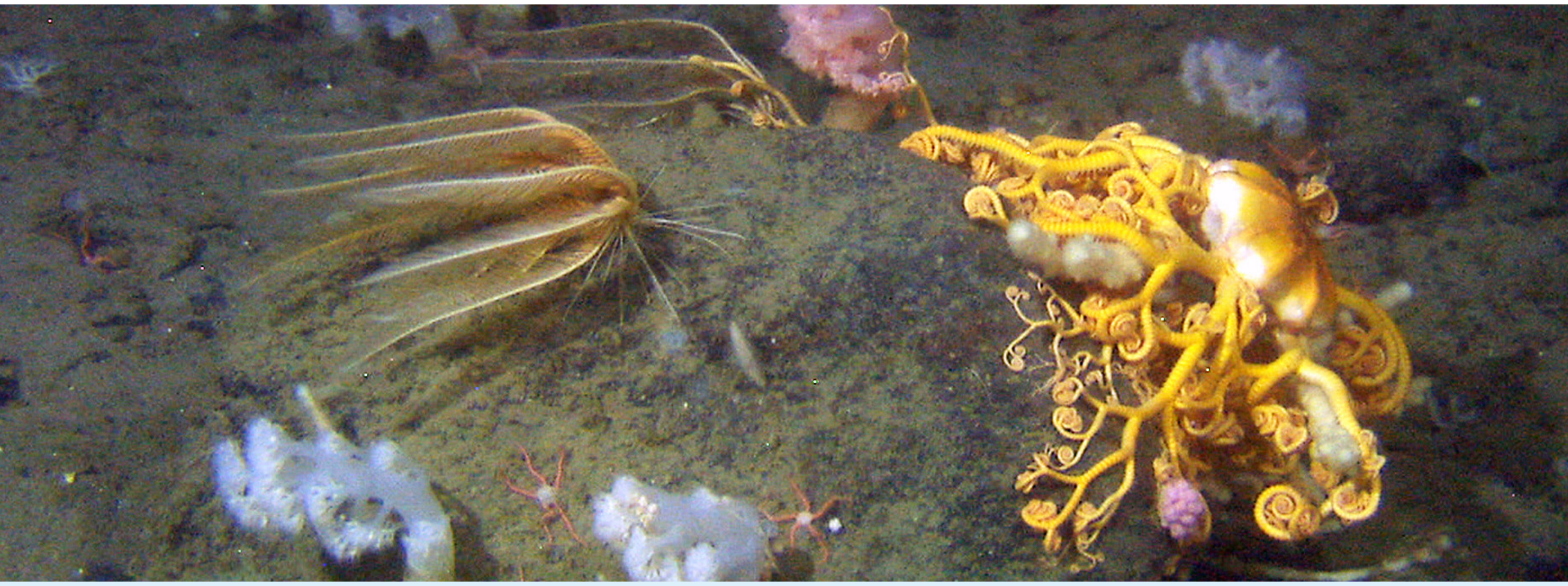




A sediment grain size map of Iverryggen shows the distribution of the various seabed sediment classes.

Coral reefs are home to large numbers of species from many different groups of animals. More than 600 species have been reported at coral reefs along the Norwegian coast. Here we can see the yellow sponge *Aplysilla* and a bush hydroid with amphipods.





Here we can see how the powerful bottom current 800 metres below the surface at Skjoldryggen drags and tears at the frilled anemone's many tentacles, while a yellow gorgon's head brittle star (*Gorgonocephalus*) and several colonies of deep-water soft corals (*Drifa*) catch food particles with their tentacles. Sessile organisms like these, which are attached to the seabed, are able to withstand strong currents, and they benefit from the large quantities of food particles passing by.

Another peculiarity of these kinds of areas is that particles don't sink to the bottom, and instead drift with the currents. This means that such areas often have hard bottom types. MAREANO's video surveys have observed the greatest biodiversity right by the coast and along the shelf break (the transition between the continental shelf and continental slope). The relatively strong currents at the shelf break favour species that are anchored to the sea floor, such as sea anemones, sea pens, corals and bristle worms with impressive feeding crowns.

These groups thrive here because the currents transport food particles that they can catch with their "arms", tentacles and nets. The presence of these species also provides plenty of food for fish that feed on the sea bottom.

Doors closing! This beautiful tube worm catches food particles drifting with the currents, while it is vulnerable to feeding fish and other predators on the sea bottom. It is a few centimetres long, and was filmed at a depth of around 360 metres. The bright light from MAREANO's video rig frightened it, and at lightning speed it withdrew into its calcareous tube (see right), closing the door behind it with a tightly fitting round lid – an excellent defence mechanism against predators.

SKJOLDRYGGEN – NORWAY'S BIGGEST TERMINAL MORAINE

Further evidence of the last ice age can be found at Skjoldryggen, Norway's largest terminal moraine. It is 65 km long, up to 16 km wide and 100 to 150 metres high, and sits right on the shelf break off Nordland. The top of Skjoldryggen is scarred by numerous ploughmarks left by icebergs that broke off the ice edge as the ice retreated after the last ice age.

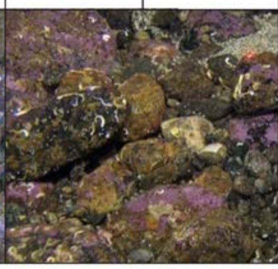
Like most moraine ridges, Skjoldryggen consists of unsorted sediments containing a mixture of boulders, cobbles, gravel, sand, silt and clay. Coarse-grained sediments occur at the top of the ridge, where gravel, cobbles and boulders form a hard surface. On the slopes there is mostly gravelly muddy sand, while the deepest sections are coated in softer sandy mud.

This great variety of bottom types means that many species of animals can thrive here. The most prominent animals on MAREANO's videos are coral species such as *Lophelia pertusa*, bubblegum coral and red tree coral, as well as file shells and Norway redfish. Occasionally you see "forests" of various sponge species. Greenland halibut is common out on the slope, at depths of around 500–600 metres. In this area we also observed frequent trawl marks from fishing gear.

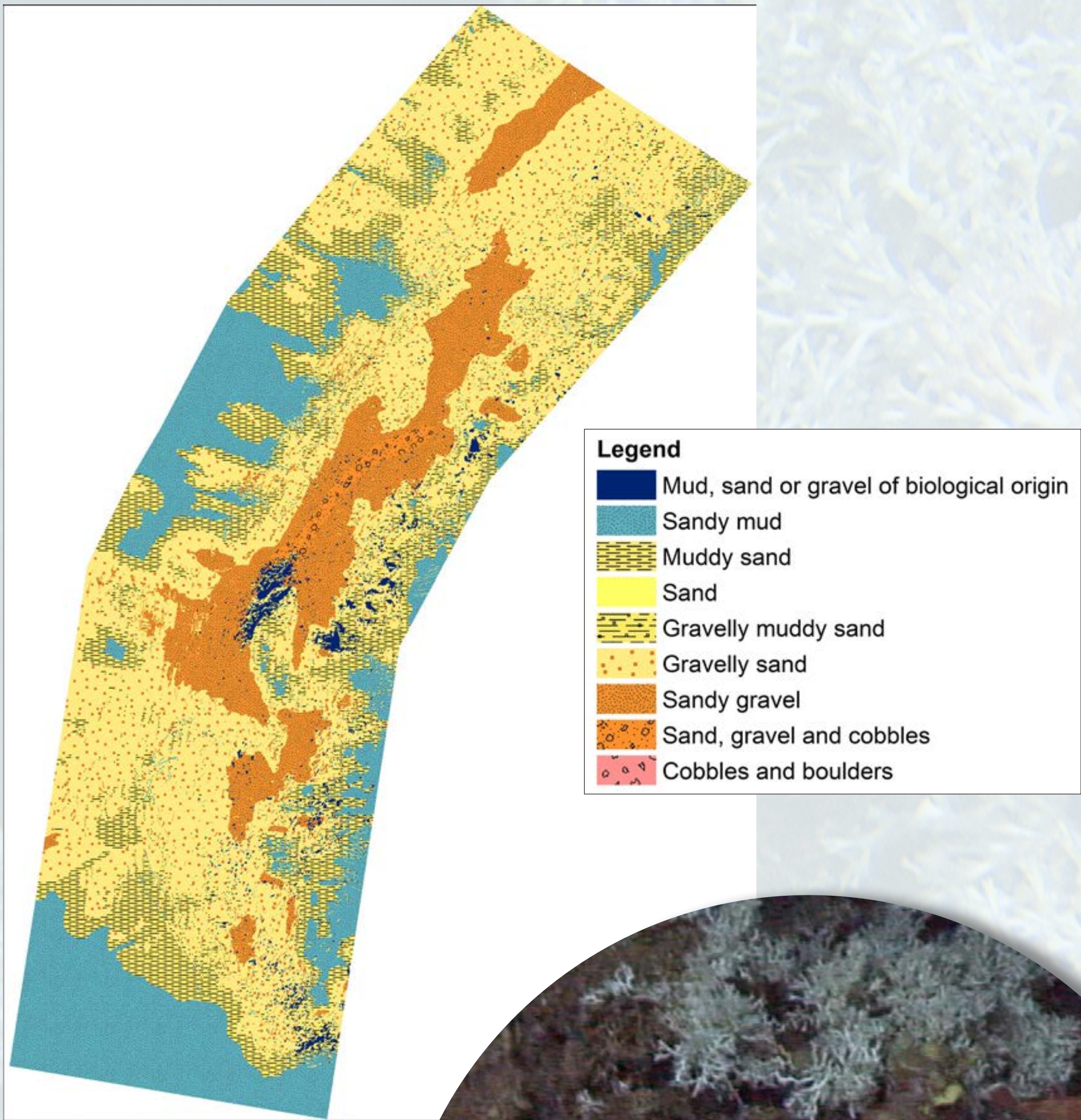
FACT BOX

What is the seabed made of?

The seabed can either be made of bedrock (solid rock) or sediments. Sediments are divided into various categories based on criteria like the grain size of the sediments. For example, mud is a mixture of clay and silt, and consists of tiny grains that are far smaller than one millimetre in diameter, while boulders have a diameter of over 25 cm. Often the sediments on the seafloor contain a mixture of grain sizes. The sediment composition is important to animals, and different species prefer different kinds of sea bed. For example, many kinds of bristle worms and mussels prefer soft bottom types consisting of silt and clay, whereas anemones require harder bottom types. The MAREANO programme has produced a number of sediment maps describing the sediment grain size, genesis and sedimentary environment. These maps provide important input to MAREANO's biotope maps.

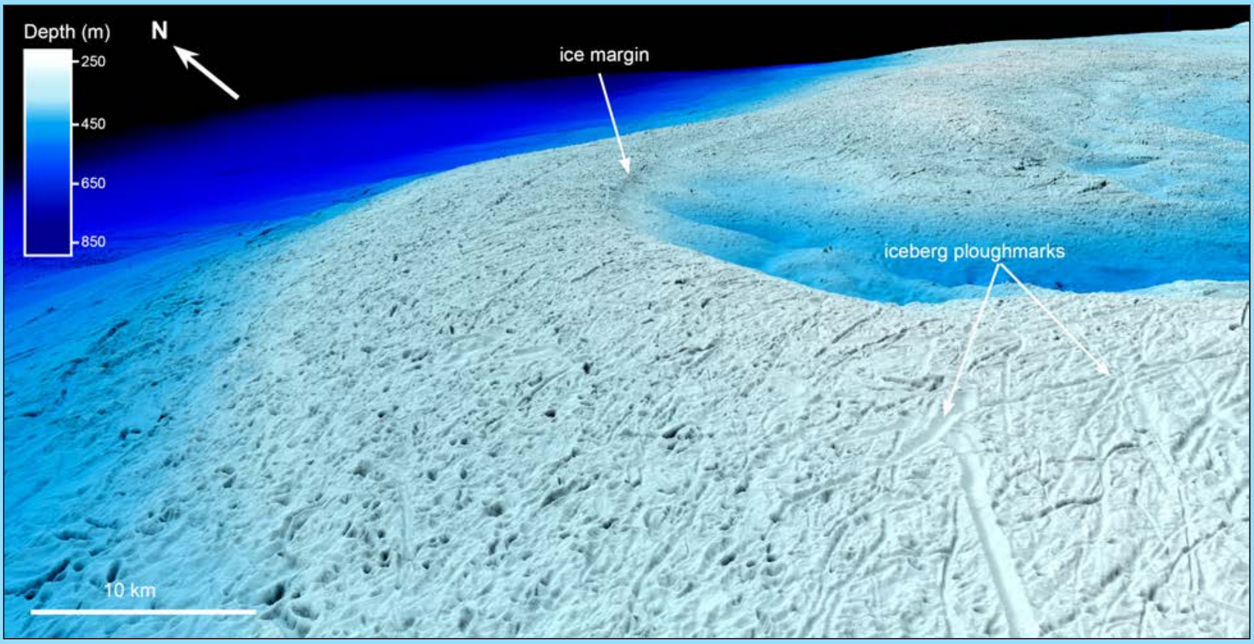
Mud		Sand	Gravel	Cobbles	Boulders	Bedrock
Clay	Silt					
						
< 0,002 mm	0,002-0,063 mm	0,063-2 mm	2-64 mm	64-256 mm	> 256 mm	
						
Bacteria	Cobweb	Salt grain	Berries	Tennis ball	Microwave	Skerries

It was already known that there are many coral reefs on Skjoldryggen, from fishermen who have used trawls or longlines in the area. Past efforts to clear up lost nets organised by the Directorate of Fisheries have also shed some light on the locations of coral reefs. These nets can catch fish for years after they have been lost, and any coral colonies observed in the nets during the clear up are recorded and reported.



Sediment grain size map of Skjoldryggen.

One of Skjoldryggen's many coral colonies. Here the corals attach themselves to cobbles and boulders and mixed sediments in the terminal moraine that runs along the shelf break.



3D terrain model (5 m resolution) from Skjoldryggen, a large terminal moraine at the shelf break in the Norwegian Sea, south-west of the Lofoten Islands. The ploughmarks on the top of the ridge were formed by drifting icebergs towards the end of the last ice age.

FACT BOX

Bristle worms – numerous and diverse

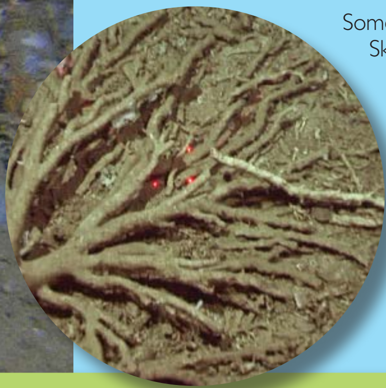
The bristle worms belong to the phylum Arthropoda. Around 11 000 species have been described, and they have been observed at all depths and in most marine environments. We almost always find them down in the seabed mud, or between cobbles and boulders, in cracks in the rock or amongst sessile animals attached to the sea floor. Of the 2 400 species and groups of species (taxa) recorded by MAREANO, around 25 percent belong to the bristle worms.

Bristle worms can be anything from a few millimetres up to tens of centimetres long. There are numerous species with highly varied feeding habits, and they contribute significant to the biological production on the sea floor. This means that they play a key role in the seabed ecosystem. Some species eat mud in order to extract nutrients from the 2–4 % organic material that it contains. Others have developed "nets" that emerge from the mud surface to catch food particles transported by the bottom currents. Some bristle worms are carnivores that use specialised grabbing organs to catch other small animals, while yet others can push their stomachs out of their mouths to reveal razor-sharp teeth that they use to catch their prey. A number of bristle worm species are an important food source for demersal fish. They also help to support life in the mud on the sea floor by digging passages that allow oxygen-rich sea water to reach the fauna further down in the mud. Their faeces sustain a teeming bacterial community that breaks down organic material and helps to recycle nutrients for plankton production in the waters near the surface.

A 20 cm long paddle worm (Phyllodocidae) passed MAREANO's video camera at a depth of around 250 metres in the Barents Sea. This millipede-like creature is one of many carnivores on the sea bottom. Like most carnivores, but unlike many bristle worms that are buried in tubes in the seabed, it can move freely.

Maldanidae are often 10–15 cm long, and stand with its head down into the sea bottom sediments eating mud. The rear end of the animal, which only just emerges from the mud, deposits faeces on the sea floor. Photo: Jon Kongsrud, University Museum of Bergen.

A sponge community from the upper part of the Skjoldryggen terminal moraine. The picture shows various sponge species along with a tusk that has found shelter beneath a stone. Such behaviour is common in coral reefs, but in this case it was observed on a moraine ridge. More than 80 sponge species have been identified so far in the samples retrieved by MAREANO from the seabed. Sponges filter tiny particles (often the size of bacteria) from the bottom waters for consumption. When a sponge dies, the remains represent valuable organic material that are exploited by other members of the sea-floor community.



Some coral reefs at the top of the Skjoldryggen terminal moraine seem to have been damaged by fishing activities. Single bubblegum coral colonies may break up due to strong currents and unstable bottom substrate, and thus die naturally. This coral skeleton, however, was observed within a "corridor" of crushed corals, which is indicative of human impact.

FACT BOX

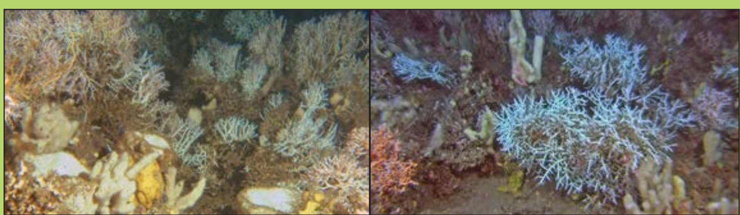
Corals provide shelter and food

Coral reefs in Norway are mainly formed by the stony coral *Lophelia pertusa*. This cold-water coral lives in water temperatures of 4–8 °C. On the Norwegian continental shelf, it is found at depths of up to 450 metres. *Lophelia* reefs are often found near the shelf break, where the currents supply the corals with nutrient particles. The polyps that form corals belong to the phylum Cnidaria, and they look like miniature versions of sea anemones. *Lophelia* reefs are composed of colonial individuals that build a calcium carbonate exoskeleton. Each individual is only a few millimetres long.

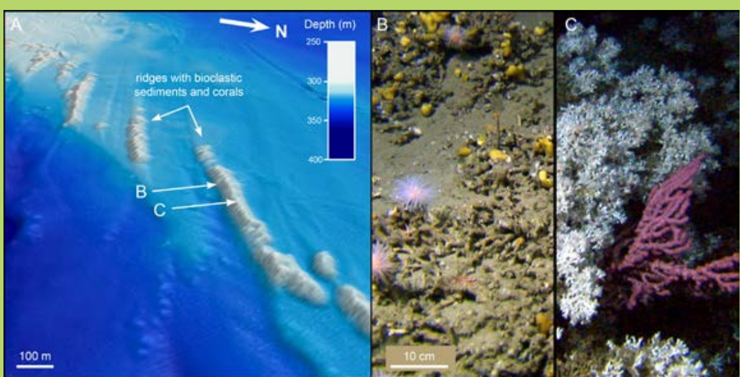
In Norwegian waters, *Lophelia* reefs can become tens of metres high, but they only grow a few millimetres per year, so they are vulnerable to physical damage. The reefs create very valuable biotopes with great biodiversity, providing shelter and food for a variety of benthic fauna. They are also important habitats for fish. Attempts to estimate the age of some of the biggest reefs suggest that they were established 8 000–9 000 years ago. Røstrevet on the edge of the Trænadjupet Slide is the biggest *Lophelia* reef complex observed to date. Located at a depth of 300–400 metres, it is 35 km long and 2.8 km wide.

The northernmost *Lophelia* reef observed is just north of Sørøya in Finnmark.

In general, living corals are only found at the top of the reefs, or at the most current-exposed parts of the reefs. The core of a coral reef consists of broken corals and the remains of other organisms that form calcium carbonate shells or skeletons, in addition to other sediment particles, which are known as bioclastic sediments. Clastic sediments consist of fragments, so the term bioclastic sediment refers to sediments formed of fragments of biological material. The MAREANO programme has mapped the distribution of these sediments. In the areas surveyed, approximately one percent of the sea floor is covered by bioclastic sediments. However, it should be noted that areas with many coral reefs, such as Sularevet and Iverryggen, have a higher proportion of bioclastic sediments than elsewhere.



On the left, coral reef with lots of sponges at Aktivneset, west of Mørebankene. On the right, white and red varieties of zigzag coral (*Madrepora oculata*) at Storneset, north-east of Mørebankene. These corals often dominate the reefs in this area.

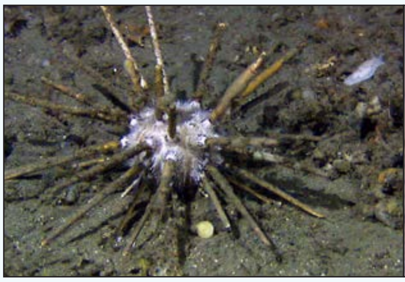


Ridges composed of bioclastic sediments and corals at Sularevet. A: 3D model of the ridges, indicating the location of B and C. B: bioclastic sediments from the middle part of the ridge. C: living corals.

Deep-sea benthos

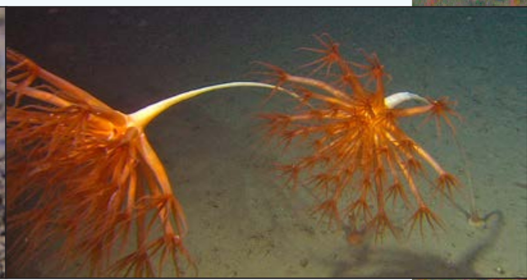
At the shelf break, where the currents are strong, coral reefs of all sizes and sponge "forests" are common, while the bottom conditions in deep troughs and depressions left by submarine landslides are very different. Here the composition of the seabed is very varied, and this variation means that the fauna is quite diverse, although in general there are fewer species in deep waters. The water temperature falls quickly with increasing depth. The fall in temperature from 5–6°C down to -1°C at depths below 800 metres represents a dramatic change in environmental conditions. MAREANO's findings show that there is greater biodiversity in the temperature transition zone between 500 and 800 meters depth than in the surrounding areas. This is not yet fully understood, but may be caused by the observed shift in species in this transition zone – from those that thrive in areas with relatively high temperatures to those that can cope in the deep and cold areas.

Cold deep-water enters the area from the Norwegian Sea in the west, but originates from the Arctic. This water is therefore heavier than the warmer Atlantic waters above it. This abrupt shift in the environmental conditions generally has a direct or indirect impact on animal life. One of the key factors is that the deeper we go, the less food is available for sea floor living organisms, and this have a major influence on the species composition.



The long-spine slate pen sea urchin (*Cidaris cidaris*) was observed quite frequently on Storegga during our survey of the sea floor off the coast of Møre. This is a strange sea urchin with apparently easily movable large pencil-like spines. Small crustaceans often ride as stowaways on the tips of its spines. The species is found in deep waters from the west coast of Africa up to Norway, where it has been recorded off Mid-Norway by MAREANO.

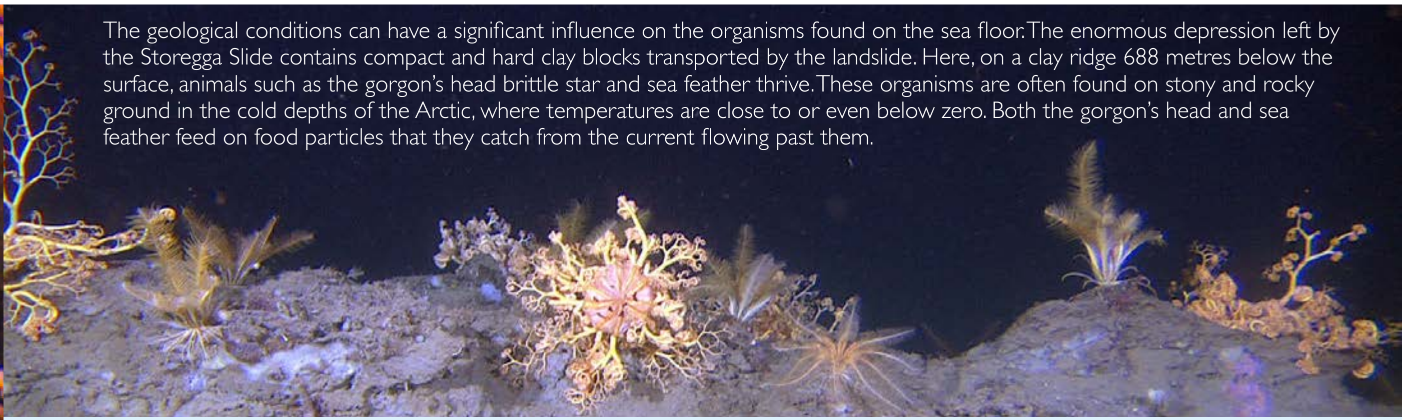
This hydroid (*Corymorpha*) also likes the cold, deep waters along the shelf break in the Norwegian Sea. The tentacles have stinging cells that help to catch particles that come drifting past in the bottom currents. *Corymorpha* are a kind of polyp in the phylum Cnidaria. We found this specimen at a depth of almost 1000 meters off Mørebankene.



On MAREANO cruises we have observed the deep-sea pen *Umbellula encrinus* in deep waters on the continental slope off the Lofoten Islands and Troms, as well as at Skjoldryggen. The species likes mud, can reach a height of two metres and attaches itself to the seabed with a "foot" up to 15 cm deep. The deep-sea pen is vulnerable to external pressures such as trawling.

The bristle worm *Calibregma hanseni* is one of several new species discovered by MAREANO. It was scientifically described in 2014 in a joint project involving the Norwegian University of Science and technology (NTNU), the University Museum of Bergen and the Norwegian Institute for Water Research (NIVA). *Scalibregma hanseni* is named after Gerhard Armauer Hansen, the doctor from Bergen who discovered the bacteria that cause leprosy. Hansen was also a knowledgeable marine zoologist who studied bristle worms. Photo: Katrine Kongshavn, University Museum of Bergen.

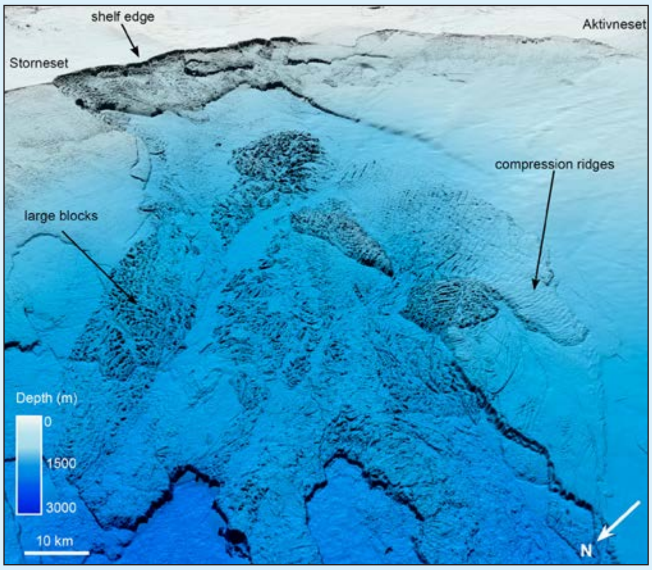
The tube-dwelling anemone *Cerianthus vogti* is typical of deep and cold areas, where it sits submerged in the seabed mud, waiting for a morsel of food to come drifting past, preferably less than an arm's-length away.



The geological conditions can have a significant influence on the organisms found on the sea floor. The enormous depression left by the Storegga Slide contains compact and hard clay blocks transported by the landslide. Here, on a clay ridge 688 metres below the surface, animals such as the gorgon's head brittle star and sea feather thrive. These organisms are often found on stony and rocky ground in the cold depths of the Arctic, where temperatures are close to or even below zero. Both the gorgon's head and sea feather feed on food particles that they catch from the current flowing past them.

Submarine landslides

The shelf break and the upper part of the continental slope off central Norway have experienced numerous underwater landslides. The most famous one is the Storegga Slide, which occurred around 8 200 years ago, generating a huge tsunami across the North Atlantic. Traces of this tsunami can be found in lake sediments on the west coast of Norway, and in several areas along the North Atlantic. On the blocks in the upper part of the Storegga Slide, MAREANO has observed corals as well as a number of species that like deeper waters, such as the gorgon's head brittle star. Large landslides influence the fauna on the seabed, because the packed clay and blocks of sediments provide a home for sessile species that normally attach themselves to stony and rocky surfaces.



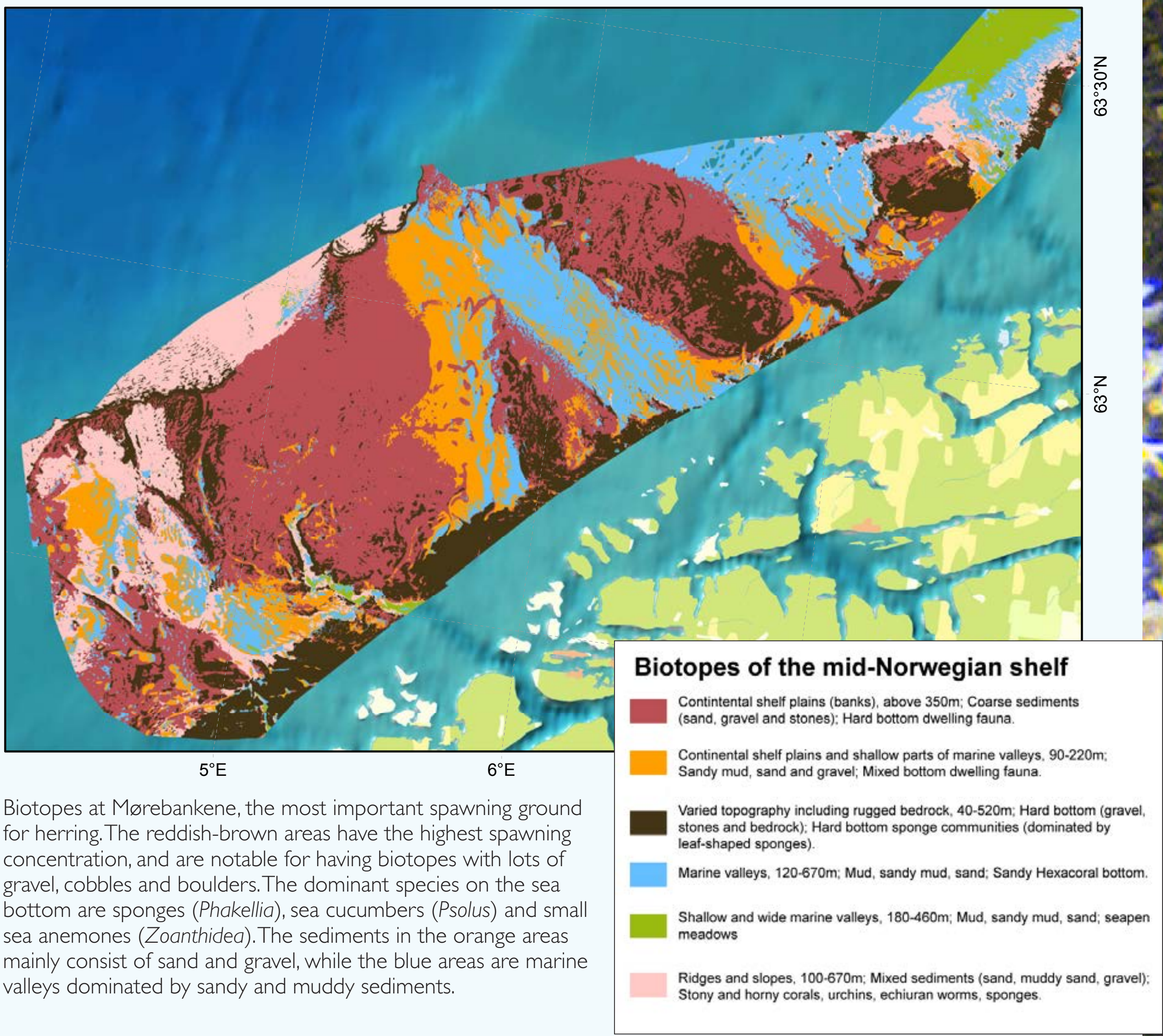
The shelf break outside Mørebankene follows the upper headwall of the Storegga Slide. In several places the headwall is over 100 metres high, creating an abrupt divide between the relatively flat continental shelf plain and the continental slope. The topography of the bowl left by the landslide is complex and dramatic, with ridges, hundreds of blocks and steep cliffs.

Biotopes at Mørebankene

The results and information generated by the MAREANO programme are used to divide the sea floor into different biotopes. Information about the landscape, bottom type and distribution of species is used to predict the extent of biotopes with the help of advanced computer models. Biotopes are defined as recognisable combinations of the physical environment and bottom-dwelling fauna.

Biotope maps are one of several main products generated by the MAREANO programme. They provide the management authorities with information about which areas are of particular value, or require special management measures. The biotope map for Mørebankene is a particularly good example of the wider ecological relevance of the biotope maps. The bank areas (see figure) which are identified as a specific biotope type are also an important spawning area for the Norwegian spring spawning herring, who favour the sandy gravel and associated conditions on the banks at this important stage in their life cycle.

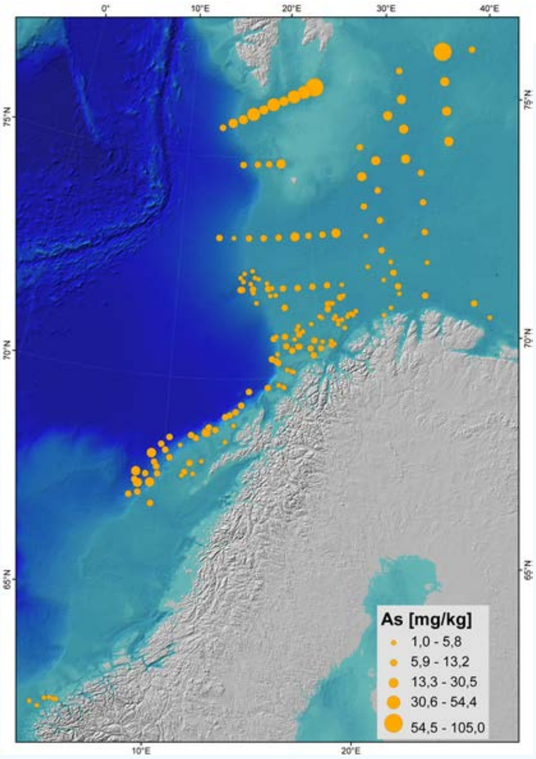
Maps showing the predicted distribution of biotopes are presented alongside maps showing the predicted extent of selected vulnerable habitats at www.mareano.no.

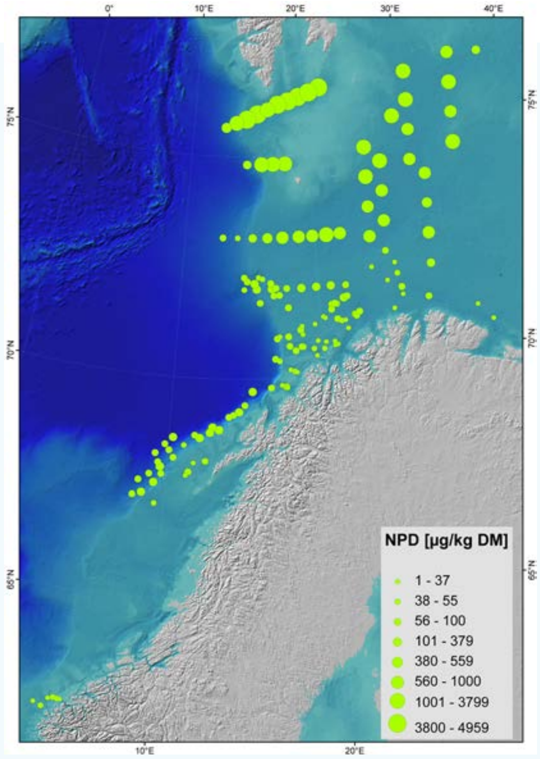


Biotopes at Mørebankene, the most important spawning ground for herring. The reddish-brown areas have the highest spawning concentration, and are notable for having biotopes with lots of gravel, cobbles and boulders. The dominant species on the sea bottom are sponges (*Phakellia*), sea cucumbers (*Psolus*) and small sea anemones (*Zoanthidea*). The sediments in the orange areas mainly consist of sand and gravel, while the blue areas are marine valleys dominated by sandy and muddy sediments.

Is the sea floor polluted?

The MAREANO programme collects sediment core samples from the seabed. Sediment analyses provide information about both current levels of pollution and changes over time, particularly during the past 100–150 years since industrialisation began. The sediment cores are brought up in tubes and are then cut into 1 cm slices to determine the age of the sediments. This is done using the lead-210 isotope (^{210}Pb), which has a half life of 22.3 years, and the carbon-14 isotope (^{14}C). The analysis of more than 40 of these core samples has revealed that each centimetre can be equivalent to at least 5–20 years of sedimentation. This means that the top 20 centimetres may represent the sedimentation from the past 100–200 years. The deepest layers of sediment in a 50 cm core sample may be several hundred, or even several thousand, years old. Core samples are analysed for a number of environmental pollutants, such as heavy metals, polycyclic aromatic hydrocarbons (PAHs) and other organic pollutants. This chemical analysis provides us with important information on background levels. For instance, the high arsenic levels south of Svalbard are not necessarily linked to human pollution, but may instead come from the bedrock on Svalbard, which means they should be classified as





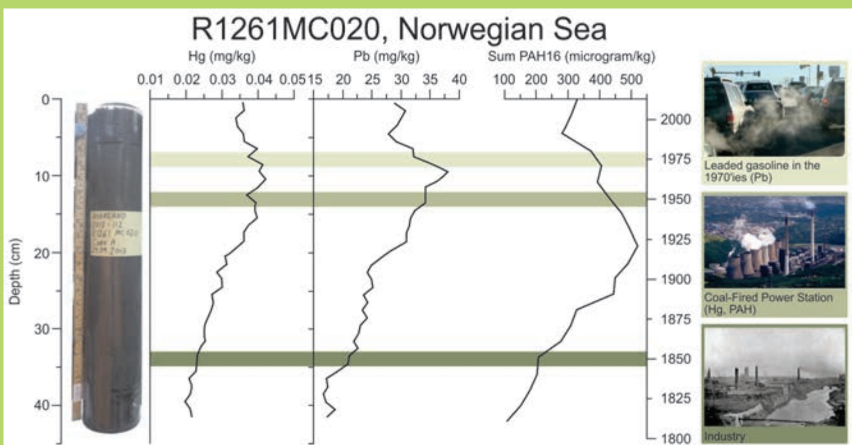
the natural state (background level). The same applies to some petroleum-derived hydrocarbons (some kinds of PAHs such as NPD) in certain areas of the Barents Sea.

The levels of heavy metals and organic compounds are generally low and consistent with background levels. So there is little evidence of pollution in the open seas. There are elevated levels of PAHs, lead (Pb) and mercury (Hg) on the seabed surface compared with the background levels deeper in the sediments (see figure). This is due to human emissions over the past 150 years. This can be attributed to industrialisation from the mid-19th century onwards, resulting in greater consumption of fossil fuels, and particularly coal.

FACT BOX

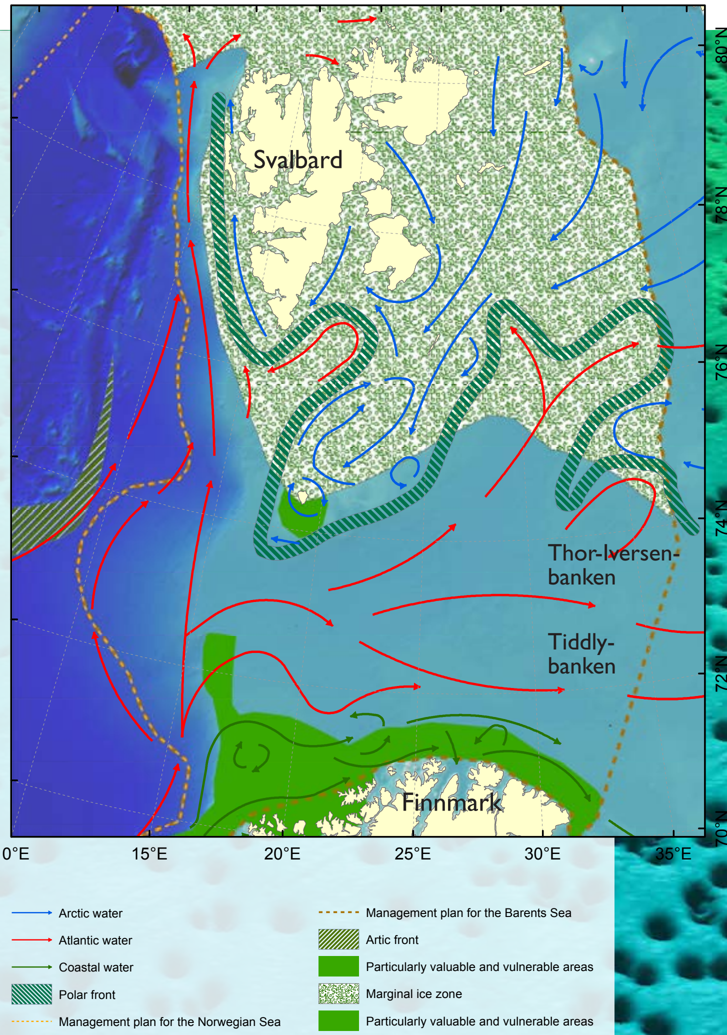
Environmental condition of seabed sediments

The core sample from station R1261MC020 in the Norwegian Sea shows a typical example of the environmental condition of the areas surveyed. The core sample, which is around 40 cm long, shows how mercury, lead and PAH levels have changed over the past 200 years. The three substances become more prevalent from the mid-19th century onwards, in parallel with industrialisation and the growing use of fossil fuels. Lead levels have fallen since the mid-1970s, which can be explained by the ban on leaded petrol in many industrialised countries. Mercury levels are still elevated. In the case of PAH, which is often produced by burning organic material (coal, wood, various fuel types, etc.), levels have fallen slightly in the upper, youngest sediment layers since around 1950. This may be because coal consumption has fallen in the western world over recent decades.



THE BARENTS SEA

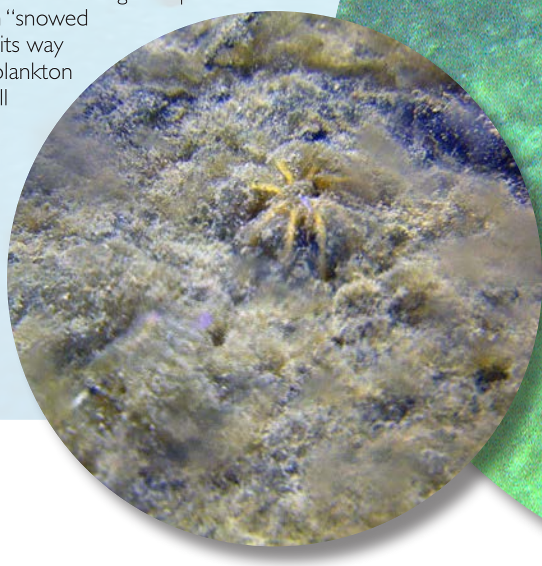
The Barents Sea differs from other Norwegian waters. It is mostly shallow, around 200–350 metres deep, with a mix of relatively large shallow banks and some deeper areas. This is where the warm Atlantic waters meet the cold Arctic waters, at a transitional zone known as the Polar Front. Large parts of the Barents Sea are also covered in sea ice for extended periods. The Barents Sea is rich in nutrients, is highly productive, and is an important fishing area.

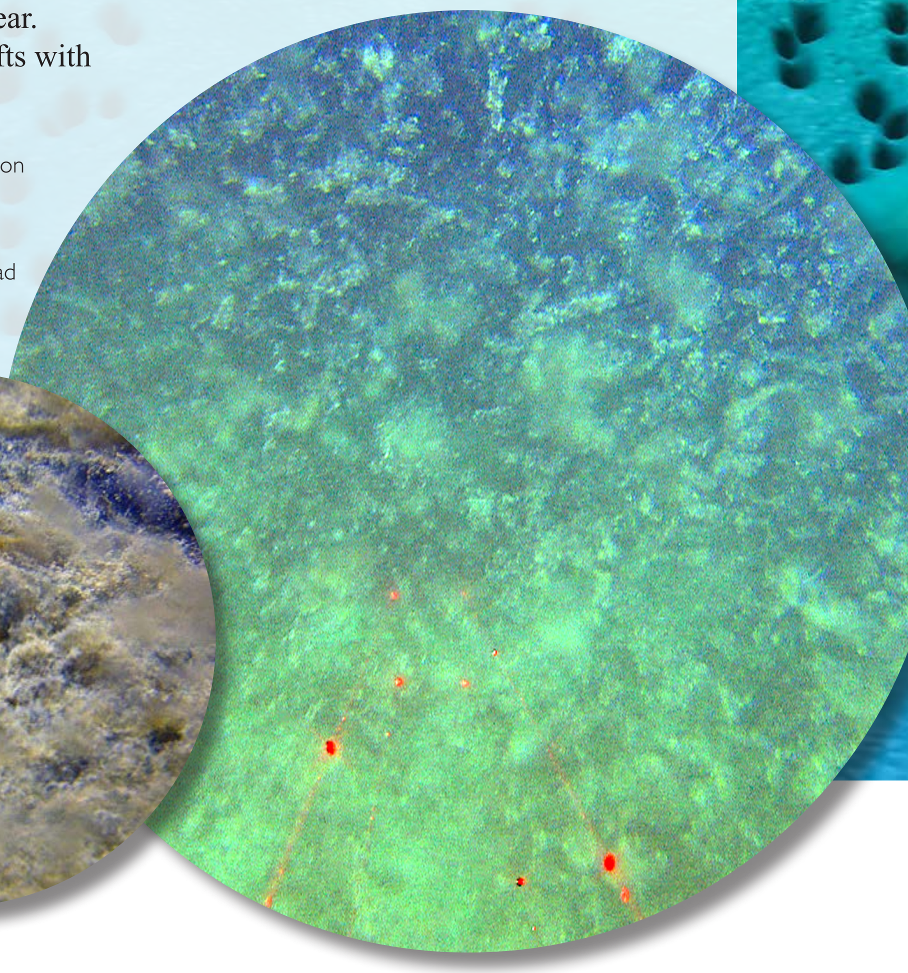


A sea of food

The ocean currents supply nutrients to the Barents Sea that are concentrated during the winter, and when the sun returns, a huge phytoplankton bloom begins. The blooming follows the retreating ice as the Sun's heat pushes the ice edge northwards, opening up new areas where the algae can grow. The resulting production of plankton only lasts for a few weeks, but it provides the basis for life in the far north until the algal again blooms the following year. Much of the plankton produced drifts with

"Marine snow" filmed by a MAREANO expedition in the central Barents Sea in June 2015. This phenomenon has not previously been filmed in the Barents Sea. The picture on the left shows enormous quantities of "snow", consisting of dead organic material, falling to the bottom after the plankton bloom in the upper water layers. Note how a five centimetre-long sea spider that has been "snowed under" fights its way through the plankton remains (small picture).





It is rare to see a yellow sea anemone on the mud banks of the Barents Sea. Sitting anchored to a cobble and hunting for scraps of food carried by the current, it stands magnificently above its neighbours. The feeding crowns of several sea cucumbers can be seen emerging from the sediments, while round colonial sea squirts are scattered across the seabed. The distance between the red laser points is 10 cm.

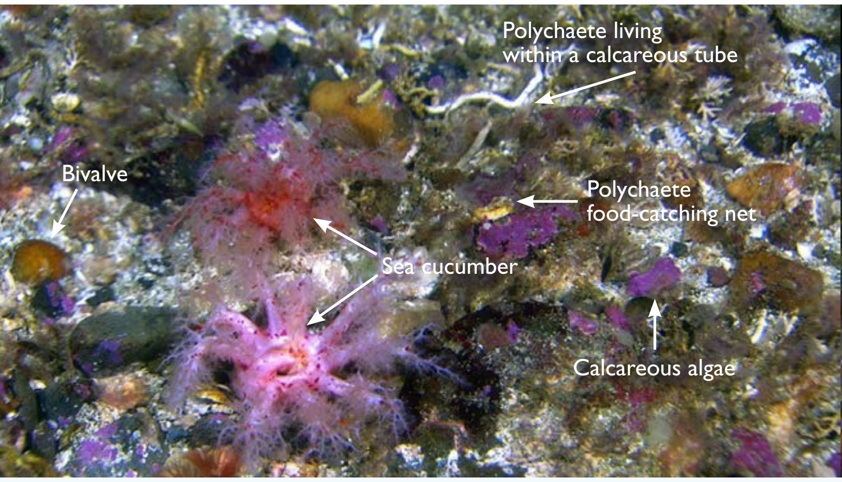
the currents and eventually sinks to the bottom as a kind of marine "snow", providing a rich diet supplement for the animals on the sea floor. These animals are in turn eaten by larger animals, such as fish. A large proportion of the energy is therefore recycled back up the water column as food for fish that are then eaten by whales, seals and seabirds – and not least as nutrients that allow the production of new plankton.

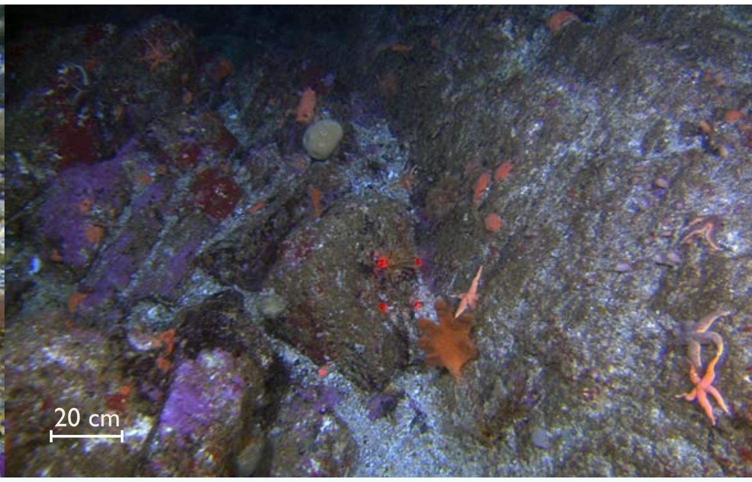
The seabed varies from old bedrock to younger sediments formed during and since the last ice age. Clear traces of the ice age can be seen on the relatively flat continental shelf plain, including deep furrows left by enormous icebergs that ploughed into the bottom.

In the shallowest areas the sediments are generally coarser and more gravelly, because the bottom currents have often removed the finest particles. In the deeper areas further from land, by contrast, the sediments contain more silt and clay, and there is less variation.

At the shallow stations near the coast of Finnmark (up to 20–30 km from land), gravel, cobbles and bedrock are common. In some places, the bottom is sometimes partly covered by hydroids, sea squirts and sponges.

The colourful and varied community of animals and plants found in shallow waters often forms a "mosaic" that reflects variations in the bottom type. Some animals need to bury themselves in a muddy bottom, and eat pure mud, while others attach themselves to stony bottoms, filtering food particles from the water. And of





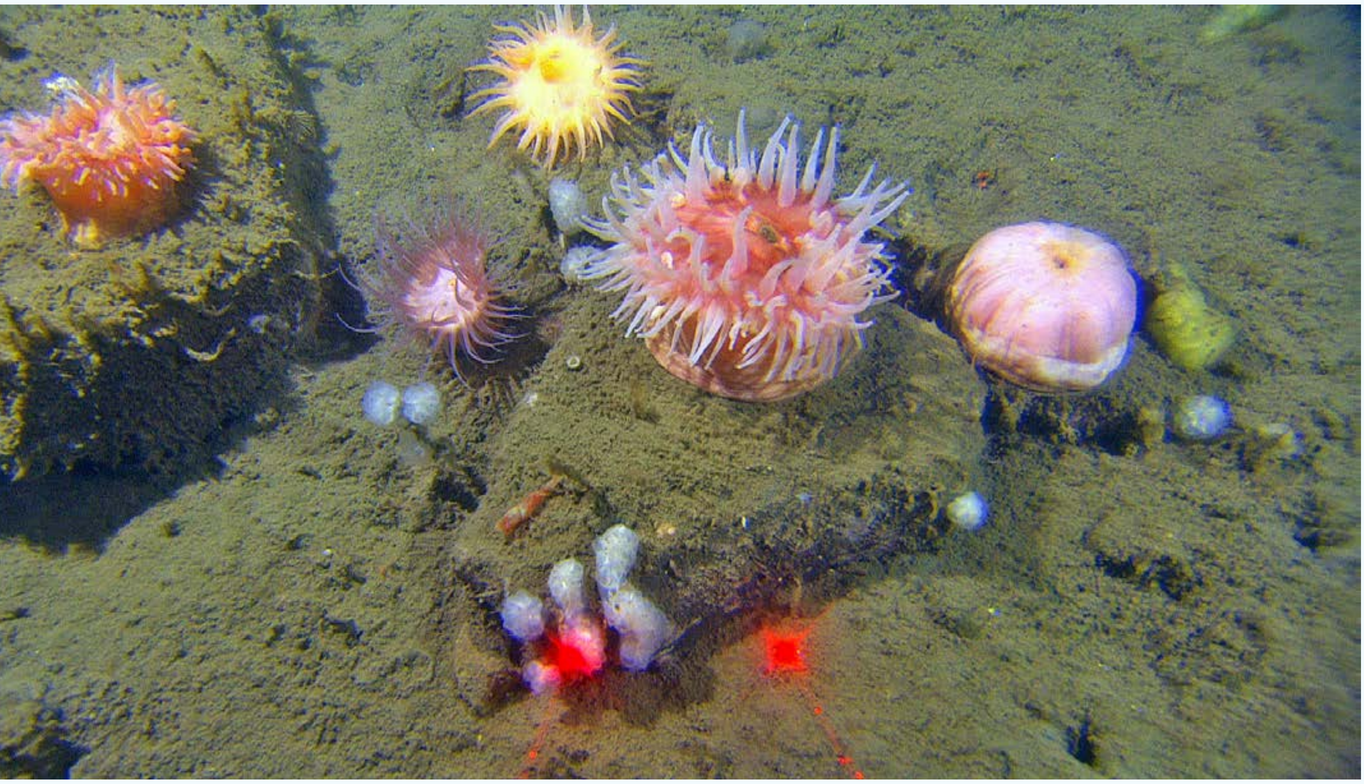
Gravel bottom with crushed shells off Finnmark. The gravel is teeming with life that is hard to detect. Here the most visible groups of animals have been marked. Note the two sea cucumbers buried in the seabed, with only their feeding tentacles visible.

The bottom type can vary significantly within small areas. This can be clearly seen in the picture above, from the coastal waters off Finnmark, where a mixture of cobbles and boulders, sand and mud has been deposited in depressions in the bedrock.

course predators lie in wait, including starfish and some species of bristle worms and snails.

Farther out in the Barents Sea there are different types of animals from those found on the hard bottom nearer the coast. On the large mud flats, e.g. around Tiddlybanken and Thor Iversen-banken, the seabed mainly consists of sandy mud and muddy sand. This creates a good habitat for several species of bristle worms, which are the dominant animals here. In these areas, most of the animals on the sea floor are buried in the mud, which makes them invisible on our video recordings, but there is nevertheless plenty of different species and lots of organic material is produced. Many of the animals feed on mud, while others filter the water after transporting it to their feeding organs through long tubes reaching up to the surface of the sediments. The latter group includes various species of mussels, while a number of animals e.g. bristle worms have feeding crowns that barely emerge from the sea floor, catching organic particles from the bottom waters.

A beautiful "bouquet" of deep-water soft corals at a depth of 70 metres off Fruholmen lighthouse in eastern Finnmark.

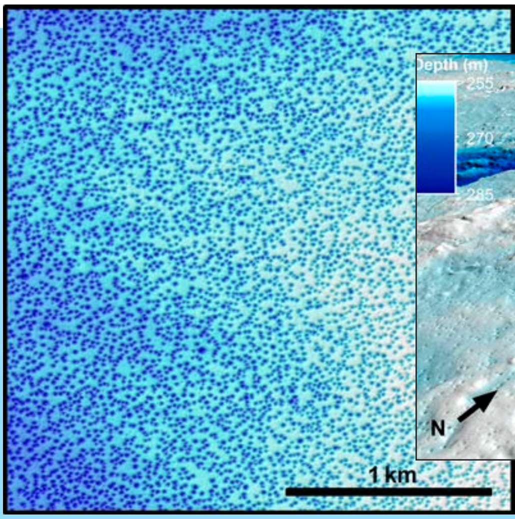


On the shallowest banks in the Barents Sea there are "islands" of coarser sediments with cobbles and boulders, where creatures such as anemones can attach themselves. Photograph of sea anemones taken near the large mudflats of Thor Iversen-banken, with colonial sea squirts at the bottom of the picture. The sea anemone on the right has closed up, probably to digest some food that it has caught with its tentacles. The tentacles have stinging cells to weaken its prey. The red points produced by the video rig's laser are 10 cm apart.

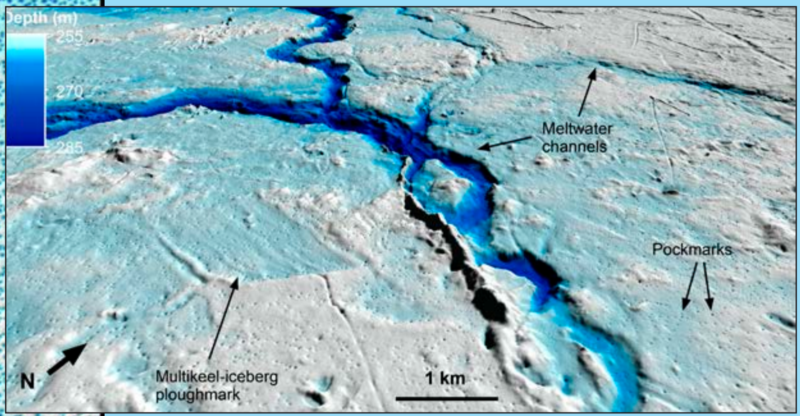
The sediments in the central Barents Sea are relatively uniform, but conversely the terrain is highly varied. The various land forms bear witness to dynamic geological processes lasting thousands of years, or even hundreds of millions of years. One example of this can be found in the eastern part of the Norwegian Barents Sea, where the sea bed is reminiscent of a sieve or a pancake being cooked, with countless small depressions, known as pockmarks. Pockmarks are formed when water and/or gas seeps out from the sea bed. Most of them were probably formed during a period lasting just a few centuries after the last ice age.

Although the landscape in the central Barents Sea is less dramatic than out at the shelf break, there are nevertheless interesting traces of bygone

The soft sediments in the Barents Sea result in large trawl samples – up to 1600 litres of mud weighing around two tonnes. The biologists got plenty of exercise digging the samples into buckets before washing and sieving them to find the many different creatures hidden in the mud. Photo: Anne Helene Tandberg.



In the eastern Barents Sea there are countless pockmarks on the seabed. Each pit is approximately 20 metres across and 2-3 metres deep.



The meltwater channels are the most conspicuous sea floor features in the area. We can also see pockmarks and iceberg ploughmarks.

times. Here too there is evidence of the ice age, including traces of the meltwater that drained from the glaciers out into the open seas. The meltwater carried sediments with it, that contributed to the erosion of large channels and river valleys on the sea floor. Occasionally there are coarse sediments in the channels, probably deposited by the

FACT BOX

Salt domes and the Barents Sea landscape

The landscape at the bottom of the Barents Sea has been formed by many different geological processes. Apart from the ploughmarks left by icebergs, it is worth noting the salt diapirs that rise up to the surface from deeper geological layers. During the warm Permian period (approximately 300–250 million years ago), water evaporated from shallow marine basins, leaving thick layers of salt. Due to its low density, the salt rises up through the sediment layers as pillar or mushroom-shaped towers known as salt diapirs. When salt diapirs rise, they push the sediments above them aside. The sediment layers become offset, creating faults. This in turn creates traps for oil and gas, which is why information about salt diapirs is of interest to the oil industry. In some places it is easy to identify the salt diapirs on the sea floor. One such example is Hjelmen ("The Helmet"), which MAREANO surveyed in the summer of 2015. Videos from that expedition show that the seabed around Hjelmen consists of soft muddy sediments. The slopes, on the other hand, are made of coarser and harder sediments that gradually become coarser towards the top. At the top the hard salt layers can sometimes be seen, but usually they are covered by a thin layer of sediments.

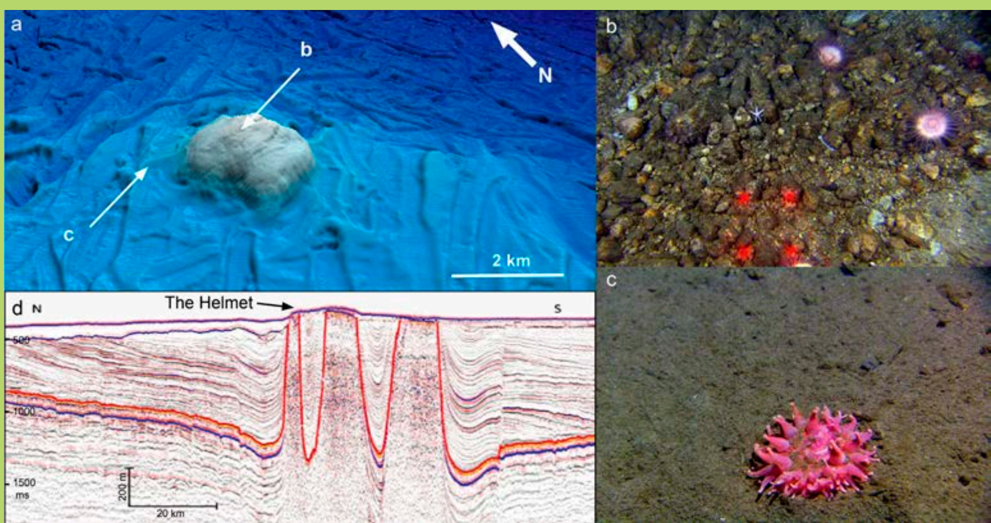
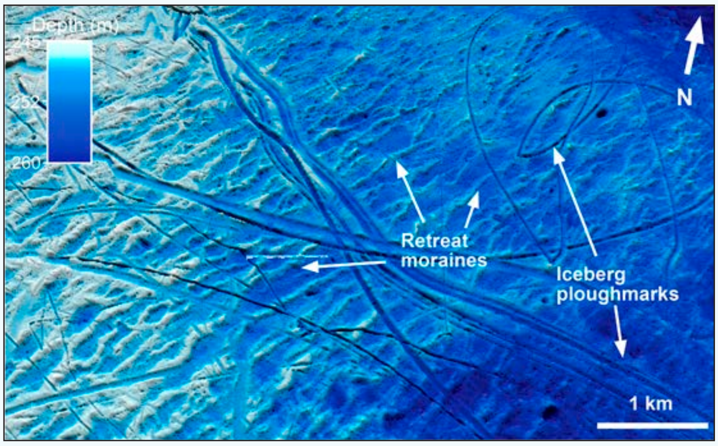
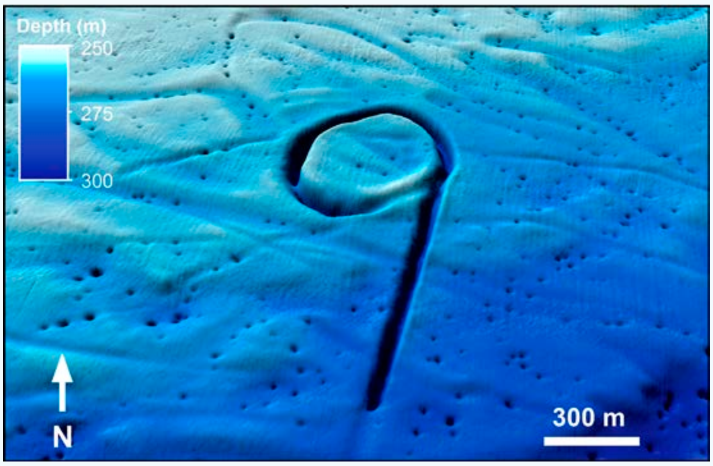
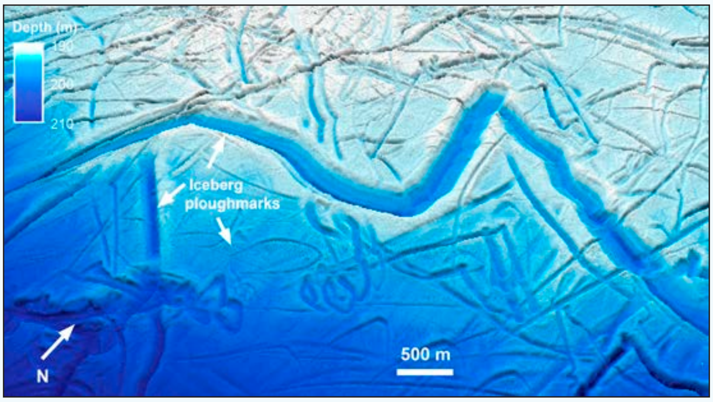


Figure: a) Hjelmen is a hillock formed by a salt diapir pressing up through the sea floor. The furrows are ploughmarks produced at the end of the last ice age by drifting icebergs ploughing into the seabed. b) Gravel with pink anemones on the top of Hjelmen, at a depth of around 170 m. c) A single anemone on the soft silty clay bottom at the foot of Hjelmen, at a depth of around 215 m. d) The Norwegian Petroleum Directorate's seismic data for this area shows clearly that Hjelmen is the top of a salt diapir rising up from the deep and pushing the overlying sediment layers aside.



Numerous moraines were pushed up by the ice sheet in the Barents Sea during times of still-stand and/or slight advances at the end of the last ice age.



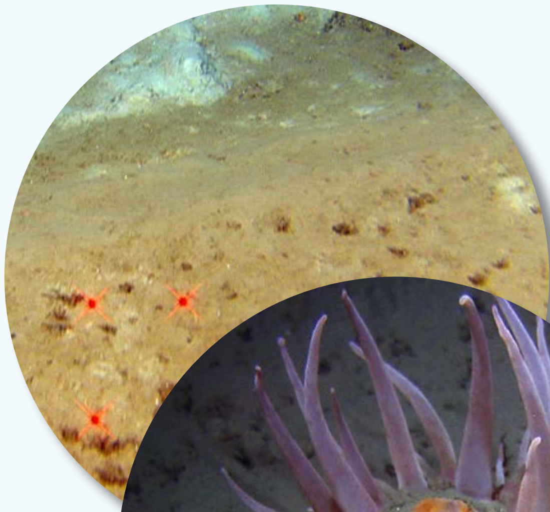


3D terrain model (5 m resolution) showing iceberg ploughmarks. Top: Ploughmarks in the shape of a nine, 250-260 m below the surface. The "nine" is 1 km long, 60 m wide and 8 m deep. Bottom: Ploughmarks in the seabed. Ploughmarks vary greatly in appearance: some are straight lines, while others appear like doodles on the sea floor.

meltwater rivers under the ice. Today many of the channels act as deposition basins – depressions where sediments collect. The seabed in the channels mainly consist of soft sediments that provide a good habitat for digging organisms such as snails and worms. However, the sessile animals living at the sediment surface are not very different from those found around iceberg ploughmarks.

Periodically, the ice formed moraines by pushing together sediments at the ice margin, rather like a bulldozer. In some places you can see row upon row of these ridges. They are the result of relatively small advances at a time when the ice sheet was generally retreating, towards the end of the last ice age.

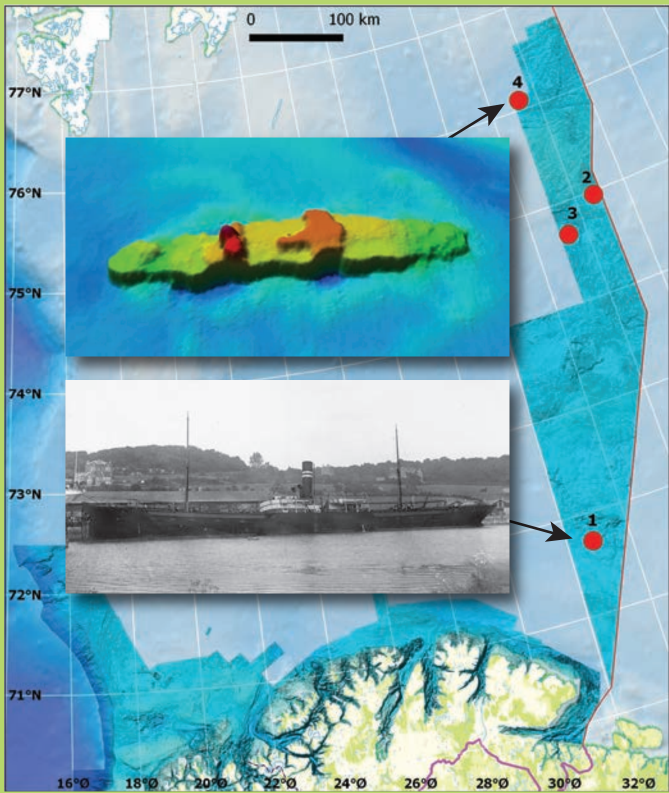
Some sediments were transported away from the glacier front by icebergs. Icebergs that calved from the glaciers set out on long and tortuous journeys, leaving ploughmarks where they dug into the seabed.



FACT BOX

Wrecks on the sea bottom

While collecting bathymetry data using multibeam echosounders, four wrecks have so far been found at the bottom of the Barents Sea, at depths of 200-300 metres. The positions of the wrecks are shown on the figure on the right. The four wrecks are 120–140 m long, 15–21 m wide and 13–16 m high. It is very likely that the three wrecks farthest north are from the Murmansk convoys in the Second World War, while the fourth one is from the First World War.



Source: Erling Skjold, Norwegian Shipwreck Register

Figure: Shaded relief map of the sea floor in the Barents Sea. Four wrecks have been drawn in and numbered with the date they were measured. The top picture shows the northernmost wreck in the terrain model (based on depth points obtained by echosounder). The bottom photograph shows the DS Iolo before it was sunk. This British vessel was approximately 112 metres long and 15 metres wide. It was loaded with 5 200 tonnes of coal when it was seized by the German submarine U-46 on 11 October 1916. After being inspected, it was torpedoed and then subjected to artillery fire. The submarine took the whole crew on board and handed them over to a Norwegian patrol vessel at Vardø. The DS Iolo is probably the southernmost wreck.

FUTURE ACTIVITIES

The future of the MAREANO programme is closely tied to the management plans for the Barents Sea, Norwegian Sea and North Sea, and will depend on the government's priorities with respect to building up knowledge to support good management regimes for Norwegian waters. The needs of the management authorities have largely been met by the work done so far with respect to the continental shelf and slope. The deeper waters have not yet been so extensively studied. Globally, there is a lot of interest in exploiting deep-water biological and geological resources. However, we know relatively little about deep-water ecosystems and how vulnerable these are to human activities.

There are also big gaps in our knowledge about the Arctic Ocean. While there is significant international interest in exploiting the resources there, many people are concerned about the potential impacts on its ecosystems. By filling the knowledge gap, the MAREANO programme should be able to make a valuable contribution to the sustainable management of the natural resources in both deep-sea areas and the Arctic Ocean. This should provide a scientific basis for environmental considerations to be balanced with the desire to exploit geological and biological resources.

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