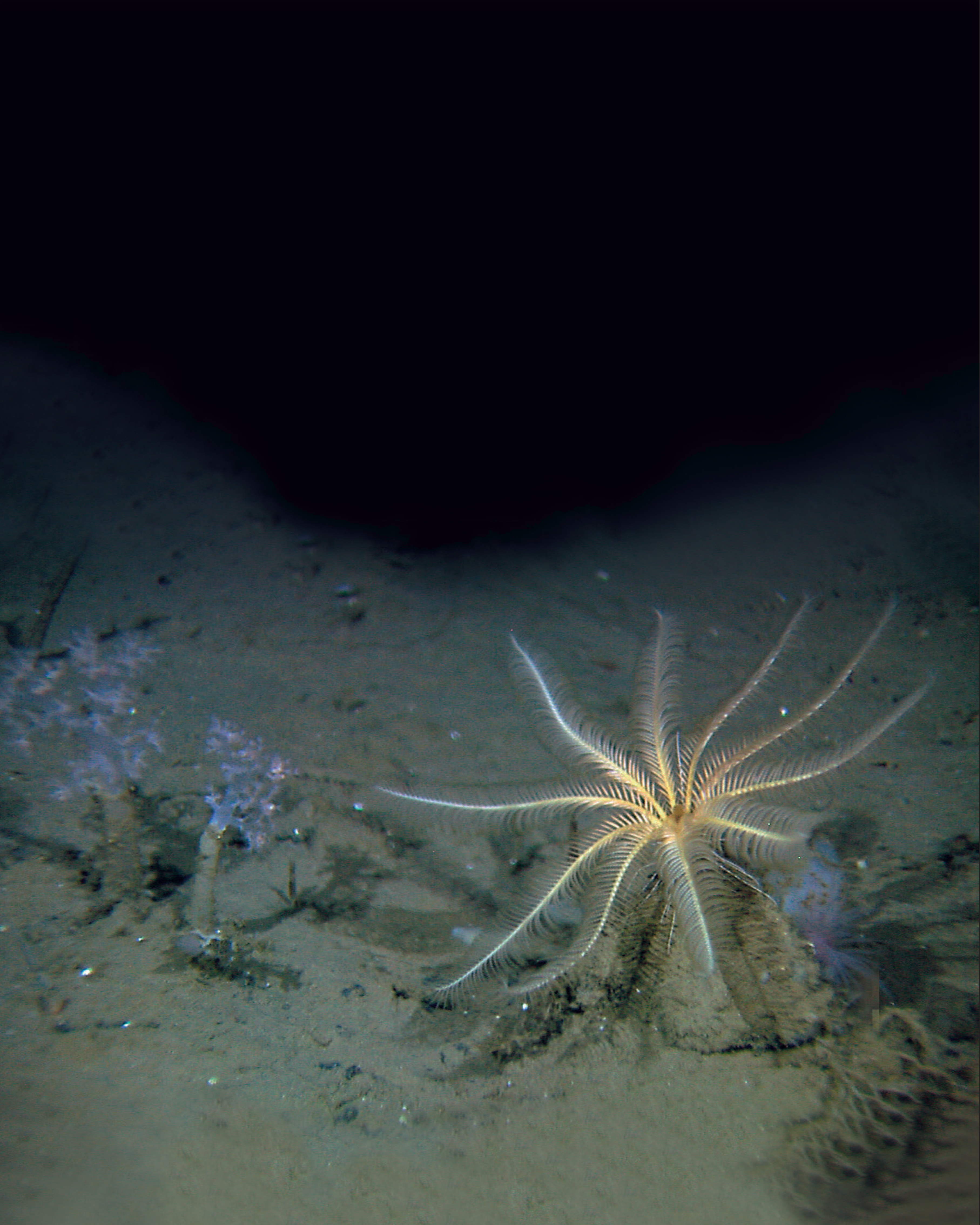

OCEANOGRAPHY, GEOLOGY AND FAUNA AT THE BOTTOM OF THE BARENTS SEA – REGIONAL SURVEYS

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For more than 50 years, the official monitoring of the Barents Sea has been a Norwegian-Russian collaboration between the Institute of Marine Research (IMR) and PINRO* . Annual meetings have been held between scientists and between the Fisheries Commissions of both countries. Shrimp (*Pandalus borealis*) and the commercial fishery with scientific trawl (bottom trawl) have been part of the bilateral collaboration from the beginning. In 2003, the first attempt was made to analyse the entire demersal catch, not only fish, and a wide range of bottom fauna was recorded.

In the period 2003-2005, standard procedures for the collection and handling of bottom fauna samples were introduced on all research vessels participating in the annual Norwegian-Russian ecosystem survey. In 2006, PINRO and IMR presented the first overview of benthic fauna caught with scientific survey trawl in both the Russian and the Norwegian parts of the Barents Sea and in the so-called Grey Zone. This collaboration has continued every year since and is currently the only long-term monitoring series for annual sampling of bottom fauna by trawl (megafauna) covering the full extent of the Barents Sea.

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[1] *PINRO (Polar Research Institute of Marine Fisheries and Oceanography): IMR's Russian partner in Murmansk.

11.1 THE SEABED – GEOLOGY

During the Ice Age, the Barents Sea was covered by an icecap reaching as far west as the edge of the continental shelf. About 18,000 years ago, the ice started receding and three thousand years later most of the western Barents Sea was ice-free. What happened after the ice pulled back had a considerable impact on the bottom fauna.

The ice started breaking up in Bjørnøyrenna and the Ingøydjupet (figure 1), whereas the retreat was slower on the shallow banks. The ice edge remained close to the coast or in the coastal zone until 12,000 years ago; while the ice melting was substantial. Large amounts of fine-grained sediments (fine sand, silt and clay) were deposited at the seabed or carried out by rivers and transported further by ocean currents. For at least four thousand years, the ocean was coloured grey by sediment particles falling to the seabed like snow, forming mud over vast areas. During this period, large icebergs scraped along the seabed leaving trench-like plough marks on the bottom. The fine-grained sediments were mixed with sand, gravel and cobbles dropped by the icebergs. The resulting sediment layer, which geologists call ”glacio-marine clay”, is thicker in deep troughs and trenches where the ocean currents are weak. The deeper parts of some troughs may have more than one metre of fine-grained sediments that have been deposited over the past 12,000 years. In these sediments there is little ice-dropped gravel. The soft layer of glaciomarine sediments is probably widespread in the southwestern Barents Sea. Over large areas, however, the thickness is reduced to less than 3-5 metres. Small seafloor depressions (so-called pockmarks; 2-3 m deep and 20-40 m wide) are common where fine-grained sediments occur. In general, the layer gets thinner and contains more sand as the water becomes shallower towards the banks. As a rule of thumb, we say that bottom sediments become finer as the water gets deeper. This is due to the fact that bottom currents generally weaken as the

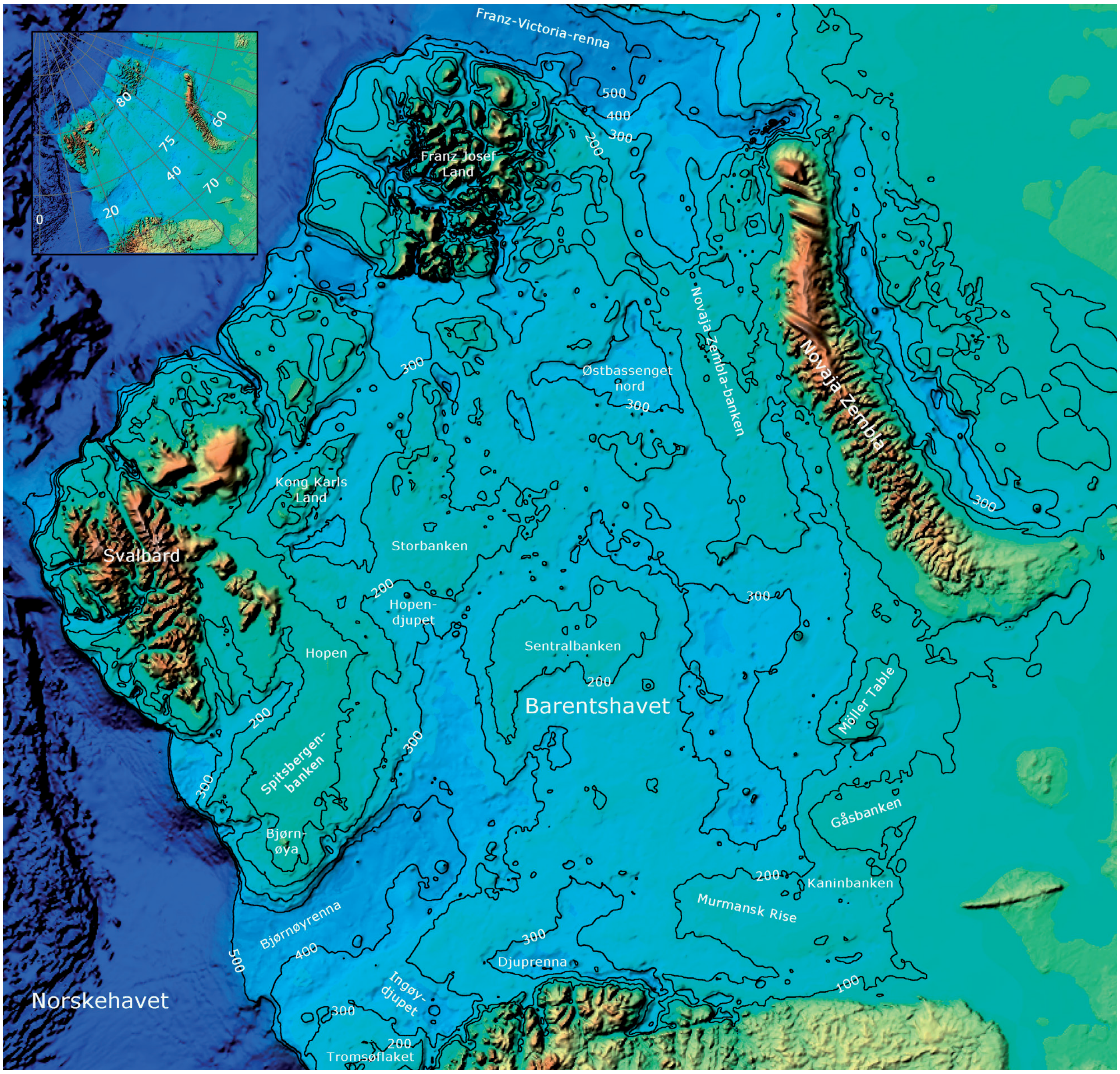


Figure 1. The Barents Sea is a shallow sea with banks and trenches formed by ice flows. The sediments vary from mud in the trenches and troughs to sand, cobbles and boulders on the shallowest banks. This has influenced the living conditions of benthic organisms. See index map for latitude and longitude.

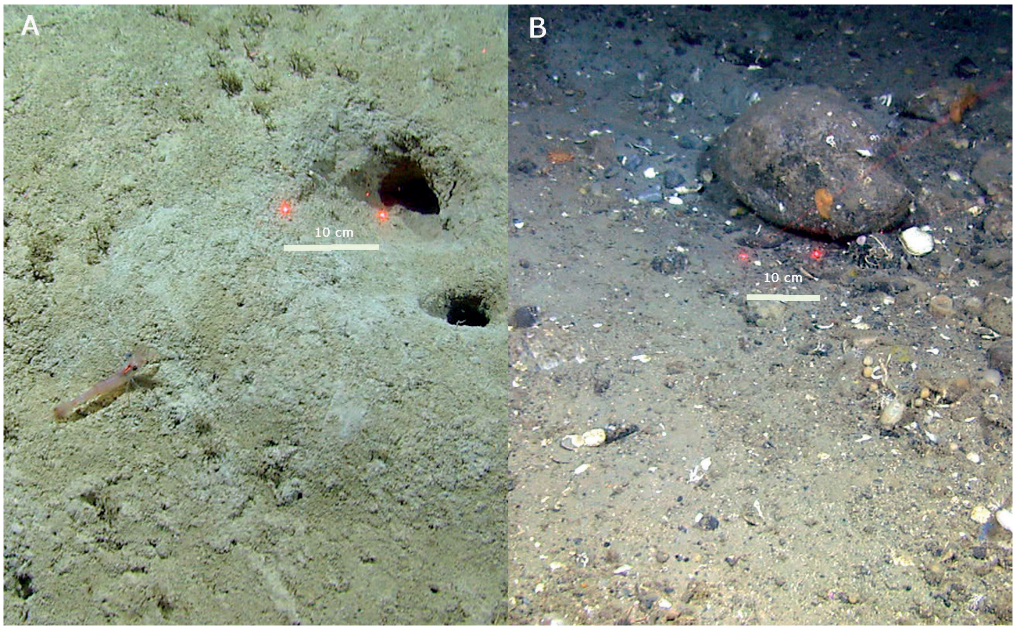


Figure 2. A – silt and clay are common in trenches and troughs. B – sand, cobbles and boulders define the seabed on the shallow banks.

depth increases, particularly in closed troughs and basins. But currents can also be strong in deep water – as is the case in the Sørøydjupet (between Tromsøflaket and the coast), where we find sandy gravel, cobbles and boulders.

High numbers of large and small moraines in shallow areas indicate that the ice has been dynamic and that it, for periods during the retreat, pushed forward again. The morphology of the banks is characterised by a criss-cross of ridges and trenches formed by icebergs that have grounded and ploughed the seabed in various directions. Generally, the sediments are coarser on the ridges (till with cobbles/boulders), while fine-grained sediments transported by bottom currents have been deposited inside the trenches leeward of the dominating current. At the bottom of some plough marks there are so-called pockmarks indicating that the fine-grained sediments are more predominant in parts of the trenches. The shallower parts of the banks are dominated by gravel and cobbles, with localised occurrences of large boulders. A major part of this material was washed out of the till right after the ice melted. Back then, the sea level was far lower than today and the shallowest areas were exposed to wave erosion and strong bottom currents. The coarser material (figure 2) forms a skin that has protected the seabed from further erosion. The slightly greater depths (Tromsøflaket below 200 metres) are dominated by sandy gravel or gravelly sand. This layer is rarely more than 25 centimetres thick and in patches the underlying till is left bare. In some places, fine sand has been washed out and transported by bottom currents to depressions or slopes leading down from the banks.

With the exception of the deepest trenches and troughs, the entire shelf is covered in a thin top layer that is coarser than the underlying sediment. In addition to waves and strong bottom currents – which were particularly active when the sea level was lower – the interaction between sediments, bottom fauna, fish and currents has been particularly important for formation of the top layer. Small amounts of fine particles are constantly stirred up and it did not take much current to form a coarse top layer over a period of 12,000-14,000 years; where fine particles have been transported away and coarser particles have accumulated in the upper stratum. In some places, this coarse layer is only 5-10 centimetres thick, which means that benthic fauna may have lived in the fine-grained sediments underneath.

11.2 THE OCEAN CURRENTS IN THE BARENTS SEA

The Barents Sea is the deepest of the shelf seas located around the Arctic Ocean. The depth varies from 20 metres on the Spitsbergen Bank to almost 500 metres in the Bear Island Trench, the average being 230 metres. The influx of warm, nutritious Atlantic and Coastal Water is the dominating feature of the oceanographic conditions in the southern part of the Barents Sea, which is relatively warm, whereas the northern part is dominated by cold Arctic Water (figure 3).

In the southwest, the Atlantic Water is always warmer than 3°C but, as a whole, Atlantic conditions are defined by temperatures above 2°C. The Arctic Water is always below 0°C. The divide between the two water masses is often referred to as the Polar Front. In the

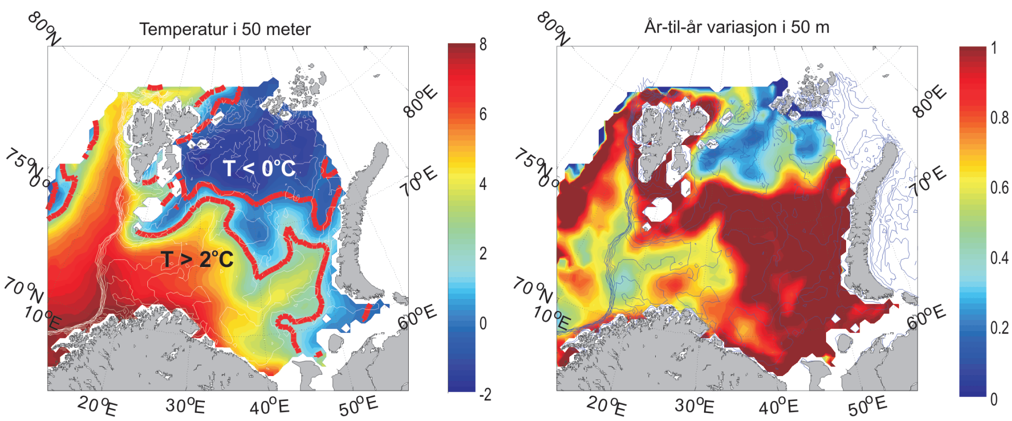


Figure 3. Mean temperature (left) and standard deviation (right) from measurements at 50 meters depth. The standard deviation is a measure of year-to-year variation: red indicates large variations in temperature between consecutive years while blue indicates small variations. The figures are based on data from the period 1970-2008. The maps also show bottom contours.

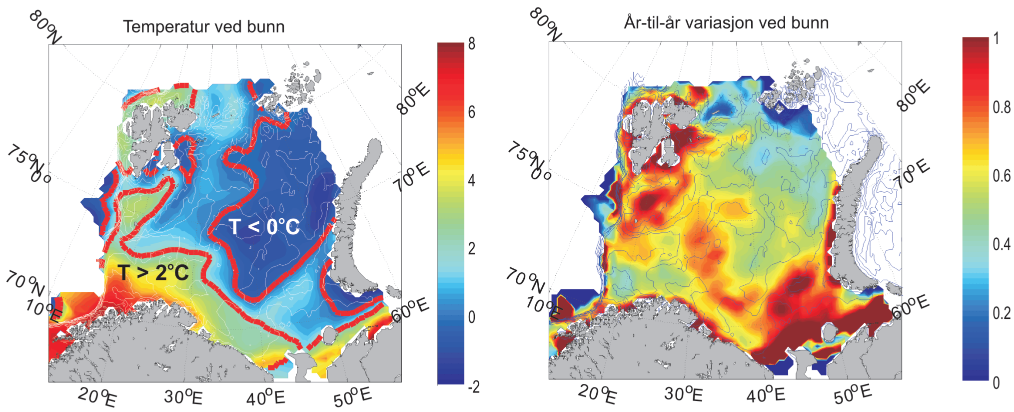


Figure 4. Mean temperature (left) and standard deviation (right) from measurements at the bottom. The standard deviation is a measure of year-to-year variation: red indicates large variations in temperature between consecutive years while blue indicates small variations. The figures are based on data from the period 1970-2008. The maps also show bottom contours.

west, the front is closely linked to the bottom topography and clearly defined; whereas in the east, the position varies from year to year and the front is overall more diffuse.

Variations in temperature and influx of warm water in the west generate large temperature variations from one year to another, particularly in the eastern Barents Sea (figure 3, right). This reflects variations in the position of the Polar Front in the upper part of the water column. As the warm Atlantic Water brings nutrients and zooplankton from the Norwegian Sea, the area at, and south of, the Polar Front is generally productive. If the production in the upper part of the water column reaches the seabed, it has a significant impact on the benthic organisms.

The temperatures at the bottom are quite different from temperatures in the upper 50 metres, the divide at the bottom going more east-west than north-south (figure 4). Atlantic conditions (T>2°C) dominate in the far south while Arctic conditions (T<0°C) dominate in most of the eastern Barents Sea. In the west, a belt with bottom temperatures between 0°C and 2°C runs north. Year-to-year variations at the bottom are generally far smaller than in the upper 50 metres and more localised in specific areas (figure 4, right). In the area around the front, there are large variations, particularly just south of the Eastern Basin. There are also considerable variations on the shallow banks (Spitsbergen Bank, the bank between Kong Karls Land and Egdeøya, the shallow banks in the southeast and the Novaya Zemlya Bank). Otherwise, there are only small year-to-year variations in bottom temperatures and thus stable temperatures in the southwest (Tromsøflaket and the North Cape Bank) and in the northeast.

The current in the Barents Sea is mostly defined by the topography, particularly the bottom currents (figure 5). Consequently, water tends to run alongside slopes, rather than down them, and currents tend to be stronger above the slopes than above the plateaus. Generally, the bottom currents follow the slopes clockwise around the shallow banks and anti-clockwise around the deeper basins. This is not only the case for the Barents Sea but for the northern hemisphere in general.

In the Barents Sea, the warm, salty Atlantic Water is cooled down and becomes heavier, thus sinking towards the bottom. This is a gradual process but additional sinking in particular areas makes the process more efficient (figure 5). Consequently, water coming into the Barents Sea in the upper part of the water column in the southwest leaves the Barents Sea in the bottom part of the water column in the northeast. Because of this – and because the Barents Sea is generally shallower in the east than in the west – the bottom currents are stronger in the east (figure 5).

The sinking of water can have a significant impact on local conditions, as it affects not only the bottom temperatures but also the sedimentation of organic material from planktonic production in the upper water layers. Benthic species feed on this organic material, and thus areas where sinking takes place can give rise to particular benthic biotopes (see chapter 4.2.1).

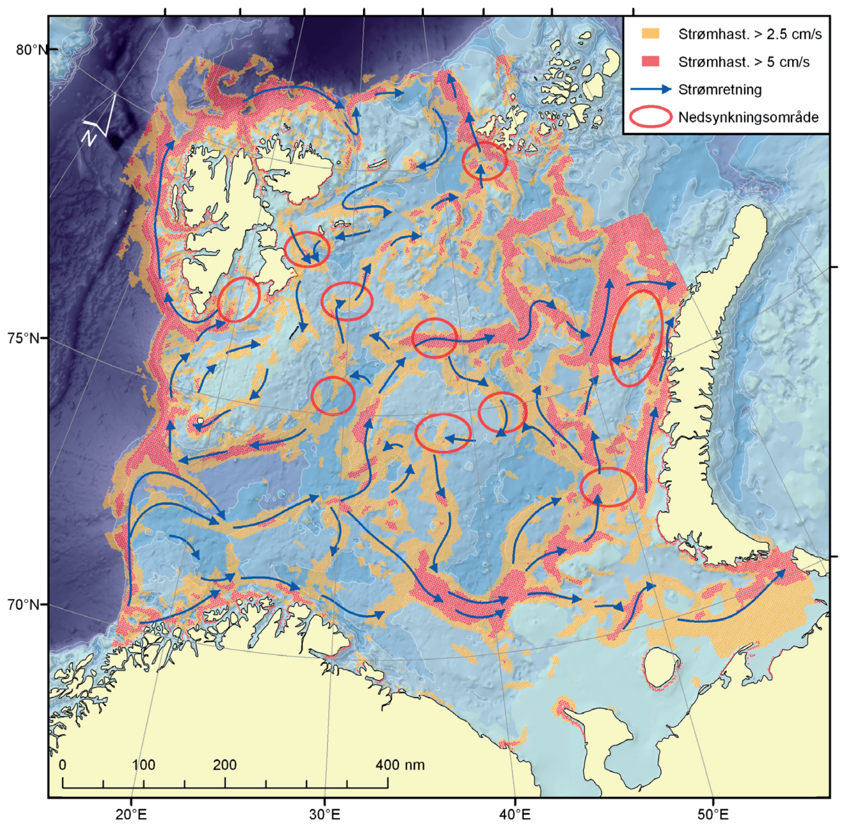


Figure 5. Currents at the bottom and areas where the water is known to sink in the water column. There are currents everywhere but only currents with a mean speed of more than 2.5cm/s have been plotted. The information is taken from simulations with a numeric model.

11.3 BENTHIC FAUNA: LONG-TERM MONITORING AND THE SEARCH FOR ENVIRONMENTAL INDICATORS

The benthic fauna project includes 1682 trawl samples from banks, shelves, basins and trenches taken in Norwegian and Russian waters during the period 2006-2008. All species or groups of species (32 main groups of benthic fauna) have been counted and weighed as a basis for further semi-quantitative handling of the data. The trawl samples have provided considerable information and can be used to estimate variations within individuals and species, indications of biomass and statistical changes in the benthic biotopes in all areas of the Barents Sea. It is important that this work continues in order to detect man-made and/or natural variations in the biotopes.

Benthic Fauna Numbers and Weight

The bottom trawl survey data have been collected in a common Norwegian-Russian database that currently includes information about the distribution and occurrence of 476 benthic species, of which 337 have been identified down to species level. Most species belong to molluscs (e.g. snails, mussels), crustaceans (e.g. amphipods, shrimp, crabs), cnidarians (e.g. hydroids, jellyfish, sea anemones, corals) and echinoderms (e.g. starfish, brittle stars, sea urchins, crinoids). The number of species recorded per location has varied from one to 84.

The largest records of biomass taken by trawl was made at the Tromsøflaket, on the Spitsbergen Bank, west of Storbanken, south of Franz Josef Land, in the East Barents Basin, on the Kanin Bank and along the Murmansk coast (figure 6).

High plankton production in nutrient-rich water masses favours high production of benthic fauna consequently high biomass of benthos. Topographically influenced vertical currents, shallow areas with strong currents and areas where tidal water blend generally provide a stable supply of nutrients to zooplankton. The high benthic fauna biomass on the Spitsbergen Bank, Storbanken and in the area between Kong Karls Land and Franz Josef Land suggests the presence of one or several of these physical factors maintaining the plankton production, which in turn favours a high benthic fauna biomass.

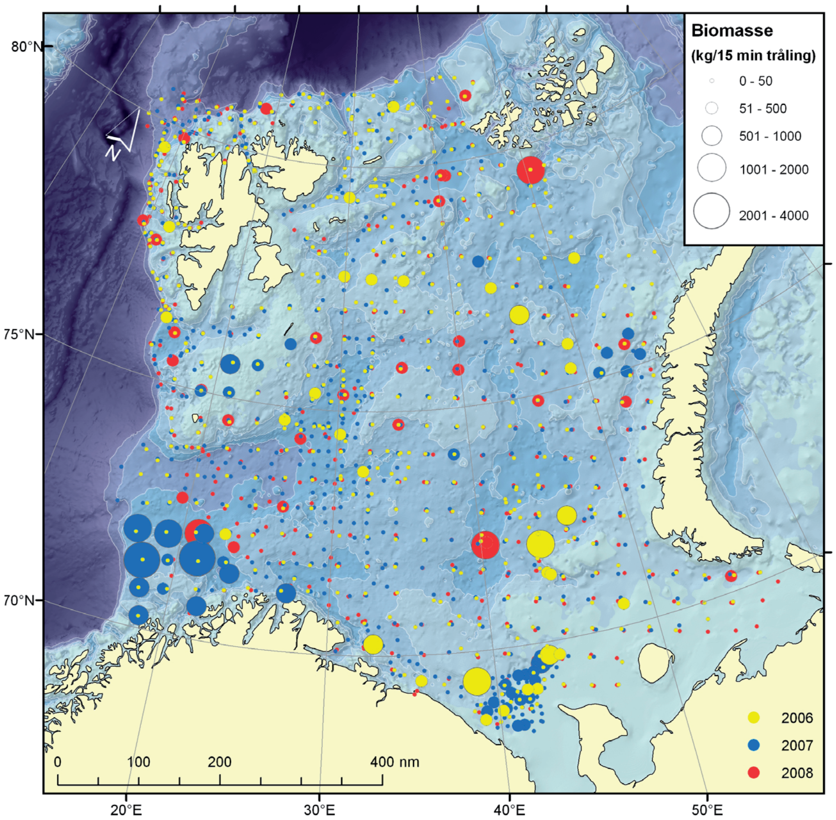


Figure 6. Distribution and biomass of benthic fauna caught by bottom trawl in the period 2006-2008. Total trawled area is about 30 km^2. The colours indicate depths of 400-600 m (dark blue), 200-400 m (blue), and 100-200 m (light blue).

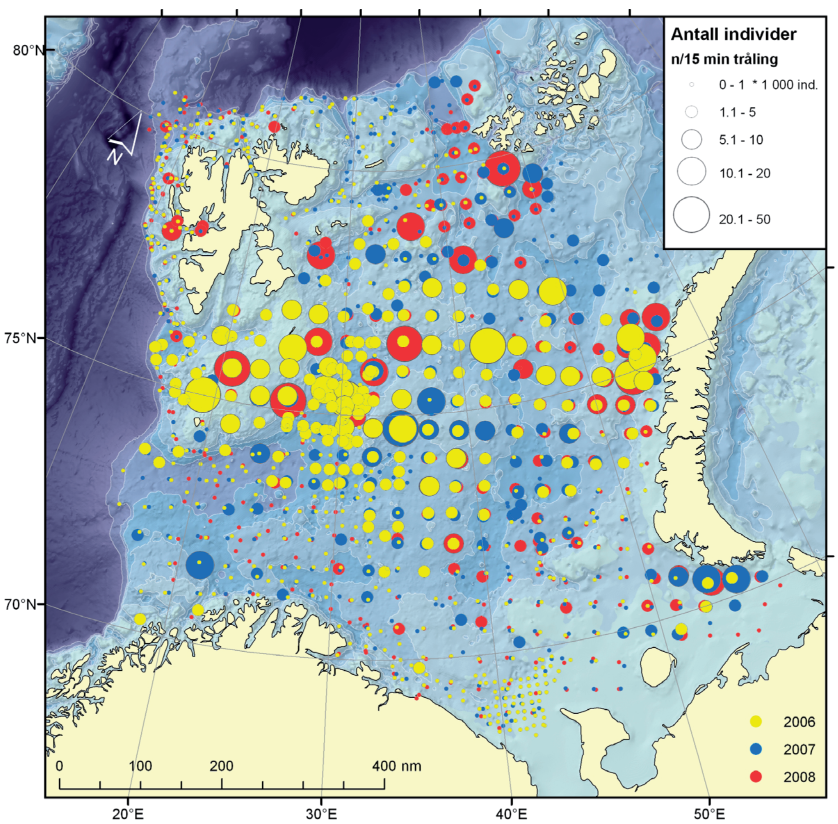


Figure 7. Distribution in number of benthic individuals caught by bottom trawl in the period 2006-2008. Total trawled area is approximately 30 km^2.

The influx of Atlantic water to the Barents Sea brings nutrients and plankton in over Tromsøflaket and further into the Barents Sea along the coast of Finnmark and Kola, making this area productive.

Looking at the number of individuals per trawl sample (figure 7), most high count samples are recorded north of 75°, particularly east of Svalbard, around Franz Josef Land and west of Novaya Zemlya. However, the number of individuals is a problematic term when referring to colony-forming species (e.g. bryozoans and hydroids) or sponges which cannot be counted in the traditional sense of the word because they may be composed of thousands of tiny individuals that it would be impossible to count one by one. In such cases, one colony counts as one individual. Due to this conversion, the number of individuals appearing in the data may be misleading.

Distribution of the Largest Animal Groups

The 2006 survey showed that different animal groups dominate in different parts of the Barents Sea (figure 8). Sponges dominate in Tromsøflaket, in the Norwegian and Russian coastal zone, on the northwestern coast of Svalbard and north of Svalbard (north of 80°).These findings coincide with the distribution of Atlantic water flowing into the Barents Sea and around the western side of Svalbard (figure 3 and 4).

In the southeast, between Cape Kanin and the Murmansk coast, a large biomass of king crab was found in 2006 while snow crab was found in the East Barents Basin (see also figure 16). The central and eastern Barents Sea was dominated by echinoderms.

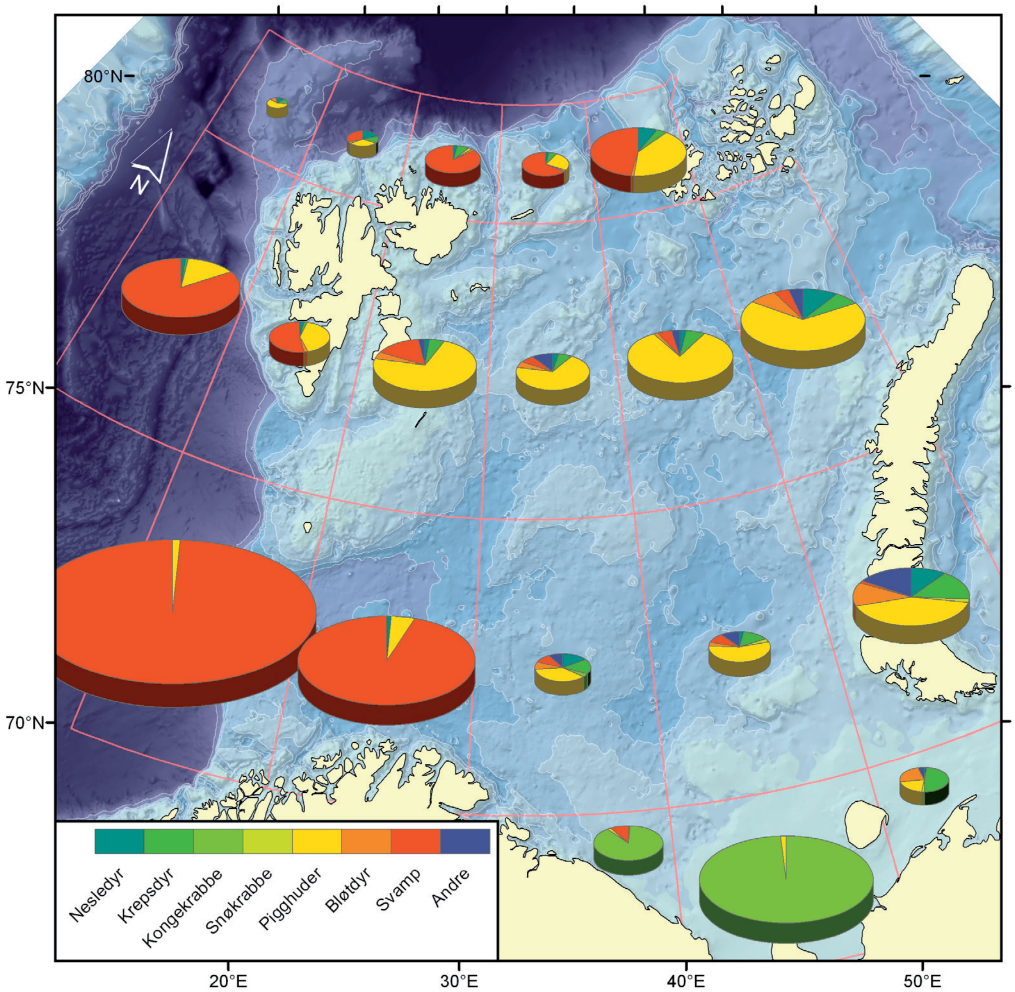


Figure 8. Biomasses from the 2006 survey by main groups of benthic fauna. The colours in the pie charts represent different animal groups (see legend in the bottom left corner): cnidarians (e.g. sea anemone and soft coral), crustaceans (e.g. crayfish, shrimp, lobster, crab), king crab (*Paralithodes camtschaticus*), snow crab (*Chinoecetes opilio*), echinoderms (e.g. starfish, brittle star, sea cucumber, crinoids), molluscs (e.g. mussels and snails) and sponges. "Others" refer to the remaining 30 groups that the benthic fauna was divided into in this survey.

Biotopes

The extensive bottom fauna data from the Barents Sea surveys were analysed by means of advanced statistic computer programmes. The analyses showed that geographically close locations have similar biotopes and can thus be grouped. This result was expected, as the physical environment (e.g. temperature, depth and sediment type) often is similar in neighbouring locations. Conversely, the biology of dominating perennial species says something about the physical conditions in the area. The results show three different biotopes, each with one dominating food source:

- Filter feeders depend on currents bringing live or dead nutrient particles to the filtrating organs. Some animals filter the water as it runs pasts, while others actively pump water in to filter out particles.
- Detritus feeders pick up organic particles from the seabed by "grazing" or by using sticky tentacles or appendages that are spread out in the water or on the seabed. Alternatively, they drill one part of their body into the sediments and bring the feed to their mouth. Thus, detritus feeders are not dependent upon currents bringing them food, but they do depend on particles sinking to the seabed from higher water masses.
- Predators feed on other living or dead (scavengers) animals and are not directly dependent upon currents to find food.

Generally speaking, benthic fauna may experience natural or man-made environmental change (climate/temperature, pollution), physical wear (trawling, anchoring) and/or changes in biological processes (grazing, competition). Some species endure and survive these changes, while others diminish in numbers or die. The change in animal composition can be estimated by means of statistical and mathematical methods, where the frequency and distribution of each species, as well as the number of different species, are determining factors. Environmental change with subsequent change in the fauna composition may be perceived as signals and trigger research and management processes, which again lead to measures against unwanted, and possibly man-made, environmental impact. In this context, however, it is important to distinguish between natural and man-made changes.

Filter Feeders

Shelf areas with coarse sediments (figure 2) and strong currents (figure 5) are dominated by filter feeders.

At depths between 200 and 300 metres in the northern East Barents Basin (biotope 1, figure 9), on the shelves around Kong Karls Land, east of Svalbard in the slopes of the southern East Barents Basin and in the Storfjord Trench, the biotopes are dominated by a brittle star called northern basket star, *Gorgonocephalus arcticus* (box 1). In the northern East Barents Basin, this species dominated together with the brittle stars, *Ophiopleura borealis* and *Ophiacantha bidentata*. These areas are characterised by Arctic conditions well suited for such coldwater species.

The shelves around Kong Karls Land and the areas east of Svalbard are dominated by the northern basket star and the starfish, *Ctenodiscus crispatus*, the crinoid, *Heliometra glacialis* (box 1), and the shrimps, *Sabinea septemcarinatai* and *Lebbeus polaris* (biotope 7, figure 9). The northern basket star is a plankton feeder, thus the large numbers of this species are a sign of good current and production conditions.

Further south along the coast of Finnmark, quite a few different species of sponge were sampled by trawl (biotope 10, figure 9). Previous studies with a small beam trawl on the North Cape Bank showed that most of the fauna in the area consisted of at least 45 different species of sponge but also large amounts of bryozoans and brachiopods, which means that the fauna is dominated by filter and suspension feeders. Grab samples revealed an entirely different kind of fauna in the sediments. In these samples (343 species recorded), polychaetes and molluscs were more widely represented than in fauna collected by beam trawl (347 species recorded). In the IMR/PINRO surveys in this specific area of the North Cape Bank, 29 species were collected by fish trawl while 46 were video recorded. When large areas were sampled (more than 100 m^2), a large part of the faunal biomass consisted of brachiopods and crustaceans. In total, 517 species were found in all gears put together, which indicates that a selection of gears are required to form a comprehensive picture of the bottom fauna.

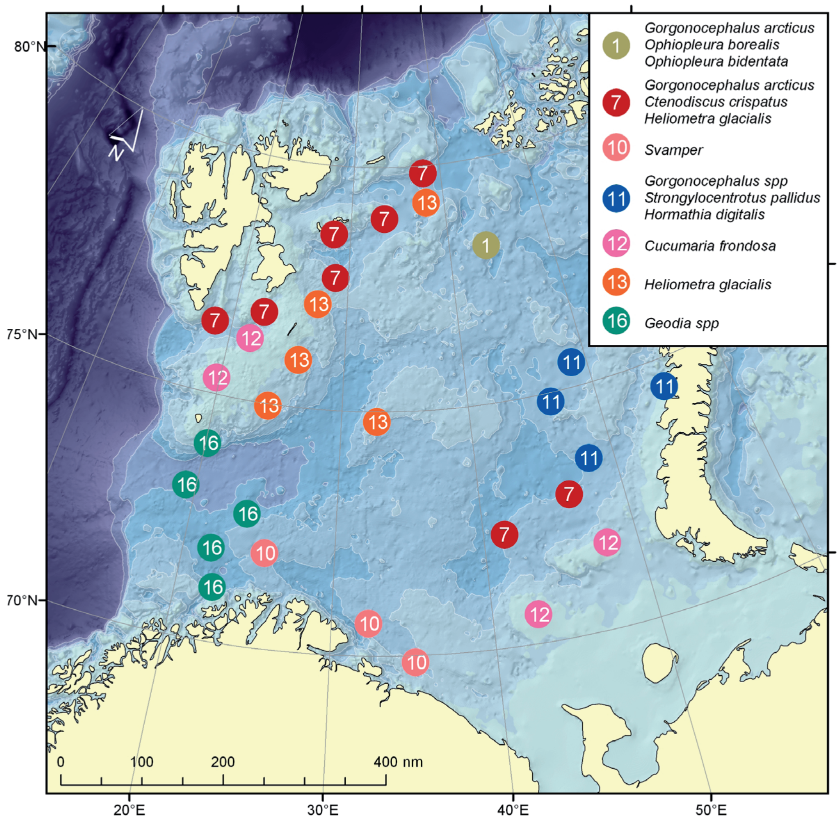


Figure 9. The Barents Sea biotopes dominated by suspension feeding species. Other species occurring in significant numbers have also been included. Biotope 1: *Gorgonacephalus arcticus*, *Ophiopleura borealis*, *Ophioscolex glacialis*. Biotope 7: *Gorgonacephalus arcticus*, *Ctenodiscus crispatus*, *Heliometra glacialis*. Biotope 10: sponges (various species). Biotope 11: *Gorgonacephalus* spp., *Strongylo-centrotus pallidus*, *Hormathia digitata*. Biotope 12: *Cucumaria frondosa*. Biotope 13: *Heliometra glacialis*. Biotope 16: *Geodia* spp.

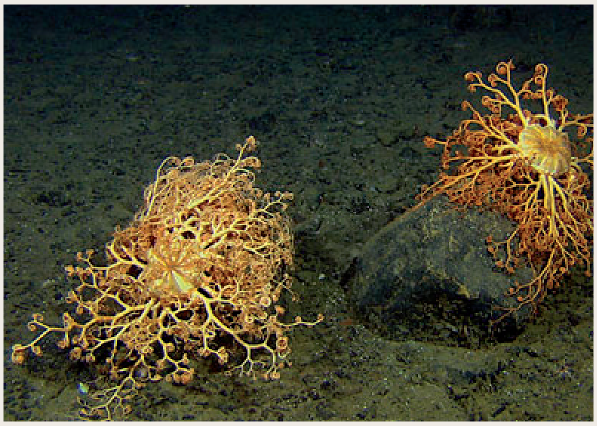
West of Novaya Zemlya at depths between 100 and 300 metres (biotope 11, figure 9), the northern basket star species, *Gorgonocephalus arcticus* and *Gorgonocephalus eucnemis*, were among the dominating species. The sea urchin, *Strongylocentrotus pallidus*, the sea anemone, *Hormathia digitata*, the tunicate, *Ciona intestinalis*, the soft coral, *Gersemia* sp. and the starfish, *Crossaster papposus*, were quite numerous in this area.

On the Spitsbergen Bank, at depths between 50 and 100 metres, the sea cucumber, *Cucumaria frondosa*, was recorded (biotope 12, figure 9) together with the sea urchin, *Strongylocentrotus droebachiensis*. Also recorded were the barnacles, *Balanus balanus* and *B. crenatus*, several species of sponge, bryozoans, hydroids and tunicates, all of which need relatively strong bottom currents to feed. *Cucumaria frondosa* was also recorded on the Goose Bank and Kanin Bank at depths shallower than 100 metres. The largest amounts (hundreds of kilos) were found in the west, while the quantities were considerably smaller on the southeastern fishing banks (some tens of kilos).

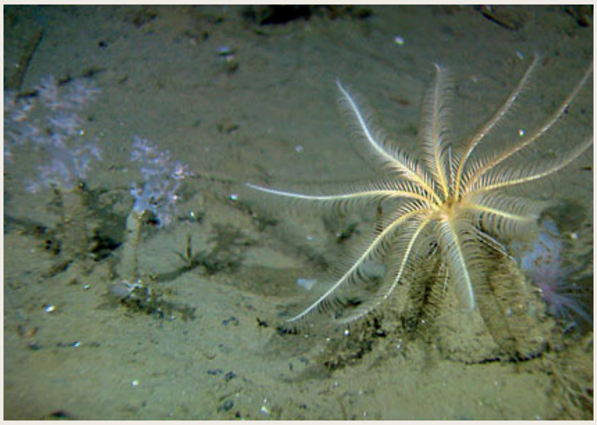
On the Spitsbergen Bank and the Central Bank at depths between 100 and 300 metres (biotope 13, figure 9), the crinoid, Heliometra glacialis, was recorded together with the brittle star, *Ophioscolex glacialis*, and the mollusc, *Chlamys islandica* (scallop, box 1). This biotope is located in the Polar Front area where cold Arctic water meets warmer Atlantic water (figures 3 and 4).

On Tromsøflaket and northwards on the shelf at depths between 300 and 400 metres, relatively large amounts of the sponges, *Geodia baretti* and *G. macandrevi*, were recorded (box 1 and biotope 16, figure 9). These sponges lived with other species commonly found in Atlantic water (figure 3 and 4) such as the sea cucumber, *Stichopus tremulus*,

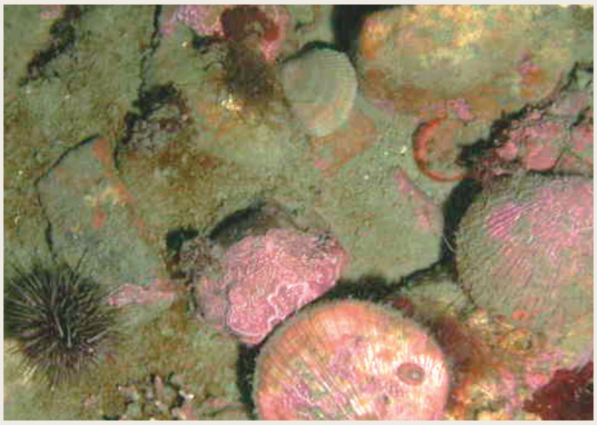
BOX 1



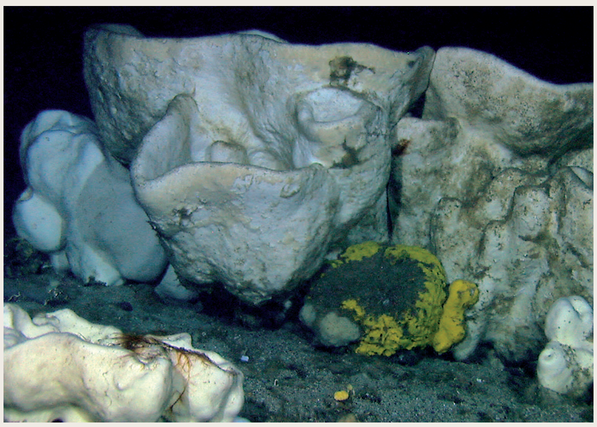
Brittle stars of the cold-water genus *Gorgonacephalus* (also called northern basket star). The long arms capture nutrients, providing a large capture surface for particles drifting with the currents. Northern basket stars live for several years and have the ability to regenerate lost parts of their bodies as long as the central plate remains intact.



Crinoids (feather stars) grip the seabed and extend their ten arms like a parabola in the water to capture particles drifting with the currents. Soft tentacles on the arms lead the particles down to the mouth, situated at the base. Crinoids are sensitive to physical strain and easily break up into small parts and die.



The scallop, *Chlamys islandica*, lies on top of the sediments or attaches itself to a solid surface with its byssus. The shells open slightly and the gills pump water in and filter it for particles. The nutrients are then led to the mouth. The scallop reaches sexual maturity at 3-6 years and can live for up to 30 years. The shell grows slowly and is sensitive to damage.



Sponges are long-living species generally attached to stones or other hard surfaces. The picture shows a species of the *Geodia* genus recorded in the Barents Sea. The flagella drive water into the sponge where nutrients are filtrated from the water and digested. Some sponges can live for up to 100 years and are extremely sensitive to cuts and damage.

and the lobster, *Munida sarsi*. Geodia sponges can live up to one hundred years and form an old biotope that thrives in the northeasterly bound Atlantic water bringing large amounts of zooplankton into the Barents Sea.

Detritus Feeders

A biotope dominated by the large sea cucumber, *Molpadia borealis*, and the starfish, *Ctenodiscus crispatus* (box 2) was recorded in deep waters (>300 metres) in the southern East Barents Basin (biotope 8, figure 10) and the Bear Island Trench (biotope 4, figure 10). The temperature in these basins is below 2°C all year round and, in the East Barents Basin, often below 0°C (figure 4). The biotopes in these two basins are dominated by detritus feeders hiding just under the sediment surface. They are rarely recorded by video and, due to their size and scattered occurrences, are difficult to quantify using a grab.

These species are known to form relatively large populations in sediments rich in organic material, either produced locally or transported by currents from the Norwegian Sea over the Bear Island Trench, where it sinks to the bottom when the currents weaken. In the southern East Barents Basin, the starfish, *Pontaster tenuispinus*, the shrimp *Sabinea septemcarinata*, the brittle star, *Ophiacantha bidentata*, and soft coral (Nephtheidae) are among the dominating species, while the sponge, *Thenea muricata*, the mussel, *Bathyarca glacilis*, and the isopod, *Saduria sabini* (box 2) dominate in the Bear Island Trench.

Several locations in the eastern Barents Sea (biotope 14, figure 10) are dominated by the sea urchin, *Strongylocentrotus pallidus* and the starfish, *Ctenodiscus crispatus*. Such biotopes are often found on coarse and mixed sediments in coastal waters and on offshore shallow banks at depths between 60 and 260 metres. In these areas, there are large variations in water temperatures at the bottom (-1.8-8°C), indicating that these species are robust to temperature swings.

In the Hopen Deep, *Ctenodiscus crispatus* replaces *Mopadia borealis* (biotope 2 and 3, figure 10) as the dominating species. Tubes from the polychaete, *Spiochaetopterus typicus*, were recorded together with two species of the polychaete, *Brada* sp. The brittle star, *Ophiura sarsi*, was evenly distributed on the seabed, while large individuals of more sporadically distributed starfish (*Urasterias linkii*, *Icasterias ponopla*) were recorded in the bottom trawl samples. These relatively large starfish (10-30 centimetres in diameter) probably live far apart and are rarely caught by grab or beam trawl.

However, more species are caught by grab and small beam trawl than by bottom trawl. In total, 213 species were recorded in the Hopen Deep, 156 of which were caught by grab and 69 by beam trawl. Sponges (*Tetilla cranium*), echinoderms (*Strongylocentrotus* sp., *Pontaster tenuispinus*, *Ophiura sarsi*) and crustaceans (*Pandalus borealis*, or "deep-sea prawn") dominated the beam trawl catches, whereas molluscs (*Astarte crenata*) and polychaetes (*Amphitrite grayi* and *Nephtys ciliata*) dominated the grab catches.

Predators on the Southeastern Fishing Banks

Species such as king crab (*Paralithodes camtchaticus*), snow crab (*Chionoecetes opilio*), spider crab (*Hyas araneus*), crangonid shrimp (*Sabinea septemcarinata*) and sea anemone (*Hormathia digitata*) (box 3) were relatively dominant among the recorded predators in the Barents Sea (figure 11).

The king crab (biotope 15, figure 11) is found on coarse mixed sediments in the coastal zone of the southern Barents Sea. While keeping close to the coast in Norwegian waters it migrates further out to sea on the Russian side. On the Kanin Bank and the Murmansk Rise it needs to migrate far out to find deep water. Close to the Norwegian coast, however, it finds steep terrain leading down to deeper areas.

The snow crab (biotope 16a, figure 11) is a large crab that, like the king crab, has become commercially interesting. In 2006, it was recorded in the eastern Barents Sea close to the Goose Bank but has gradually moved west since then. In 2008, it was recorded by the Central Bank and in 2009, on muddy bottom on the Central Bank and on slightly coarser sediments (sandy mud) in the eastern Barents Sea.

The spider crab (biotope 9, figure 11) dominates on the Kanin Bank on sandy sediments. The species is widely distributed and is often found on sandy bottom together with the sea anemone, *Hormathia digitata*, the scallop, *Chlamys islandica*, the starfish, *Urasterias linckii*, as well as sponges.

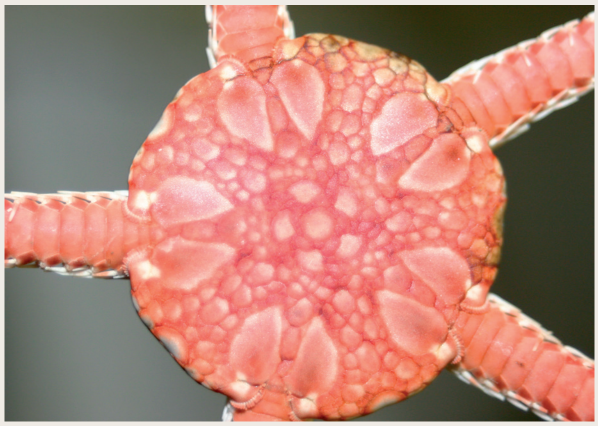
The seveline shrimp (biotope 6b, figure 11) is found on sandy bottoms in the Pechora Sea together with the shrimp *Sclerocrangon boreas* and *Eualus gaimardi*.

BOX 2

Mopadia borealis is a sea cucumber (echinoderm). It lives just below the sediment surface where it eats mud. Organic material in the mud is absorbed by the intestines. The picture shows the brown, oblong animal. On top of the sea cucumber we see the isopod, *Saduria sabini*, also found on muddy bottoms in deep, cold waters.

The starfish, *Ctenodiscus crispatus*, is an echinoderm that lives just below the sediment surface. The mouth is situated centrally under the animal. Just like the sea cucumber, the starfish eats sediments and digests organic material while non-organic material passes through the intestines.

The genus *Astarte* belongs to a group of molluscs that captures nutrients (organic material) in the mud by extending its mouth tentacles. Sediment particles stick to the tentacles and are transported to the labial palps where organic material is filtered out. Non-digestible particles are pumped out and do not go through the intestines.



Ophiura sarsi is a brittle star (echinoderm) that uses its long, flexible arms to move around on the seabed. When it finds food it uses the palps and teeth in its mouth under the body plate. It eats organic particles from the sediments.

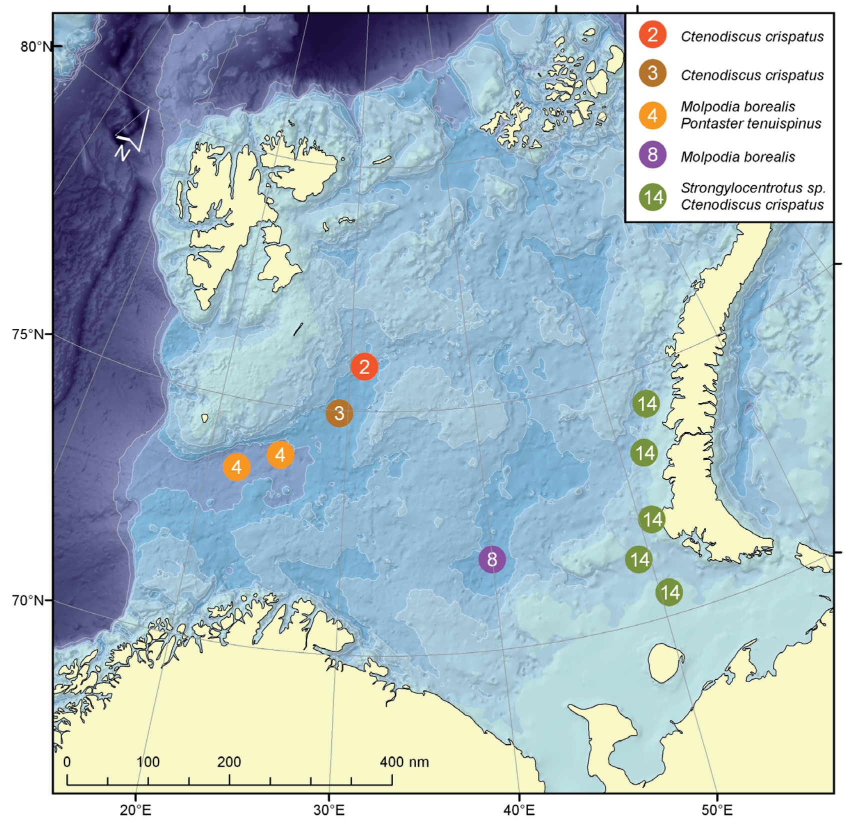


Figure 10. The Barents Sea biotopes dominated by detritus feeders (in bold below). Other species also occurred in significant amounts, including biotopes 2 and 3: *Ctenodiscus crispatus*; biotope 4: *Molpadia borealis*; biotope 8: *Molpadia borealis*, *Pontaster tenuispinus*; and biotope 14: *Strongyloc-entrotus* sp, *Ctenodiscus crispatus*.

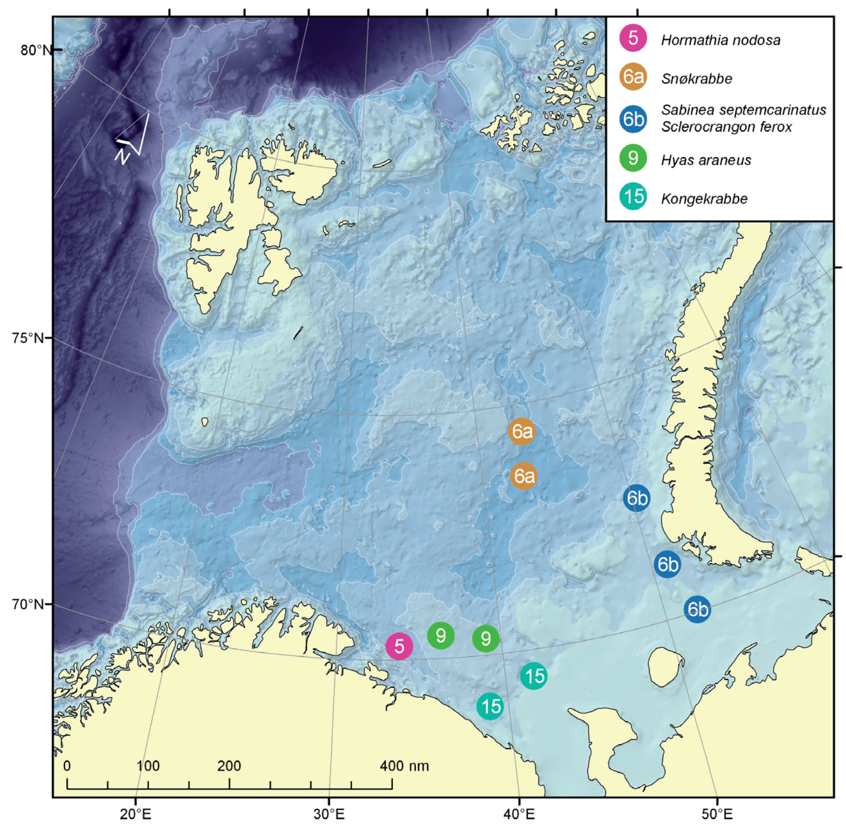
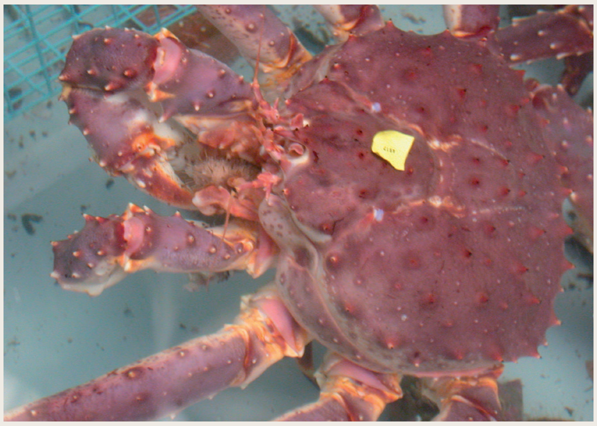


Figure 11. The Barents Sea biotopes dominated by predators. Biotope 5: *Hormathia nodosa*. Biotope 6a: snow crab. Biotope 6b: *Sabinea septemcarinatus*, *Sclerocrangon ferox*. Biotope 9: *Hyas araneus*. Biotope 15: king crab.

Sea anemones (biotope 5, figure 11) are also widespread in the Barents Sea and this biotope dominates in a range of locations in deep water off the Murmansk coast and in the trenches between the eastern fishing banks. Sea anemones were recorded on muddy bottoms between depths of 150 and 280 metres together with a whole range of sponges (e.g. *Phakellia* sp., *Radiella grimaldi*, *Polymastia mamillaris*, *Myxiella incrustans*, *Tetilla polyura* and *Suberites ficus*).

The two biotopes dominated by king crab and snow crab form a "crab belt" from the Murmansk coast northwards through the eastern banks to the Möller Table. Taking the sea anemone biotope into account, the south-eastern Barents Sea may be defined as an area influenced by predators. The sediments in this cold area are varied, consisting mainly of sand and soft bottom mixed with gravel. Previous grab surveys carried out by Russian scientists in the souteastern part of the Barents Sea west of Cape Kanin (the Kanin Bank, the Murmansk Rise and the southern East Barents Basin) have revealed up to 855 species of benthic fauna in the area. Molluscs dominated with up to 95% of the biomass in the area closest to Cape Kanin, while echinoderms dominated in the northern part of the surveyed area. The largest amount of species was found on shallow banks and plains, and the lowest in the deep southern East Barents Basin. Species thriving in both cold Arctic and warmer Atlantic water dominate in the southern areas close to Cape Kanin, whereas Arctic species dominate in the northern and northeastern areas. Most of the species caught by grab are detritus feeders, but filter feeders have the largest biomass, particularly in the shallowest areas.

BOX 3



The king crab is a predator with a number of bottom animals on the menu. With its maximum weight of 10 kilos and a carapace of up to 22 centimetres, it is one of the world's largest crustaceans. The king crab migrates from shallow to deep areas, which indicates that its needs with regards to prey, temperature and substrate varies according to age and season.

Just like the king crab, the **snow crab** eats a wide variety of bottom animals. The snow crab lives on sediments ranging from clay and sand to solid rock. The snow crab was first recorded in the Barents Sea in 1996. With age, it migrates from shallow to deep water.

The **sea anemone** is generally found on solid surfaces. The species, *Hormathia nodosa*, attaches itself to the shell of hermit crabs (an empty gastropod shell). The anemone paralyses and eats prey that gets in contact with its tentacles. Thus, the sea anemone offers protection to its host, which in turn carries the anemone around its "hunting grounds".

11.4 ENVIRONMENTAL THREATS

The Barents Sea is among the world's richest, cleanest and most productive marine environments. This, however, does not mean that the Barents Sea ecosystem is not vulnerable, particularly to human impact and climate change. An ecosystem-based management of human activities requires a continuous evaluation of how the ecosystem changes according to defined environmental quality objectives concerning habitat destruction, biodiversity, etc. The *Integrated Management of the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands* ("The Management Plan") was established to favour a holistic and ecosystem-based management. Another important reason for introducing an ecosystem-based management is the increasing awareness of the interaction between biological and physical elements in an ecosystem. Changes in one part of the ecosystem can have large repercussions and severely damage a completely different part of the same ecosystem. This applies to human activities and natural changes alike.

In this chapter, we present some of factors that have the strongest impact on the ecosystem. Because different animal groups, species and biotopes may respond differently to various kinds of impact, it is crucial to monitor a number of different benthic animals or species. The benthic fauna of the Barents Sea is rich and varied, and allows for future monitoring to be directed at specific impact factors.

Climate Change

Since the late 1970s, the sea temperature in the southern Barents Sea has increased by 1-1.5°C and the ice has receded. In areas dominated by Atlantic conditions, there has been a steady but relatively slow increase since the cold period at the end of the 1970s (figure 12). Areas dominated by Arctic temperatures have had considerably larger variations. During the cold period in the late 1970s, almost two thirds of the Barents Sea had Arctic conditions. In the period 2006-2008, there were almost no such areas left.

In Tromsøflaket, which is dominated by Atlantic and Coastal Water (figure 4), the temperatures in 2006-2008 were higher than normal temperatures for the period

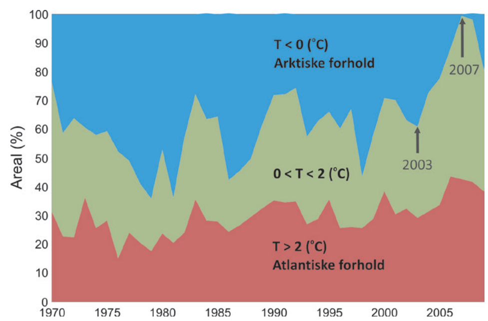


Figure 12. Distribution of bottom water in the Barents Sea during the period 1970-2009. The figure shows the area of seabed with water temperatures lower than 0°C (Arctic Water – blue), between 0°C and 2°C (green) and higher than 2°C (Atlantic water – red).

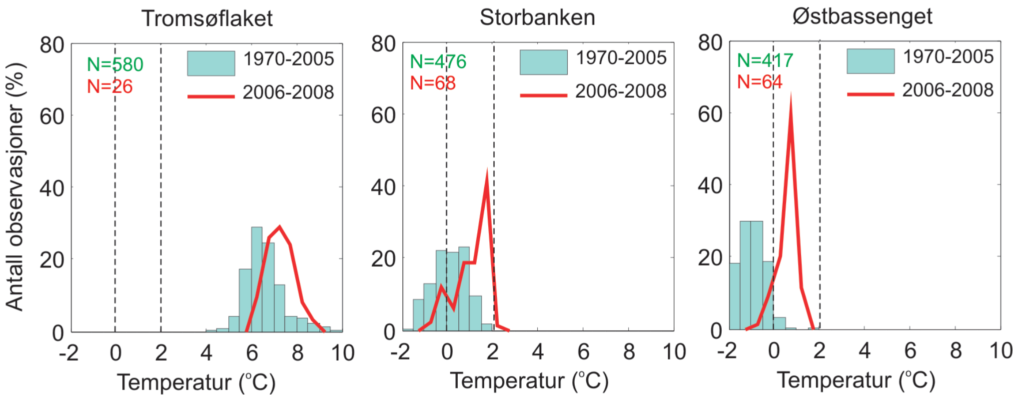


Figure 13. Histogram showing observed temperatures in selected banks and basins of the Barents Sea. N refers to the number of observations.

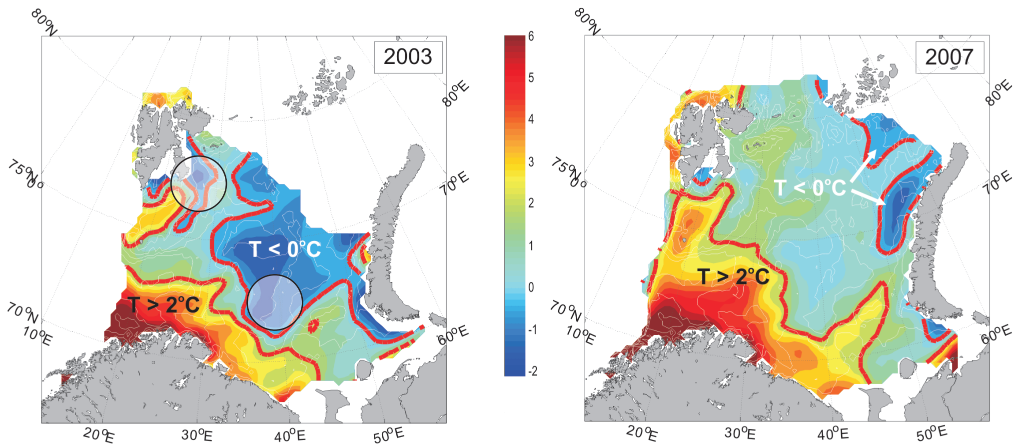


Figure 14. Temperatures in the Barents Sea bottom water in 2003 and 2007. The thick, red lines indicate the isotherms 0°C and 2°C. The bottom topography is shown in thin, white lines and surface covering colours. Suggested monitoring areas are marked by circles.

1970-2005 (figure 13, left). In Storbanken, which is affected both by Atlantic and Arctic Water masses (figure 4), the temperature increase in 2006-2008 was stronger than in Tromsøflaket. In addition, the distribution changed in 2006-2008, even if the bottom temperatures remained within previously observed limits. In the Eastern Basin, however, where we find the coldest and most homogenous bottom temperatures in the Barents Sea, the temperature increase in 2006-2008 was clearly greater than in Tromsøflaket and Storbanken. These results indicate that future climate change in the Barents Sea will have the biggest impact on areas dominated by Arctic bottom water temperatures such as the Eastern Basin. During the period where there has been a benthic fauna survey (2003-2009), bottom water temperatures in 2003 were between 0°C and 2°C, while relatively large areas had Arctic conditions (figure 14). This changes substantially toward 2007, where the areas with temperatures lower than 0°C were considerably smaller than in 2003.

Fisheries

The Barents Sea is an important breeding and harvesting area for Norwegian seafood, resulting in fishing activities both on the seabed and in open waters. Studies show that bottom trawling has an impact on benthic fauna and suggest that organisms living on bottom sediments in the most heavily trawled areas have been affected.

Catches of non-commercial species are defined as ”by-catch”. By-catch from bottom trawling in the Barents Sea affects more than 350 species of benthic fauna, most of which are invertebrates. Up to 84 species of invertebrates have been recorded in one single tow.

Norwegian fishing has been particularly intense in the areas around Bear Island, along the shelf in the southwestern Barents Sea, off the coast of Finnmark, in the northern parts of the Hopen Deep, south of the Central Bank and on the fishing banks of the eastern Barents Sea (figure 15, see figure 1 for names of areas).

King Crab and Snow Crab

Increasing amounts of king crab and snow crab (figure 16) are spreading to new areas of the Barents Sea, which means that the crab's prey may be, and has been, affected in increasingly large areas. Studies have shown that one adult king crab can capture as much as 300 grams of prey (such as mussels, sea urchins, starfish and brittle stars) per day. Thus, in areas with a low prey production (due to longevity, a multi-annual reproduction cycle, slow growth etc.) grazing may exceed what can be replaced by natural population growth. Hence, areas were the crab population is growing should be monitored over time. This means that the monitoring areas should follow to the crab's migration pattern. Such monitoring should not only include crab but also its prey, i.e. the species found in its stomach content.

Monitoring Areas

Monitoring areas are suggested in figures 14, 15 and 16. These areas have been partially monitored since 2006 through analyses of by-catch from research-survey bottom trawling. However, these areas should also be mapped by grab, small beam trawl, sledge and video to obtain sufficient quantitative and qualitative knowledge of various bottom biotopes. These gears supplement each other by catching benthic fauna at different levels in the benthic systems. Productivity, benthic-pelagic interaction, breeding and feeding areas for benthic fauna and fish are important factors. In addition, it is important that Norwegian and Russian experts collaborate to follow up previous mapping and monitoring using various benthic gears. Video is recommended in areas vulnerable to physical pressure (*Geodia* sponge in Tromsøflaket and crinoid forests dominated by *Heliometra glacialis* on the shelf). This would allow us to monitor the largest and most distinct indicator species that can easily be handled in a lab and identified cost-efficiently.

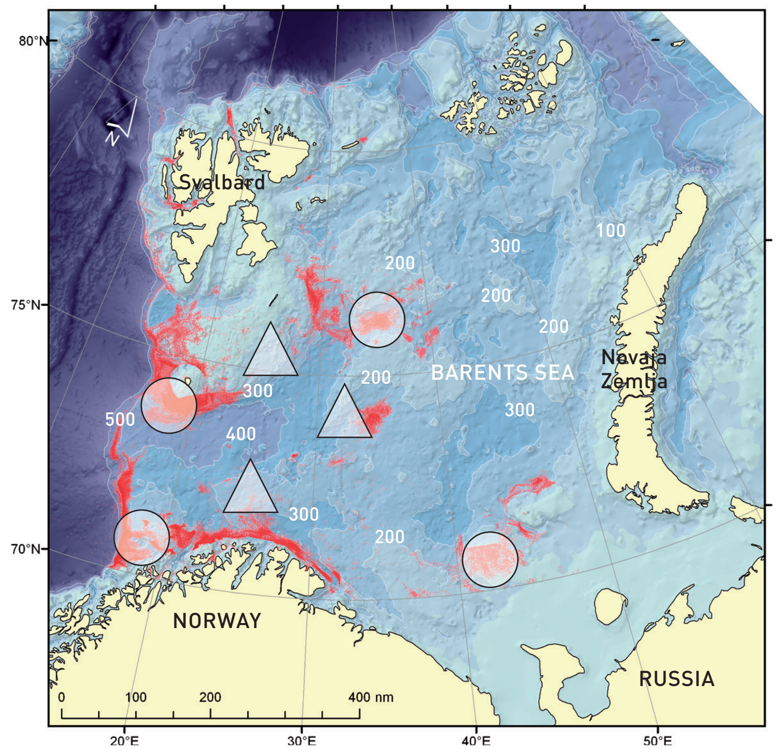


Figure 15. Norwegian fisheries (red dots) in the Barents Sea in 2006-2008 based on VMS (Vessel Monitoring System) data. Only data from vessels having submitted catch logbooks in the period have been used and all data have been filtered only to include bottom trawling (speed ca. 3-5 knots). Suggested monitoring areas are marked by circles (areas with high fishing intensity) and triangles (areas with low fishing intensity and thus potential reference areas).

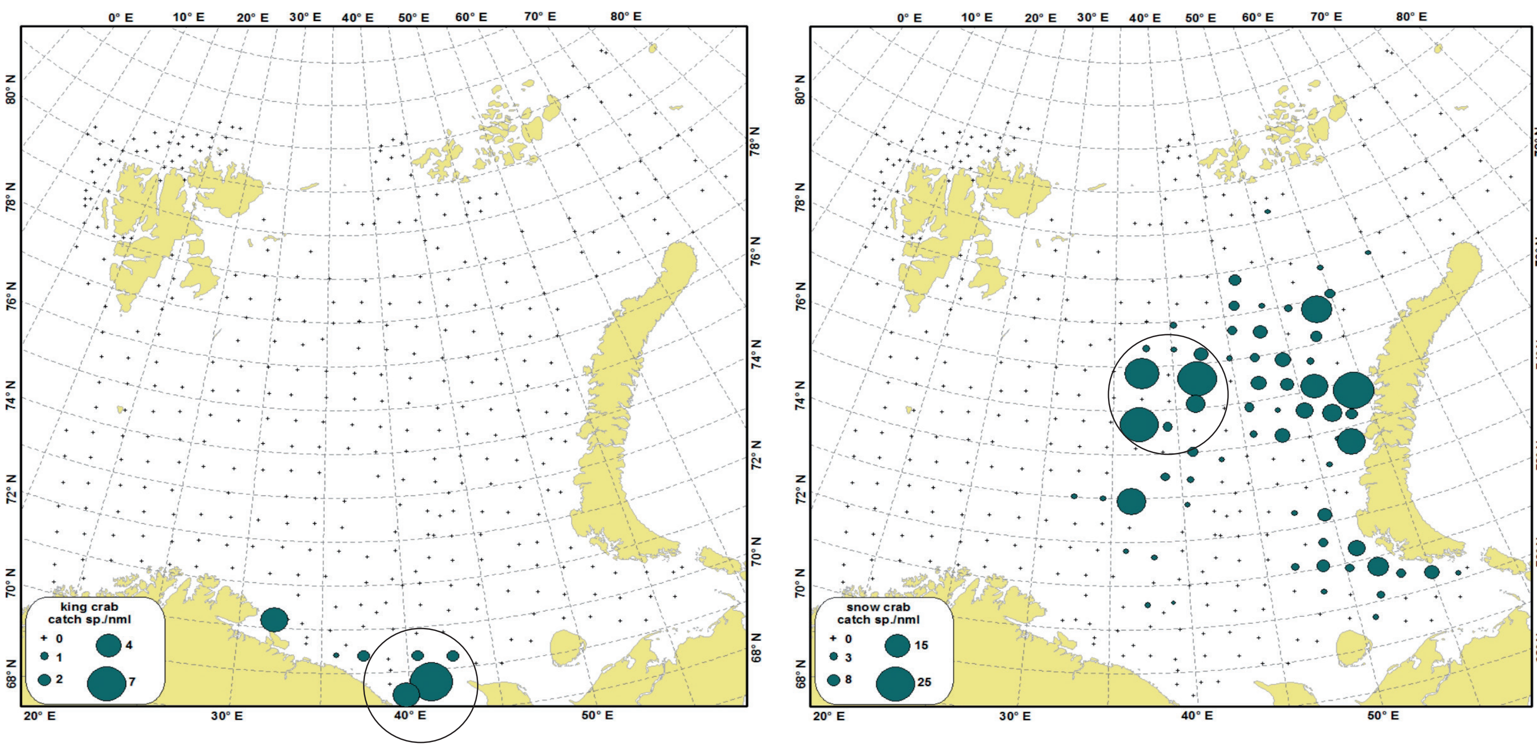


Figure 16. Distribution of king crab on the left (*Paralithodes camtschaticus*) and snow crab on the right (*Chionoecetes opilio*). Data from August/September 2009. The crab was caught with a Campelen bottom trawl and standardised to the number of individuals per nautical mile. Suggested monitoring areas are marked by circles.