EXECUTIVE SUMMARY

The MAREANO (Marine AREAdatabase for Norwegian coast and sea areas) programme aims to fill gaps in knowledge about seabed conditions, habitats and biodiversity through detailed mapping of depth, sediments, bottom fauna and pollutants in Norwegian waters. The results are available on www.mareano.no, through a user friendly GIS based interface.

It is a multi-disciplinary programme, bringing together biologists from the Institute of Marine Research (IMR), geologists from the Geological Survey of Norway (NGU), and the Hydrographic Service (SKSD). In addition to responsibilities for different fieldwork activities, the partners collate existing information and present it integrated in the web portal www.mareano.no. The programme is financed by the ministries of the Environment, Fisheries and Coastal Affairs, and Trade and Industry.

Chapter 2 presents the background and start up of the MAREANO programme. After many years of development and preparation the MAREANO programme was launched in 2005. Since then 51 000 km^2 has been mapped by multibeam surveys, and 48 000 km2 has been mapped for geology, biology, and pollutants (fig. 4). The continental margin studied by MAREANO offshore North Norway lies between 68-72 degrees N, and 10-25 degrees E. The margin comprises continental shelf, slope and parts of the continental rise. Water depths range from approximately 40 m to 2900 m, and the width of the shelf varies from less than 10 km to more than 150 km. The continent-ocean boundary occurs only 60 km from the coast, outside Vesterålen (fig. 5). During the first mapping period in 2005-2010 the main task has been to provide new knowledge about environment and resources in the Barents Sea to support the implementation of the Norwegian Barents Sea management plan and its revision in 2010. The goal is to obtain information for the regulation of human activities such as petroleum industry and fisheries. The new information provides a baseline for management of the environment and biodiversity in the area.

Mapping methodology is described in **Chapter 3**. Topography is the first to be mapped in a "new area", and high resolution bathymetric maps are available from all areas (5-m grid above 500 m depth). The substratum is analyzed using terrain modelling and backscatter interpretation before selecting localities for sampling and video recordings of sediment and fauna. Selection of sampling sites is done following a stratified and semi-random procedure to ensure an even geographic coverage, in addition to provide details about transition zones and rare structures. The task of mapping marine substratum, biodiversity and vulnerable biota in a varied seascape is challenging. The MAREANO mapping program tries to take this into account by applying a wide set of sampling techniques to capture the diversity of bottom fauna and environment. Bottom fauna is mapped using video, grab, beam trawl and epibenthic sled. At all stations, 700 – 1000 m long video-transects are conducted. With this information at hand locations for sampling of fauna and sediments are selected. Patterns in fauna distribution are related to habitat descriptors using multivariate analysis which produces a model that can be used for predicting biotopes in adjacent areas. The multibeam echosounder data provides environmental descriptors with full areal coverage (e.g. slope, rugosity, curvature, bathymetric position index, and acoustic reflection).

Some results and highlights from the mapping in the Tromsøflaket and Eggakanten mapping areas are described in **Chapter 4**. Six biotopes were identified at Tromsøflaket (fig. 20). Many of these biotopes were also found within the Eggakanten mapping area (fig. 38). At 200-500 m depth "sponge-bottoms" with dense patches of sponge colonies are common, occurring on a seabed consisting of a matrix of sponge spicules and mud. In these areas trawl-marks and signs of damaged sponge colonies were observed. At Eggakanten another spectacular biotope is the morainic shelf-break gravel areas with basket stars (*Gorgonocephalus eucnemis*) and cauliflower corals (fig. 47). These biotopes are intersected by areas with strong currents and large sand waves. Similar sand waves were also observed in the Hola area in the Nordland VII mapping area. In general the fauna is poor and currents are strong in these sand-wave fields. At greater depths (700-900 m), in the Bjørnøya slide area the gorgonian coral *Radicipes* was observed for the first time in Norwegian waters (fig. 42). This coral occurred in relatively dense stands within a restricted area. On the soft bottom on the lower slope (900-1100 m) at Eggakanten a rich fauna of small crustaceans (Peracarida) were found living on stalks and tubes of other organisms (polychaets, crinoids, hydroids, sponges, etc). In this area the carnivorous sponge *Chondrocladia gigantea* was much more common than further south in Nordland VII.

Chapter 5 describes results from the continental shelf off Nordland VII, Lofoten and Vesterålen. This seabed is characterized by banks and shelf plains, in water depths of between 40 and 200 m, which are separated by broad troughs (water depths 200 – 500 m). The banks and plains are generally flat, with a gentle slope in an offshore direction. They are usually covered by a coarse-grained erosional lag which varies in thickness from a few centimetres to a few decimetres. Sandy gravel is the most common sediment type, while gravel with cobbles and boulders dominate the shallowest areas and elevated moraine ridges. Iceberg plough marks and moraine ridges are common features.

The gravelly areas of shallow banks have a great biodiversity with colourful encrusting sponges and calcareous area. Coral reefs occur several places within the area. The Malang Reef is located on a ridge between the banks Malangsgrunnen and Fugløybanken. In the shelf trough area called Hola there is a larger coral reef area with around 330 elongated reefs (fig. 32 og 33), all aligned in the same direction, towards the main current. This current flows from land towards the shelf break. In the troughs the sediments are commonly sand, gravelly sand and gravelly sandy mud. Till/moraine material is common along bank margins and on moraine ridges not covered by finer-grained sediments, for example in the outer parts of the troughs. Sandwaves and sandwave fields occur in several troughs. Straight-crested and barchan-type sandwaves in Hola are up to 3 km long and 7 m high, and are interpreted to have been formed by tidal and geostrophic currents with bottom current speeds reaching 0.7- 0.8 meters per second. The troughs are in some cases the direct continuations of fjords. Ridge/groove structures up to 16 m high, 700 m wide and many kilometres long are found in many of the troughs, and have been interpreted to have been formed under fast-flowing ice streams. Troughs with weaker currents than in Hola typically have finer sediments with sea-pens and burrowing megafauna. Holothurians are also common in such troughs.

The slope off Nordland VII, Lofoten and Vesterålen representing a spectacular landscape is presented in **Chapter 6**. Here the continental slope occurs between the shelf break at around 400 m water depth and the continental rise, starting at around 2500 m. The average slope is 7°. There is a gradual transition from coarse grained sediments on the upper continental slope to more fine-grained sediments on the lower slope. Sandy gravel dominates the shelf edge and the uppermost slope. This is followed by gravelly sand, which dominates on terraces on the uppermost slope. On the middle and lower slope there is a predominance of gravelly muddy sand, but the sediment type varies depending on depositional process. In this area the slope is incised by 10 large and several small canyons (fig. 5). The largest canyon is the Bleiksdjupet canyon, which is up to 1 km deep, 10 km wide and 30 km long, and with local slopes of up to 30°. Some canyons are finger- or pear-shaped, or have more complex forms. They are interpreted to have been formed by a combination of fluid-flow processes and sliding. Canyon margins are often steep and irregular, and sub-vertical walls with rock fall activity occur where there has been erosion and sliding. Submarine fans and blocky slide deposits occur seaward of several of the canyons. Canyons exhibit great variation in sediment type, and one side of a canyon may be very different from the other. Gravelly sand is common in the upper parts, while gravelly muddy sand and gravelly sandy mud is common lower down the canyons. Sand and gravelly sand are common in channels. Consolidated sediments or sedimentary bedrock crop out in steep slopes. The continental rise and deep sea plains occur below around 2500 m. Submarine sediment fans with material derived from the canyons or slides on the continental slope dominate. In some places, large blocks (up to several hundred metres high) occur. Gravelly sandy mud is the dominant grain size, but more coarse-grained sediments may be found outside the canyons.

The fauna of the shelf and slope off Nordland VII reflects a strong gradient in hydrography. Three water masses characterize three different faunistic regions related to depths (fig. 13). Above ~600 meters, in the north Atlantic water, temperature stays above +0,5° C. At 600 – 900 meters depth there is a transition layer of Norwegian Sea Arctic Intermediate Water with temperatures between 0,5 and -0,5° C. Below, in the Norwegian Sea deep-water, the temperature is permanently below zero, between -0,5 and -1,1° C. The greatest depth sampled in this area was 2700 m. The megafauna at these depths appear to be common for the deep northern parts of the Atlantic and the Norwegian Sea. This fauna was dominated by the holothurians *Elpidia* sp. and *Kolga hyalina*, the stalked crinoid *Rhizocrinus lofotensis* together with the crustaceans *Bythocaris leucopis* and *Saduria* sp. and the sea urchin *Pourtalesia* cf. *jeffreysi*. The fauna is not species rich, but specific for the arctic deep-water. The abundance of infauna at these depths is also low and the fauna is clearly richer on the shallower slope than at 2000 m. The highest diversity of megafauna was observed on the gravelly bottoms just below the shelf break (fig. 18). Some strange formations were observed at 2100 m that are difficult to explain both biologically and geologically. The deep and wide tunnels (~40 cm across) that have been observed several times on the slope are hard to imagine having been produced by any marine organism we know from these depths. Seepage of gas or fluids is a possible cause, but has not yet been proven. In the vicinity, bacteria coating on gravel indicates that cold seeps may occur. We also observed the peculiar hydroid *Candelabrum* sp. which is known from areas at the Mid-Atlantic ridge in relation to gas seeps.

Chapter 7 describes the bottom circulation off Northern Norway based on numerical modelling and direct observations. The circulation in the area is dominated by the Norwegian Atlantic Current. This is an extension of the Gulf Stream and carries relatively warm and saline water masses. The flow is strongly controlled by the coastal bathymetry. In the MAREANO area the complexity of the bathymetry contributes to a complex bottom circulation.

The numerical simulation of bottom current averaged over the period January to May 2009 is show in figures 2 and 6. The strongest mean bottom current (30 cm/s) is found over the shallower parts of the continental shelf slope. The weakest currents are found upon the shallow banks and at deep water. The flow generally follows the topography with shallow water to the right (fig 3). This gives clockwise circulation over the banks and counter-clockwise in the depressions (fig. 6). The current vary with time. Overt the shelf slope, the probability of strong currents (fig. 4) and the directional stability (fig. 5) is high. On the banks, the bottom current seldom reaches 5 cm/s (disregarding tidal current) and the direction is more variable.

The intensification of the Norwegian Atlantic Current at the shelf-edge is evident from the in situ observations in October 2009 (fig. 7). The vertical section in figure 8a shows strongest current near surface and a reduction towards zero at 500 m depth. This depth corresponds to the thermocline separating the Atlantic Water from the much colder intermediate water masses in the Norwegian Sea (fig. 8b). The year-long record from a current meter mooring deployed in the MAREANO region suggests that the depth of the thermocline varies seasonally (fig. 9). During winter the warm Atlantic Water reaches bottom giving a strong and directionally stable bottom current (tab. 1, fig. 10a). During spring the bottom is covered with cold intermediate water with weaker and less stable current (tab. 2, fig. 10b). The short-term characteristics of the bottom current and temperature were vastly different between the two periods (figs. 11, 12). In the spring season there are strongly cyclic fluctuations with a period close to 12 hours. This indicates internal tidal waves at the thermocline at the base of the Norwegian Atlantic Current.

In **Chapter 8** content of pollutants and signs of fisheries impact is presented from the areas mapped by MAREANO. The levels of heavy metals and organic compounds in fine-grained sediments (deposition areas) have been studied. Heavy metal levels are generally low in surface sediments, except for lead and nickel which display slightly elevated levels at some locations. For nickel, this is because of natural variations. Naturally high levels of arsenic are found south of Svalbard. Cores with sediments deposited over the last few hundred years show that levels of mercury and lead have increased slightly from background levels since around 1850, due to long range transport of these metals. The levels of PAHs (polycyclic aromatic hydrocarbons) and THC (total amount of hydrocarbons) are low, with levels at or close to background levels. A few stations in the deep areas offshore Lofoten show slightly elevated PAH levels in the sub-surface sediments. Just south of Svalbard, north of the MAREANO area, sediments with elevated levels of PAH and THC are found. This is due to erosion of coal-bearing sediments from Svalbard, and is not the result of anthropogenic pollution.

Each year, at depths above 200 m an area corresponding to half the world's continental shelves is trawled. MAREANO quantifies signs of trawling by counting trawl marks along video transects. Such trawlmarks can be up to ca 50 cm deep, and remain for months or years, depending on bottom type and bottom current strength. Therefore, it is not necessarily a clear relationship between density of observed trawlmarks and the trawling intensity. Large organisms (corals, sponges, and sea-pens) with a long life-span seem to be the first to disappear with heavy trawling. Those are replaced by smaller organisms of rapid reproducing species. Some other organisms like scavengers and opportunistic species may benefit from the turning over of the sediments. This implies that seabeds repeatedly trawled will be depleted with regards to species diversity and production. Satellite tracking data of fishing vessels represent a new tool for managing the fishing activities. Comparison of such data with observed density of trawl marks generally gives a good match. MAREANO has documented that the bottom trawling is most intense at the Tromsøflaket bank and in certain areas in the Eggakanten area. Within these areas many places have been over-trawled several times within the time-span it takes before a trawl mark disappear. At Tromsøflaket, trawlmarks were observed at 90 % of all inspected locations, with 4.2 trawlmarks per 100 m on average, and a maximum of 10 trawlmarks. At Eggakanten trawlmarks were observed at 81 of 115 localities. Deep and shallow fisheries (for Greenland halibut and white fish respectively), are reflected as two peaks (600 and 400 m depth) and in trawlmark density versus depth. The average density of trawlmarks was 2.3, and the maximum was 11. Also in Nordland VII the trawlmarks were distributed in two depth intervals. Highest density of 4.9 trawlmarks per 100 m observed seabed was found at 620 m depth in the northern part of Nordland VII

Chapter 9 presents a study integrating the entire Barents Sea including both Russian and the Norwegian zones. The seabed of the Barents Sea continental shelf has been shaped during repeated glaciations. The entire shelf has been covered by ice caps extending as far west as the shelf break. Broad banks and shelf plains are separated by broad troughs, with gentle slopes. An erosional lag deposit with sand, gravel and blocks dominates the shallowest parts – down to around 200 metres. This lag deposit covers glacial till and moraine material. Below 200 metres, there is a gradual transition to sandy gravel or gravelly sand. In the deepest parts of the troughs, muddy deposits dominate. Iceberg plough marks and moraine ridges are commonly found on banks and plains. In the muddy parts of the troughs, pockmarks are commonly found. Variations in local current conditions influence sediment distribution significantly, and coarser sediments may be found in the troughs if strong bottom currents occur. The ocean currents in the Barents Sea are strongly linked to the topography. The bottom currents flow along-slope around banks and basins, and velocities are higher over the slopes than elsewhere. Species as the basket stars (*Gorgonacephalus* sp.), sea lilies (*Heliometra glacialis*), the bivalve *Chlamys islandica*, sponges, brachiopods, bryozoans and hydroids prevails in these strong currents. The slopes are covered with sand, gravel and blocks, and make up a substrate for the animals to attach. The animals filtrates the water for food particles brought along with the strong currents. Vertical convection where surface water sinks to bottom occurs frequently in localized areas. This sinking has large impact on the local conditions because it affects the bottom temperatures, but it may also impact on the sedimentation of organic material coming from algae growth and zooplankton production in the upper water masses. The Barents Sea is dominated by warm Atlantic Water in the southwest and Arctic Water in north and east. The Atlantic water was characterised by species as the sponges *Geodia*, and the sea cucumber *Stichopus tremulus*, while Arctic waters by the brittle stars *Ophiopleura borealis* and *Ophiacantha bidentata*. The borderline between the warm and cold waters is called the Polar Front, and the location of the front varies due to climate variability. Since the late 1970s there has been a gradual warming. The largest increase has occurred close to bottom in the colder Arctic areas, indicating that climate change and variability may have strongest impact on areas which at present is dominated by Arctic conditions. Bottom trawling, impact from new species and a warmer climate influence the distribution of the fauna, and make it possible to use benthos as environmental indicators. A time and cost efficient "Long Term Monitoring Programme" of the entire Barents Sea benthos has therefore been established by a joint Russian-Norwegian programme. The by-catch of the scientific demersal fish trawl on research vessels was analysed and recorded in a standardized way, and all data collected in a joint database. Today 1682 stations has been analysed with a result of 337 species from 32 animal groups. Statistical analyses defined ~16 faunal communities distributed.

Chapter 10 describes the management of data in MAREANO. The dataflow in MAREANO starts with data acquisition from vessels in Barents Sea, followed with a distributed system for data management and eventually distribution to users through www.mareano.no and www.geonorge.no. Metadata is important information about the data that is added to the data as well as other results from the program. Metadata increases the value of these data for both today's users and future users. It is an important principle that data is maintained by the department responsible for the different data types. Institute of Marine Research (IMR) is responsible for biological data, Geological Survey of Norway (NGU) is responsible for geological data and the Norwegian Mapping Authority, Hydrographic Service (NHS) is responsible for depth data. In www.mareano.no it is possible to combine different types of data to produce self defined maps.

The main goal of MAREANO is providing baseline information of natural recourses that ca underpin management strategies and decisions. The use of results from MAREANO is presented in **Chapter 11**. The results from MAREANO are already being used for different purposes. The management plan for Barents Sea and the sea outside Lofoten is being revised during spring 2010, and different types of data from MAREANO is used in this process. For example is information about vulnerable "nature types" important information when planning how this sea area is going to be used in the future. The results from MAREANO are also used by the fishing industry. The detailed information about the sea bottom gives fishing boats information of great value when they decide where to fish, and which equipment to use. The oil and gas industry is also very interested in detailed seabed data in connection with planning their activity. Some of the oil companies have established the internet portal www.arctic.com to get easier overview of where there exist relevant data and from whom to get them.

It is stated by the Norwegian prime minister that MAREANO will continue mapping in relation to the need for new knowledge connected to the management plan for the Norwegian Sea. Thoughts about the future of MAREANO are presented by the directors of the three institutes conducting the MAREANO programme in **Chapter 12**.