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# Rapid Assessment of circum-Arctic Ecosystem Resilience

Marine areas off the coast of northern Norway, and the northern Norwegian Sea

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WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by: conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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SUMMARY

The majority of Norway's Arctic comprises marine areas, managed with plans which on paper state that Norway has an integrated ecosystem based approach. However, Norway's implementation of ecosystem based management lacks specific targets and environmental goals, including implementation of ecologically significant marine protected areas. The lack of satisfactory protection for ecologically important marine areas from destructive cumulative effects of human activities and climate change is outstanding, and currently Norway is not doing enough to address this management gap in its jurisdiction. Holistic and adaptive arctic environmental management must ensure successful navigation of the rapid changes under way, also in the planning and establishment of Marine Protected Areas (MPA).

A crucial management component must involve Norway collaborating with its arctic neighbours in securing protection for a representative selection of arctic environments based on the criteria of heightened ecological resilience, including strict restrictions on specific activities. With the effects of climate change rapidly deteriorating the Arctic, management needs a way to quickly define what areas are most important to conserve. Norway's Marine Protected Area plan process remains based on conservation objectives that do not reflect contemporary marine conservation needs, and a reopening of discourse among managers and decision makers that re-evaluates the intent of establishing MPAs is needed. The role of MPAs in climate change mitigation, expressly with regard to the Arctic marine environment, deserves explicit focus that up to this point has not been present.

This report presents results from work conducted within the RACER (Rapid Assessment of circum-Arctic Ecosystem Resilience) project framework in Norway, and is intended to help inform stakeholders, managers and decision makers in Norway about the necessity and convenience of RACER as a management tool. It is also meant to help build awareness about areas and features in Norwegian marine jurisdiction which could be significant components for building ecological resilience across the circum-Arctic under future climate change scenarios.

The RACER project is intended to help direct focus towards areas and features considered to be significant for building social-ecological resilience across the circum-Arctic and that are likely to persist in future arctic climate change conditions under different warming scenarios. The focus of the RACER analysis is to identify the underlying drivers of key ecosystem processes, as these variables will be what is modelled into the future to determine how a system will respond to climate change. This focus is also seen as a catalyst for discussion on how to best manage these areas in the future.

Climate change is the most severe danger to the continuity of the Arctic's unique and important ecology, aggravating all other threats. Without tangible action in the very near future to abate climate change, temperatures in the Arctic will rise to levels unprecedented in recent geological history, inflicting severe changes on the environment. At present, abrupt changes are already being observed across the Arctic. Coupled with climate-induced changes is the increased accessibility of the Arctic to human industry such as oil and gas exploration, shipping, and fishing. The cumulative environmental impacts from industrial activity works in conjunction with climate induced impacts. This yields even greater pressure and further imperils arctic biodiversity and important ecosystem services. Economic activity in the Arctic is necessary, yet its rise is outpacing the precautionary implementation of sufficient holistic environmental management.

**"Holistic and adaptive arctic environmental management must ensure successful navigation of the rapid changes under way."**



Amphopod (Stenopleustes latipes), resting on a deep water coral (Paramuricea placomus).

As part of a wider circum-Arctic RACER process, WWF-Norway commissioned Sweco Norway to undertake the characterization of two arctic ecoregions within Norwegian jurisdiction; the marine areas off the coast of northern Norway, and the northern Norwegian Sea. Based on the Sweco characterization study, a two-day RACER workshop was held with marine scientists experienced in working with resilience, for the purpose of assessing the persistence of the Sweco proposed drivers of exceptional productivity or diversity in a climate changed future.

This report presents the main conclusions of the persistence assessment, which demonstrates two points:

I: Specific areas have been identified in Norway's High-North marine jurisdiction which could be significant for safeguarding ecological resilience under future arctic climate change scenarios. The areas deserve attention under an MPA plan process which has modernised its criteria.

II: RACER has great relevance for climate-adaptive marine management in Norway, as a tool for translating future threats and pressures to the arctic environment into effective forward-looking planning.

Recognition of the importance of ecological resilience under climate change is missing from the Norwegian MPA plan process, which is otherwise operating on outdated criteria and methodology that does not reflect mitigating the current and future threats to the marine environment. RACER's practical application of a forward-looking ecosystem approach has great potential for stimulating policies in Norway that will improve the management of arctic marine natural resources, at a time of mounting pressure from climate change, industrial development and other interests.

Minke whale, © Morten Lindhard / WWF-Canon

## INTRODUCTION

**"Rising human activity in the high north is currently outpacing the implementation of sufficient environmental management."**

A key finding of the Arctic Biodiversity Assessment report is that *Climate change is by far the most serious threat to arctic biodiversity and exacerbates all other threats*[1]. An accepted scientific view is that the increase in average global temperature should be kept below 2°C compared to the preindustrial level, in order to avoid dangerous societal consequences. This is recognized by signatory countries in the Copenhagen Accord, who are responsible for more than 87 per cent of the world's carbon emissions. At large, warming of the air in the Arctic is expected to be two to three times greater than in the rest of the world[1]. Thus, a 2°C average global temperature increase implies 4 to 6 °C increase in the Arctic. Without implementation of global climate change intervention measures in the very near future, we are headed for an average global warming of 4 to 6 °C by mid-century. This means a devastating minimum 8 °C increase in the Arctic. In comparison with the past 2000 years, summer temperatures in the Arctic have been warmest during recent decades. The Arctic oceans will also experience warming as the protective shield of sea ice increasingly diminishes. The Barents and northern Norwegian Seas are those arctic marine regions that have experienced the greatest loss of sea ice. The resulting exposure of open water to direct sunlight, in combination with warmer influx of Atlantic currents, will cause disproportionate warming compared with other arctic marine regions.

Shifting amalgamations of warmer temperatures, increased winds and greater precipitation will give rise to very different climates in the Arctic[1]. According to the Arctic Resilience Interim Report[2], abrupt changes are already being observed across the Arctic, and there is extensive evidence of major changes taking place in arctic landscapes and marine environments[2]. Many of these changes are sudden, large scale and possibly irreversible. Some thresholds are crossed; others are at risk of being so, with long-term consequences for future economic development options and human habitation[2].

On top of this, climate-induced changes are contributing to an increase in the accessibility of the Arctic to economic interests, enabling increased industrial activity such as oil and gas exploration, shipping and fishing[1]. These human induced changes will work in conjunction with those that are climate induced, yielding increased stresses and risks to arctic biodiversity[1]. Economic activity in the Arctic is a necessity and a reality,
human activity in the high north is currently outpacing the implementation of sufficient environmental management. The continuity of the Arctic's unique and important ecology is thus critically threatened by rapid changes due to global warming, coupled with the cumulative impacts of rising unsustainable human activity. Rapid Aactic change is likely to produce surprises, so strategies for adaptation and, if necessary, transformation, must be responsive, flexible and appropriate for a broad range of conditions[2].

The Norwegian government's recent white paper on climate adaptation[3] states that the rapid changes in climate, environmental conditions and activity in the Arctic highlights the need for an ecosystem-based approach to the management of the natural environment in the Arctic, which incorporates the ability for management to adapt. In addition, the climate adaptation white paper states that such an approach should both facilitate sustainable use and maintain environmental and biological diversity in the Arctic. It is furthermore stated that management measures contributing ecosystem resilience are essential, and asserts that intact ecosystems help to better ensure nature's resistance to the effects of climate change. The majority of Norway's Arctic comprises marine areas, managed with plans that state the intention to practice an integrated ecosystem based approach[4,5]. Implementation of ecosystem based management however is not fully operational. Specific targets and environmental goals lack, including establishment of appropriate marine protected areas (MPAs).

Areas with exceptional ecological features that strengthen regional ecosystem resilience lack protection from destructive cumulative effects of human activities. Since 2003, a Marine Protection Plan[6] in Norway has been undergoing a stagnant process. Out of 49 reviewed and 36 recommended Marine Protected Areas, three have been established up to now. Conservation criteria involve Representativeness, Uniqueness, Vulnerability, Threat and Reference value. Additional to conservation criteria are six location categories: Tidal pools, Strong current areas, Special shallow water areas, Fjords, Open coastal areas, and Ocean shelf areas[7]. Unfortunately the process has not taken into regard adaptation to rapid climate change to safeguard ecosystem function, and the majority are small and disproportionally coastal. For an adaptive marine management approach to successfully aid Norway in navigating through rapid change in the circum-Arctic, a very important part must involve securing protection not only for a representative selection of marine environments, but this protection must to the greatest possible degree reflect criteria of conferring ecological resilience to the wider ecoregion.

Taking into account the rapid pace of changes occurring in the Arctic, how can management quickly define what areas are most important to secure from negative cumulative effects of human activity? WWF's Global Arctic Programme has embarked on a new cutting edge project called RACER; Rapid Assessment of Circum-Arctic Ecosystem Resilience[8]. RACER is a tool for finding and mapping the sources of ecological resilience that help keep ecosystems functioning and contributing ecosystem services throughout the Arctic, as targets for future conservation and management efforts. RACER poses an answer to the stewardship challenge of identifying key features where important drivers will continue to support places with exceptional ecological vitality that confer resilience to ecosystems across arctic regions now – and for the remainder of this climate-altered century[8]. This manner of thinking is missing from the Norwegian MPA plan, which is utilizing outdated criteria and methodology that does not reflect mitigating the current and future threats to the marine environment.

**"RACER poses an answer to the stewardship challenge of identifying areas that will continue to support exceptional ecological vitality for the remainder of this climate-altered century."**

The purpose of RACER is to change the way environmental management handles change in the Arctic. As a tool for environmental or land management agencies and organizations, RACER provides a new forward-looking view of arctic conservation that sees the regions of the Arctic as functioning ecosystems. RACER is an instrument to manage change by maintaining the ecological machinery responsible for the conditions that living things, and northern communities need. When this machinery is working well, ecosystems have the resilience to adapt to change and to cope with shocks and respond to opportunities, while continuing to function in much the same way[8].

The rationale for RACER began with a review of the current state of arctic conservation during a WWF workshop in Oslo, Norway in May 2009. Conference participants agreed that the scale and the speed of climate-related ecological change in the Arctic would soon outpace efforts to conserve species and habitats where they are found today. The immensity of this challenge demanded a significantly new way of thinking about planning and management in the Arctic. The Oslo workshop concluded that a first step must be a rapid assessment of where arctic ecosystems are functioning particularly well now, and how likely they will continue to function in the climate-altered future. The assessment would take a mechanistic view and look for the features (on the landscape or at sea) whose characteristics drive exceptional productivity and diversity and lend resilience to regional ecosystems. Both the current location of features and the ecological drivers at work in these places should become important targets for conservation and management efforts in the face of change[8].

In 2010, WWF equipped with resilience science and a better understanding of the limits of arctic data, developed the RACER analytical framework – a model that could be both quick and effective at identifying the most important sources of ecosystem strength within arctic ecoregions. A series of ecoregional workshops followed, to further develop the on-the-ground methods and to examine the preliminary conclusions of the sample pilot studies, including those in the Beaufort Sea, the Laptev Sea, the Central Canada tundra, and the Eastern Chukotka region of Russia. The overall RACER framework also continued to develop to bridge the gaps between its ecosystem-theoretical foundations and the practicable approaches to ecological assessments identified by the case studies.

This report presents results from work conducted within the RACER project framework in Norway, and is intended to help inform stakeholders, managers and decision makers in Norway about the necessity and convenience of RACER as a management tool. The report is also meant to build awareness about areas and features in Norwegian marine jurisdiction which could be significant components for building ecological resilience across the circum-Arctic, under future Arctic climate change scenarios.



**Deep sea cirrate octopod (Sauroteuthis syrtensis)**

**RACER TERMS**
**Resilience in RACER**
In ecology, ***resilience*** is the capacity of an ecosystem to absorb perturbation and disturbance and, by doing so, maintain essential ecological functions.

RACER uses biological ***productivity*** and ***diversity*** of key features to indicate the likely sources of resilience of the ecosystems and the conferred benefits (e.g. ecosystem services) to the wider surrounding ecosystems to which they belong and to the people who rely on them[8].

This is based on two important concepts: the first argues that productivity and diversity are two central engines that keep ecosystems going and generating useful services. The second suggests that features where these engines are working especially well, that is where productivity and diversity are above the ecoregion average, can confer resilience beyond the places they are located and unto the ecosystem of the wider region.

Productivity, for example, reflects the work of plants and plankton that capture energy from the sun and carbon from the atmosphere, to pass it along as energy-rich organic compounds within ecosystem food webs. The productivity of a place, therefore, is one indicator of how well the surrounding ecosystems, including the services they provide to people, are functioning. The animals and other life that feed on the plants represent another level of biological production. This level is directly linked, even if for only periods in their life cycle, to primary productivity. Secondary productivity, as this level is known as, is often especially relevant to the livelihoods of people and communities who harvest fish and larger animals throughout the north.

Diversity is the number and variety of forms of life and habitats that interact to make ecosystems function. In the Arctic, the many interactions that comprise ecosystems are often very efficient at passing energy from photosynthetic life to large predators. Because conditions are harsh, the diversity of life is often relatively limited. Distribution is sparse and the numerous food chains it comprises are simple. Each link in these chains is represented by only a few species. This means that these ecosystems are considered vulnerable, because the decline or loss of a single species threatens to break a link and imperil a chain. Higher levels of diversity mean that when species and habitats disappear or move elsewhere, there is a higher chance that other animals and plants with an equivalent function in the system can fill in to replace the lost links, protecting the ecosystems against catastrophic loss of function. Thus, productivity and diversity work together to power arctic ecosystems and to enable these systems to better absorb environmental shocks[8].

The work of these ecological engines generates ecological resilience, ensuring an ecosystem's capacity to work in much the same kind of way, and keep the same or a similar identity, while enduring stress. Productivity and diversity enables resilience by ensuring that ecosystems are better equipped to recover from disturbance, to respond to new ecological opportunities and to adapt to change.

**Features**

In general, ***features*** are places that stand out on the landscape or in the sea, such as canyons, river mouths, mountains, or ocean polynyas. These features combine characteristics, such as topographic variety, currents, ice edges, and nutrient upwelling that drive productivity or diversity or both. Features are understood and located where these *drivers* align in unique combinations. Although some features represent locations fixed by a physical structure that is not expected to change much over the coming century (e.g., canyons), others are defined by characteristics directly or indirectly affected by climate change and can move (e.g. ocean polynyas). RACER assessments test ecosystem resilience for entire ecoregions. This allows RACER to make conclusions that are relevant to planning in regions that represent ecological communities, biodiversity, and natural values and services across the circumpolar Arctic[8].

**Key Features and their Drivers**

RACER's spotlight on the importance of key features and their drivers marks a significant shift in thinking for natural resource management and conservation in the Arctic. From among the many features in an ecoregion, RACER identifies and maps only ***Key features***, which are found where the combined effect of currents, soil types, sea ice, and other ***drivers*** generate exceptional ecological vitality compared to the ecoregion as a whole.

The combination of drivers at key features work together better than the drivers do at other features when it comes to feeding, fertilizing, and otherwise encouraging plant and animal growth (biological productivity) and supporting large numbers of different kinds of life and habitats (diversity) or both. Decision makers and managers can use this new perspective to discover and safeguard the discrete locations of key features that contribute to the ecosystem functioning of the ecoregions in which these features are found. Preserving one local-scale key feature can affect ecosystem resilience at a far larger scale. Meanwhile, recognizing the importance of drivers can encourage management efforts that are strategically aimed at the functional underpinning of the ecosystems that support arctic life.

Importantly, RACER focus on key features and their drivers also allows researchers to assess whether the ecosystem resilience of ecoregions is likely to continue despite climate change. The relationship between the climate variables used in General Circulation Model predictions and the drivers that characterize key features offers the capacity to base current strategic planning and management decisions on the best-informed scientific scenarios of future change[8].

**RACER METHODS**

RACER's method is an innovative ecosystem-based approach that finds and evaluates the local sources of exceptional productivity and diversity – or ecological vitality. These local sources are behind the continued viability (i.e., continued functioning) of their larger-scale, regional ecosystems now, and into the climate affected future. These local sources of ecological vitality are landscape or sea features that support exceptional biological productivity or diversity (or both) in discrete, readily identified places within arctic regions. The relationship between the resilience of the large regional ecosystems–*ecoregions*–and the most productive and ecologically diverse features that support resilience is central to the RACER method[8].

RACER uses the best available data as rapidly as possible to identify, assess and map the key features that currently support ecosystem resilience in 50 ecologically distinctive regions (ecoregions) throughout the circumpolar North, 50 of which are marine (Figure 1). The wild card is climate change: Arctic warming, shrinking ice, changes in rain and snow, shifts from wet to dry, and multiple climate impacts can disrupt the biological and physical characteristics of features that are responsible for generating productivity and diversity. By identifying key features that will remain exceptionally productive and diverse into the future, managers and planners can safeguard the sources of resilience important for the continued functioning of arctic ecosystems and the ecosystem services people in the North depend on.



View towards Solvær. Austvågøy, Lofoten, Norway


Map 1: Arctic Marine ecoregions used in RACER, based on Spalding et.al.[9].

**The RACER Process**

Part 1: Mapping resilience

- Step 1. Map places of exceptional productivity and diversity. Uses literature and remote sensing analysis to identify places with exceptional productivity and diversity within each ecoregion.
- Step 2. Identify key features. Describes the unique combinations of drivers considered responsible for the exceptional local-scale productivity and diversity (above). Identifies these driver combinations as key features that confer ecoregion-wide resilience and shows these features on a map.

Part 2: Assessing persistence

- Step 1. Assess the impact of climate change on the ecoregion. This involves identifying the General Circulation Model variables that are relevant to the ecoregion and describeing the General Circulation Model projected change of these variables through to 2100.
- Step 2. Estimate how drivers of exceptional productivity and diversity of key features are affected by climate change. This involves projected how foreseen changes in General Circulation Model variables affect the ecoregion-scale drivers, and interpreting their impact on the drivers of the exceptional productivity and diversity at the scale of key features.
- Step 3. Assess the persistence of the capacity of key features to confer resilience on the ecoregion affected by climate change. This involves judging the likely persistence of a key

feature's continued ability to confer resilience by interpreting whether feature-scale drivers will continue to support exceptional productivity and diversity for identified key features.

**RACER in Norway**

**Commissioned Sweco Characterisation Report**

In 2011, WWF-Norway commissioned Sweco Norway to undertake part one of the RACER process for the characterization of two of the ecoregions under Norwegian jurisdiction, namely Northern Norway/Finnmark (M46) and Norwegian Sea (M47) (Map 1). An important aspect for these two regions is that they are affected by human activity in some of the most densely populated areas in the Arctic. The focus of the Sweco-analysis was to describe geophysical processes/drivers/features and ecosystem/biological features[10].

**Expert Workshop**

As part two of the Norwegian RACER process, Martin Sommerkorn from WWF's Global Arctic Programme and Nils Boisen from WWF-Norway held a two-day RACER workshop with scientists in Tromsø, Norway, in November 2012. The workshop participants, all regional scientific experts, accustomed to incorporating their specialist knowledge into an ecosystem view, assessed the persistence of drivers enabling exceptional productivity or diversity for each of the 13 key features (Map 2) identified by the ecoregion characterization done by Sweco on behalf of WWF-Norway. Sweco's analysis was part one of the RACER method, characterising the ecoregions and identifying potential key features and drivers conferring resilience. The workshop experts were given the opportunity to discuss and improve the Sweco key feature recommendations, and their knowledgeable contribution in assessing the Sweco characterization was highly valuable.

**Norwegian Ecoregions Addressed in this Report**

**Northern Norway and Finnmark**

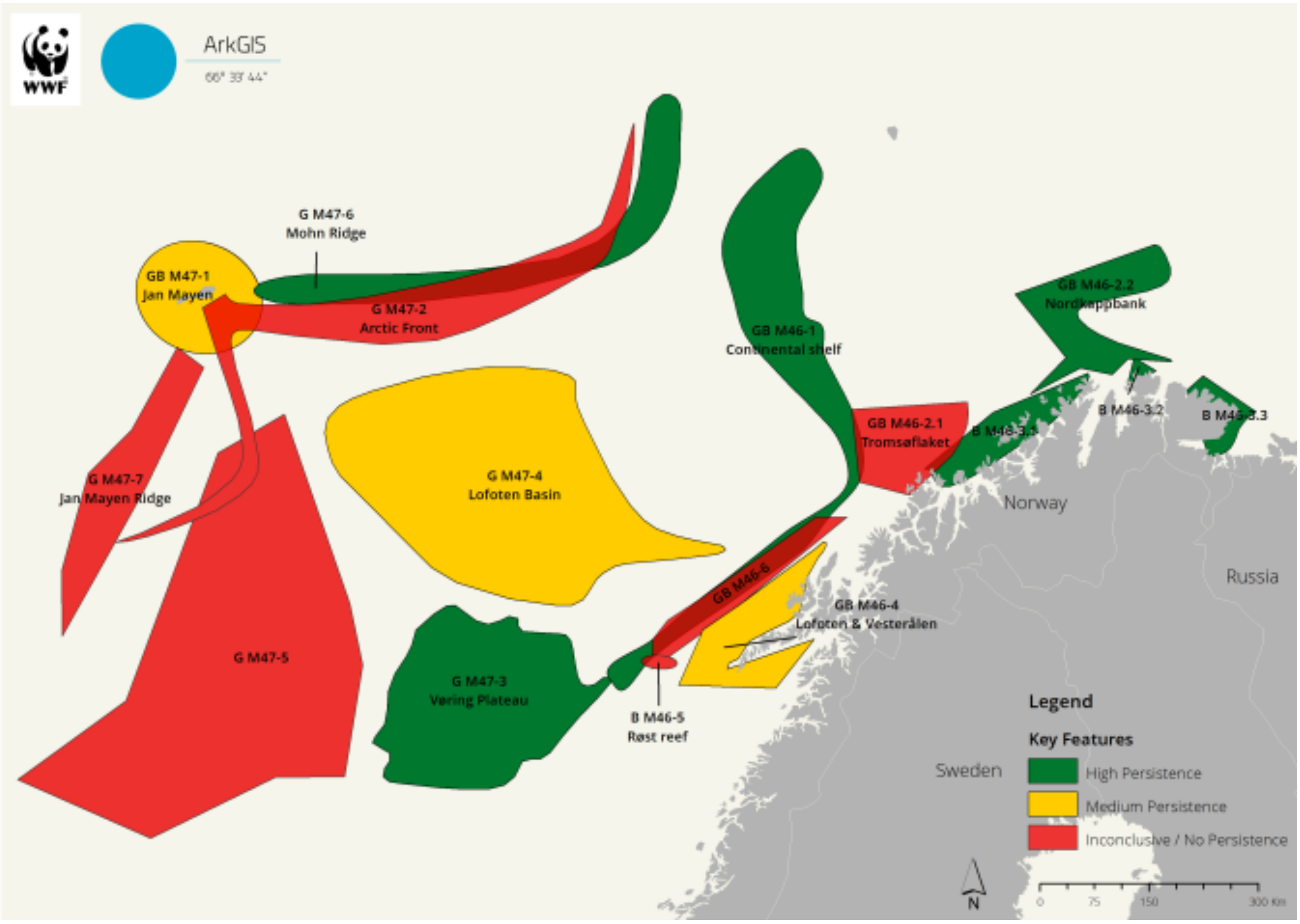
The Northern Norway and Finnmark ecoregion (M46) (Map 1) stretches from the Northern Norwegian coast, and westward into the Atlantic Ocean. The shelf is approximately 300 meters deep near the coast, but goes down to depths up to little more than 3000 meters along the steep descending continental slope, Eggakanten, outside of Lofoten. The continental slope bends off north towards off the coast of Troms, making the border to the Barents Sea. Off the coast of Finnmark and the Kola Peninsula the area is less deep. The coast consists of many fjords along Lofoten and Finnmark. However, fjords are much less frequent along the coast of the Kola Peninsula. Islands are frequent from Lofoten up to mid part of the Finnmark coast. No major riverine input are found in these areas, however several minor ones are found along the coastline and within the fjord systems. Sand, sediments and gravel dominates the bottom surface of the ocean floor in the region. Occasionally, hard rock surfaces can also be found. The costal Norwegian current goes northward, while the North Atlantic current brings warm saline water from the Norwegian Sea and into the Barents region, making area M46 ice free all year around[10].

**Norwegian Sea**

The borders of the Norwegian Sea (M47) (Map 1) vary in the literature. M47 constitutes a narrow and shallow continental shelf (50-300 meters in depth), but is dominated by deep sea areas (down to 4000 meters). The average depth is 1800 meters. The Norwegian Sea is dominated by two basins: the Norwegian Sea Basin and the Lofoten Basin. The North Atlantic Current brings warm water through the Norwegian Sea, while the Icelandic East Current brings cold water from the Icelandic sea in the south-western parts of the area, making this part colder than the rest.

Great variation in climate persist, both seasonal and annually, due to three causes: I) variations in temperature from the incoming Atlantic water; II) the amount of water input from Arctic waters from the west; and III) heat loss to the atmosphere. Warm Atlantic water also makes the Norwegian Sea ice-free throughout the year. Mixing of Atlantic water and costal water along the continental slope creates areas of water circulation, mixing and upwelling[9].

**Key Features Documented in Sweco Characterisation**




Map 2: RACER Key Features in the Northern Norway/Finnmark and Norwegian Sea ecoregions, as characterized by Sweco Norway[10]. Colour definitions based on later persistence assessment by expert group.

**Sweco Key Feature Explanation**

| Number* | Name and Description |
|---|---|
| GBM46-1 | Continental shelf. Important mixing area. Important for many species, including whales and deep water corals. Separates the Norwegian Sea and the Barents Sea. |
| GB M46-2.1 & .2 | Several fish banks. Tromsøflaket (2.1). Nordkappbank is a single large one. |
| B M46-3.1, .2 & .3 | Capelin breeding grounds. Breeding grounds can however shift and can be occasionally found as far south as Vesterålen. |
| GB M46-4 | Lofoten-Vesterålen: High zooplankton production. Important habitat for several species (herring, seabirds, killer whales). Important spawning area (Norwegian arctic cod area and haddock). |
| B M46-5 | Røst Reef. World's largest known deep water coral reef. |
| GB M46-6 | Area with several marine canyons. Important habitat for several species of fish juvenile. |
| GB M47-1 | Jan Mayen. High productivity, important area for many species. |
| G M47-2 | The Arctic Front. Weather system. Separates the Arctic Ocean and the Norwegian Atlantic Current. |
| G M47-3 | Vøring Plateau. A characteristic "submarine peninsula" off the continental shelf, surrounded by deep water. |
| G M47-4 | Lofoten Basin. Deep water area. 3000-4000m deep. Together with G M47-5 contains the main body of water in the Norwegian Sea. |
| G M47-5 | Norwegian Sea Basin. Deep water area. 3000-4000m deep. Together with G M47-4 contains the main body of water in the Norwegian Sea. |
| G M47-6 | Mohn Ridge. 2000m deep. With the Arctic Front separates the Arctic Ocean and the Norwegian Atlantic Current. |
| G M47-7 | Jan Mayen Ridge. 2000m deep. West border of M47. |

*Number clarification: GB_M47_1 = Geophysical and Biological area M47 key feature 1. G_M47_6: = Geophysical area M47 key feature 6

**Expert Assessment of Key Feature Persistence (Map 2)**
**High Persistence**

| Key Feature | Commentary | Persistence Assessment Remarks |
|---|---|---|
| GB M46-1<br>Continental shelf | • Geophysical drivers drive productivity (primary pelagic sources of productivity for other features).<br>• There are coral reefs around, but not widespread; they are probably less of a defining element for this key feature.<br>• There is considerable fish diversity in the deep water and at the bottom that is driven by primary productivity, topography and oceanography, but this fish diversity has a low productivity.<br>• Intensity of The North Atlantic Current (volume, temperature) important. | The experts thought that drivers at feature scale were sufficiently described here and rank the persistence of M46-1 as high. No further remarks given. |

| Key Feature | Commentary | Persistence Assessment Remarks |
|---|---|---|
| GB M46-2.2<br>Nordkappbank | • Unclear if Sweco's delineation follows the 200 m depth contour.<br>• Primary productivity established reasoning, but more information should be gathered to underpin this.<br>• Primary productivity extends all the way through the 'wedge' currently cutting into the east side delineation of the key feature. Outline should reflect this.<br>• Spawning and larval areas of cod, capelin, haddock and pollock.<br>• Benthos: diverse, soft-bottom communities.<br>• High diversity, high secondary productivity (benthic and pelagic), high degree of benthic-pelagic coupling.<br>• Drivers: Norwegian Coastal Current, topography (induces turbulent mixing), mixed seafloor sediment types (benthic habitat diversity).<br>• Need to establish with physical oceanography whether North Atlantic Current (Barents Sea Branch) mixes with Norwegian Coastal Current over the bank (volume flow is the driver); if so then interaction between the two is an important driver. | The experts thought that the separation of the two areas for the key feature, currently combined as 46-2.1 and 46-2.2, should be separated before assessing the persistence of current M46-2.2. Information gaps exist mainly because of the present combining of two areas into one key feature, but based on what is available experts tend to a preliminary persistence assessment of high. |

| Key Feature | Commentary | Persistence Assessment Remarks |
|---|---|---|
| B M46-3.1, .2 & .3<br>Capelin breeding grounds | • Delineation and reasoning for separation unclear.<br>• Needs to extend all the way into the fjords.<br>• Feeding areas for some fish species<br>• Spawning areas for fish<br>• Important bird areas<br>• Fjord-produced primary productivity (microalgae)<br>• High diversity of habitats<br>• Data from the Norwegian Coastal Current project reinforce this as a key feature<br>• Drivers:<br>  ▪ 1 Fjords: topography , nutrient input from land and coastal | Experts rank persistence as high. The area has a high buffering capacity because of high habitat diversity and environmental variability. |

| | | |
|---|---|---|
| | (fjord) systems: precipitation (inshore), wind (offshore) to mix stratified layers, freshwater input)<br>▪ 2 Norwegian Coastal Current | |
| **Key Feature** | **Commentary** | **Persistence Assessment Remarks** |
| G M47-3<br>Vøring Plateau | • Primary productivity reasoned with SeaWifs (Actus).<br>• Drivers:<br>▪ Local scale current pattern: waters pushed upwards and mixing eddies formed caused by North Atlantic Current**.**<br>▪ Topography: slope complexity.<br>• Check with physical oceanographer whether Arctic waters can up-well there, or if it is modified East Icelandic water. | Experts rank persistence of as high. No further remarks given. |
| **Key Feature** | **Commentary** | **Persistence Assessment Remarks** |
| G M47-6<br>Mohn Ridge | • The front corresponds with this/is this key feature. Note that the front can move somewhat from year to year.<br>• Associated with 47-2, but a reason for keeping -6 separate would be the likely distinct diversity of the benthos, including bottom fish.<br>• Drivers: topography. | Experts rank persistence of as high. No further remarks given. |

**Medium Persistence Key Features**

| **Name** | **Commentary** | **Persistence Assessment Remarks** |
|---|---|---|
| GB M47-1<br>Jan Mayen | • Primary productivity reasoned.<br>• Benthos extremely important, but not considered in Sweco characterisation. Highly diverse and productive communities of clams (even important for fisheries), scallops, sea cucumbers.<br>• Birds likely feed at the front (secondary productivity).<br>• Drivers:<br>▪ Branch of North Atlantic Current<br>▪ East Greenland Current<br>▪ Benthos<br>▪ Current speed<br>▪ Land-ocean interface | Experts rank persistence as medium-high. The land-ocean interface and topography are persistent. The North Atlantic Current will probably become stronger, but with higher variability though the jury is still out. In case there will in the future be a weaker North Atlantic Current the Atlantic water doesn't reach the shelf and the result would be a decreased productivity. |
| **Key Feature** | **Commentary** | **Persistence Assessment Remarks** |
| GB M46-4<br>Lofoten & | • High zooplankton productivity, high biomass concentration (spawning | The experts rank persistence of GM47-4 as medium, but with a high |

| | | |
|---|---|---|
| Vesterålen | area), attracting fish, mammals and birds.<br>• Drivers are therefore predominantly biological.<br>• Other drivers NAC, close to the shelf also topography/habitat complexity.<br>• An open question is whether the productivity is established in-situ or whether it is a product of the drivers of 46-1. | uncertainty. The uncertainty arises from the ecological nature of the drivers. Importantly, whether or not zooplankton *Calanus finmarchicus* will be replaced by a less nutritious species with increasingly warmer waters. This would endanger fish nutrition and productivity, despite the fact that with warmer water temperatures cod will arrive at the key feature from further South. |

| **Key Feature** | **Commentary** | **Persistence Assessment Remarks** |
|---|---|---|
| G M47-4<br>Lofoten Basin | • Should not be a geophysical feature as bottom is sediments; pelagic aspects are diverse, but poorly described.<br>• Experts ask why the northern part of the basin is not included in this KF.<br>• System has 'two layers' at this key feature:<br>  ▪ Herring, blue whiting, zooplankton. High fish productivity enabled by zooplankton.<br>  ▪ "Mesopelagic" layer ("deep scattering layer") at 300-800 m depth with high diversity but low productivity. Descriptive knowledge only available so far.<br>• Tightly connected pelagic-benthic system.<br>• North Atlantic water is driver, linked to thermohaline circulation. | The experts ranked persistence as medium, potentially medium-high. Though highly variable, a predominantly variable system will persist. This system is not well understood, nor is the bottom well monitored. |

**Inconclusive / No Key Feature Persistence**

| Name | Commentary | Persistence Assessment Remarks |
|---|---|---|
| GB M46-2.1<br>Tromsøflaket | • Benthic system similar to Nordkappbank, but possibly more sponge communities.<br>• Benthic substrate supposed to be diverse, but there is a large information gap here.<br>• Larval areas of cod, capelin, haddock and pollock transported as plankton.<br>• Norwegian Costal Current eddies retain plankton and cause tertiary pelagic productivity and high degree of pelagic-benthic coupling.<br>• Drivers:<br>▪ Norwegian Costal Current (critical for eddy formation)<br>▪ North Atlantic Current: Need to establish whether its Barents Sea Branch mixes with Norwegian Costal Current<br>▪ Topography<br>▪ Benthic-pelagic coupling | The experts believed that the separation of the two areas for the key feature should be done and information separated before assessing the persistence of current M46-2.1. Comparatively M46-2.1 may be less persistent than the adjacent shelf break system because of the critical driving role of eddies. Not enough is known about the persistence of those eddies, so currently high uncertainty exists for assessing the persistence of this key feature. |

| Key Feature | Commentary | Persistence Assessment Remarks |
|---|---|---|
| B M46-5<br>Røst reef | • Should be a geophysical feature (G) as well as biological.<br>• Highly diverse<br>• Drivers:<br>▪ High currents<br>▪ Cold temperature due to depth<br>▪ Moderate sedimentation | The experts did not feel confident to rank persistence of this key feature as its uncertainty was perceived as too high. The drivers create a highly localised set of conditions. How these in concert will be affected by projected change in climatic conditions is uncertain. |

| Key Feature | Commentary | Persistence Assessment Remarks |
|---|---|---|
| GB M46-6 | • Geophysical drivers drive productivity, primarily pelagic sources of productivity for other features.<br>• Southern point should end further North.<br>• Focus on particle flux /downslope transport.<br>• Benthic habitat diversity; hydrodynamic conditions generate complexity at mesoscale.<br>• It was discussed whether or not to keep separate M46-1 and M46-6, but because mesoscale diversity is generated differently and to | Due to time taken on M46-1 and M46-6 separation discussion, no persistence assessment was made. |

different quantities compared with M46-1, it is deemed justifiable to keep them separate.

| Key Feature | Commentary | Persistence Assessment Remarks |
|---|---|---|
| G M47-2<br>Arctic Front | • Passive front, density compensated front temperature on one side compensates for salinity on the other), i.e. no upwelling.<br>• Fish "hang out at the fence" in the warmer waters, but it is unclear whether they actually accumulate there. Probably not.<br>• It is really more a border between M47-2 and M47-4. | Non-conclusive discussion. Perceived as an important feature, but probably not a RACER key feature. |

| Key Feature | Commentary | Persistence Assessment Remarks |
|---|---|---|
| G M47-7<br>Jan Mayen Ridge | • Limited ecological studies available.<br>• Several whale species feed in the area, but experts present don't know on what.<br>• Similar potential as for 47-6 for benthic diversity driven by topography.<br>• Drivers: topography. | 47-6 and 47-7 should be combined. Non-conclusive discussion. |

| Key Feature | Commentary | Persistence Assessment Remarks |
|---|---|---|
| G M47-5 Norwegian Sea Basin | • A distinctive basin with distinctive water mass.<br>• There is no indication of exceptional productivity or diversity. | Experts concluded that this should not be a RACER key feature. |



**Atlantic Cod (Gadus Morhua)**

**Conclusion**
The expert assessments from this initial Norwegian component of the RACER project, and the underlying framework through which they are based, clearly demonstrate two points:

I: Areas exist in Norwegian High-North marine jurisdiction which could be significant for safeguarding ecological resilience for their wider ecoregions under future Arctic climate change scenarios, and these areas needs closer attention from experts and decision makers.

II: RACER has great relevance for climate-adaptive marine management in Norway as a tool for translating future threats and pressures to the arctic environment into effective forward-looking planning.

Only one recommended area in Norway's Marine Protection plan appears to overlap with a High Persistence RACER key feature, and herein only slightly; Lopphavet[7] and B M46-3.1 (capelin breeding grounds). There is otherwise only slight overlay between the management's recommended MPAs and recommended key features. Certainly with regard to climate change, and expressly with regard to the Arctic, Norway's MPA plan process must re-evaluate both the intent of establishing MPAs, and therein the criteria for which they are selected. A modern marine environmental management approach that is ecosystem based, implicitly involves adaptation measures to climate change. If Norway is to successfully navigate through rapid change in the circum-Arctic, a crucial component of its ecosystem based management must involve securing protection not only for a representative

selection of marine environments, but selection criteria must as f
ar as possible consider to what degree the area in question confers ecological resilience to the wider ecoregion. RACER is the tool needed here to quickly translate future threats and pressures to the arctic environment into effective forward-looking planning[8].

**"A modern marine environmental management approach that is ecosystem based implicitly involves adaptation measures to climate change."**

Among the recommendations from the Arctic Biodiversity Assessment report are that resilience and adaptation of biodiversity to climate change must be incorporated into arctic development plans. Furthermore, that important areas for biodiversity should be identified and safeguarded, taking into account ecological resilience in a changing climate[1]. RACER is in other words a starting point for discussion among stakeholders. Outside of Norway's MPA plan process, an additional example is the Arctic Council and Norway's involvement in its associated working groups. Many current activities of the Arctic Council are focusing on resilience, including the Arctic Resilience Report, the work of the Ecosystem-Based Management Experts Group, Arctic Biodiversity Assessment, Arctic Ocean Acidification Assessment and Arctic Ocean Review[2]. Other activities are delivering essential knowledge for understanding resilience, including on-going work with the Arctic Human Development Report-II[2]. Resilience in an Arctic setting can also be a valuable guide for further work within the Adaptation Actions for a Changing Arctic initiative[2].

**OUTLOOK**

RACER's practical application of a forward-looking ecosystem approach has great potential for stimulating policies in Norway that will improve the management of arctic marine natural resources at a time of mounting pressure from climate change, industrial development and other interests. To the Marine Protection Plan and its involved ministries and directorate, RACER presents itself as both a necessary tool and an approach that has been missing up to now for identifying geographically discrete conservation targets that will remain significant through this climate-altered century. To the processes of updating Norwegian Marine Management plans, RACER offers an approach for initiating stakeholder discussions about how to manage and safeguard these targets. Finally, to experts involved in biodiversity research, monitoring and conservation, RACER provides a framework to advance our understanding of the functional role of biodiversity for arctic ecosystems, for the services they provide and for people.

**Floating ice blocks between Spitsbergen (Svalbard) and Greenland, Arctic Ocean. © Sylvia Rubli / WWF-Canon**

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in the high north is currently outpacing the implementation of sufficient environmental management.

## CLIMATE CHANGE

is the most severe danger to the continuity of the Arctic's unique and important ecology, aggravating all other threats.

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in the Arctic that is holistic and ecosystem based must ensure successful navigation of the rapid changes under way.

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poses an answer to the stewardship challenge of identifying areas that will continue to support exceptional ecological vitality for the remainder of this climate-altered century.

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