State of the Arctic Marine Biodiversity

Key Findings and Advice for Monitoring

CIRCUMPOLAR BIODIVERSITY MONITORING PROGRAM

CAFF
Conservation of Arctic Flora and Fauna

ARCTIC COUNCIL

State of the Arctic Marine Biodiversity: Key Findings and Advice for Monitoring

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- Environment and Climate Change Canada
- Faroese Museum of Natural History
- Finnish Ministry of the Environment
- Ministry of Independence, Nature, Environment and Agriculture, Greenland
- Icelandic Institute of Natural History
- Norwegian Environment Agency
- Russian Federation Ministry of Natural Resources
- Swedish Environmental Protection Agency
- United States Department of the Interior, Fish and Wildlife Service

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- Saami Council

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State of the Arctic Marine Biodiversity Key Findings and Advice for Monitoring

Ice diver. Changes in sea ice biota are very challenging to detect because sea ice is a dynamic system that has large natural variability, and there has been a lack of consistent sea ice biota monitoring. Photo: Jeremy Stewart, Fisheries and Oceans Canada

Introduction

The ***State of the Arctic Marine Biodiversity Report*** (SAMBR), is a product of the **Circumpolar Biodiversity Monitoring Program** (CBMP) of the Arctic Council's **Conservation of Arctic Flora and Fauna** (CAFF) Working Group. The SAMBR is a synthesis of the state of knowledge about biodiversity in Arctic marine ecosystems, detectable changes, and important gaps in our ability to assess state and trends in biodiversity across six Focal Ecosystem Components (FECs): sea ice biota, plankton, benthos, marine fishes, seabirds and marine mammals.

By compiling available information, this report provides an important first step to identify knowledge gaps in circumpolar biodiversity monitoring efforts. Current biodiversity monitoring is not sufficient to describe the status and trends for many of the FECs. Snapshots of the state of knowledge and trends for each FEC are provided.

Based on the available information, general trends include:

- Food resources are being lost for many Arctic species in Arctic marine environments.
- Some Arctic species are shifting their ranges northwards to seek more favourable conditions as the Arctic warms.
- Northward movement is easier for more mobile open-water species such as polar cod compared to those linked to shelf regions.
- Increasing numbers and diversity of southern species are moving into Arctic waters.
- Current trends indicate that species reliant on sea ice for reproduction, resting or foraging will experience range reductions.
- Arctic marine species and ecosystems are undergoing pressure from cumulative changes in their physical, chemical and biological environment.
- Increases in the frequency of contagious diseases are being observed in Arctic marine species

Advice for monitoring includes better coordination, standardisation of methods, improved consideration of Traditional and Local Knowledge (TLK), and attention to filling key gaps.

The ***Arctic Marine Biodiversity Monitoring Plan*** is an agreement across Arctic nations to compile, harmonize and compare results from existing Arctic marine biodiversity and ecosystem monitoring efforts, across nations and oceans.

Six Expert Networks (Sea ice biota, Plankton, Benthos, Marine fishes, Seabirds and Marine mammals) have identified key elements, called **Focal Ecosystem Components (FECs)**, of the Arctic marine ecosystem. Changes in FECs status likely indicate changes in the overall marine environment.

For the purposes of reporting and comparison, eight physically and bio-geochemically distinct **Arctic Marine Areas (AMAs)** were identified (Fig 1).

This work is coordinated under the **Circumpolar Biodiversity Monitoring Program** (CBMP) of the Arctic Council's **Conservation of Arctic Flora and Fauna** (CAFF). The CBMP is a network of scientists and traditional knowledge holders, governments, Indigenous organizations and conservation groups working to harmonize and integrate efforts to monitor the Arctic's living resources.

Key Findings

Food resources are being lost for many Arctic species in Arctic marine environments

Many species have to travel further and expend more energy to feed, leading to concerns about individual health and potential effects at the population level.

- Ivory gull declines coincide with reduction in their sea ice feeding areas.
- Reduced ice cover has also led to increased polar bear predation on ground-nesting common eiders and cliff-nesting murres, potentially leading to local population declines.
- Black guillemots in Alaska feed at the ice edge and have been forced to travel greater distances to foraging areas as sea-ice retreats, leading to lower breeding success.
- Barents Sea harp seals have reduced body condition associated with reduced food availability as their travel time to the ice edge to feed is longer.
- Some Indigenous communities have noted a change in walrus stomach contents, with more open water fishes and less clams, indicating that the distribution and availability of benthic resource species are changing in some areas.

Reduced ice cover has led to increased polar bear predation on ground-nesting common eiders and cliff-nesting murres, potentially leading to local population declines. Photo: Jenny E. Ross/naturepl.com

Figure 1. Map of Arctic Marine Areas as defined by the Circumpolar Biodiversity Monitoring Program (CBMP), with one sample finding from each area.

Some Arctic species are shifting their ranges northwards to seek more favourable conditions as the Arctic warms

These movements pose unknown consequences for Arctic species and their interactions, such as predation and competition.

- The northward expansion of capelin has led to changes in seabird diet in northern Hudson Bay. It also may affect marine mammals.
- Warming can have surprising and contradictory effects on species e.g. rising temperatures in the Chukchi Sea have been associated with an increase in nutritious copepods with high fat content.

Northward movement is easier for more mobile open-water species

Open water species such as polar cod, are more mobile compared to those linked to shelf regions, such as benthic species including some fishes for which suitable habitat may be unavailable if they move northward.

- Greenland halibut have the potential to expand into the Arctic Basin with climate change, but only given the availability of suitable prey and topography.

Increasing numbers and diversity of southern species are moving into Arctic waters

In some cases, they may outcompete and prey on Arctic species, or offer a less nutritious food source for Arctic species.

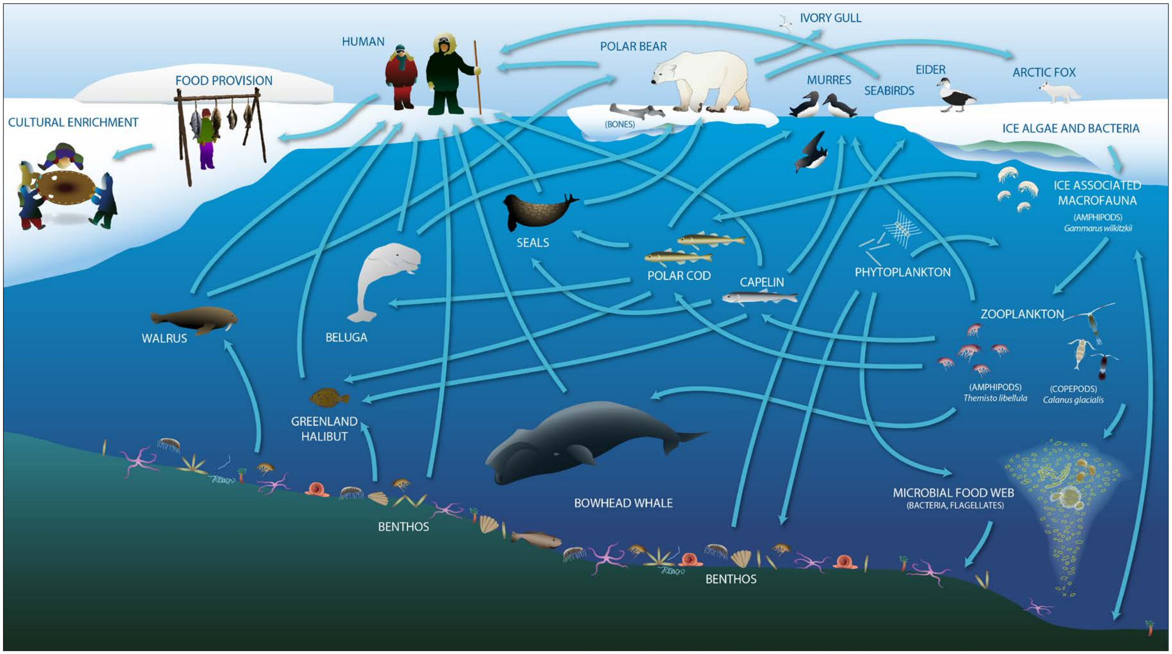
- The boreal copepod *Calanus finmarchicus* is expanding north from the Atlantic and replacing its more nutritious Arctic relatives *C. glacialis* and *C. hyperboreus*.
- Complex patterns of benthic biomass change in the Barents Sea are related to, amongst other pressures, warming of the Barents Sea improving conditions for boreal species to move further north.
- The distribution of Atlantic cod is expanding in the Atlantic Arctic and increasing predation pressure on the polar cod, an important nutrient-rich prey fish, important for other fishes, seabirds and marine mammals, especially seals.
- The more temperate killer whale is expanding in Arctic waters and may compete with other apex predators for nutritious seals.

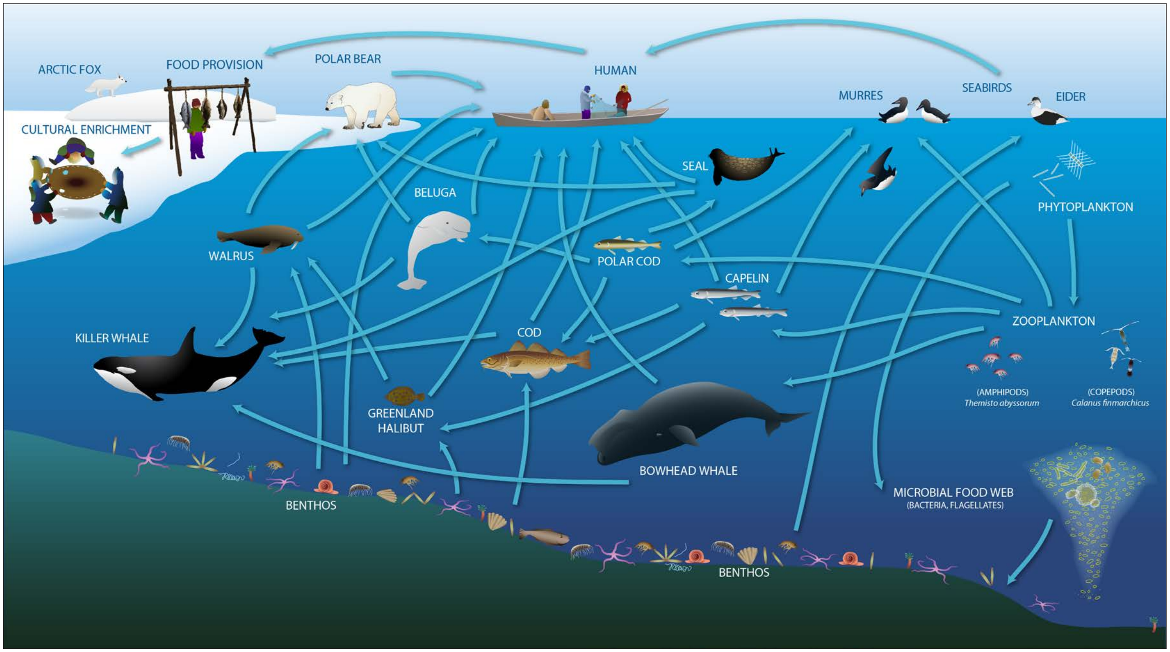
Benthic biomass change in the Barents Sea are related to warming amongst other pressures. Photo: Bodil Bluhm, University of Alaska, Fairbanks

Belugas in Hudson Bay varied timing of migration in response to variations in temperatures. These migrations may affect the ability of people to find and use these resources. Photo: Vicki Beaver/Alaska Fisheries Science Center, NOAA Fisheries Service

Current trends indicate that species reliant on sea ice for reproduction, resting or foraging will experience range reductions as sea ice retreat occurs earlier and the open water season is prolonged

- Since the 1980s, ice amphipod abundance has declined around Svalbard and it is possible that sea ice algal community structure has changed in the central Arctic.
- Although there are no documented cases of widespread population changes, some Arctic-breeding seabirds and some resident marine mammals have been observed shifting behaviours.
- Ducks breeding on the Siberian tundra and wintering at sea have shortened migration in response to declines in winter sea ice cover.
- Belugas in Hudson Bay varied timing of migration in response to variations in temperatures. These migrations may affect the ability of people to find and use these resources.
- Changes in sea ice conditions are probably linked to declines in the abundance of hooded seals, lower reproduction rates of Northwest Atlantic harp seals, reduced body condition of Barents Sea harp seals, and changes in prey composition of bearded seals.
- Extirpation of some stocks of ice-dependent seals are possible, but is expected to vary locally because of large regional variation in ice cover decline.
- Early spring sea ice retreat also reduces suitable breeding and pup rearing habitat for ringed seals. This affects the ability for polar bears, which feed on ringed seals, to rebuild energy stores after fasting during their own breeding period.
- Historically, walruses rested on sea ice located directly over prime feeding areas, but due to late season ice formation are increasingly using coastal haul-out sites instead of sea ice. In addition to travelling further to access foods, this also increases the risk of calf mortality due to stampede.


IVORY GULL
HUMAN
POLAR BEAR
FOOD PROVISION
EIDER
ARCTIC FOX
MURRES
SEABIRDS
CULTURAL ENRICHMENT
(BONES)
ICE ALGAE AND BACTERIA
ICE ASSOCIATED MACROFAUNA
(AMPHIPODS)
Gammarus wilkitzkii
SEALS
POLAR COD
CAPELIN
PHYTOPLANKTON
WALRUS
BELUGA
ZOOPLANKTON
(AMPHIPODS)
Themisto libellula
(COPEPODS)
Calanus glacialis
GREENLAND HALIBUT
BOWHEAD WHALE
MICROBIAL FOOD WEB
(BACTERIA, FLAGELLATES)
BENTHOS
BENTHOS


ARCTIC FOX
FOOD PROVISION
POLAR BEAR
HUMAN
MURRES
SEABIRDS
EIDER
CULTURAL ENRICHMENT
SEAL
BELUGA
PHYTOPLANKTON
WALRUS
POLAR COD
CAPELIN
KILLER WHALE
COD
ZOOPLANKTON
(AMPHIPODS)
Themisto abyssorum
(COPEPODS)
Calanus finmarchicus
GREENLAND HALIBUT
BOWHEAD WHALE
MICROBIAL FOOD WEB
(BACTERIA, FLAGELLATES)
BENTHOS
BENTHOS

Arctic marine species and ecosystems are undergoing pressure from cumulative changes in their physical, chemical and biological environment

Some changes may be gradual, but there may also be large and sudden shifts that can affect how the ecosystem functions.

It is hard to determine where and when these "tipping points" exist because the Arctic marine environment experiences a variety of stressors and subsequent reactions that can interact in complex and surprising ways. For those charged with managing natural resources and public policy in the region, it is crucial to identify the combined effects of stressors and potential thresholds to prepare effectively for an uncertain future.

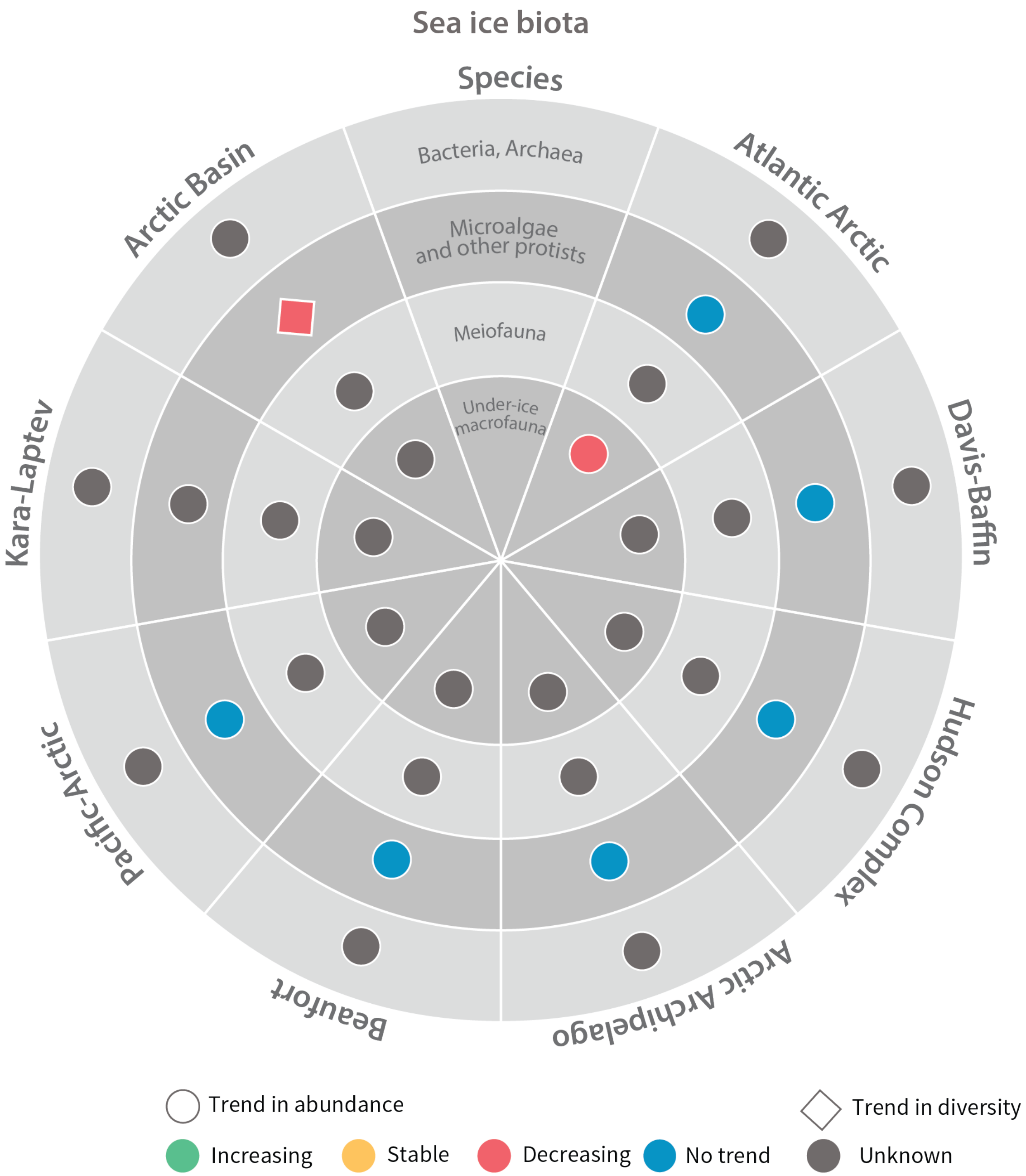
Increases in the frequency of contagious diseases are being observed

- Incidents of avian cholera have increased in the northern Bering Sea and Arctic Archipelago.
- The first designated Unusual Mortality Event in the U.S. Arctic occurred in 2011 and involved species of seals and walrus—essential food resources—affecting coastal community health, nutrition, cultural and economic well-being in areas of Canada, the U.S., and Russia.

Opposite page above: Figure 2a: Conventional conceptualization of energy flow in the High Arctic marine environment. The Arctic marine food web includes the exchange of energy and nutrition, and also provides cultural, social and spiritual meaning for human communities. Adapted from Darnis et al. (2012) and the Inuit Circumpolar Council-Alaska (2015).

Opposite page below: Figure 2b: Changes expected or underway in the energy flow in the High Arctic marine environment. The Arctic marine food web includes the exchange of energy and nutrition, and also provides cultural, social and spiritual meaning for human communities. Adapted from Darnis et al. (2012) and the Inuit Circumpolar Council-Alaska (2015).

Nitzschia frigida *in division.*
Photo: Michel Poulin, Canadian Museum of Nature


Sea ice biota
Species
Bacteria, Archaea
Microalgae and other protists
Meiofauna
Under-ice macrofauna
Arctic Basin
Atlantic Arctic
Kara-Laptev
Davis-Baffin
Pacific-Arctic
Hudson Complex
Beaufort
Arctic Archipelago
Trend in abundance
Trend in diversity
Increasing
Stable
Decreasing
No trend
Unknown

Summary Snapshots

Six Marine Expert Networks (Sea ice biota, Plankton, Benthos, Marine fishes, Seabirds and Marine mammals) provide the framework to implement the *Arctic Marine Biodiversity Monitoring Plan* and generate the information required for this report. This section provides a summary for each and includes a diagram that presents the overall trends for each AMA. In addition to providing a snapshot of trends by FEC and AMA, the diagrams provide clear indication of the state of knowledge. The results of each network are then compiled to provide an overall snapshot of the state of monitoring for each AMA.

Sea ice biota

Why is sea ice biota important?

- Sea ice is an important Arctic habitat that supports a rich diversity of species—many of which we know little about. Many different organisms live in and under sea ice, including microbes, single-celled algae, and small multicellular animals. Higher trophic levels are directly or indirectly supported by over 2000 species of small algae and animals that are associated with sea ice, but are often inconspicuous to the naked eye.

What is happening and why does it matter?

- Ice amphipod abundance has declined around Svalbard since the 1980s, coinciding with declining sea ice conditions.
- It is possible that sea ice algal community structure has changed in the Arctic Basin between the 1980s and 2010s. This uncertainty exists because sea ice extent and thickness declined, but sampling efforts and regions shifted, so it is difficult to attribute change.
- Multiyear sea ice is disappearing and is being replaced by first-year sea ice, which will cause shifts in ice algal communities with cascading effects on the ice-associated ecosystem.
- Seasonal duration of first-year sea ice is becoming shorter, with more snow on the ice, which may decrease the growth season for ice algae, with unknown consequences for biodiversity.

What are the most important drivers?

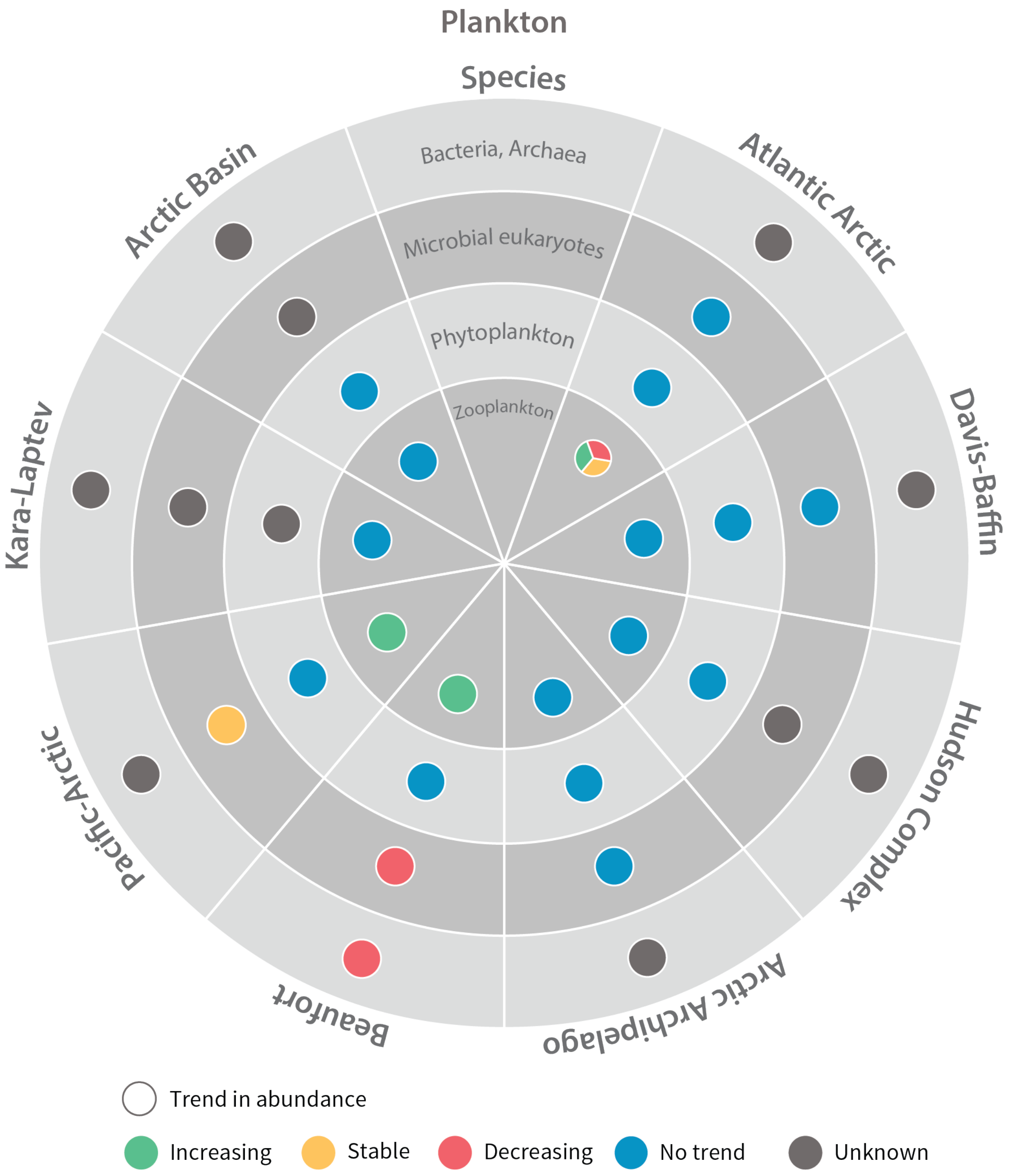
- Sea ice biota are affected by temperature and salinity, nutrient and space limitations and the ephemeral nature of the ice habitat, therefore making them very susceptible to climate change.

What should you know about the monitoring data?

- Changes in sea ice biota are very challenging to detect because sea ice is a dynamic system that has large natural variability, and there has been a lack of consistent sea ice biota monitoring.

Where is monitoring happening?

- Sea ice biota data have been gathered most frequently in the Arctic Basin, and Atlantic Arctic (Svalbard) and Barrow (Alaska) and the Canadian Arctic, with new sites developing in Greenland.


Plankton
Species
Bacteria, Archaea
Microbial eukaryotes
Phytoplankton
Zooplankton
Arctic Basin
Atlantic Arctic
Davis-Baffin
Hudson Complex
Arctic Archipelago
Beaufort
Pacific-Arctic
Kara-Laptev
Trend in abundance
Increasing
Stable
Decreasing
No trend
Unknown

Plankton

Why is plankton important?

- Micro plankton (Bacteria, Archaea, microbial eukaryotes and phytoplankton) and zooplankton are the base of the Arctic marine food web, feeding large-sized zooplankton, fishes, seabirds and marine mammals. Changes in these species can have cascading effects throughout the ecosystem and can represent the first sign of overall ecosystem shifts. Despite their importance, plankton are scientifically underappreciated and inadequately known.

What is happening and why does it matter?

- Warming can have contradictory and surprising effects on plankton. Increased temperature in the Barents Sea and around Svalbard has led to the presence of more southern species of unknown nutritional value to Arctic feeders. However, rising temperatures in the Chukchi Sea are associated with an increase in the presence of larger fatty copepods.
- There is an unknown, but potential, risk of harmful/toxic phytoplankton blooms. If strong algal blooms become increasingly common in Arctic waters, this could have impacts on seabirds and fish, due to either toxic effects or increased turbidity affecting foraging for visual predators, and fitness in marine mammals.

What are the most important drivers?

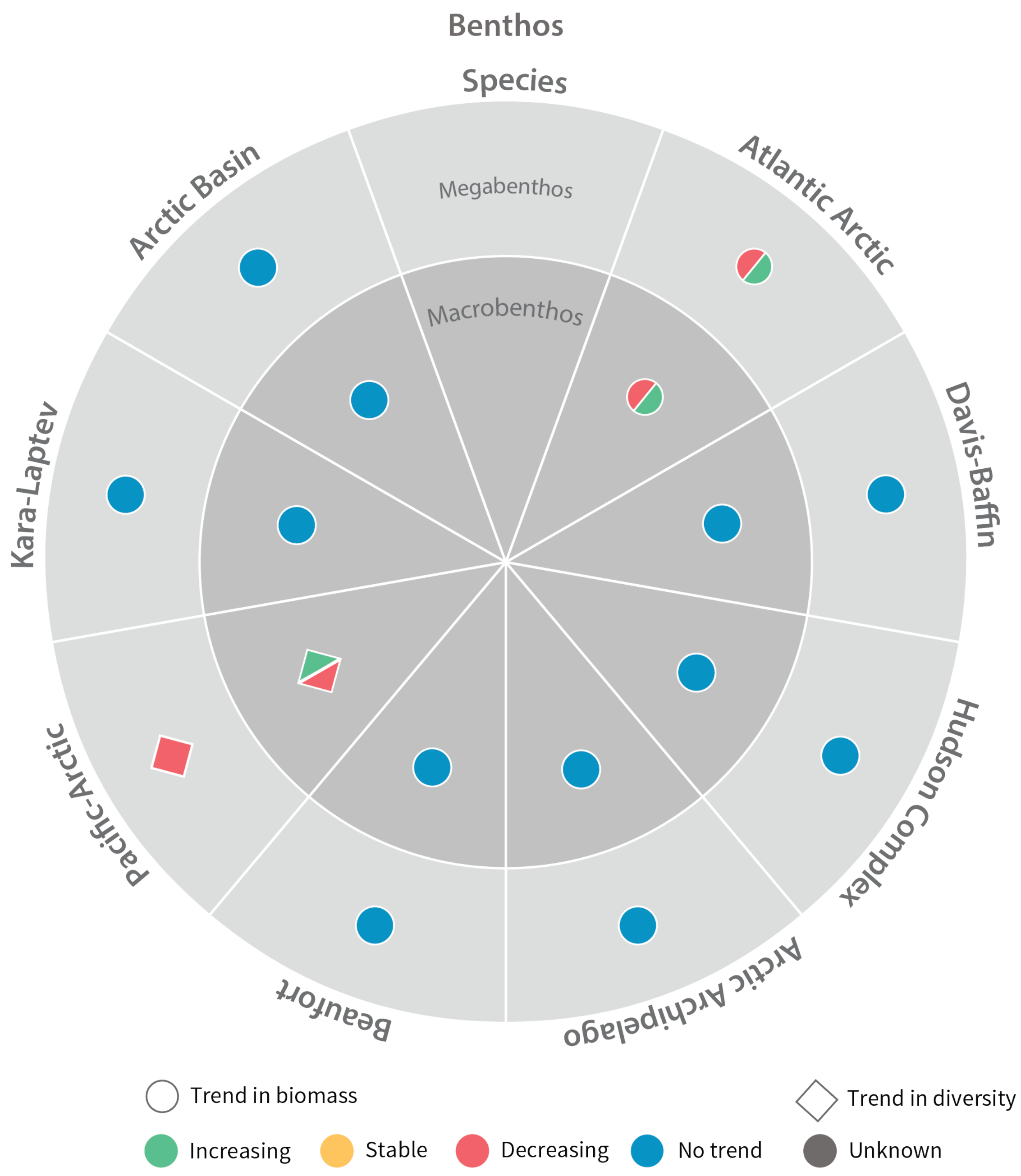
- Plankton are strongly affected by climate and differ between open water and ice-cover conditions, current patterns and salinity. Increased open water and less saline surface water could lead to range shifts so that Arctic species become replaced by non-Arctic species, again with unknown consequences for the Arctic marine food web.

What should you know about the monitoring data?

- Particularly unknown elements include the diversity of Bacteria, Archaea, and plankton and their distribution over time and space in the Arctic. This impedes better understanding of Arctic marine ecosystem structure and processes, and thus the ability to apply ecosystem based management.

Where is monitoring happening?

- Systematic monitoring of phytoplankton and zooplankton has most frequently occurred in Svalbard and Jan Mayen, the Barents Sea, Iceland, Greenland and the southern Bering Sea. Partial monitoring of phytoplankton and zooplankton in Canadian waters has been related to several major research initiatives. The Bering Strait region and northward into the Chukchi Sea have been studied intermittently and inconsistently for nearly a century by the U.S. and Russia, with the southern Bering Sea sampled in recent decades.
- There is no ongoing monitoring for Bacteria and Archaea anywhere in the Arctic.
- Smaller single-celled eukaryotes have been studied using molecular techniques in the Arctic Archipelago, Baffin Bay-Davis Strait, Atlantic Arctic, Pacific Arctic, and Beaufort AMA.


Benthos
Species
Megabenthos
Macrobenthos
Atlantic Arctic
Davis-Baffin
Hudson Complex
Arctic Archipelago
Beaufort
Pacific-Arctic
Kara-Laptev
Arctic Basin
Trend in biomass
Trend in diversity
Increasing
Stable
Decreasing
No trend
Unknown

Benthos

Why are benthos important?

- Benthic invertebrates such as shrimps, crabs, sea spiders, amphipods, isopods, bristle worms, gastropods, and bivalves, live on or in the seafloor and are important food sources for fishes, marine mammals, seabirds and humans, with several commercially harvested species. Benthic organisms rely on organic material produced in the overlying water column. They break down this material and release nutrients that later become available for primary producers such as phytoplankton. Currently, there are more than 4000 known Arctic macro- and megabenthic species.
- TK emphasizes the link between the benthic species and their predators, such as walrus, and their significance to culture.

What is happening and why does it matter?

- Increasing numbers of species are moving into, or shifting, their distributions in Arctic waters. These species are likely to outcompete, prey on or offer less nutritious value as prey for Arctic species.

What are the most important drivers?

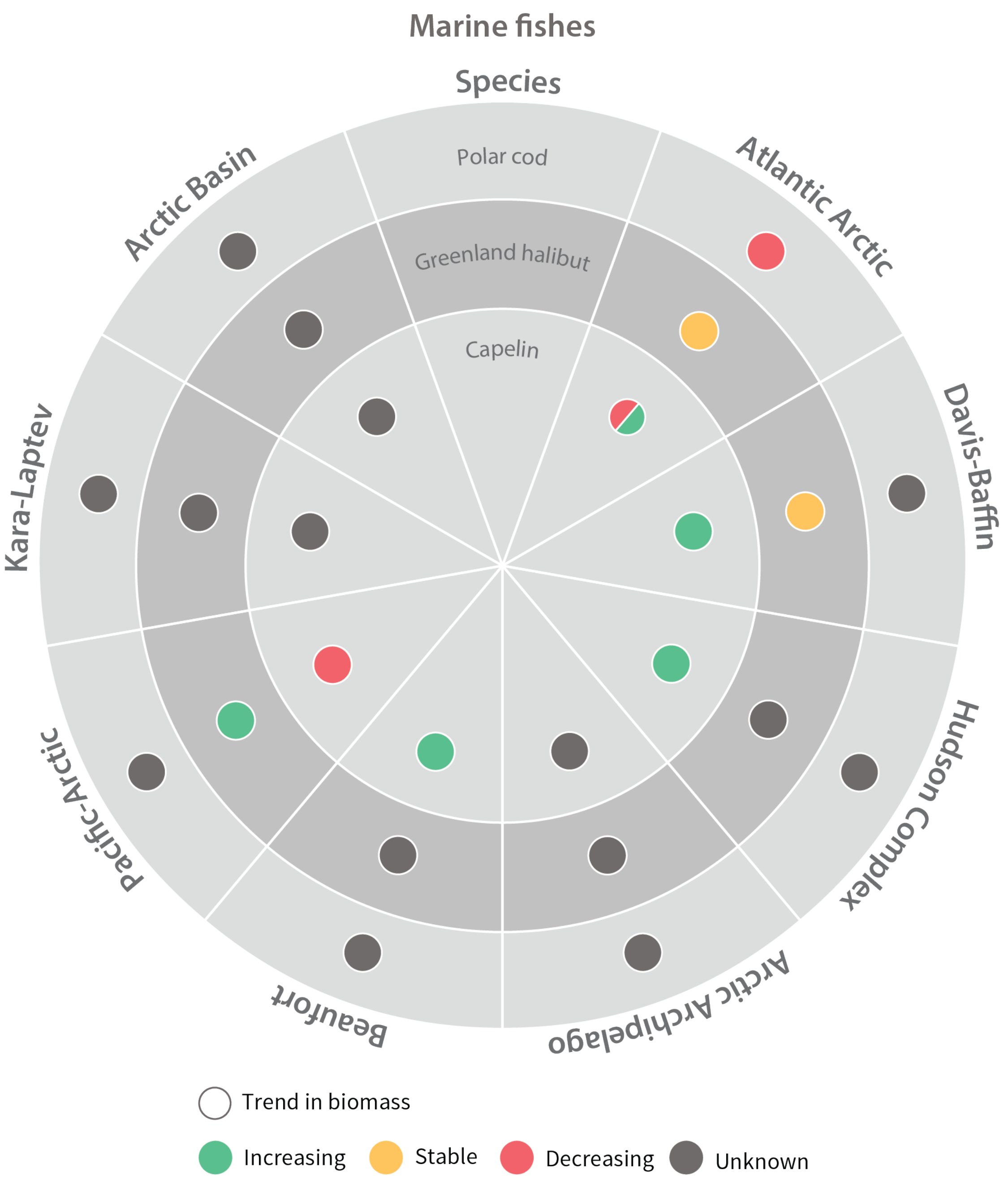
- Drivers related to climate change such as warming, ice decline and ocean acidification can affect the benthic community on a circumpolar scale, while drivers such as trawling, river/glacier discharge and invasive alien species have significant impact on regional or local scales.

What should you know about the monitoring data?

- Decadal changes in benthos biodiversity have been observed in some well-studied regions, such as the Barents Sea and Chukchi Sea.

Where is monitoring happening?

- Current monitoring efforts have focused on macro- and megabenthic species, but have been confined to the Chukchi Sea (Pacific Arctic) and the Barents Sea (Atlantic Arctic). Coordinated cross-nation efforts are increasing in the waters of Greenland, Iceland, the Canadian Arctic, and in the Norwegian Sea. All other AMAs are lacking long-term monitoring of benthos.


Marine fishes
Species
Polar cod
Greenland halibut
Capelin
Atlantic Arctic
Davis-Baffin
Hudson Complex
Arctic Archipelago
Beaufort
Pacific-Arctic
Kara-Laptev
Arctic Basin
Trend in biomass
Increasing
Stable
Decreasing
Unknown

Marine fishes

Why are marine fishes important?

- Pelagic and benthic fish species are important in Arctic marine ecosystems because they transfer energy to predators such as seabirds, marine mammals, and people.

What is happening and why does it matter?

- Northward range expansions are underway and pose unknown consequences for Arctic species and their interactions such as predation and competition.
- The ecologically important polar cod declined rapidly in the Barents Sea between 2004 and 2015, and is at a very low level, potentially due to predation from Atlantic cod, a more southern species that has expanded northwards. However, the 2016 survey showed an increase in abundance of young (one-year-old) polar cod for the first time in over a decade.
- Capelin stocks throughout the Arctic are shifting northward, but there is a strong variability: increases in recent years have been associated with warming trends, but declines have occurred in the Barents Sea and around Iceland.
- The northward expansion of capelin has led to changes in seabird diet in northern Hudson Bay. It also may affect marine mammals
- Greenland halibut have undergone declines and subsequent recoveries over the last two decades. Populations in the Barents Sea, Baffin Bay-Davis Strait are considered stable or increasing.
- There has been an overall decline in occurrence of Arctic fishes in the Barents Sea between 2004 and 2015.
- Increases in the relative abundance of warmer water species have already been documented in the Bering Sea, Barents Sea, Eastern Canadian Arctic, Greenlandic and Icelandic waters. Boreal species moving north seem to be negatively affecting the abundance of polar cod.

What are the most important drivers?

- Fishes are affected by environmental conditions such as sea ice extent and salinity, and are constrained by prey availability and predator pressure, which can be influenced by climate change.
- The main commercial marine fishes in the Arctic, Greenland halibut and capelin, do not yet seem to be adversely affected by climate change although their distributions appear to be changing. Northward advance of valuable boreal species, retreat of Arctic species and increased accessibility due to less ice cover will increase the total fishing pressure and open new areas for fishing in northern areas. Overfishing of target fish species is generally not of concern, as these fisheries are considered well managed.
- Little is known about effects on non-commercial marine fishes in the Arctic.

What should you know about the monitoring data?

- A large number of species have been documented, but in many cases their distribution, abundance and relationships are largely unknown.
- Only a few species of commercial interest have been studied extensively. The most important of these covered by this report are capelin, polar cod and Greenland halibut.
- Indices and monitoring programs based on harvested species or that rely on fishery-related data are inherently affected by changes in stock size and exploitation rate, making them imperfect sources of information.

Where is monitoring happening?

- Monitoring is conducted on commercial fish species in the Barents Sea and the Norwegian Sea, which fall within the Atlantic Arctic AMA.
- Sporadic monitoring is occurring in the Hudson Complex, Arctic Archipelago, and Beaufort Sea, while poor to moderate monitoring is occurring in the Baffin Bay-Davis Strait and Pacific Arctic. No monitoring is taking place in the Arctic Basin or the Kara-Laptev.


Seabirds
Species
Black-legged kittiwake
Common murre
Thick-billed murre
Ivory gull
Common eider
Glaucous gull
Least auklet
Little auk
Atlantic Arctic
Davis-Baffin
Hudson Complex
Arctic Archipelago
Beaufort
Pacific-Arctic
Kara-Laptev
Arctic Basin
Trend in abundance
Increasing
Stable
Decreasing
Unknown
Absent (FEC not in AMA)

Seabirds

Why are seabirds important?

- Seabirds link marine, coastal and terrestrial ecosystems inside and outside the Arctic because they nest on land but forage and moult at sea, and, thus, they are important components of Arctic ecosystems
- Seabirds provide valuable ecosystem services to humans, notably for food, clothing, tourism and as nutrient recyclers where they help break down organic and inorganic materials to replenish minerals and nutrients in the ecosystem.

What is happening and why does it matter?

- Although seabird trends are variable, many species have declined within the Atlantic Arctic, in colonies in Norway, Iceland, Greenland, and the Faroe Islands.
- The sea-ice-associated ivory gull has declined in the Arctic Archipelago and Atlantic Arctic by an estimated 80-90% over the past 20 years. In Russia, ivory gull distribution has also shrunk, which correlates with the summer ice edge moving northward.
- Some seabird species have adapted their feeding behaviours because of shifts in their food supply due to climate change and reduced ice-cover—in some cases travelling farther for food or foraging on less nutritious species. The consequences vary, but have resulted in lower breeding success for some species, including black guillemots.
- Reduced ice cover has led to increased polar bear predation on ground-nesting common eiders and cliff-nesting murres, potentially leading to local population declines.
- More southern seabird species have been more commonly reported in Arctic regions, for example, albatrosses in the Bering and Chukchi Seas and ancient murrelets in the Pacific Arctic, which are thought to follow northward-moving prey species and/or currents. There is also evidence of individuals moving between Atlantic and Pacific Arctic regions.
- In some areas, such as the Atlantic Arctic, FEC species, e.g. Black-legged kittiwakes, common and thick-billed murre populations are decreasing while in other areas such as the Pacific-Arctic, species are increasing.

What are the most important drivers?

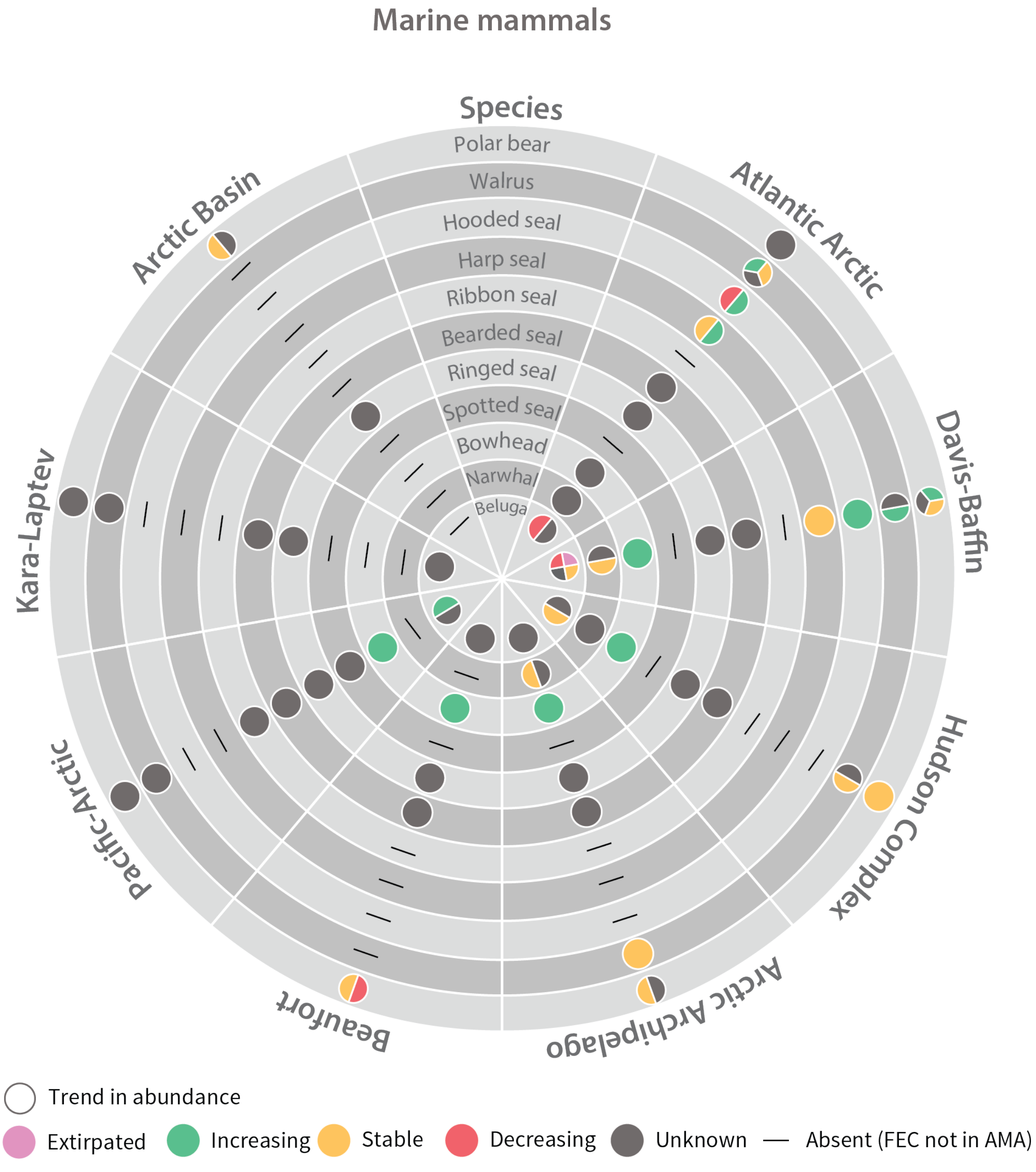
- Important drivers for seabird population changes include climate change, reduced sea-ice, changes in sea temperatures, changes in food webs and species interactions, disease outbreaks, hunting, fisheries bycatch, and pollution (contaminants and oil pollution).

What should you know about the monitoring data?

- Seabird population trends are relatively well known, although not for all species.
- Some of the most widely monitored species groups in circumpolar regions include common and thick-billed murres (diving piscivores), black-legged kittiwakes (surface piscivores), and common eider (benthivores); these species groups make it possible to conduct comparative studies across circumpolar regions.
- Demographic data is lacking for most species and colony sites.

Where is monitoring happening?

- Most circumpolar nations have at least one source of long-term seabird monitoring data, but efforts vary across regions. Colony-based monitoring occurs regularly or annually, although most sites do not have fully implemented plans, with diet and survival data often lacking. At-sea surveys are more opportunistic, and often occur in conjunction with resource exploration and extraction.
- Monitoring of seabird FECs is conducted in the Atlantic Arctic, Baffin Bay-Davis Strait, Hudson Complex, Arctic Archipelago, Beaufort and Pacific Arctic AMAs. The situation for the Kara-Laptev AMA is unknown.


Marine mammals
Species
Polar bear
Walrus
Hooded seal
Harp seal
Ribbon seal
Bearded seal
Ringed seal
Spotted seal
Bowhead
Narwhal
Beluga
Atlantic Arctic
Davis-Baffin
Hudson Complex
Arctic Archipelago
Beaufort
Pacific-Arctic
Kara-Laptev
Arctic Basin
Trend in abundance
Extirpated
Increasing
Stable
Decreasing
Unknown
Absent (FEC not in AMA)

Marine mammals

Why are marine mammals important?

- Marine mammals are top predators in Arctic marine ecosystems and are key to ecosystem survival.
- Many Arctic marine mammal species are an important resource and hold special cultural significance in Arctic communities.

What is happening and why does it matter?

- Changes underway are affecting marine mammal abundance, growth rates, body condition and reproduction, impacting the resilience of marine mammal populations with concomitant effects on the people who rely on them for subsistence, economic, and cultural purposes.
- Most populations with known status are increasing or stable, but populations of beluga in the Atlantic Arctic (White Sea) and Baffin Bay-Davis Strait, polar bear in the southern Beaufort Sea, and hooded seal in the Greenland Sea are declining.
- Predictions are difficult to make for some ice-associated whale species because the nature of their affiliation with sea ice is not clearly understood. For example, bowhead whales are doing well, both at the population and at individual level, in the increased open-water conditions of the Arctic Archipelago, Hudson Complex, Baffin Bay-Davis Strait, Beaufort and Chukchi Sea of the Pacific Arctic AMAs. However, this could reflect recovery from historical harvest levels masking effects of environmental change.

What are the most important drivers?

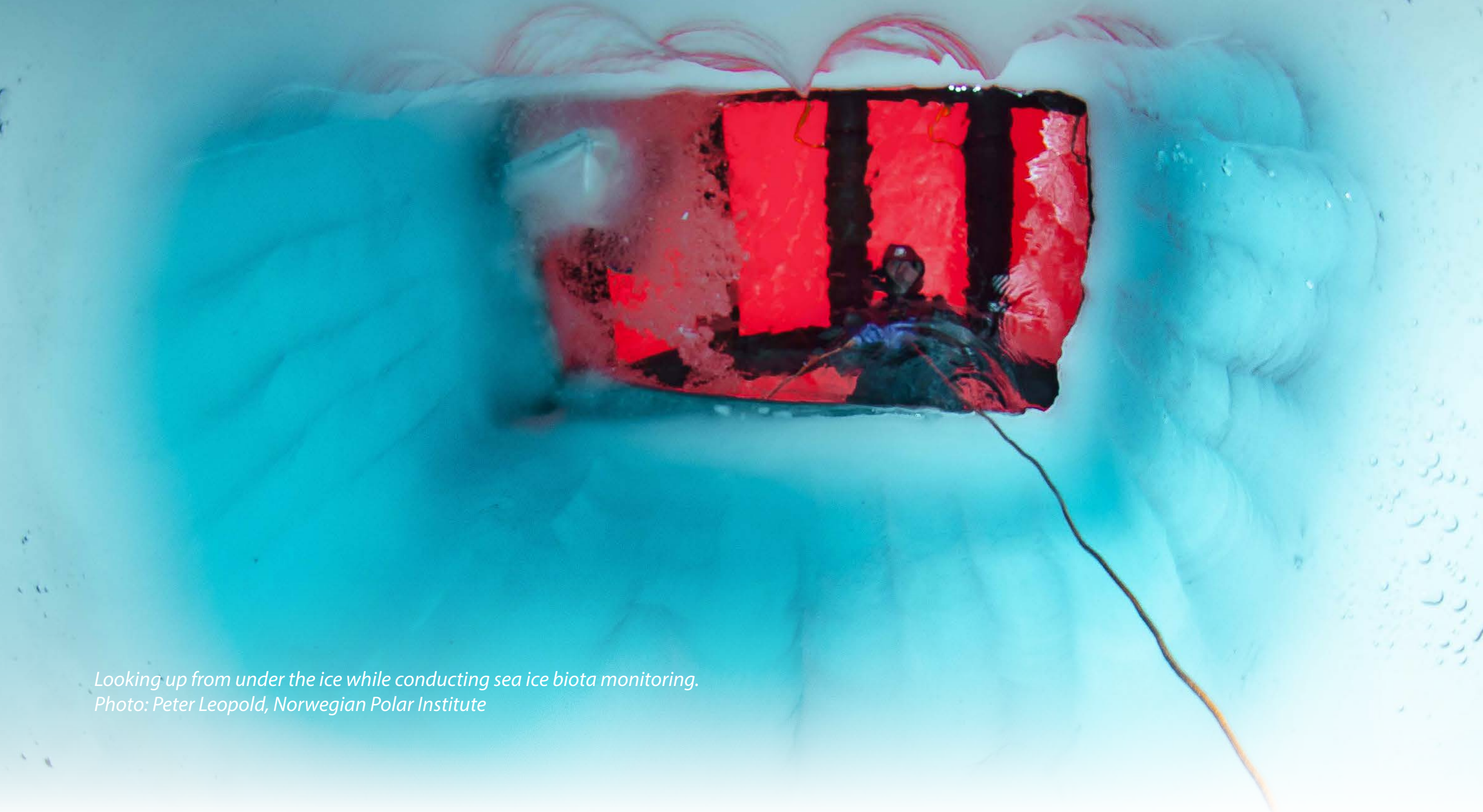
- In a warmer Arctic, endemic marine mammal species face extreme levels of habitat change, which is expected to result in dramatic reductions in sea ice dependent species. Extirpations of some marine mammal stocks are likely.
- The effects of climate change are expected to be exacerbated by increasing oil and gas exploration and production, marine mining, commercial fisheries, tourism, pollution, noise and shipping, and in combination can profoundly impact marine mammal populations and further disrupt already complex social-ecological relationships.
- Because many stocks were reduced by past unsustainable harvest, harvest history has to be included as an important driver of observed trends. Many stocks are still recovering from past harvest (e.g., bowhead whale, walrus), while others have not been able to do so, probably due to climate change (e.g., Greenland Sea hooded seal).

What should you know about the monitoring data?

- In general, trends for wide-ranging species with little population structure (e.g., ringed seals, bearded seals, and ribbon seals) are least understood, while distinct populations or stocks that occur in well-defined geographic areas have documented trend information (e.g., narwhal and some polar bear populations).
- Interpretation of current population dynamics and trends has to take into account historical overharvest, which can mask the potential effects of climate change.
- It is difficult to evaluate species response to climate warming across the Arctic due to high regional variability as well as differences in the level of understanding of the status of different marine mammal species, populations and stocks. To help solve this problem, detailed monitoring plans such as those for the ringed seal and polar bears have been created, but these plans have not been fully implemented across the Arctic.
- TLK provides a long-term and detailed wealth of information and understanding of the wildlife and resources upon which they depend.

Where is monitoring happening?

- Little abundance and trend information is available for the many populations that occupy the Pacific Arctic and Atlantic Arctic. Both areas include extensive open-ocean as compared with other regions that are comparatively more defined seas over continental shelves or within archipelagos. The Arctic Basin and adjacent Beaufort and Kara-Laptev have the lowest number of marine mammal populations and trend information is limited in these regions.
- Population surveys are generally conducted by resource management agencies with cooperative efforts between jurisdictions to assess shared populations.



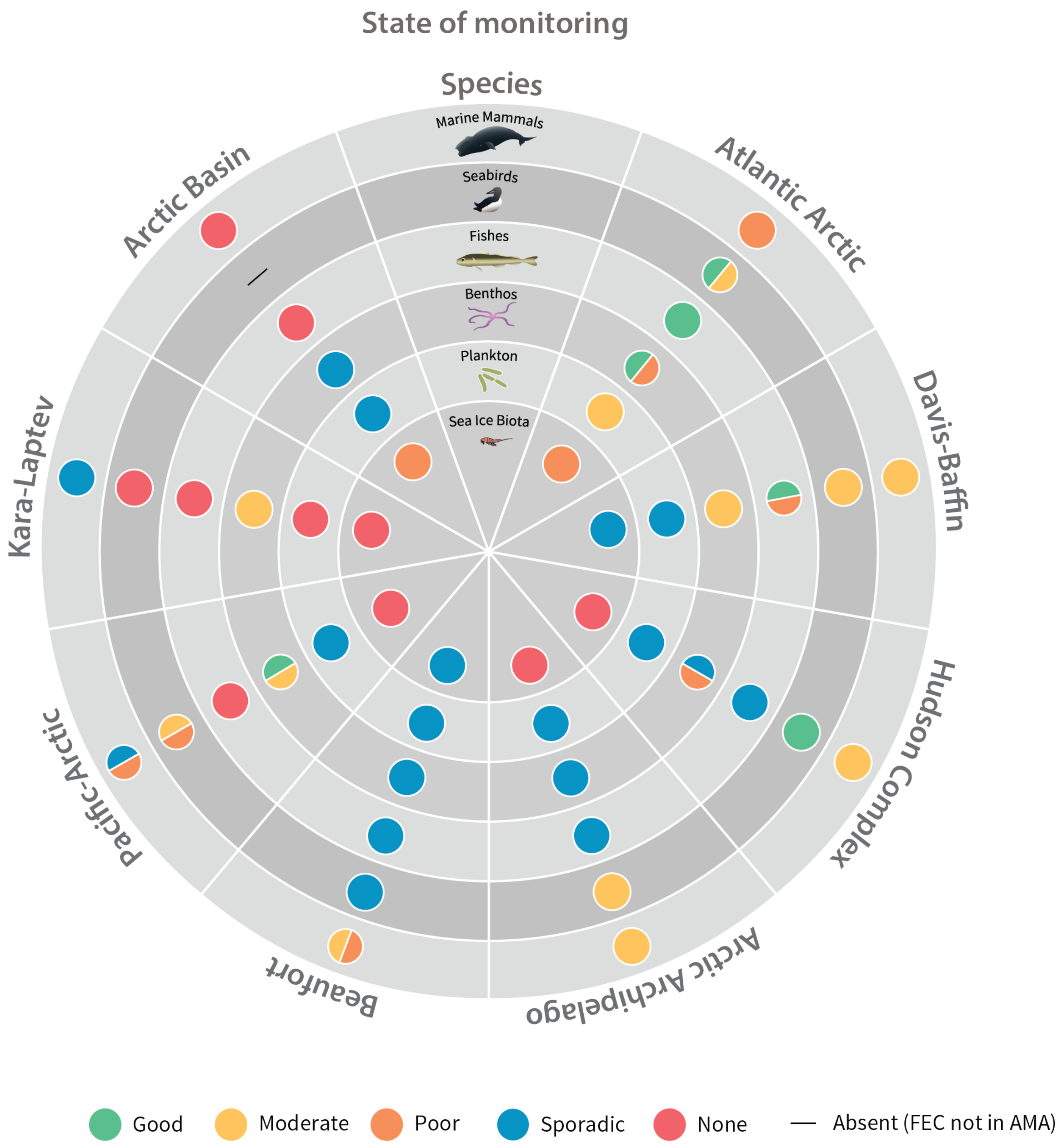
Looking up from under the ice while conducting sea ice biota monitoring.
Photo: Peter Leopold, Norwegian Polar Institute

Advice for monitoring

The ***State of the Arctic Marine Biodiversity Report*** builds on the ***Arctic Biodiversity Assessment*** and is an important first step towards better understanding and management of our living resources in the Arctic marine environment. It helps understand the limitations of what existing biodiversity monitoring is able to tell us about the Arctic environment and provides a path forward for improving knowledge.

Monitoring the status and trends of Arctic biodiversity and attributing causes of change are challenging. Complexity, logistics, funding, international coordination, natural variability, and availability of expertise and technology combine to limit available data and knowledge. These limitations affect biotic groups unevenly.

Traditional and local knowledge (TLK) is a valuable source of information for marine areas, and the CBMP Marine Plan worked to address this issue by trying to engage and include Traditional Knowledge (TK) and TK holders within its design and implementation, a lack of funding, support, and capacity hindered its effect within the Marine Expert Networks and this report. With the understanding of the importance to utlize both science and TLK in order to understand the current state of the marine environment, examples are provided of the type of information that TK holders have to offer in the *State of the Arctic Marine Biodiversity Report*.


State of monitoring
Species
Marine Mammals
Seabirds
Fishes
Benthos
Plankton
Sea Ice Biota
Atlantic Arctic
Davis-Baffin
Hudson Complex
Arctic Archipelago
Beaufort
Pacific-Arctic
Kara-Laptev
Arctic Basin
Good
Moderate
Poor
Sporadic
None
Absent (FEC not in AMA)

Coordination

Better coordination allows for increased value for investment in monitoring programs, better opportunity to compare results, and more ability to draw meaningful conclusions from data.

- Strategically locate Arctic research stations and monitoring vessels, and use all collected specimens, to allow the collection and analysis of as many CBMP FECs as possible.
- Ensure research stations operate all year to better study FECs year round.
- Combine national monitoring with collaborative approaches that allow for sufficient integration and standardization to conduct syntheses across the circumpolar region.
- Standardize how data are collected, managed and made available. This is a key component in ensuring circumpolar Arctic comparability and should be an important consideration in the implementation of monitoring plans.
- Encourage states to increase the implementation of existing internationally coordinated monitoring plans.
- Connect monitoring initiatives and report across scales so that results are meaningful for local, sub-national, national, regional and global decision-makers.
- Continue to increase coordination between CBMP and other regional and global monitoring initiatives e.g., the Group on Earth Observations Biodiversity Observation Network (GEOBON), International Council for the Exploration of the Sea (ICES) and the Intergovernmental Platform on Biodiversity and Ecosystem Service (IPBES).

Methods

Increased attention to methodology allows for more precise and comparable results, standardized data collection, and ability to link regional monitoring to circumpolar efforts.

- Ensure that Arctic monitoring programs are ecosystem-based and include as many CBMP FECs as possible to include functionally important taxonomic groups and improve our understanding of how the ecosystem functions, and how its components are related. Such monitoring programs can serve to underpin management of human activities in the Arctic marine environment.
- Standardize methodology, including taxonomic identification in order to allow production of comparable data and results.
- Ensure training of personnel performing sampling and analyses.

Traditional and Local Knowledge (TLK)

Utilizing TLK and involvement of TK holders allows for increased understanding of relationships and changes underway in Arctic ecosystems, current and historical trends, and serves to build valuable partnerships on the ground in Arctic communities.

- Use TLK within the design and implementation of monitoring plans. The TLK of people living along and off the Arctic Ocean is an invaluable resource for understanding changes in Arctic marine ecosystems and its inclusion should be supported by national governments.
- Increase engagement and partnerships with local residents and easy to access technology in monitoring programs. Indigenous communities are important 'first responders' to catastrophic events. More importantly, their knowledge systems provide a wealth of knowledge that should be involved in the analysis of collected data for increased understanding of current trends and filling historical gaps.
- There is a need for TLK on a range of FECs and to engage networks of TLK holders and Indigenous organisations.
- Use both TLK and scientific information on the analysis of harvest levels and status when evaluating overall population health and managing hunts.

Community-based monitoring networks and community relationship building

- Increase the span of networks in the CBMP to include Community-based monitoring networks.
- Communicate information on changes and the results of monitoring between scientists and the public in both directions. This is crucial to the development of effective management strategies and human activities.

Knowledge gaps

Filling gaps in knowledge helps us better understand key elements and functions of the ecosystem that can help explain change and understand the system.

- Encourage the monitoring of relevant physical parameters alongside some FECs that are particularly sensitive to their effects, including sea ice biota and plankton.
- Expand monitoring programs to include important taxonomic groups and key ecosystem functions. These gaps are likely due to logistical challenges or lack of expertise in specific fields.
- Expand monitoring programs to include those utilizing both TK and science; involvement of Indigenous organizations and build capacity to provide a co-production of knowledge platform.

Retrieving sampling equipment. Photo: NOAA

Marine Expert Networks

Proactive biodiversity monitoring can help anticipate and provide future knowledge needs. Each CBMP Marine Expert Network has provided advice for their area of expertise to help Arctic biodiversity monitoring programs deliver relevant information and advice for policy-makers.

Sea ice biota

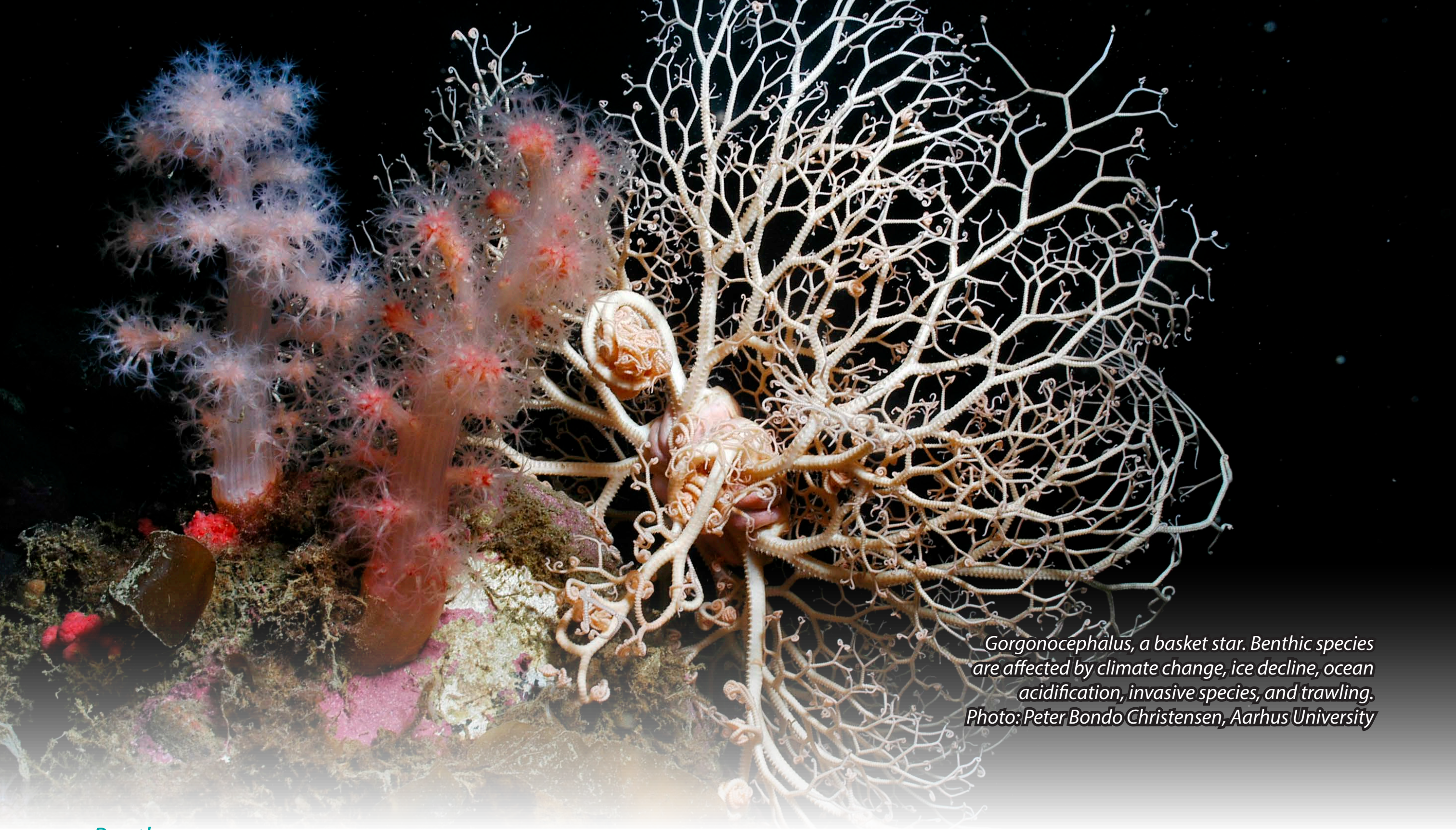
- Establish an annual monitoring programme from landfast sea ice at selected Arctic field stations in Canada (Resolute, Cambridge Bay), Greenland (Kobbefjord, Disko Bay, Zackenberg), Norway (Kongsfjorden, Billefjorden, Van Mijenfjorden), and the U.S. (Barrow).
- Establish a standardized monitoring protocol, including sample collection, preservation, microscopic and genetic analyses, taxonomic harmonization, and data sharing.
- Establish opportunistic monitoring from drifting sea ice during cruises of opportunity.
- Collect macrofauna samples in drifting sea ice via ship-based activities, scuba diving, electrical suction pumps, under-ice trawl nets, and remotely operated vehicles.

Ice amphipod Gammarus wilkitzkii. *Ice amphipod abundance has declined around Svalbard since the 1980s, coinciding with declining sea ice conditions. Photo: Shawn Harper, University of Alaska, Fairbanks*

Systematic monitoring of phytoplankton and zooplankton has most frequently occurred in Svalbard and Jan Mayen, the Barents Sea, Iceland, Greenland and southern Bering Sea. Photo: Fernando Ugarte, ARC-PIC.com

Plankton

- Follow standardized protocols for monitoring plankton, including sample collection and preservation, microscopic and genetic analyses with taxonomic harmonization.
- Ensure that full data sharing occurs between scientists, and is deposited in publicly-accessible national data centers. Continue to consolidate older data.
- Train highly qualified personnel to perform plankton sampling and species-level analyses, including the use of molecular techniques.
- Establish long-term funded annual monitoring programmes of plankton from selected Arctic field stations or Arctic campaigns/cruises in Canada, the U.S. and Russia, which together with the ongoing monitoring in Greenland, Iceland and Norway will secure a pan-Arctic coverage.
- Develop species indexes and if possible, identify indicator taxa for monitoring.



Gorgonocephalus, a basket star. Benthic species are affected by climate change, ice decline, ocean acidification, invasive species, and trawling. Photo: Peter Bondo Christensen, Aarhus University

Benthos

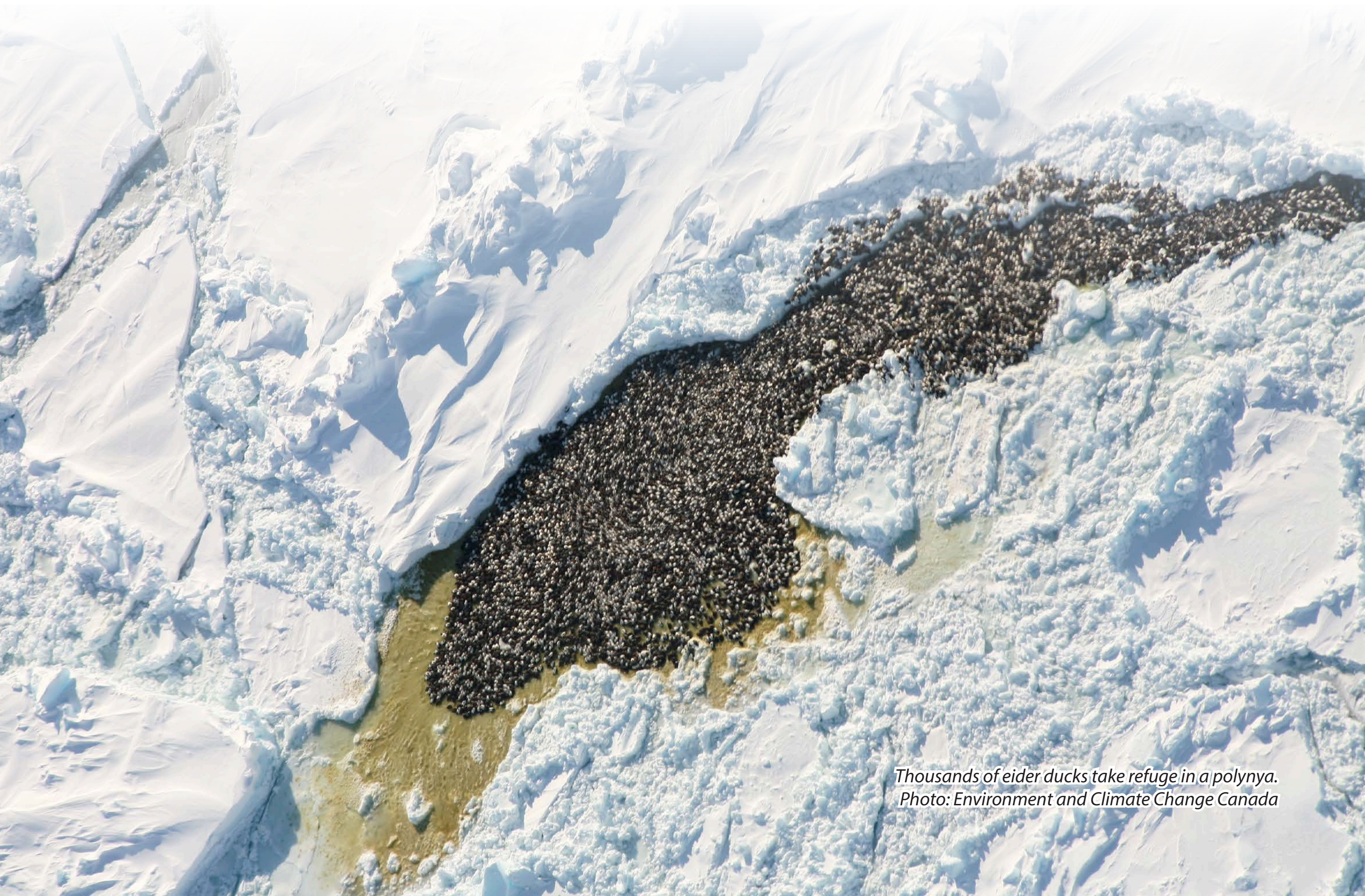
- Develop a time- and cost-effective, long-term and standardized monitoring of megabenthic communities in all Arctic regions using regular national groundfish assessment surveys. Expanding monitoring on micro-, meio- and macrobenthic groups is encouraged.
- Gather information from research programs in regions without regular groundfish-shellfish trawl surveys. These are usually short-term and do not guarantee spatial consistency in sampling, but provide valuable information on benthic biodiversity and community patterns.
- Generate information on benthos from little-known regions, such as the Arctic Basin and Arctic Archipelago, on cryptic or difficult taxonomic groups, and on biological "hotspots".
- Systematic studies of macrobenthos (grab investigations) and megabenthos (trawl bycatch of regular fishery surveys including both annual studies, as in the Atlantic Arctic, and periodic studies as in the Northern Bering and Chukchi Seas) are the most suitable and practical approach to long-term monitoring.
- Standardize methodology, including taxonomic identification, across regions to assist in regional comparisons.
- Recognize and support the use of TLK as an invaluable resource for understanding of changes in Arctic benthic communities.

Marine fishes

- Conduct pan-Arctic taxonomic analyses to clarify zoogeographic patterns that are important for detecting and understanding change.
- Establish and conduct a monitoring plan that is independent of fisheries-related programs to assess changes in fish abundance and distributions. Use information from non-commercial fish species caught in groundfish surveys to provide a first step in this direction.
- Use information from TK holders for monitoring marine fishes.
- Connect monitoring initiatives across scales.
- Conduct laboratory studies to examine the possible effects of abiotic and biotic changes (e.g. temperature, salinity, acidity and diseases) on fish species
- Ensure that data on fisheries (commercial as well as artisanal) are accurate and registered in catch databases (such as the Food Agriculture Organisation of the United Nations). Information from logbooks is also relevant as it can be used to estimate the bycatch and the effects of fisheries.

Polar cod seeking shelter in its sea ice habitat. Boreal species moving north seem to be negatively affecting the abundance of polar cod.
Photo: Peter Leopold, Norwegian Polar Institute

- Develop methods for assessing diet to increase our understanding of changes in the ecosystem and how they affect seabird populations.
- When selecting sites for new monitoring, consider proximity to hotspots for marine activities, access to the sea, and inclusion of plankton monitoring.
- Expand colony-based monitoring and strive to include a more complete array of parameters, in particular, diet and measures of survival.
- Consider a higher frequency of monitoring as current levels make it difficult to identify mechanisms or causes of change in populations.
- Conduct targeted surveys and individual tracking studies of seabird interactions at sea to improve our understanding of seabird interactions at sea, where seabirds spend most of their time.
- Continue to conduct at sea surveys on an opportunistic basis.



Thousands of eider ducks take refuge in a polynya.
Photo: Environment and Climate Change Canada

Narwhal monitoring.
Photo: Carsten Egevang, ARC-PIC.com

Marine mammals

- Implement existing international monitoring plans such as those for ringed seals and polar bear, with adaptive management principles to address the eleven FEC marine mammal species.
- Expand marine mammal monitoring efforts to include parameters on health, passive acoustics, habitat changes, and telemetry tracking studies.
- Obtain more knowledge about population sizes, densities, and distributions of marine mammal populations in order to understand the relationships between sea ice loss and climate change and to manage Arctic marine mammal populations in an appropriate manner.
- Involve indigenous and local peoples in the design and implementation of monitoring programs so that scientific knowledge and TLK holders are working collaboratively.
- Pursue a multidisciplinary and multi-knowledge approach and a high degree of collaboration across borders and between researchers, local communities and Arctic governments to better understand complex spatial-temporal shifts in drivers, ecological changes and animal health.

Environment and Climate Change Canada
Environnement et Changement climatique Canada

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MINISTRY OF THE ENVIRONMENT

NAALAKKERSUISUT
GOVERNMENT OF GREENLAND

NATUR VÅRDS VERKET
SWEDISH ENVIRONMENTAL PROTECTION AGENCY

NORWEGIAN ENVIRONMENT AGENCY

Gwich'in Council INTERNATIONAL

INUIT

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