Fisheries and Oceans Canada / Pêches et Océans Canada

Canada's OCEANS NOW

ARCTIC ECOSYSTEMS 2019

Canada

Cover photo: Lancaster Sound, Baffin Island, Nunavut. Credit: Shutterstock, wildestanimal.

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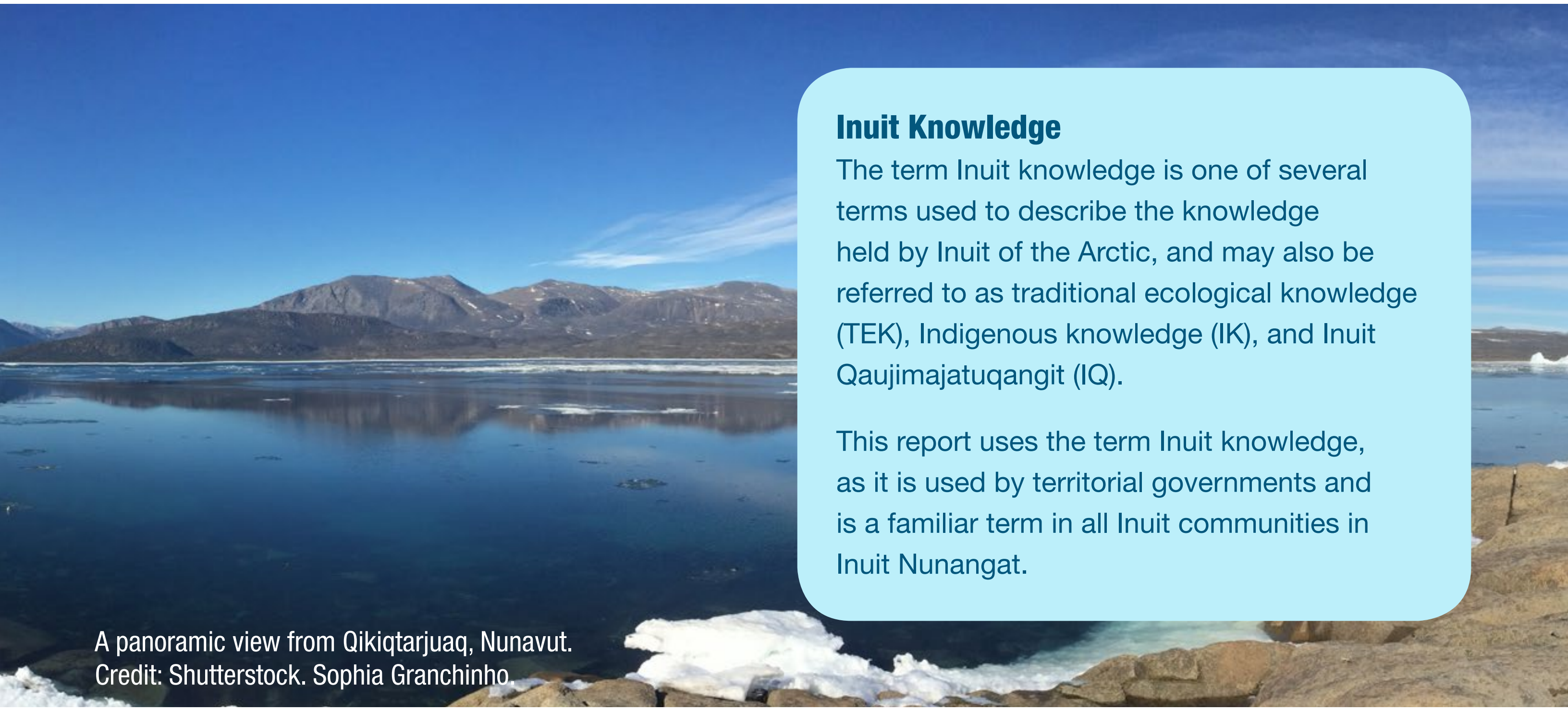
Canada's Oceans Now: Arctic Ecosystems

Canada's Oceans Now reports are summaries of the current status and trends in Canada's oceans. These reports are produced every four years, as part of the Government of Canada's commitment to inform its citizens on the current state of Canada's oceans.

Canada's Oceans Now: Arctic Ecosystems provides new knowledge and known trends for marine areas of the Canadian Arctic. The report was generated from scientific and Inuit knowledge (**Sidebar: Inuit Knowledge**) and findings provided by Fisheries and Oceans Canada, Environment and Climate Change Canada, as well as academic, co-management, and Territorial contributors.

This report is based on key findings detailed in the *Canadian Technical Report of Fisheries and Aquatic Sciences 3344, State of Canada's Arctic Seas*[1]. The scientific report presents findings related to advancements in baseline understanding of marine ecosystems in the Canadian Arctic and observed ecosystem responses to changes in sea ice. Scientific and Inuit knowledge describe current status and trends about marine habitats, species and food webs, the seasonal cycle of events (seasonality), variability over time and location, and connections between ocean areas, including coastal areas. There are major gaps in understanding of marine environments and species in the Canadian Arctic. These gaps are highlighted in the report and will need to be filled for effective ecosystem management. Information will be updated in future reports, providing an ongoing picture of the status and trends of Canada's Arctic marine ecosystems.

1. Citation: Niemi, A., Ferguson, S., Hedges, K., Melling, H., Michel, C., *et al.* 2019. State of Canada's Arctic Seas. Can. Tech. Rep. Fish. Aquat. Sci. 3344: xv + 189 p.



Inuit Knowledge

The term Inuit knowledge is one of several terms used to describe the knowledge held by Inuit of the Arctic, and may also be referred to as traditional ecological knowledge (TEK), Indigenous knowledge (IK), and Inuit Qaujimajatuqangit (IQ).

This report uses the term Inuit knowledge, as it is used by territorial governments and is a familiar term in all Inuit communities in Inuit Nunangat.

A panoramic view from Qikiqtarjuaq, Nunavut.
Credit: Shutterstock. Sophia Granchinho.

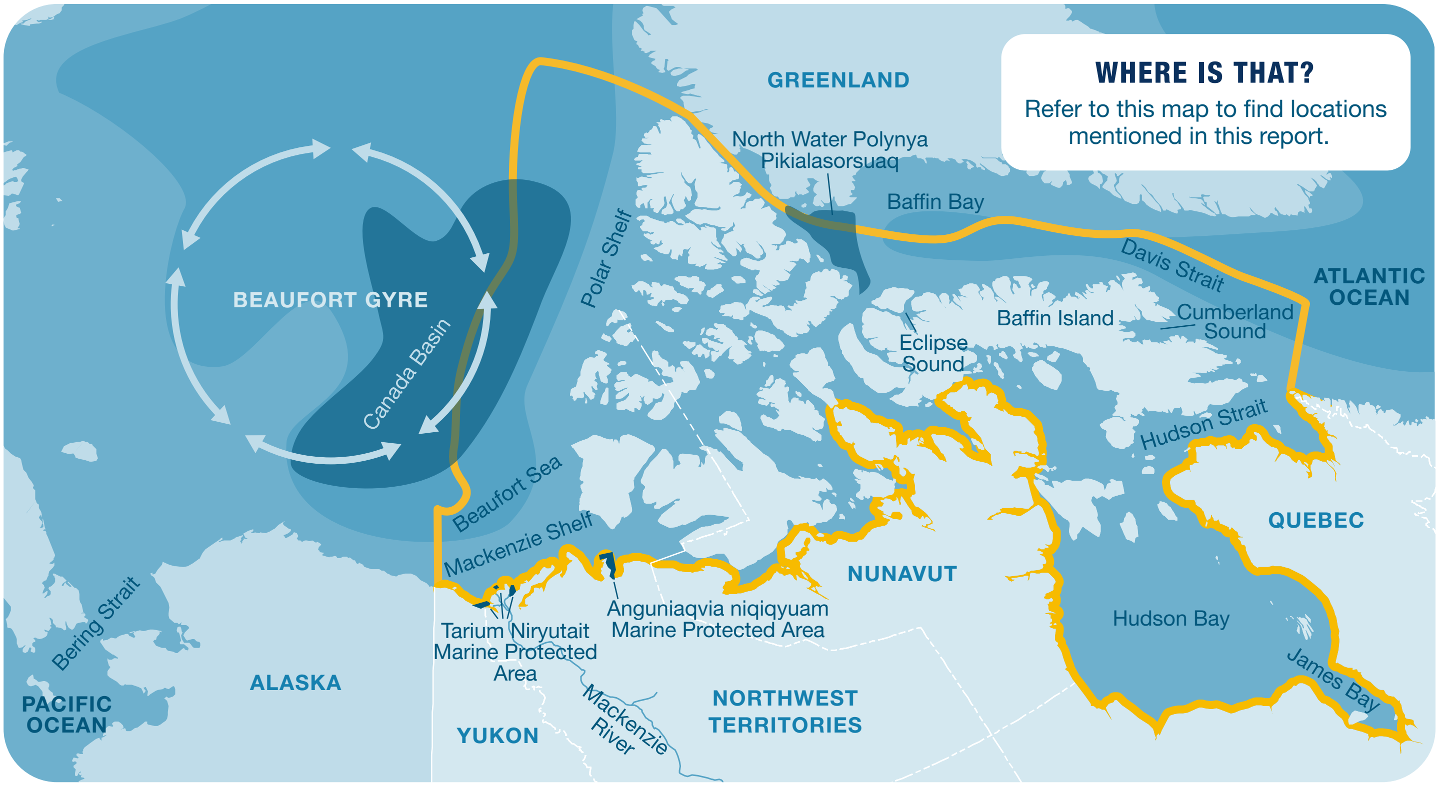


Figure 1: Key findings are described for the Canadian Arctic area outlined in yellow.

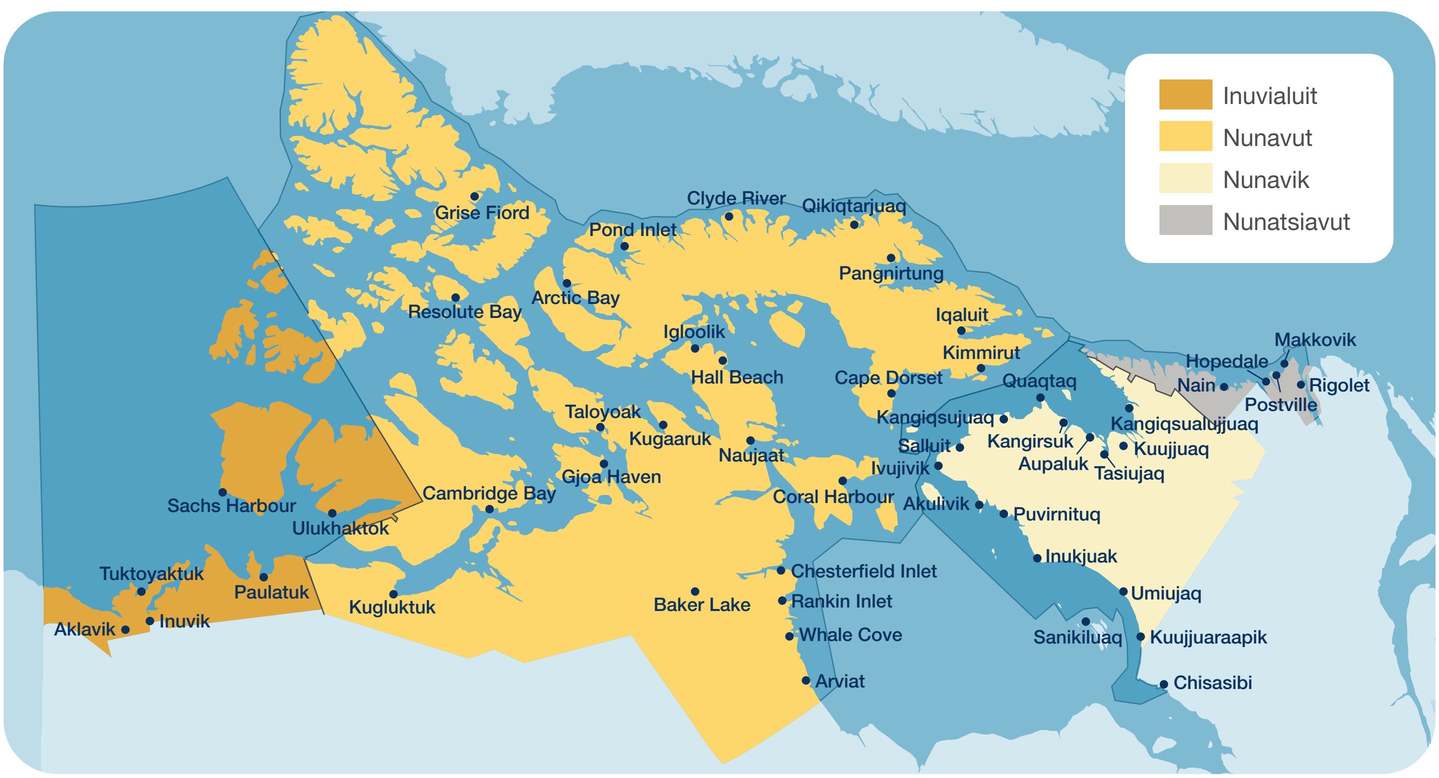


Figure 2: Inuit Nunangat, the Inuit homeland, comprised of four Inuit regions, Nunavut, Nunavik, Nunatsiavut and the Inuvialuit Settlement Region. The land, water and ice of Inuit Nunangat is integral to Inuit culture and way of life. Approximately 65,000 Inuit live in communities spread across the regions.

STATE OF THE CANADIAN ARCTIC OCEAN

The Canadian Arctic has the largest ocean area in the country. It spans 30 degrees of latitude from James Bay to the Polar Shelf, covering a wide range of ocean and coastal environments and their interconnected ecosystems (**Figure 1**). Canada's Arctic Ocean area would cover 41% of Canada's land area, making it a huge area to understand and manage. The many islands and long coastlines are areas where sea ice can freeze securely to the land, an environment integral to Inuit survival and culture. No other polar region has as much of this type of land-attached ice. See **Figure 3** for more information about the immense scale and habitat types of the Canadian Arctic.

The Canadian Arctic: Canada's Largest Ocean Area

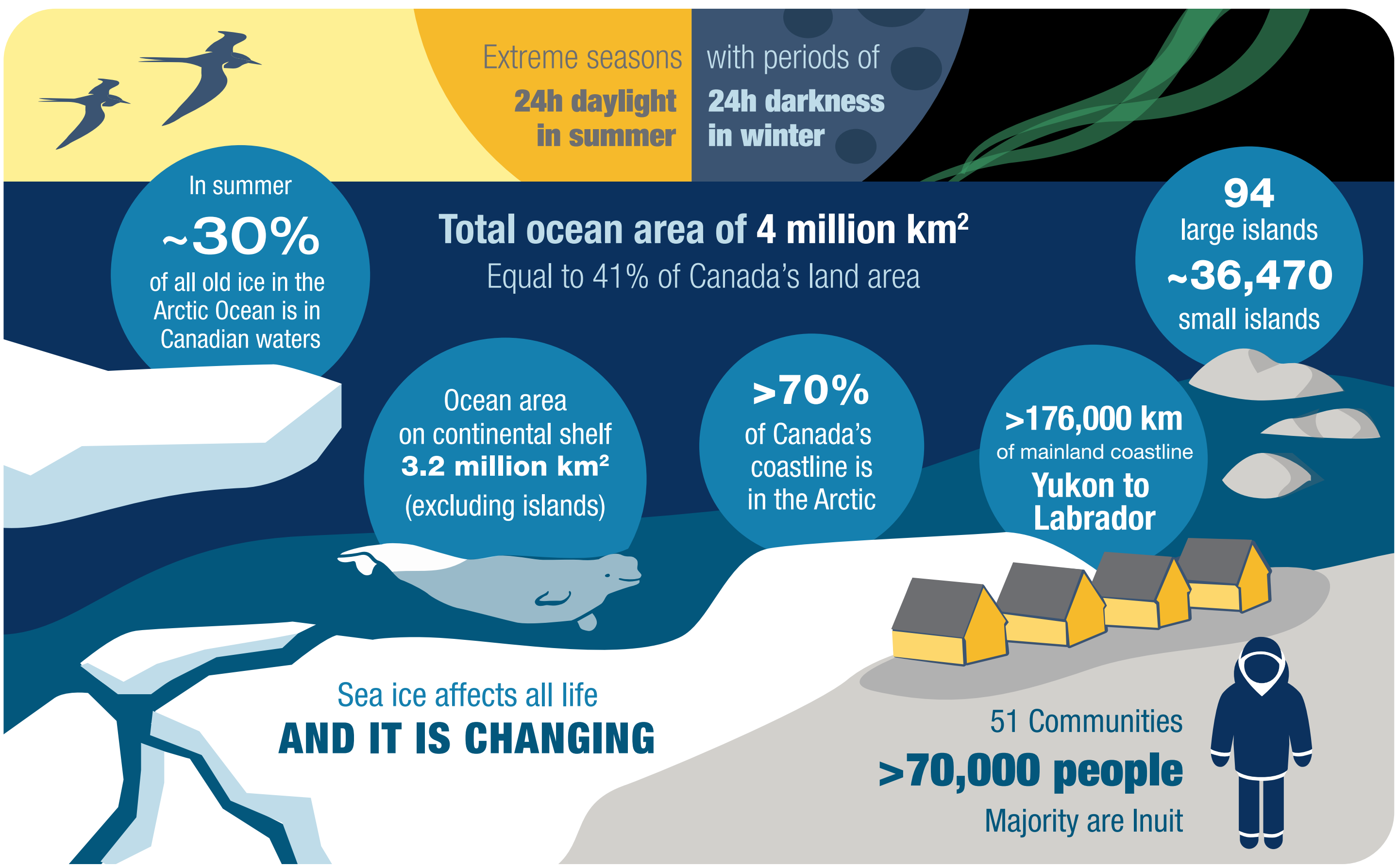


Figure 3: Canadian Arctic waters — a homeland of ice and water.

The Canadian Arctic: Climate Change is Affecting Marine Ecosystems in Many Ways

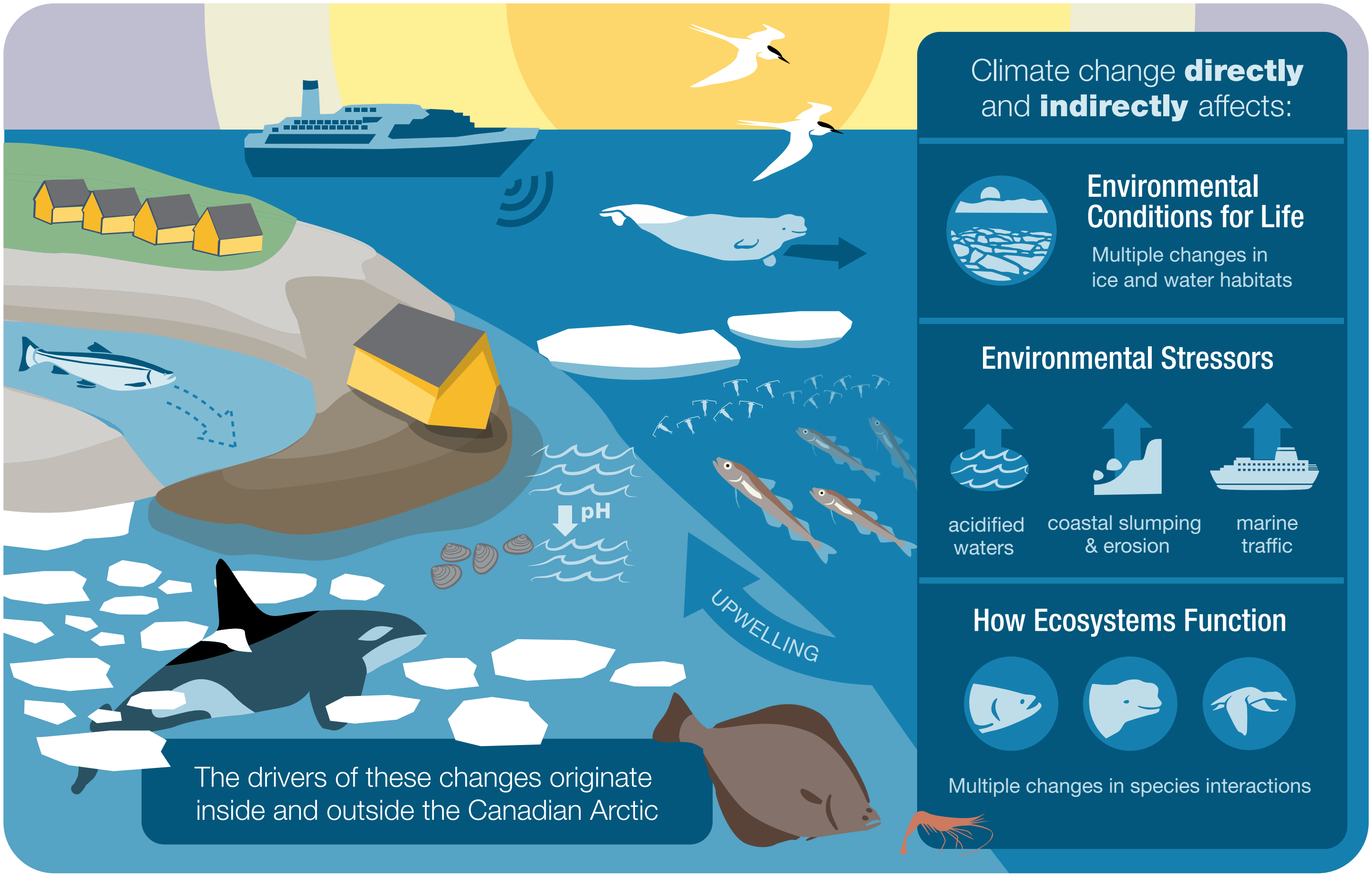


Figure 4: The effects of climate change do not occur alone, they interact to create complex outcomes for marine ecosystems.

Informing Canadian citizens on the current state of Canadian Arctic waters is a challenge. The Arctic, on a global scale, is changing but the type and speed of changes are not the same in all locations. Understanding the state of Canadian Arctic ecosystems is necessary to explain and manage present conditions and future changes. The state of an ecosystem describes conditions in a specific location — both the normal conditions and how they change over time. There is much to learn about in Canadian Arctic waters, and in many locations, there is limited information about changes in environments, food webs and biodiversity (**Sidebar: Information Needed, page 6**). Inuit knowledge provides the longest perspective over time. This valuable knowledge informs our understanding of coastal areas, especially where Inuit have lived for thousands of years (**Figure 2**).

Identifying the status of Canadian Arctic waters is more challenging than in Canada's other oceans. There has been little long-term, sustained scientific monitoring of ocean conditions and species in Canada's Arctic. As a result, scientific evidence is limited to identify, explain and predict ecosystem changes across the Canadian Arctic. Inuit knowledge and scientific research document variable (fluctuating) conditions in the marine environment. Differences from year to year are normal, but changes — moving away from normal variation — are also occurring.

Observed and measured changes in Canadian Arctic waters are directly or indirectly linked to climate change (**Figure 4**). Climate change also makes it possible for other stressors to affect marine ecosystems (**Sidebar: Ecosystem Stress, page 7**). Changes in sea ice — monitored by satellites since the 1970s — are a strong reflection of climate. Sea-ice changes affect every aspect of the ecosystem.

Species and environments do not respond independently to climate change or any other stressors. There is a strong interconnection between ecosystems — environments and the species who live there. This report identifies new knowledge and trends over the past five years, for ecosystem themes (**Figure 5**) that are all affected by changing sea ice. The findings presented in this report are based on scientific and Inuit knowledge; both are needed to provide ecosystem-based information to support the management of the ocean and its resources. **Figure 6** provides details about co-management and the need for more information to better inform the status of marine environments in the Canadian Arctic.

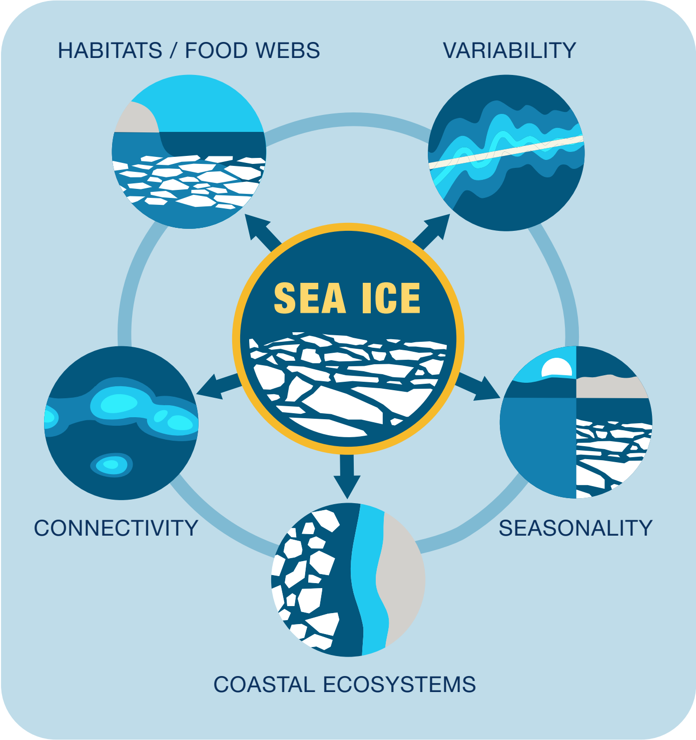


Figure 5: Five themes explored in this report provide insight into the importance of sea ice for life in Canada's Arctic marine ecosystems.

Information Needed!

Some marine areas in the Canadian Arctic have never been studied. Effort to increase our knowledge of Canadian Arctic biodiversity — offshore fishes, for example — have documented new species. But are these species new to the Canadian Arctic or just found for the first time?

In many areas, information is collected very infrequently. For example, there may be more than 10 years between population surveys for marine mammals such as the Beaufort Sea beluga or the High Arctic walrus.

Summer research cruise in the Canadian Beaufort Sea. Credit: Valerie Cypihot.

The Canadian Arctic: Building Knowledge for Ecosystem Management

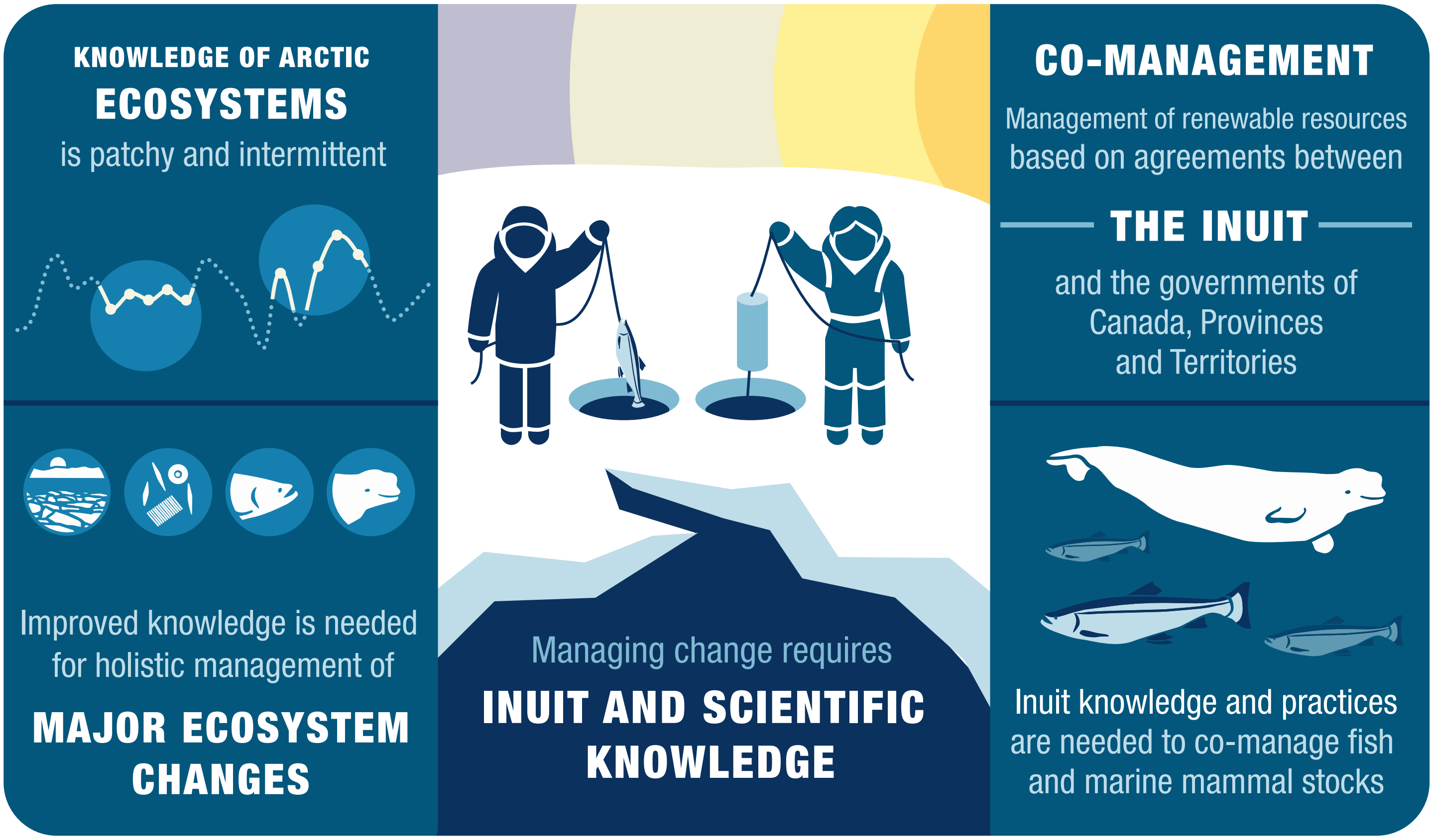


Figure 6: Verified information is a critical element in protecting Canadian Arctic marine species and their habitats. In the Canadian Arctic, decision making involves partnerships that require both scientific and Inuit knowledge.

Pangnirtung, Baffin Island, Nunavut.
Credit: Fisheries and Oceans Canada. D.L Labrie.

Ecosystem Stress

Climate change is the greatest human-caused stressor affecting the Canadian Arctic. It directly or indirectly affects other human-caused stressors in the marine environment, including shipping, the presence of microplastics and contaminants, natural resource development, and commercial fishing. Knowledge is needed on species and their environments to manage present and future effects of climate change and related stressors across the Canadian Arctic.

SEA ICE

Sea ice is the single, most influential feature in Arctic marine waters. Sea ice is a component of Arctic ocean habitats that affects interactions between species that live there, as well as daily life in Arctic communities. Not all sea ice is the same. Two important categories are **seasonal ice** (forms and melts in one year) and **multi-year, or old, ice** (survives at least two summers). Sea ice more than 50 km from coastlines typically moves year-round (pack ice). Closer to shore, sea ice attaches to the land (**land-fast ice**) and generally stays fixed in place. Sea ice is an important travel route in the Arctic. It is used by community hunters to access the **floe edge**, the boundary of land-fast ice where pack ice has been swept away by wind.

The Canadian Arctic: Sea Ice is Changing in Different Ways

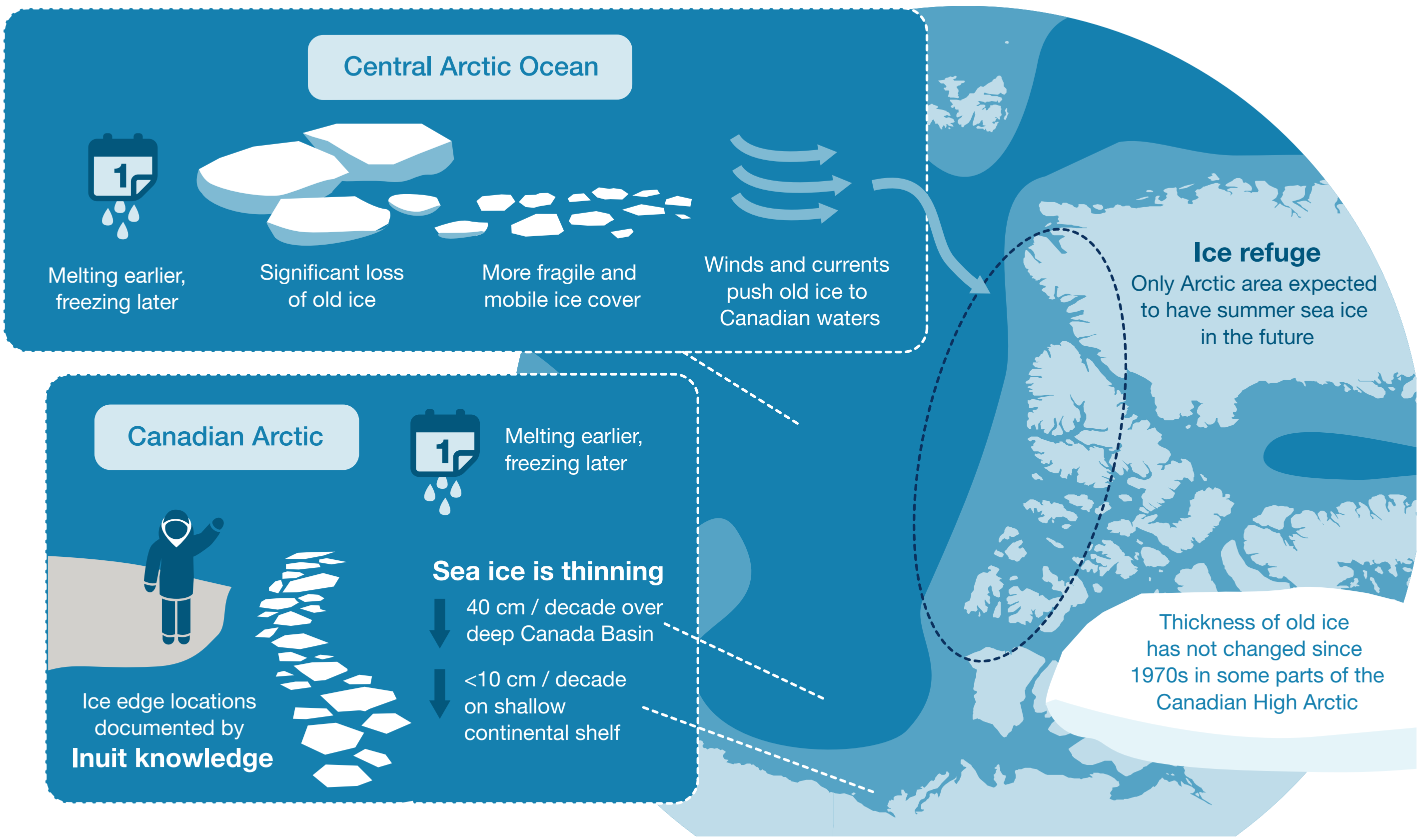
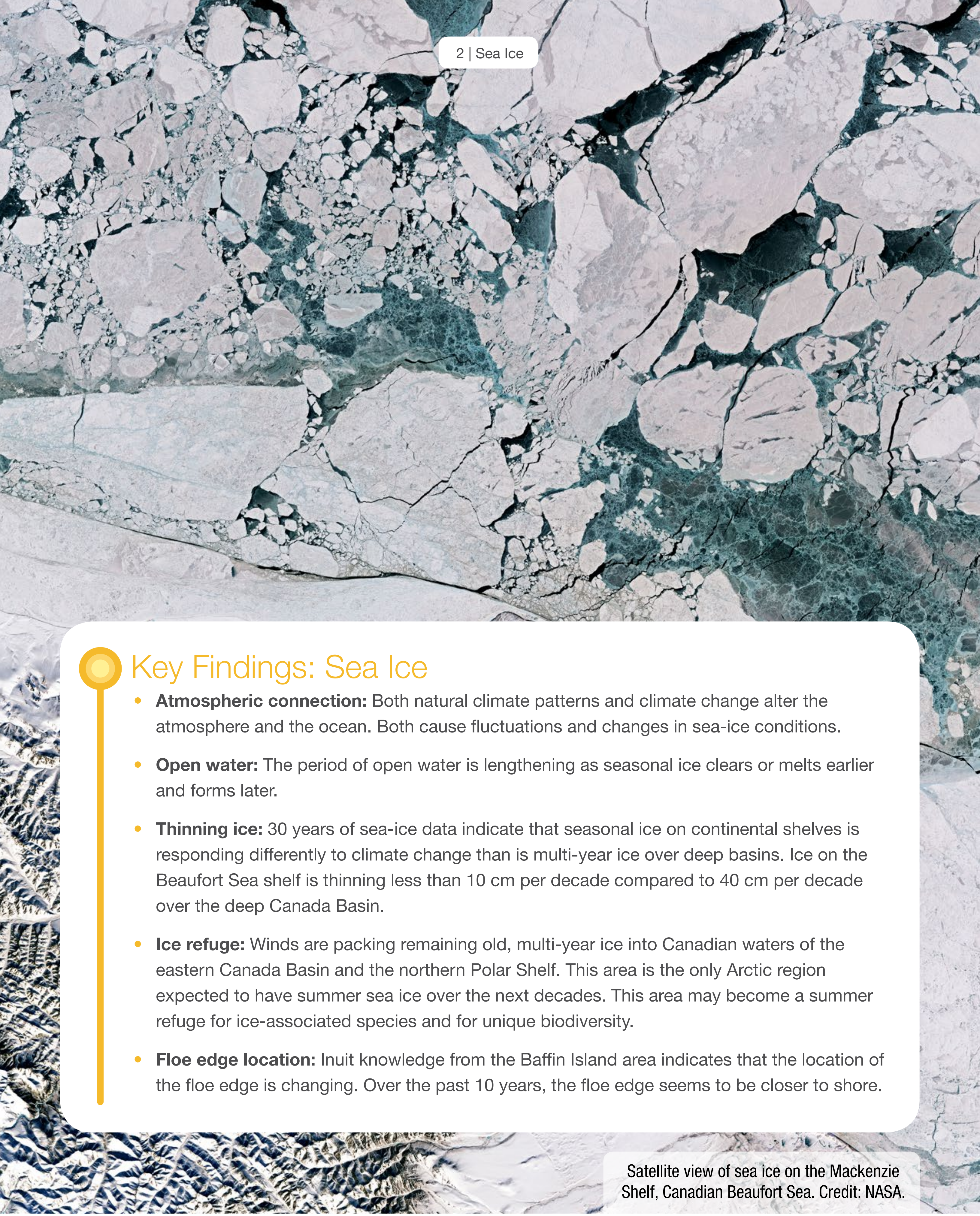


Figure 7: Canadian Arctic marine ecosystems are adapted to an environment with sea ice.

Sea ice affects how the atmosphere interacts with the ocean. For example, strong winds do not create large waves if sea ice is present. Without the ice, waves can erode Arctic shorelines. The ice is a platform for polar bears and seals, and the ice itself is a home to diverse microscopic life including ice algae. Sea ice affects the movement of species and marine traffic, allowing or preventing mobility. It also controls the timing of annual events, such as when phytoplankton (microscopic plants in the water) grow, when Arctic Char feed in the ocean, or when some whales leave the Arctic for the winter. Sea ice affects life cycles, how energy is transferred through ocean food webs and how species interact with each other. When sea ice changes, ecosystems will change too.

Changes to sea ice in the Canadian Arctic are not the same in all locations, and each type of ice changes in different ways. Sea ice is thinning more rapidly over deep-water areas (Canada Basin) than over shallower areas (**Figure 7**). There has been a major loss of old, multi-year ice around the center of the Arctic Ocean. However, because winds transport old ice from across the entire Arctic Ocean to the northern border of the Canadian Arctic, the overall loss of old ice has been lowest in the Canadian Arctic. Old ice can be found along the northern Polar Shelf and around islands in the Canadian High Arctic. New conservation efforts focus on Canada's northern border, recognizing that in the future, it will likely be the last place in the entire Arctic to have sea ice during summer.

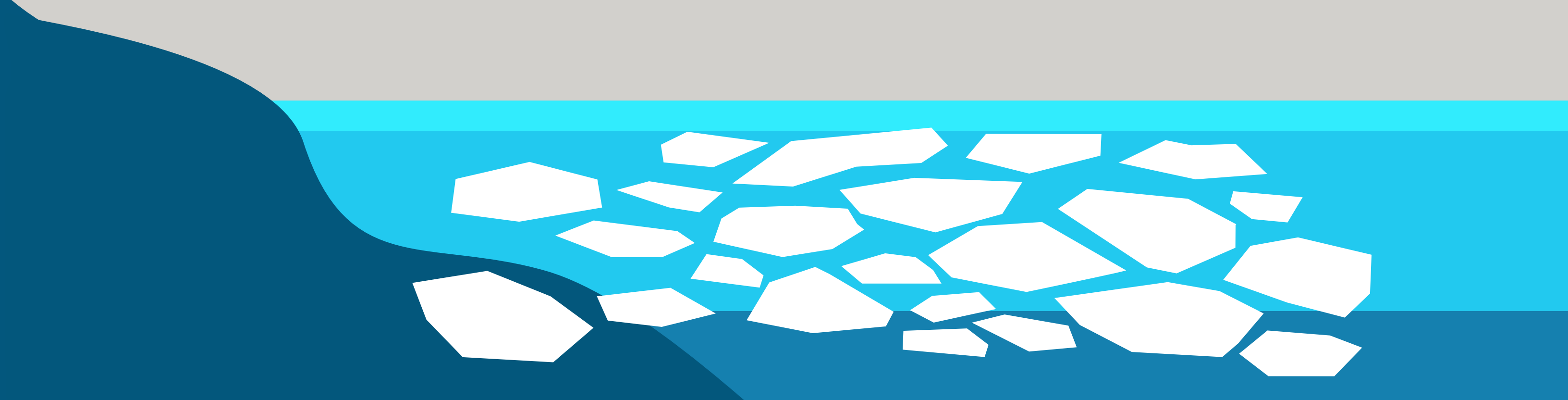
Beaufort Sea summer sea ice. Credit: Fisheries and Oceans Canada.



Key Findings: Sea Ice

- **Atmospheric connection:** Both natural climate patterns and climate change alter the atmosphere and the ocean. Both cause fluctuations and changes in sea-ice conditions.
- **Open water:** The period of open water is lengthening as seasonal ice clears or melts earlier and forms later.
- **Thinning ice:** 30 years of sea-ice data indicate that seasonal ice on continental shelves is responding differently to climate change than is multi-year ice over deep basins. Ice on the Beaufort Sea shelf is thinning less than 10 cm per decade compared to 40 cm per decade over the deep Canada Basin.
- **Ice refuge:** Winds are packing remaining old, multi-year ice into Canadian waters of the eastern Canada Basin and the northern Polar Shelf. This area is the only Arctic region expected to have summer sea ice over the next decades. This area may become a summer refuge for ice-associated species and for unique biodiversity.
- **Floe edge location:** Inuit knowledge from the Baffin Island area indicates that the location of the floe edge is changing. Over the past 10 years, the floe edge seems to be closer to shore.

Satellite view of sea ice on the Mackenzie Shelf, Canadian Beaufort Sea. Credit: NASA.



HABITATS AND FOOD WEBS

Habitats in Canadian Arctic waters are diverse, and include sea ice, water layers and the seafloor. These habitats vary between geographical locations. Seasonal and multi-year sea ice is important for species living on, in and beneath the ice (**Box: Polar bears and Sea Ice Decline, page 13**). Species also live on and in the seafloor. In some parts of the Canadian Arctic almost 60% of expected seafloor species are yet to be discovered. (**Sidebar: Worm Discovery, page 13**)

As sea ice and water in the Arctic and surrounding oceans change, they are affecting habitats and food webs in the Canadian Arctic. The water itself represents habitats that are different from east to west, and from shallow coasts and estuaries to deeper offshore waters and deep basins. Water habitat (the **water column**) is not the same from top to bottom. The ocean is made up of layers, each with different conditions and origins (**Figure 8**). Winds and ocean currents can mix the layers and change habitat conditions, sometimes for just a short time (days to weeks). As water layers change, the ocean habitat changes, and this affects marine fishes and other species that prefer specific water layers and conditions.

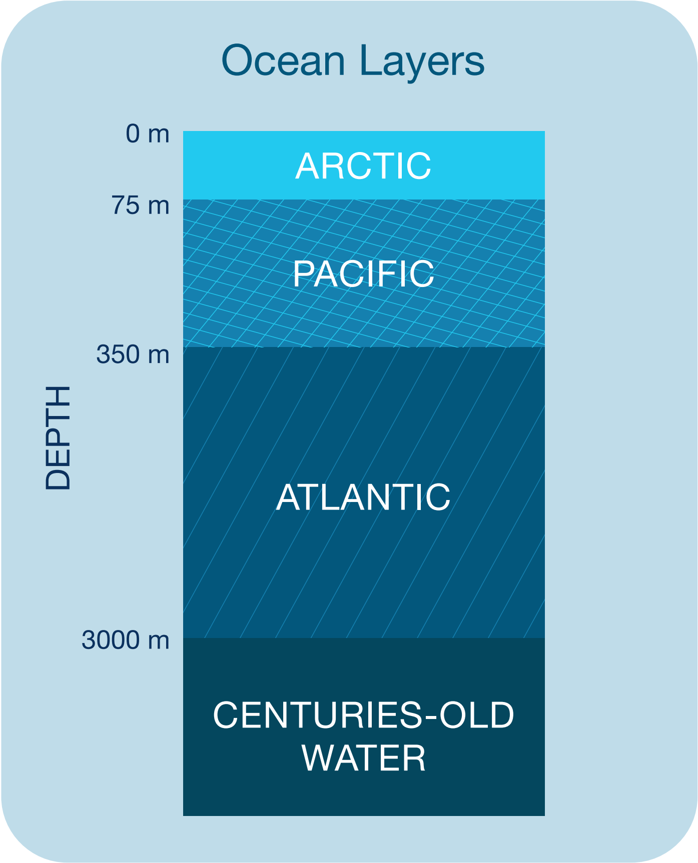


Figure 8: Ocean layers in the Canadian Arctic. Nutrients that support the food web enter Canadian Arctic waters through water from the Pacific and Atlantic Oceans. Processes that move nutrients from the Pacific layer to the Arctic layer are very important for fueling Arctic marine food webs.

At present, known changes to ocean water in the Canadian Arctic relate to chemistry and the supply of nutrients. In different areas of the Canadian Arctic, seawater has become more acidic over the last 10-20 years. While this “acidified” water is not harmful to people, the lower pH levels can damage shells of some species, snails for example, and may create a more stressful environment for fishes and invertebrates. More carbon dioxide (CO_2) is entering the Arctic Ocean. More CO_2 in the water combined with ocean currents that trap ice melt and river water, causes higher acidification in the Canada Basin than elsewhere in the Canadian Arctic.

The consequences of changing ice and water conditions for food webs are not well known across different habitats. More open-water habitat means the marine food web may be supported by increased growth of microscopic plants in the water (**phytoplankton**) and less by those in sea ice (**ice algae**). However, changes in nutrient availability, especially **nitrate** — an essential nutrient used by phytoplankton — may support or limit increases in phytoplankton. With multiple changing conditions, it is not possible to say that phytoplankton is consistently increasing or decreasing, or to say that all marine locations in the Canadian Arctic are changing in the same way. In Cumberland Sound, algae in the water column are an increasingly important energy source for the food web, with less energy coming from algae in the ice. Diet studies of beluga, ringed seals, Greenland Halibut and Arctic Char from Cumberland Sound also indicate changes in the abundance and types of prey species available in the food web (**Figure 9**).

The Canadian Arctic: Changing Sea Ice is Affecting Marine Food Webs

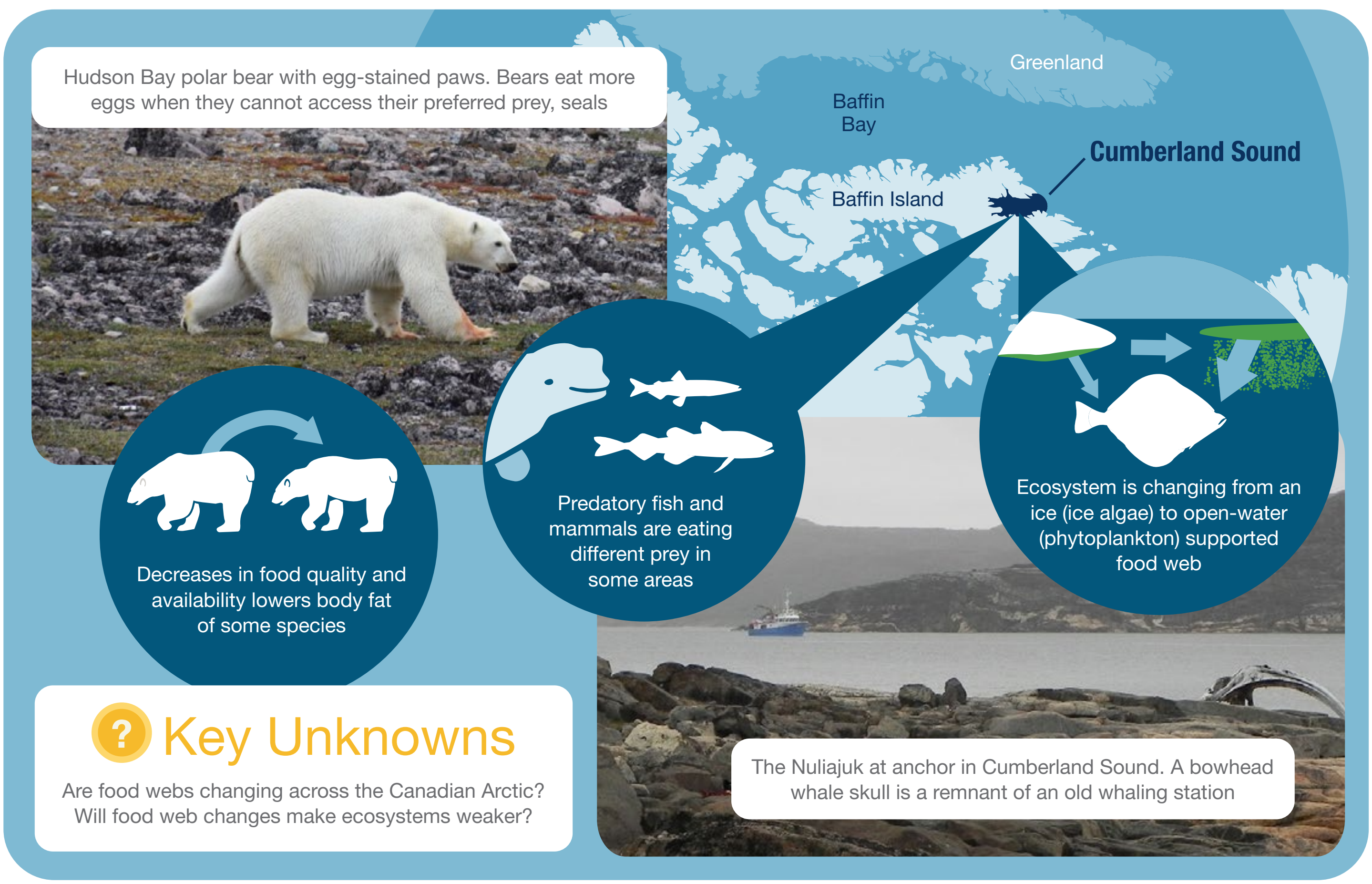
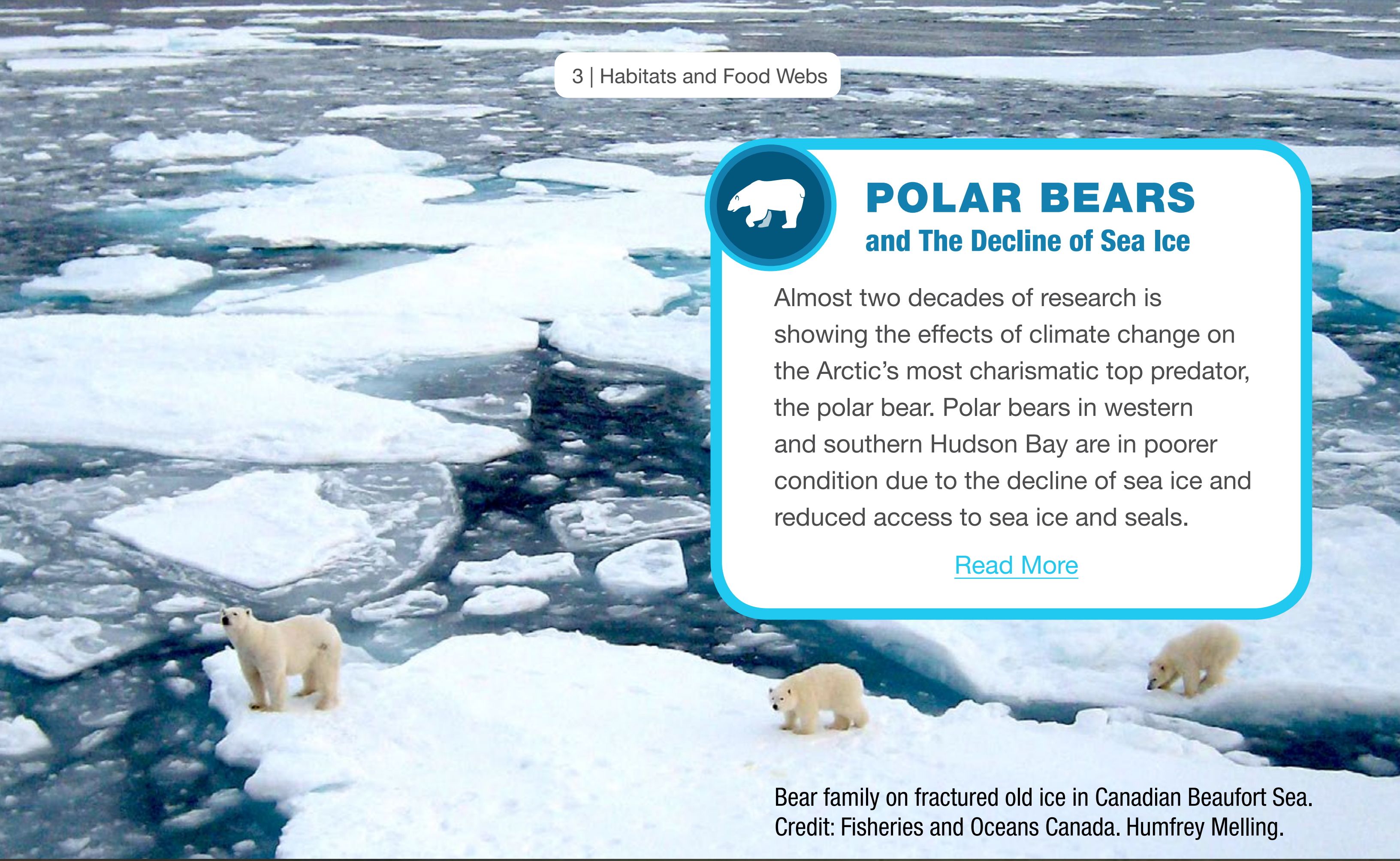


Figure 9: Energy flows through food webs, linking microscopic life to marine mammals and humans. Changes in sea ice can affect the flow and quality of food in Canadian Arctic marine food webs.



POLAR BEARS
and The Decline of Sea Ice

Almost two decades of research is showing the effects of climate change on the Arctic's most charismatic top predator, the polar bear. Polar bears in western and southern Hudson Bay are in poorer condition due to the decline of sea ice and reduced access to sea ice and seals.

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Bear family on fractured old ice in Canadian Beaufort Sea. Credit: Fisheries and Oceans Canada. Humfrey Melling.

Worm Discovery

In 2013, millions of tubeworms were discovered living on active mud volcanoes in the Canadian Beaufort Sea (280-740 metres water depth). The volcanoes, 600-1100 metres across and 30 metres tall, spew warm mud and gases, including methane. The worms have no eyes and no stomach. To survive they use gases from the volcanoes as an energy source (chemosynthesis), likely in partnership with bacteria that live in their bodies. This discovery represents the first — and only — known living chemosynthetic community in Canadian Arctic waters. The nearest similar community is in the Norwegian Arctic.

What else is waiting to be discovered in the Canadian Arctic?

Octopus lurks among tubeworms discovered on mud volcanoes in the Canadian Beaufort Sea. Image captured by MBARI's remotely operated vehicle. Credit: © 2015 MBARI.

Key Findings: Habitats and Food Webs

Habitat changes

- **Ocean chemistry:** Surface waters in the Canada Basin are more acidic now than they were 20 years ago. This is linked to a prolonged (>15 years) clockwise rotation of surface waters in the area driven by wind from the most common direction.
- **Upwelling:** Water mixing that brings nutrients from deeper water to the surface layer is called upwelling. The number of upwelling events has doubled on the Mackenzie Shelf over the last 25 years. This is also linked to the prolonged clockwise rotation of surface waters in the Canada Basin.
- **Nutrients:** The layer of water from the Pacific Ocean holds most of the nutrients needed for phytoplankton growth in Canadian Arctic waters. This layer is typically found at a depth of 150 meters. Over the last 15 years, the Pacific layer has been pushed down in the central Beaufort Sea, and up in the shallower continental shelf of the Beaufort Sea. There is more phytoplankton growth where the nutrients are closer to the sunlight.
- **More open water:** Although satellite data show that, over a year, there is more phytoplankton growth because there is more ice-free water in the Canadian Arctic, some areas have less phytoplankton growth due to declines in nutrient availability.
- **Availability of sea ice:** The availability and stability of sea ice as a platform is decreasing. This is linked to skinnier polar bears and ringed seals in Hudson Bay. Consequently, polar bear populations are declining in Hudson Bay. Changes at the population level are not yet evident for ringed seals.
- **Habitat use:** The preferred habitat of fishes in offshore waters is closely tied to the depth of Atlantic or Pacific water layers in the Beaufort Sea and Baffin Bay. Key food web species such as Arctic Cod prefer transition zones between ocean layers. Consequently, changes in ocean layers are directly related to changes in ocean habitat.

Food web changes

- **Diets:** In the eastern and western Arctic, marine predators such as Arctic Char, Greenland Halibut, seals and beluga have flexible diets. In Cumberland Sound, the diet of marine predators has changed to include different fish species, e.g., capelin.
- **Shifting energy sources:** As a result of an increasing open-water period in Cumberland Sound, food web pathways are changing. Different marine predators are now eating similar things. More energy for the food web now originates from phytoplankton rather than the algae that grows in sea ice.

Rocky bottom in Brown's Harbour, Northwest Territories.
Credit: Fisheries and Oceans Canada. Darcy McNicholl.

SEASONALITY

The Canadian Arctic has extreme seasonal changes — 24 hours of darkness and covered in ice in winter, and 24 hours of daylight and reduced ice cover in summer. Marine species and humans living in Canada's Arctic have adapted to the yearly cycle. Coastal communities are in tune with seasonal changes. People know where and how to travel to hunting grounds and when to expect different fishes and marine mammals in their areas (**Sidebar: Knowledge Inventory**). But the yearly cycle of events is changing, and marine ecosystems are not always behaving as expected.

The main reason for seasonal changes in Arctic marine ecosystems is the shortening of the ice covered period. Sea ice is clearing or melting earlier in the year. This change affects the timing of lifecycle events (e.g. birthing, feeding, migration). The longer open-water period affects the ice algae and phytoplankton at the foundation of food webs (**Box: The Ocean in Bloom, page 16**). While these changes will likely affect the entire food web, it is not well known how individuals and species, as well as interactions between species, will be affected (**Figure 10**).

The lengthening open-water period can benefit or harm fishes, marine mammals and birds, depending on their adaptability and interactions with other species. Many are important subsistence species for Inuit in Inuit Nunangat (**Figure 11**). Species such as common eiders (sea ducks) can benefit by adapting to hatch their eggs just prior to ice-free conditions. Ducklings are then able to feed in open water just days after hatching, increasing their chance of survival. Over the last 20-30 years, marine mammals studied in the Beaufort Sea and Hudson Bay have responded differently to changes in the amount and timing of sea ice. Some studies indicate that the health of young bowhead whales has improved over time, but ringed seal and beluga may have experienced declines in health (**Box: Ringed Seals in Hudson Bay, page 17**). More years of research are needed to monitor how some marine mammal populations will continue to respond to the changing Arctic seasons.

Knowledge Inventory

The close relationship between coastal communities in Nunavut and seasonal changes in the ocean are reflected in data from the Nunavut Coastal Resource Inventory — a project led by the Government of Nunavut to document Inuit knowledge on coastal and marine fish, marine mammal, bird, plant and invertebrate species. Nunavut communities are currently living with the consequences of changes in sea-ice conditions.

The Canadian Arctic: The Changing Ice Season is Affecting Algae Blooms

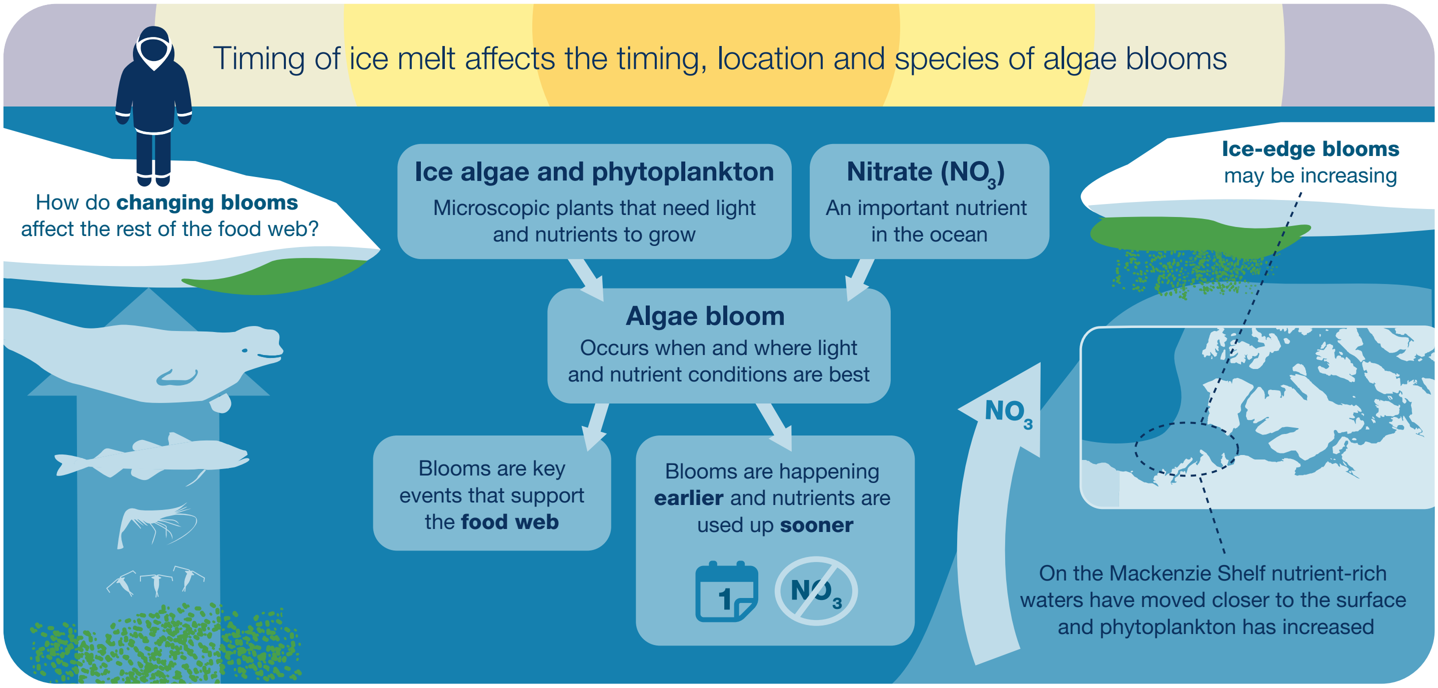

Figure 10: The foundation of the food web is made up of microscopic animals and plants, providing energy that flows through the food web. These tiny species respond quickly to sea-ice conditions.

THE OCEAN IN BLOOM

Short-lived phytoplankton blooms are important events in Canadian Arctic waters. Many species coordinate their reproduction and feeding with the timing of the bloom. The timing and location of blooms are strongly controlled by sea ice and snow cover. Blooms at the ice edge can have different effects on nutrients and the food web depending on whether the ice edge is located over deep basin or shallower (continental shelf) areas.

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Phytoplankton blooms (green) in waters of the Canadian High Arctic.
Credit: NOAA National Environmental Satellite, Data, and Information Service (NESDIS).

RINGED SEALS
and The Decline of Sea Ice

With extremely early ice breakup, ringed seals are not able to complete their moult (loss and re-growth of body hair). The accompanying high ocean temperatures may make the seals too hot causing unusual behaviour that puts them at higher risk of polar bear predation. For example, a very warm year in 2010 resulted in poor ringed seal health in Hudson Bay. Seals experienced increased stress, giving birth to fewer pups in the following years.

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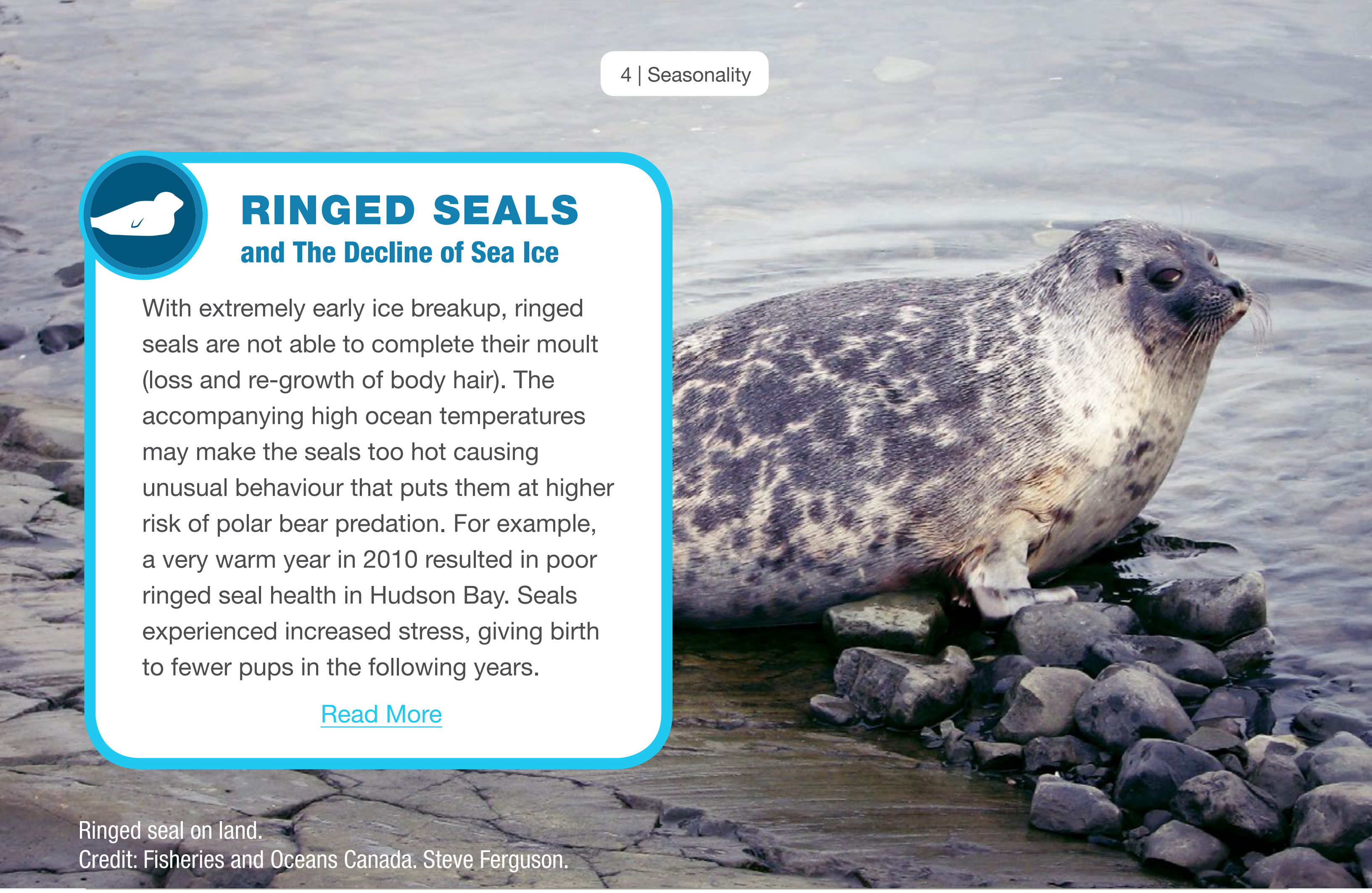


Ringed seal on land.
Credit: Fisheries and Oceans Canada. Steve Ferguson.

The Canadian Arctic: The Changing Ice Season is Affecting Subsistence Species

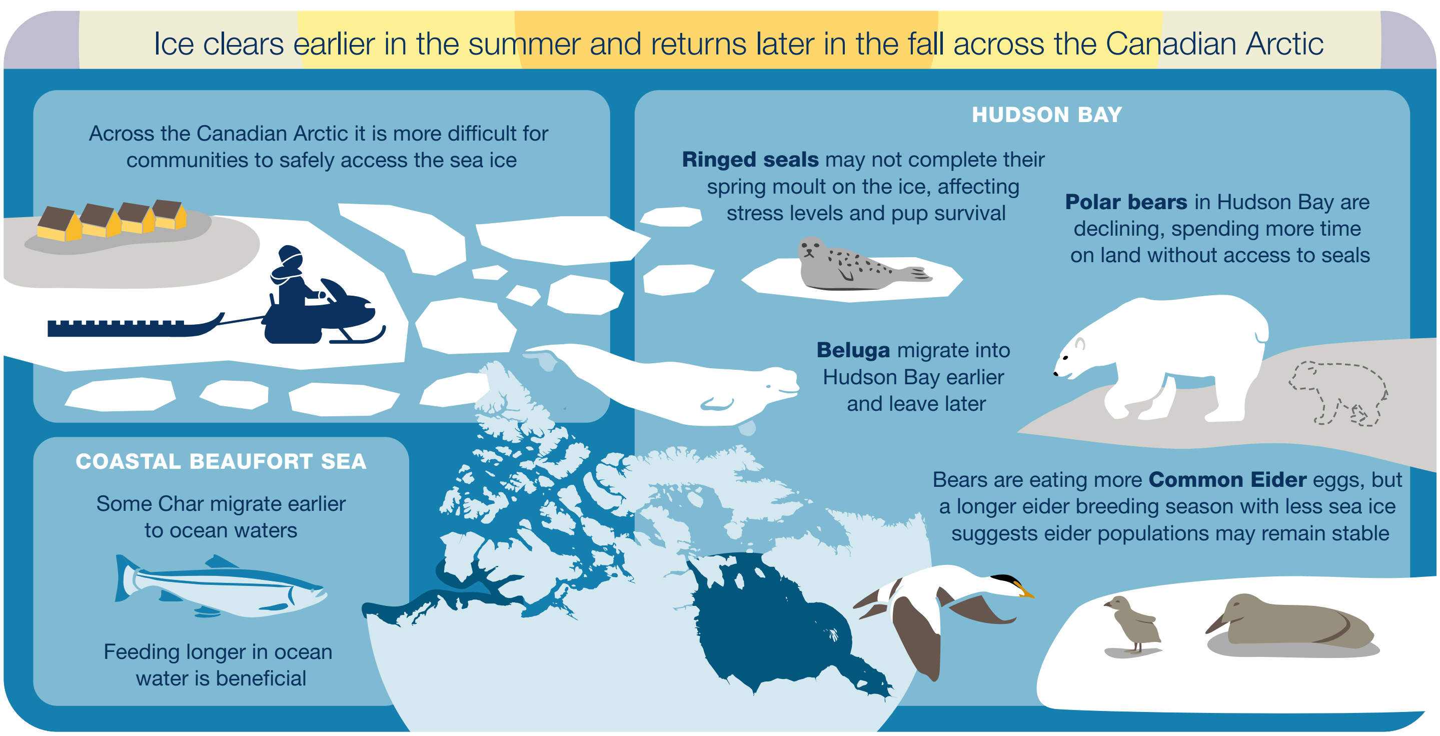


Figure 11: Species used for food or other purposes (subsistence species) by Inuit are of high importance in Arctic ecosystems. To care for these species, it is necessary to understand how changing sea ice will affect their movements, health and populations.

Key Findings: Seasonality

Changes throughout the food web:

- **Earlier blooms:** In some places, the period of peak phytoplankton growth (blooms) is happening earlier. These blooms and the response of zooplankton grazers and larval fishes, dependent on coordinated feeding with blooms, have not been monitored over time.

- **Nutrients used earlier:** Earlier blooms, possibly occurring more frequently under the ice, can reduce the amount of nutrients available for later summertime phytoplankton growth. This will alter how and when energy is transferred through ocean food webs.

- **Arctic Char migration:** The migration of Arctic Char to ocean waters in the western Canadian Arctic is occurring earlier in the year due to earlier ice break-up along the coast. This allows the fish to feed longer in ocean water. There have been improvements in Arctic Char growth in some coastal areas of the Canadian Beaufort Sea.

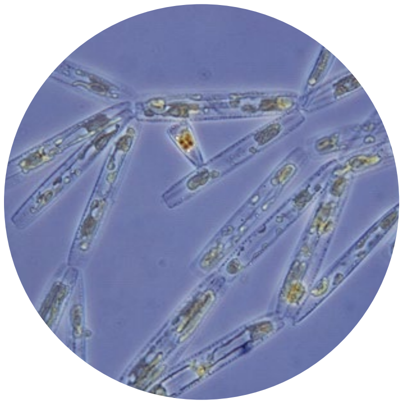
- **Seal moult:** With extremely early ice breakup, ringed seals are not able to complete their moult making the seals more susceptible to disease and predation.

- **Beluga migration:** Over the last 25 years, a shrinking ice season in Hudson Strait has allowed beluga to migrate into Hudson Bay earlier and leave later.

Responses to seasonal changes:

- **Individual decisions:** Individual responses to changes in the timing of ice cover and open water affect how populations will cope with climate change. Survival of common eider ducklings is highest if hatching is timed to occur just prior to ice-free conditions in Hudson Bay.

- **Species interactions:** The lengthening open-water feeding season supports common eider breeding in Hudson Bay, including increases in the number of eggs laid. Producing more eggs helps offset increasing nest predation by polar bears who cannot access seals, which is their preferred prey. This demonstrates that changes in sea ice can have multiple effects on a species, potentially resulting in no overall change in a population.



Microscopic image of sea-ice algae (Pennate diatom *Nitzschia frigida*). Credit: Canadian Museum of Nature, Michel Poulin.

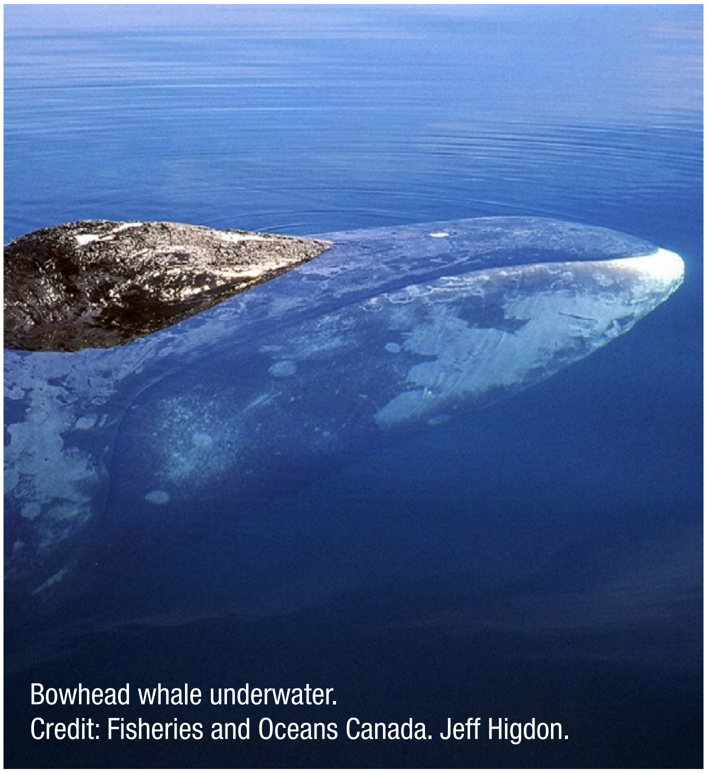
Boot Inlet, Northwest Territories. Credit: Fisheries and Oceans Canada. Ashley Ehrman.

ECOSYSTEM VARIABILITY

Environmental conditions in the Canadian Arctic differ from year to year and decade to decade. This is a normal characteristic caused by atmospheric changes. Patterns of winds and air pressure have direct effects on both the ocean and sea ice. These conditions can shift in long cycles, having anywhere between two and 20 years of higher-or-lower temperatures and more-or-less wind, for example. Understanding the range of this **natural variability** is key to distinguishing between the Canadian Arctic's normal variable conditions, and new trends linked to climate change.

Satellite data provides 40 years of information about the presence of sea ice. Air temperature, atmospheric patterns and wind conditions have also been monitored in different Arctic regions over many years. From these long-term data, expected cycles of ocean currents are also known. For example, surface water layers spin in a large circle over the deep Canada Basin. This rotating water is called the **Beaufort gyre**. Atmospheric cycles normally cause the gyre to shift between clockwise and counter-clockwise rotations every five to 10 years. However, the Beaufort gyre has stayed in a clockwise rotation for the last 19 years (as of 2017). As a result, fresh water from rivers and ice melt has been accumulating in the gyre. There is now about 33% more fresh water stored in the gyre than in 2003. The accumulated fresh water creates a barrier to nutrients held in the deeper Pacific Ocean water layer (**Figure 8**) and the fresher surface waters become naturally more acidic.

The natural variability of marine life in Canadian Arctic waters is not as well known. There is limited information about changes in populations over time, as well as changes in the distribution of individuals or species groups. Commercially harvested species, Greenland Halibut and shrimp, are studied every year in Baffin Bay and Davis Strait to understand the variability of these specific species. The populations are variable but stable overall (**Figure 12**). Complete ecosystems, from phytoplankton to whales, can be very different for just one year (**Box: A Different Year,**



Bowhead whale underwater.
Credit: Fisheries and Oceans Canada. Jeff Higdon.

The Canadian Arctic: Status of Subsistence and Commercial Species

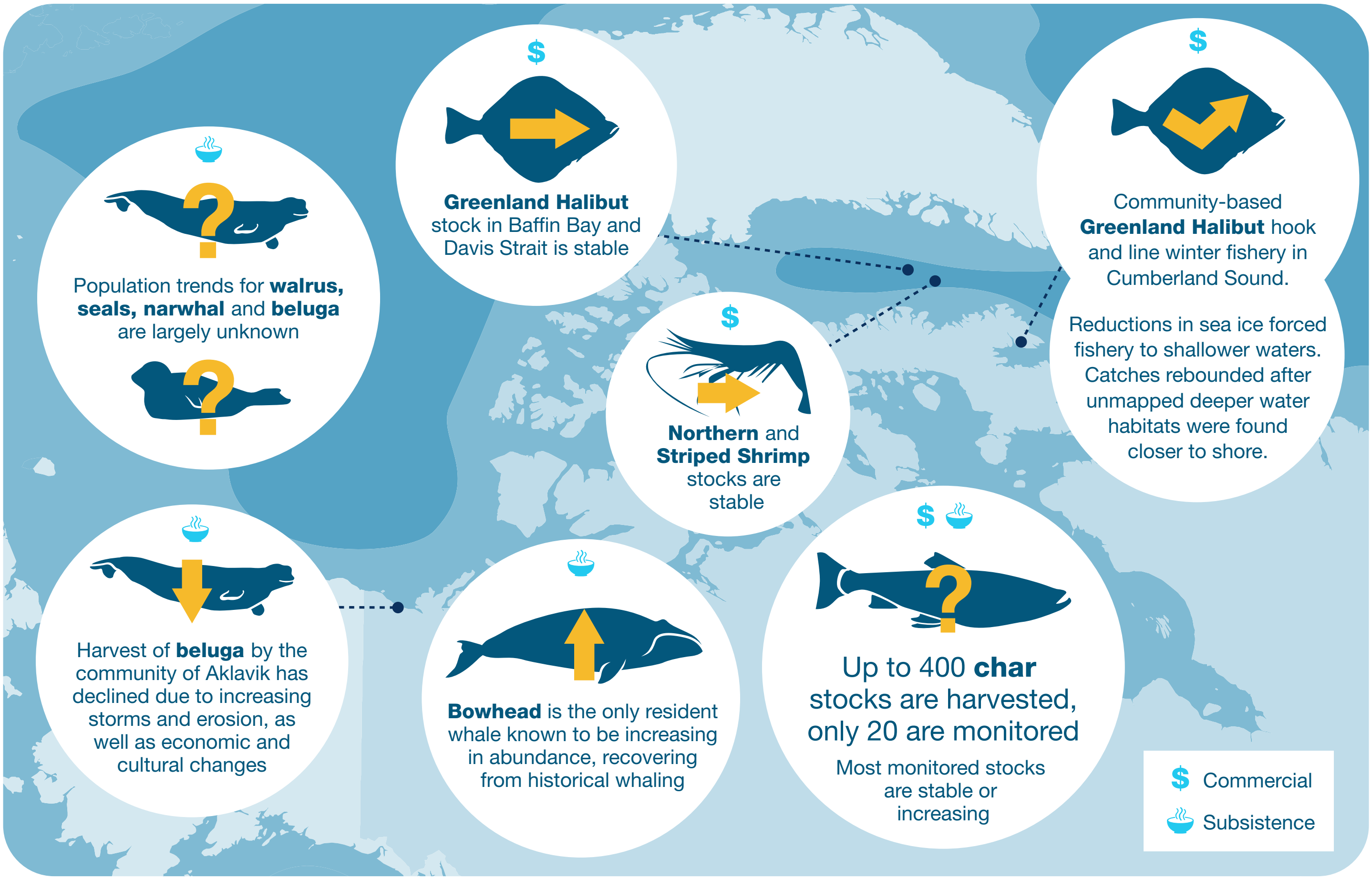


Figure 12: There are known population trends for some commercial and subsistence fishes and marine mammals in the Canadian Arctic. Trends in the species they eat are not known.

page 22). Understanding if years with low Arctic Cod abundance or unexpected distributions of beluga are becoming more common is important for predicting future change.

Some important habitats used regularly by marine mammals and other species can change dramatically from year to year. This includes the locations and sizes of **polynyas**, areas of thin ice and open water, where multiple species go to survive the winter (**Box: Arctic Sanctuary, page 22**). Variability in species abundances and distributions is closely related to habitat variability.

Knowledge of natural variability is necessary to describe the state of an ecosystem. Basic information is increasing for marine ecosystems in the Canadian Arctic, but trends over time remain scarce. With limited long-term data for Canadian Arctic waters, the information required to identify, explain and manage present and future ecosystem changes lags behind that of Canada's other oceans (**Figure 13**).

The Canadian Arctic: What Do We Need to Understand Change?

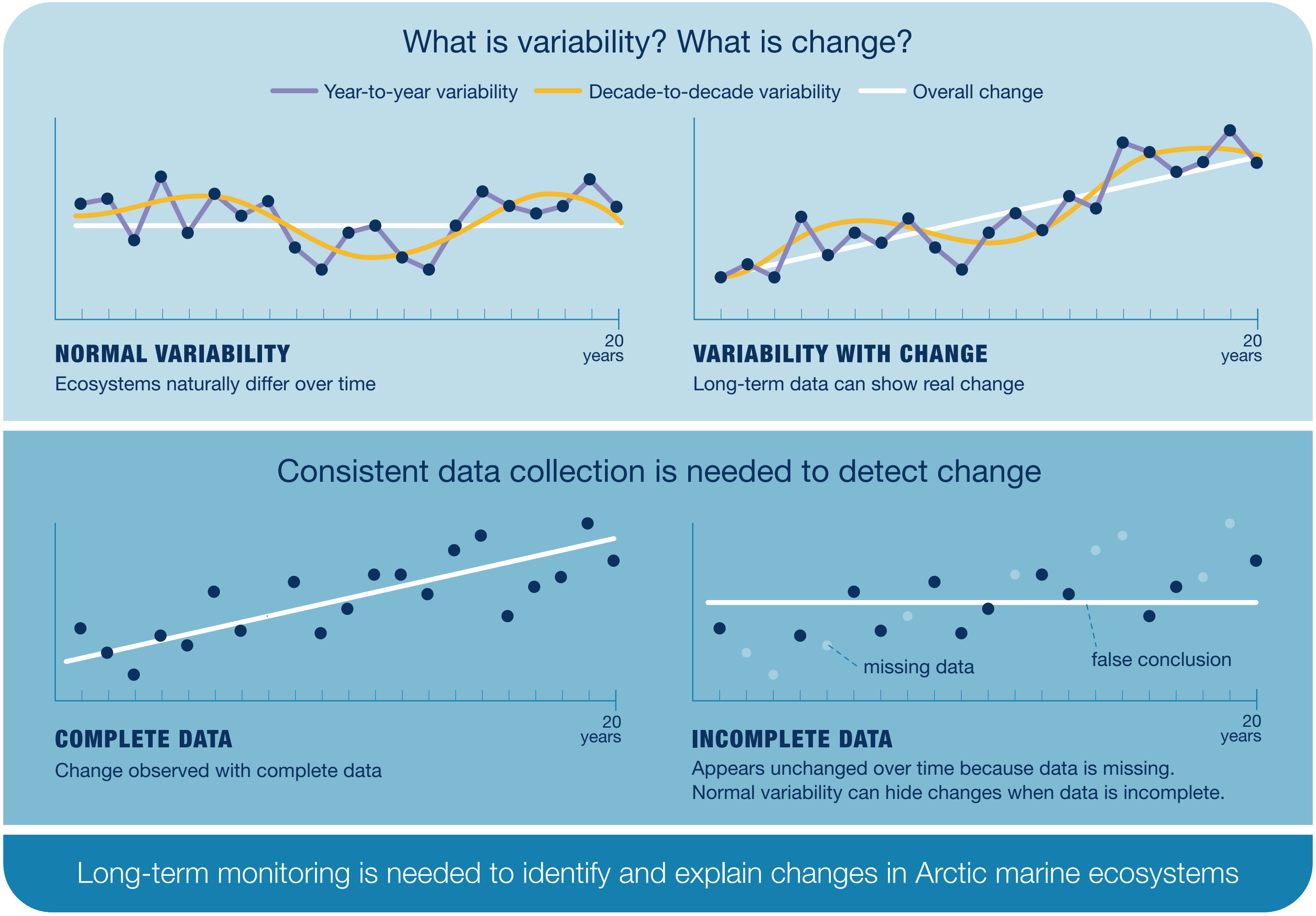
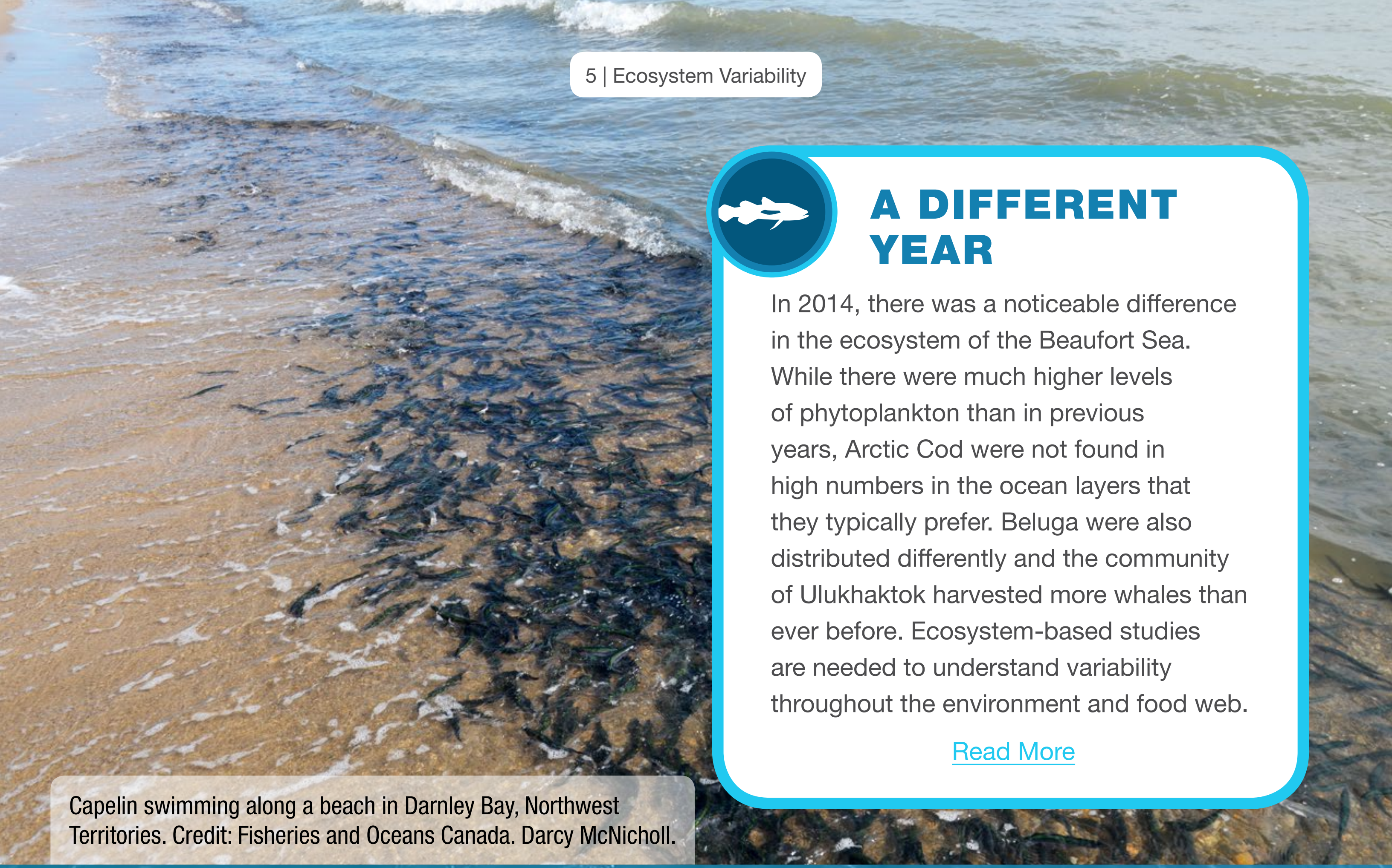


Figure 13: Verified information to support decisions that protect Canada's Arctic waters must include a measure of differences between years, as well as the ability to identify normal vs. changing conditions.

Old whale vertebra on shoreline of Brown's Harbour, Northwest Territories. Credit: Fisheries and Oceans Canada. Darcy McNicholl.



Capelin swimming along a beach in Darnley Bay, Northwest Territories. Credit: Fisheries and Oceans Canada. Darcy McNicholl.

A DIFFERENT YEAR

In 2014, there was a noticeable difference in the ecosystem of the Beaufort Sea. While there were much higher levels of phytoplankton than in previous years, Arctic Cod were not found in high numbers in the ocean layers that they typically prefer. Beluga were also distributed differently and the community of Ulukhaktok harvested more whales than ever before. Ecosystem-based studies are needed to understand variability throughout the environment and food web.

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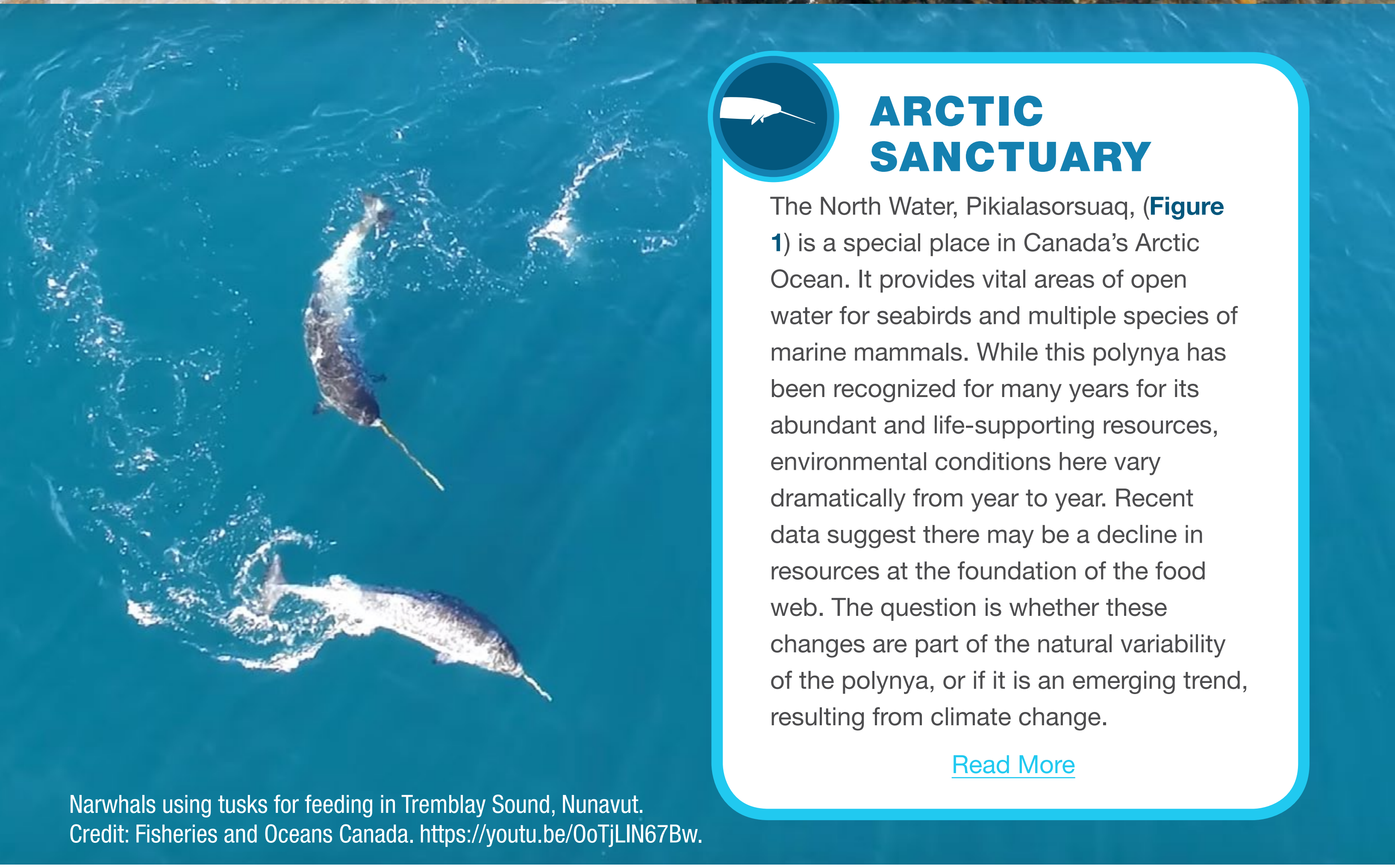

Narwhals using tusks for feeding in Tremblay Sound, Nunavut. Credit: Fisheries and Oceans Canada. https://youtu.be/OoTjLIN67Bw.

ARCTIC SANCTUARY

The North Water, Pikialasorsuaq, (**Figure 1**) is a special place in Canada's Arctic Ocean. It provides vital areas of open water for seabirds and multiple species of marine mammals. While this polynya has been recognized for many years for its abundant and life-supporting resources, environmental conditions here vary dramatically from year to year. Recent data suggest there may be a decline in resources at the foundation of the food web. The question is whether these changes are part of the natural variability of the polynya, or if it is an emerging trend, resulting from climate change.

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Key Findings: Ecosystem Variability

Types of variability:

- **Temperature:** Water temperature near the seafloor in the middle of the Mackenzie Shelf has been variable since 1985. The long-term trend shows that this location in the Canadian Arctic Ocean is not getting warmer.
- **Ocean currents:** Surface waters in the Canada Basin spin (the Beaufort gyre) and the rotation is expected to change direction every 5 to 10 years. However, for the last 19 years (as of 2017), the gyre has been spinning in a clockwise direction. This changes the ocean habitat and decreases phytoplankton growth in that area.
- **Habitats:** Despite having high variability in ice coverage from year to year, the North Water (also known as Pikialasorsuaq) supports large populations of seabirds and marine mammals both in summer and winter.
- **Marine mammals:** The amount of variability in marine mammal populations remains largely unknown in the Canadian Arctic. Currently, the Bowhead is the only Arctic resident whale known to be increasing in numbers.
- **Arctic commercial species:** While commercially harvested stocks of Greenland Halibut and Striped and Northern shrimp have variable abundances year to year, populations are stable.
- **Subsistence fisheries:** The most complete information about population trends for Arctic Char and Dolly Varden subsistence fisheries are from stocks in the Western Canadian Arctic. Several of these stocks went through previous periods of decline. More recent assessments indicate stable or increasing trends in abundance.

Challenges of variability and change:

- **Detecting change** in the environment and marine ecosystems of the Canadian Arctic is difficult due to large differences that occur naturally from year-to-year and decade-to-decade. Data of at least 20-years duration are typically needed to confidently identify trends against the background of normal environmental variability. Lengthy databases are generally not available and long-term approaches to monitoring are needed to explain changes in Arctic marine ecosystems.

Shrimp in Navy Board Inlet. Photo taken by SuMo Remotely Operated Vehicle (ROV). Credit: ArcticNet-CSSF-DFO

NEIGHBOURHOOD CONNECTIONS

The Canadian Arctic cannot be understood in isolation. Canadian waters are linked to the greater Arctic Ocean, and waters are received from both the Atlantic and Pacific Oceans. Sea ice in the Canadian Arctic may have travelled great distances, arriving from other Arctic regions. This means that drivers (natural forces) and stressors (human-caused) that affect Canada's Arctic ecosystems, often originate in other oceans and other countries.

The Pacific Ocean water flowing into the Canadian Arctic carries the essential nutrients that control growth at the foundation of the food web. This Pacific water also delivers water that is more acidic than 20 years ago, which is contributing to ocean acidification in the Canadian Arctic. Monitoring the condition of water entering and exiting the Canadian Arctic is necessary to understand how ocean habitats are changing and how ocean connections could affect subsistence and commercial fisheries (**Figure 14**).

Tracking migrations identifies long-distance connections between oceans and highlights how habitats are used at different times of the year (**Box: Hotspots, page 27**). It was recently discovered that Greenland Sharks can migrate from Jones Sound on Baffin Island to Northwest Greenland. New connections and details of migration routes continue to be discovered for migratory birds, marine mammals and fishes who rely on Canadian Arctic ecosystems. Movement patterns of Greenland Halibut, an important commercially harvested species, are currently being studied, with some fish from Cumberland Sound travelling as far as the Grand Banks and the west coast of Iceland.

Marine mammal migrations can be interrupted by sea ice. Inuit knowledge documents severe

Greenland shark with tracking tag in Scott Inlet, Nunavut. Credit: Fisheries and Oceans Canada. Kevin Hedges.

The Canadian Arctic: Species and the Environment are Affected by Neighbourhood Connections

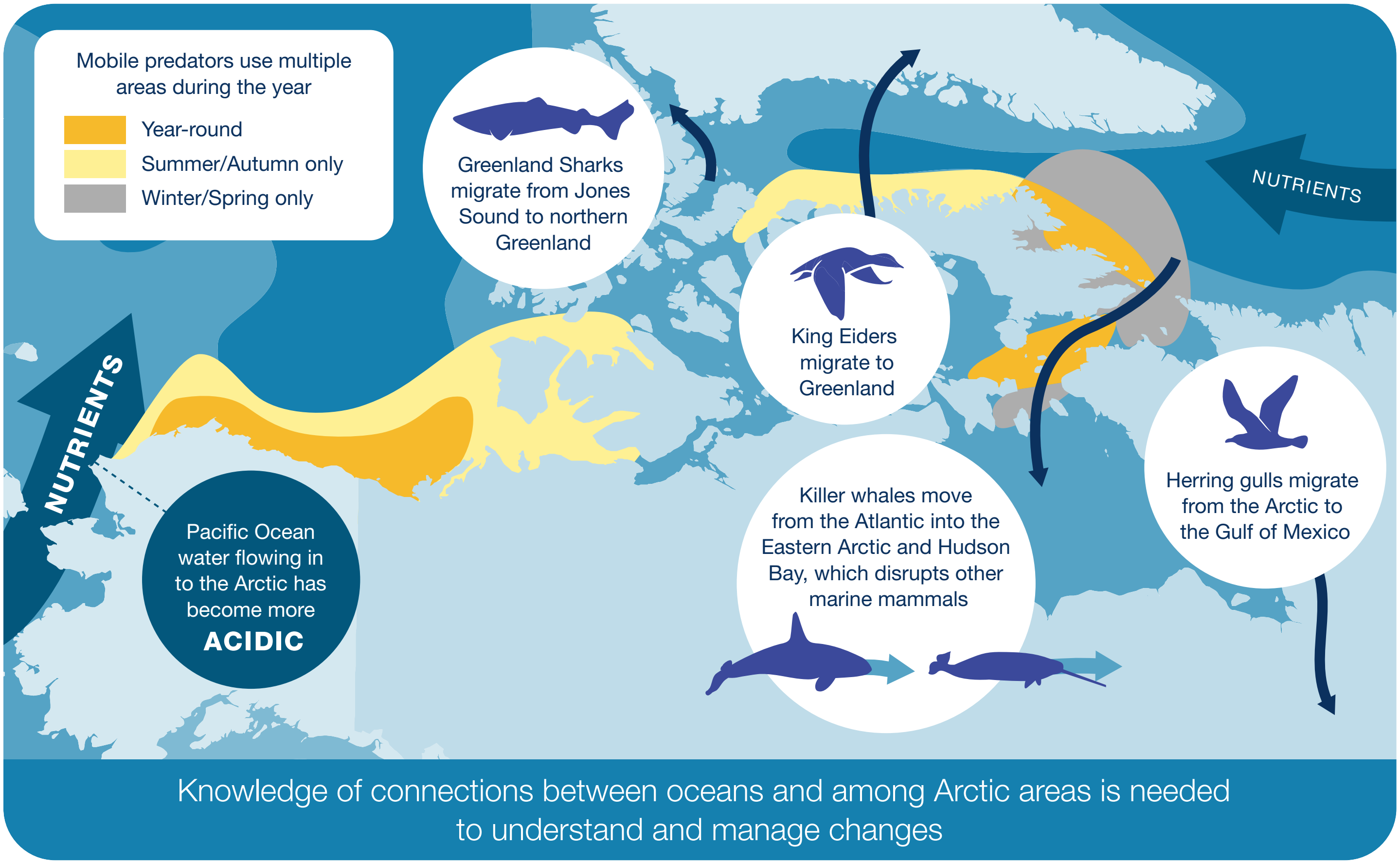

Figure 14: New knowledge is describing and mapping connections between oceans and among marine areas in Canada's Arctic. Ocean connections affect marine habitats and demonstrate that the Canadian Arctic hosts many mobile species.

outcomes for marine mammals that cannot access needed connections between areas (**Sidebar: Lost Connection, page 26**). In contrast, the lengthening open-water period in the Canadian Arctic is now allowing for new and expanded connections to occur. For example, killer whales are more frequently entering the eastern Arctic — especially Hudson Bay. The increased presence of killer whales in the Canadian Arctic changes the behaviour of other whales as they try to avoid these aggressive predators (**Box: Range Expansions, page 26**). Understanding if new connections or existing connections will change or stay the same is vital in managing fish and marine mammal populations (e.g. freshwater-ocean connections for Arctic Char).

Male King Eider in Cambridge Bay, Nunavut. Credit: Getty Images. drferry.

Lost Connection

Connectivity is essential for the survival of many marine species in the Canadian Arctic. The loss of connectivity can be detrimental to individuals and populations. The most extreme example is the entrapment of whales in sea ice before they can leave at the end of summer. It is not known how common entrapment events are, but in 2008 and 2015, two large entrapment events were fatal for hundreds of narwhal from the Eclipse Sound stock. There have also been community reports of fatal entrapments of beluga and killer whales.

RANGE EXPANSIONS

In recent years, species that were once rare in Canadian Arctic marine ecosystems are now becoming more prominent — potentially overlapping with Arctic species for prey and habitat. Although Pacific Salmon, killer whales and harp seals are not new to the Arctic, their numbers and locations are increasing. Community-based observations and research helps understand the effects of these range expansion on other marine mammals and local char species.

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Phantom DJI4 drone image of six beluga in Clearwater Fiord, Nunavut. Credit: Fisheries and Oceans Canada.

ARCTIC HOTSPOTS

Tracking the movement of individual marine species reveals the amazing distance they cover and provides insights into how they interact with sea ice and other species. Tracking information about fishes, marine mammals and birds offers a new view of how the Canadian Arctic operates as a collection of connected neighbourhoods. The information is identifying Arctic hotspots — locations that are used frequently and repeatedly by multiple species. They are important areas of energy exchange within Arctic marine food webs and represent locations where energy is brought into or removed from Canadian Arctic waters.

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Canadian Arctic in summer, viewed from space. Credit: NASA.

Key Findings: Neighbourhood Connections

Discovering species connections:

- New connections have been discovered:
  - The migration of Greenland Sharks to northwest Greenland
  - Greenland Halibut movements to shallower waters in fall
  - Individual Dolly Varden char are travelling farther offshore on the Mackenzie Shelf in summer than previously known. They are not restricted to nearshore waters.
- Knowledge of marine fish movements is informing management strategies for harvested species (e.g., Greenland Halibut, redfishes) and conservation strategies for rare species and at-risk populations (e.g., wolffishes). In contrast to other species, the movement patterns of most marine fishes in the Canadian Arctic are not directly affected by sea ice. Instead, their movements respond to water temperature and the distributions of other species.

Changing connections:

- **Pacific Ocean connection:** Pacific water flowing into the Arctic via the Bering Strait has become more acidic, highlighting the connectivity of stressors between oceans.
- **Habitat connections:** Tracking studies of numerous mobile marine predators have found distinct ecosystem hot spots in summer-fall versus winter-spring. Such data reveal how connections among habitats can guide conservation efforts.
- **Killer whale expansion:** Reduced sea ice is enabling a greater presence of killer whales in the eastern Arctic and Hudson Bay, where they prey upon and disrupt other marine mammals (e.g., bowhead, narwhal, beluga, seals).
- **Community connections:** Connections to sea ice are critical for hunting and other land use activities in all coastal Arctic communities. This includes commercial fishing for Greenland Halibut in Cumberland Sound. Changing access to sea ice has become a serious issue of safety, food security and cost for Inuit.
- **National and international connections:** The extended ice-free season enables an increase in marine traffic in the Canadian Arctic — especially cruise ships and pleasure craft. The increased frequency and extended season of vessel travel may increase noise in the marine environment in some locations.

Killer whale in Eclipse Sound, Nunavut.
Credit: Maha Ghazal.

CO-MANAGEMENT

Coastal waters of the Canadian Arctic are integral to Indigenous survival and culture. Canadian Arctic communities rely on coastal waters and adjacent areas for subsistence and economic opportunities. The protection of fish and marine mammal stocks, and the habitats that support them, is based on comprehensive land settlement agreements that include co-management boards to manage fisheries and wildlife. Co-management processes vary across the four Inuit land claims regions of Canada (Inuvialuit Settlement Region, Nunavut, Nunavik and Nunatsiavut), collectively known as Inuit Nunangat (**Figure 2**). The use of both Inuit and scientific knowledge is critical in addressing change in Canadian Arctic coastal ecosystems (**Box: Knowledge Integration, page 30**).

In the western Canadian Arctic, the erosion and collapse of thawing coastline and inshore (delta) areas interrupts access to the coast for both fishes and people (**Figure 15**). In the last 20-30 years, erosion rates have more than doubled in many regions of the Beaufort Sea coast.

The changing coastlines support different groups of fish. Understanding interactions between freshwater, coastal marine and **anadromous** (fish that move between fresh waters during the winter and coastal areas in the open-water season) species is important for protecting and managing subsistence species. However, basic knowledge is needed about their growth and the habitat they use throughout the year.

Information collected from current and past community harvesters improves understanding of coastal fish characteristics and catch rates. Community-based and community-led programs, as well as collections of Inuit knowledge, provide new and historical information about coastal areas. Inuit knowledge describes the increased presence of some species (capelin and killer whales for example), variability of coastal ice conditions and changing seasonal patterns of species in recent decades (**Box: Community Monitoring, page 30**). Community fishers, specifically in the western Arctic, are monitoring an increased occurrence of Pacific Salmon. Although these salmon are being found in coastal areas of the western Canadian Arctic, it is not yet known if they are able to reproduce there and colonize the northern part of their range.

Coastline in Argo Bay, Northwest Territories.
Credit: Fisheries and Oceans Canada, Darcy McNicholl.

COMMUNITY MONITORING

Community-based and community-led programs operate across the Canadian Arctic, collecting data and samples for a wide range of species, including beluga, seals, salmon, and chars. Data are often collected as part of traditional fishing, harvest and travel activities. Harvest data inform stock assessments and reflect harvest choices of community members. Inuit knowledge from Inuvik, Tuktoyaktuk and Paulatuk has improved ways to monitor beluga health in the Tarium Niryutait Marine Protected Area.

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Community-based monitoring in the Anguniaqvia niqiqyuam Marine Protected Area (ANMPA). Credit: Fisheries and Oceans Canada. Karen Dunmall.

KNOWLEDGE INTEGRATION

The availability and application of Inuit and scientific knowledge is essential for management decisions in the Canadian Arctic. In the Inuvialuit Settlement Region, this information was needed to make decisions about whale watching in the Beaufort Sea and fishing activities along the new Tuktoyaktuk highway. The co-development of knowledge which draws on a wide spectrum of Inuit and scientific knowledge is needed to support decision making by co-management boards.

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Drying beluga blubber and skin on the shoreline in the Anguniaqvia niqiqyuam Marine Protected Area (ANMPA). Credit: Fisheries and Oceans Canada. Darcy McNicholl.

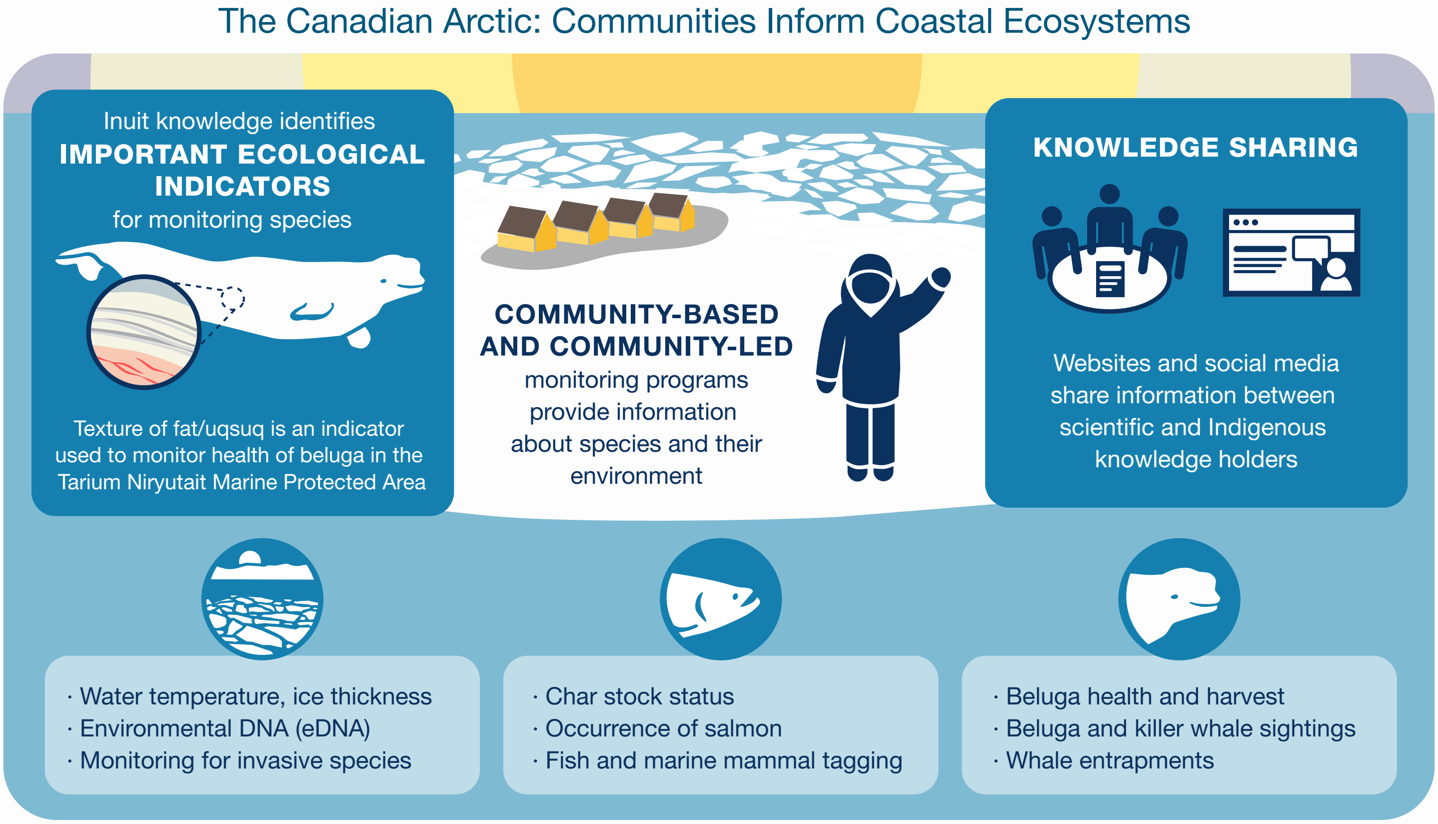
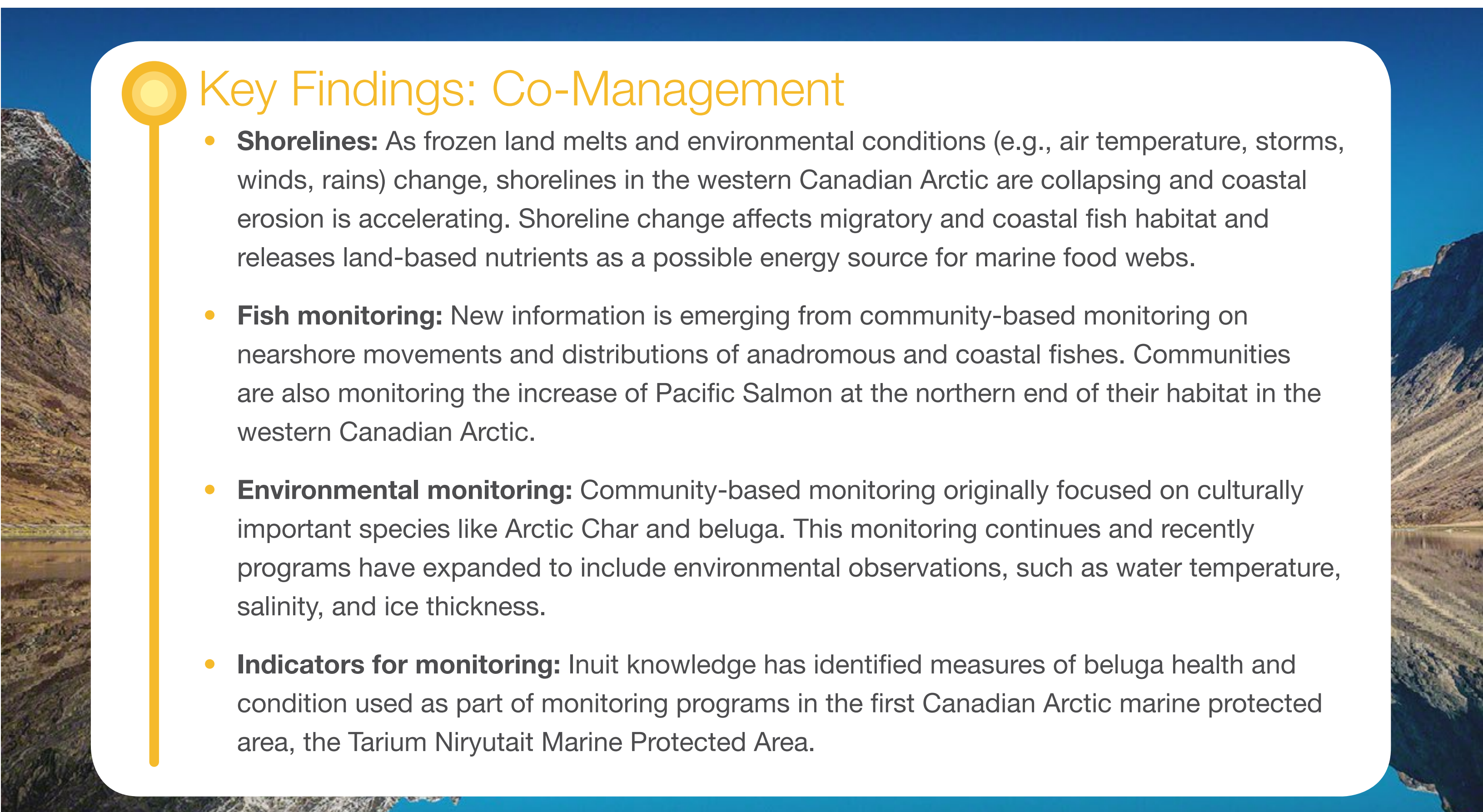


Figure 15: Across the Canadian Arctic, community programs collect information necessary to manage fishes and marine mammals, and their habitats.

Key Findings: Co-Management

- **Shorelines:** As frozen land melts and environmental conditions (e.g., air temperature, storms, winds, rains) change, shorelines in the western Canadian Arctic are collapsing and coastal erosion is accelerating. Shoreline change affects migratory and coastal fish habitat and releases land-based nutrients as a possible energy source for marine food webs.
- **Fish monitoring:** New information is emerging from community-based monitoring on nearshore movements and distributions of anadromous and coastal fishes. Communities are also monitoring the increase of Pacific Salmon at the northern end of their habitat in the western Canadian Arctic.
- **Environmental monitoring:** Community-based monitoring originally focused on culturally important species like Arctic Char and beluga. This monitoring continues and recently programs have expanded to include environmental observations, such as water temperature, salinity, and ice thickness.
- **Indicators for monitoring:** Inuit knowledge has identified measures of beluga health and condition used as part of monitoring programs in the first Canadian Arctic marine protected area, the Tarium Niryutait Marine Protected Area.


Cumberland Sound, Baffin Island, Nunavut. Credit: Fisheries and Oceans Canada. D.L Labrie.

STATE OF CANADIAN ARCTIC MARINE ECOSYSTEMS

Knowledge of marine ecosystems in the Canadian Arctic is increasing, yet basic information for some areas is absent. Scientific and Inuit knowledge is needed to better understand year-to-year differences and changes over time. It is expected that entire Arctic marine ecosystems will continue to be affected by sea-ice variability and change. A holistic approach to ocean monitoring is needed to detect and explain changes, supporting the management of marine ecosystems in the Canadian Arctic.

Narwhal tail fluke in Baffin Bay with Bylot Island and floe edge in the background, Nunavut. Credit: Getty Images. AndreAnita.