Fisheries and Oceans Canada | Pêches et Océans Canada

Canada's OCEANS NOW

ARCTIC ECOSYSTEMS 2023

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Canada

Acknowledgement

The knowledge shared in this report reflects an immense effort from researchers, technicians, ship crews, co-management boards, Hunters and Trappers Organizations, community members, and others. We appreciate the effort of Inuit organizations and scientific contributors who reviewed this report. We recognize the commitment of all those who seek to understand Arctic marine ecosystems. We gratefully acknowledge that much of the work presented in this report was undertaken within Inuit homelands (Inuit Nunangat), which includes lands, waters, ice, and all life within.

Thank You

Nakurmiik

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Quyanainni

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Merci

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Cover: Beluga swimming along the edge of the Northwest Passage ice. Photo: Mark Williams. This page: Narwhal swimming. Photo: Mark Williams.

Spotlight Infographic

Foreword

Canada's Oceans Now reports are summaries of the current status and trends in Canada's oceans. These reports are produced as part of the Government of Canada's commitment to inform the public on the current state of Canada's oceans.

Canada's Oceans Now: Arctic Ecosystems, 2023 gives new knowledge about the state of marine ecosystems in the Canadian Arctic. The report was generated by a team of co-authors from Arctic communities and Inuit organizations, academia, non-government organizations, and Fisheries and Oceans Canada.This report is based on information detailed in the *Canadian Technical Report of Fisheries and Aquatic Sciences 3633, State of Canada's Arctic Seas*.[1] The information presented reflects improved ways of understanding and learning about Arctic marine ecosystems. The current status of the environment, habitats, species, and food webs is discussed. This report highlights advancements in knowledge of biodiversity (who is there), habitat condition (how ecosystems are structured and used), and processes that affect habitat and species responses (why variability and change are occurring).

[1] Niemi A., Ehrman A., Ahmed M., Arey M., Azetsu-Scott K., et al. 2024. State of Canada's Arctic Seas. Can. Tech. Rep. Fish. Aquat. Sci. 3633: xvi + 204 p. https://www.dfo-mpo.gc.ca/oceans/publications/soto-rceo/2024/arc-technical-report-rapport-technique-eng.html

Mittimatalik (Pond Inlet), Nunavut, Canada. Photo: Shutterstock.

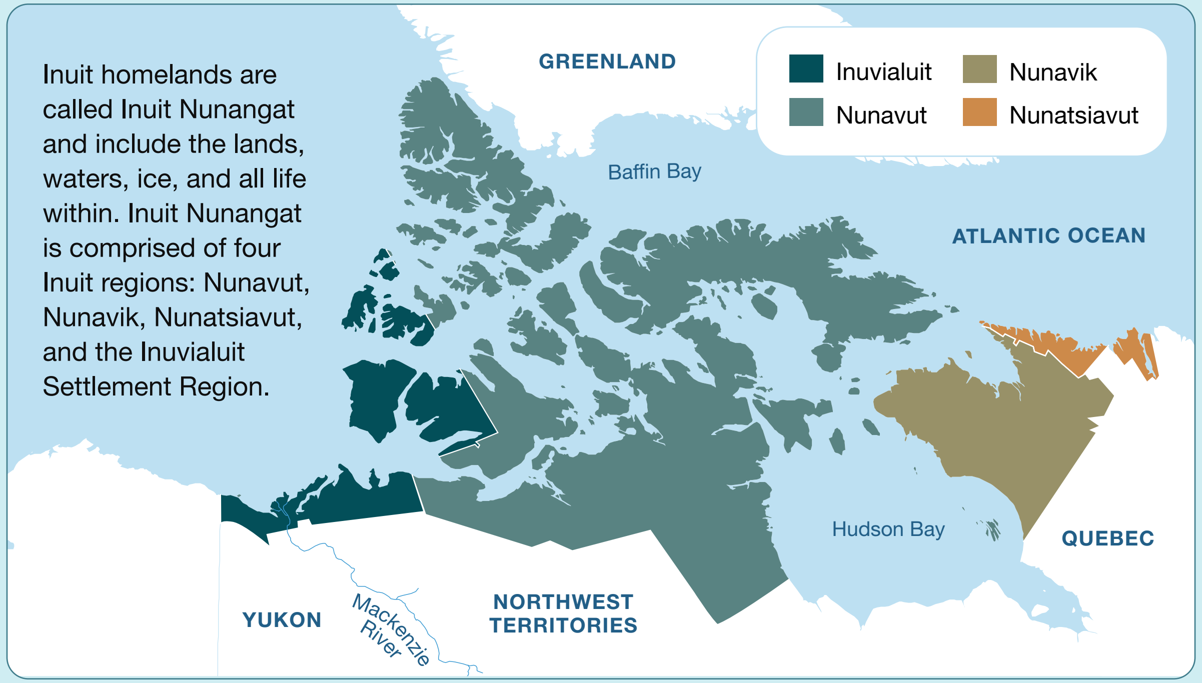
Learning together

Researchers and northern Indigenous Peoples are working together to use existing information and advance new information needed to understand and manage ecosystems in the Canadian Arctic.

The Canadian Arctic encompasses Canada's largest ocean area, stretching from James Bay to waters off the most northern point of Nunavut **(Figure 1: Report study area and communities of Inuit Nunangat)**. This Arctic area covers a wide range of coastal and offshore environments. Many locations have not been studied, and there continues to be much to learn about Arctic marine species, habitats, and ecosystem processes. Inuit across Inuit Nunangat and researchers are increasingly working together to identify and address ecosystem questions. The state of recorded knowledge varies greatly across the Canadian Arctic. It is important to know where in the Arctic the information comes from and what time of year it describes. Arctic-wide generalizations tend to be inaccurate, and are unlikely to be helpful in decision making. Through multi-year observations, we can better understand the amount and type of variability happening in the ecosystem, and identify climate-driven changes.

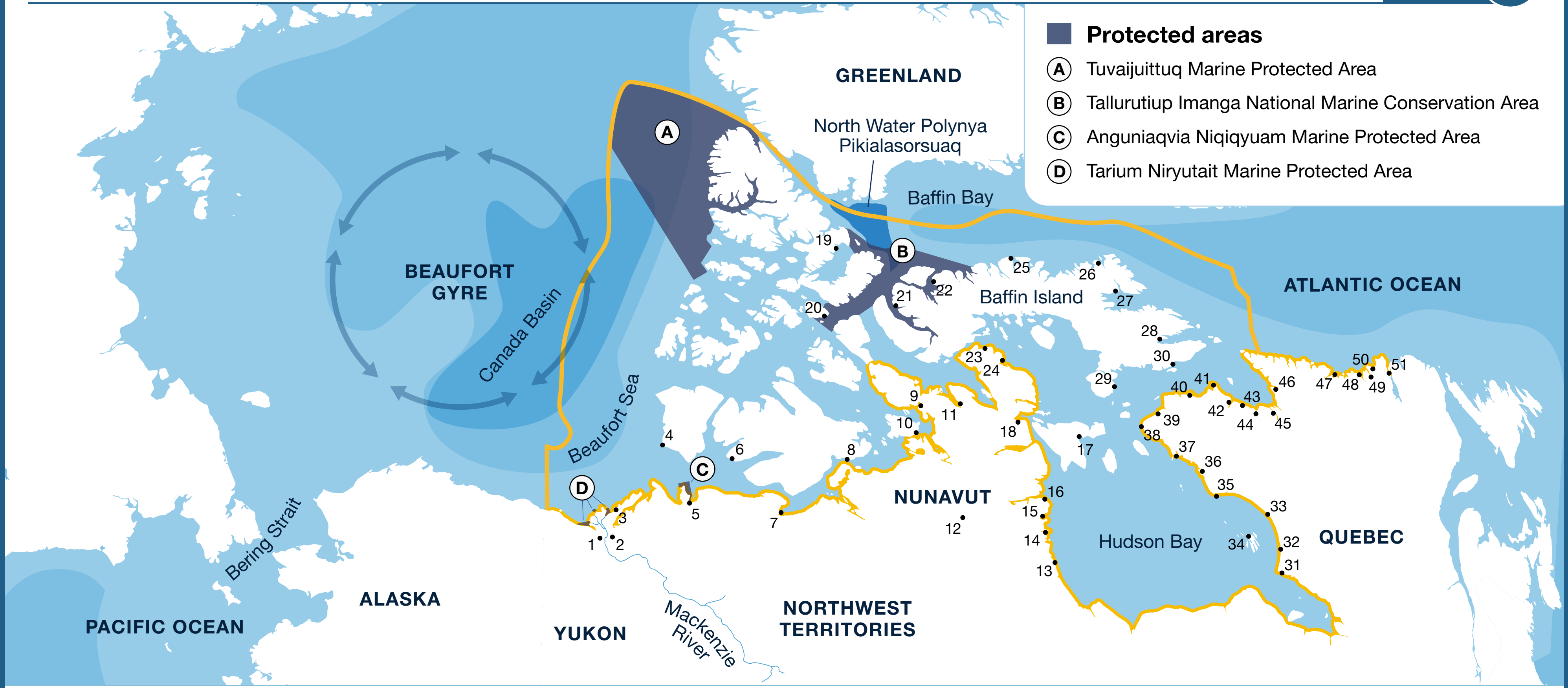
SPOTLIGHT

Inuit homelands are called Inuit Nunangat and include the lands, waters, ice, and all life within. Inuit Nunangat is comprised of four Inuit regions: Nunavut, Nunavik, Nunatsiavut, and the Inuvialuit Settlement Region.



Report study area and communities of Inuit Nunangat

FIGURE 1



Communities

Inuvialuit Settlement Region
1 Akłarvik/Aklavik
2 Inuuvik/Inuvik
3 Tuktuuyaqtuuq/Tuktoyaktuk
4 Ikaahuk/Sachs Harbour
5 Paulatuuq/Paulatuk
6 Uluhaqtuuq/Uluhaktok

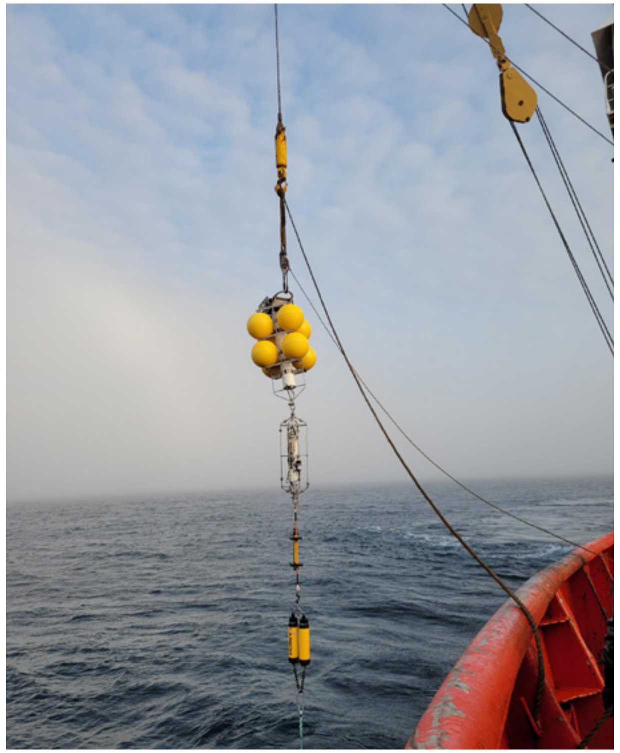
Nunavut
7 Qurluqtuq/Kugluktuk
8 Iqaluktuuttiaq/Cambridge Bay
9 Talurjuaq/Taloyoak
10 Uqšuqtuuq/Gjoa Haven
11 Kuugaarjuk/Kugaaruk
12 Qamani'tuaq/Baker Lake
13 Arviat
14 Tikiraqjuaq/Whale Cove
15 Kangiqliniq/Rankin Inlet
16 Igluligaarjuk/Chesterfield Inlet
17 Salliq/Coral Harbour
18 Naujaat
19 Ausuittuq/Grise Fiord
20 Qausuittuq/Resolute
21 Ikpiarjuk/Arctic Bay
22 Mittimatalik/Pond Inlet
23 Iglulik/Igloolik
24 Sanirajak/Hall Beach
25 Kangiqtugaapik/Clyde River
26 Qikiqtarjuaq
27 Panniqtuuq/Pangnirtung
28 Iqaluit
29 Kinngait/Cape Dorset
30 Kimmirut

Nunavik
31 Chisasibi
32 Kuujjuaraapik
33 Umiujaq
34 Sanikiluaq
35 Inukjuak
36 Puvirnituq
37 Akulivik
38 Ivujivik
39 Salluit
40 Kangiqsujuaq
41 Quaqtaq
42 Kangiqsuk/Kangirsuk
43 Aupaluk
44 Tasiujaq
45 Kuujjuaq
46 Kangiqsualujjuaq

Nunatsiavut
47 Nunainguk/Nain
48 Agvituq/Hopedale
49 Qipuqqaq/Postville
50 MaKovik/Makkovik
51 kikiak/Rigolet

Extreme conditions in the Arctic make it challenging to conduct scientific research and monitoring year-round. Most research occurs when there is open water (about July to September). This is when sites can be reached by boat and ship. Yet, the use of new technologies and continuous observations (e.g., using ocean moorings) increase knowledge of ecosystems, including species biodiversity and distributions throughout the year. Winter community-led monitoring can provide documented information in an often data-poor season. The use of new sound (i.e., acoustic) and satellite (i.e., telemetry) survey technologies improved mapping of animal movements and their population over seasons (e.g., community-based beluga telemetry program and cooperative interpretation of results).

The participation of Indigenous communities in scientific research and monitoring is growing with efforts to bridge Indigenous Knowledge and Western science data **(Figure 2: Scientific research and Indigenous Knowledge)**. While many research projects provide information about current changes, Indigenous Knowledge provides the longest perspective over time. Partnerships characterized by mutual respect and collaboration build an understanding of historical environmental and biological baseline conditions, which helps identify and monitor changes. Bridging multiple ways of knowing builds a fuller understanding of environmental change. This is critical for effective co-management of marine species and ecosystems in Inuit Nunangat.



Left: David Putumiraqtuq deploying equipment through the sea ice near Igluligaarjuk (Chesterfield Inlet) to measure ocean temperature and salinity. Photo: Darcy McNicholl, DFO.
Right: Deployment of equipment to monitor ocean and biological conditions over an entire year in the western Canadian Arctic. Photo: Andrea Niemi (DFO).

SPOTLIGHT

Co-management of Marine Protected Areas (MPAs)

In the western Canadian Arctic, two marine protected areas were established under the *Oceans Act* through the leadership of Inuvialuit communities and co-management organizations:

- Tarium Niryutait Marine Protected Area (TNMPA) established in 2010
- Anguniaqvia Niqiqyuam Marine Protected Area (ANMPA) established in 2016

Both MPAs have conservation objectives that were co-developed with Inuvialuit partners and support the Beaufort Sea Beluga Management Plan developed by the Fisheries Joint Management Committee. The ANMPA is the first Canadian MPA with a conservation objective based solely on Indigenous Knowledge; this objective is to maintain habitat for key subsistence species (e.g., Arctic char, beluga whales, seals).

Priority-setting, co-management, and monitoring in these MPAs occur through partnerships between Inuvialuit organizations and, Fisheries and Oceans Canada (DFO), with the support of other collaborators.

Scientific research and Indigenous Knowledge

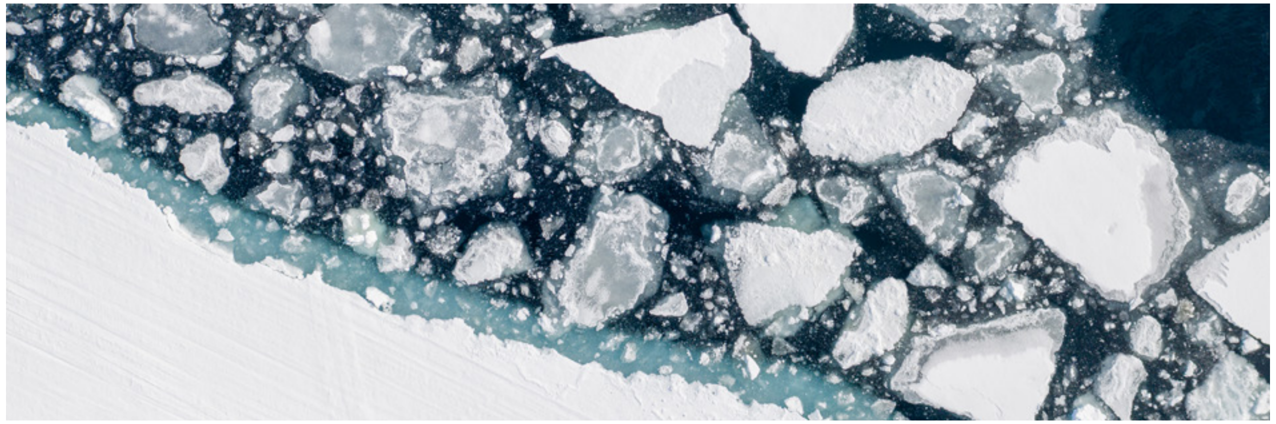
FIGURE 2

Community leadership and participation are increasing in scientific research and monitoring across Inuit Nunangat

Connected, yet different

Canada's Arctic has areas with unique sea ice and ocean conditions, despite strong influences from the Pacific, Atlantic, and Central Arctic Oceans.

Sea ice and ocean trends in the Canadian Arctic can be influenced by connected oceans, but remain unique. Datasets over 20 years and longer are critical to identify and understand changes and differences between ocean areas. Long-term scientific sea-ice trends come primarily from satellite data analysis (from 1979 to today). Satellites can also reveal conditions like temperature and algae concentration, but only at the ocean surface. Ocean trends discussed below are identified by ship-based measurements repeated each summer (i.e., the Beaufort Gyre information) and/or by ocean moorings. Long-term moorings are underwater lines of instruments that collect ocean data such as temperature, salinity, water motion, and ice thickness all year long. They are replaced each year to continue recording data. In the entire Canadian Arctic, fewer than seven moorings have measured ocean conditions continuously for more than 20 years.



Left: Sea ice near Mittimatalik (Pond Inlet), Nunavut, Canada. Photo: Shutterstock. Right: Offshore water sampling in the Canadian Artic. Photo: Caity Allison, DFO.

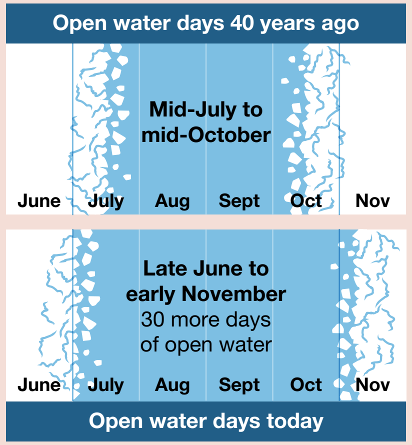
Sea ice changes

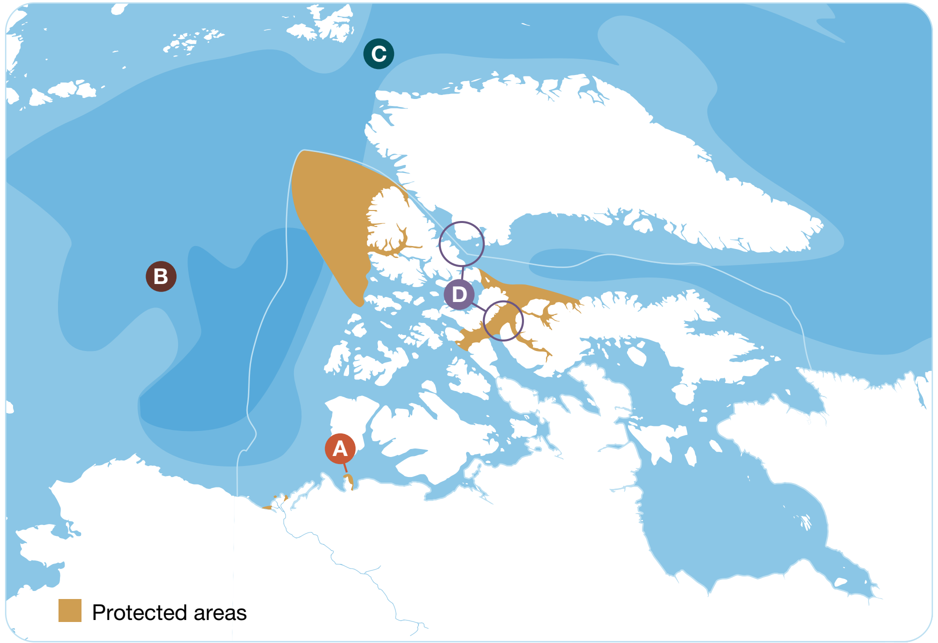
FIGURE 3

Sea ice is changing across the Arctic. These changes influence Arctic marine ecosystems in many ways. Each box shows a different way that the ice is changing.

Ice duration: Coastal zone (A)

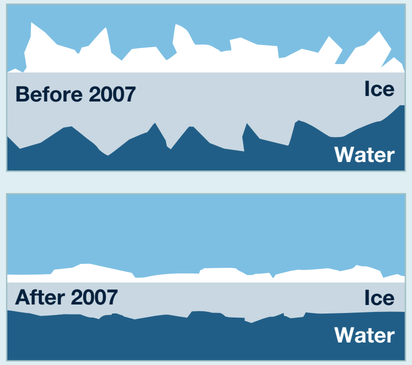
In the Anguniaqvia Niqiqyuam Marine Protected Area, coastal sea ice lasts a full month less than it did 40 years ago.





Ice transport: Fram Strait (C)

Ice moves from the Arctic Ocean into the Atlantic through Fram Strait. Until 2007, the ice was thick and rugged. Since then, the ice has been thin and much flatter.



Ice extent: Whole Arctic (B)

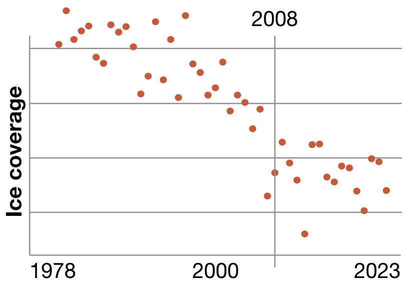
Ice extent in summer

- 42% decrease in ice extent
- Decrease occurred mostly before 2008

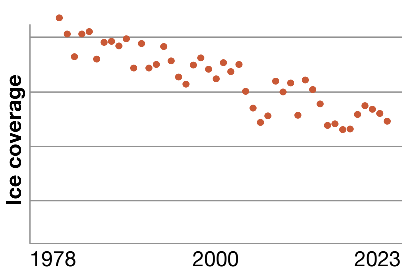
Ice extent in winter

- 10% decrease in ice extent
- Decrease has remained steady over time

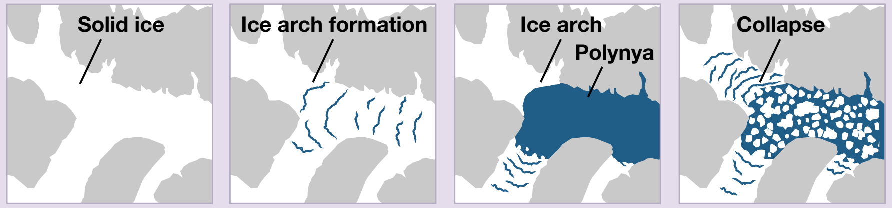
Summer ice extent



Winter ice extent



Ice structure: Arches (D)



- An ice arch is a structure that blocks mobile sea ice. This allows an area with open water (a polynya) to form beside the arch. Polynyas are important open-water habitats in otherwise ice-covered areas.
- In a polynya, phytoplankton can bloom earlier in spring, fish can gather, and marine mammals and seabirds can find food.

Forming later, collapsing earlier: 1979–2022

Lancaster ice arch: lasts on average 1.5 months less

North Water ice arch: lasts on average 3 months less. Ice arch failed to form for the first time in 2007 and then again in 2009, 2010, 2017, and 2019.

SPOTLIGHT

Types of sea ice

Seasonal ice
Sea ice that starts to grow and is completely melted or floats out of the Arctic within a year.

Multi-year ice
Sea ice that forms and lasts more than one summer.

Landfast ice
Ice near coastlines or islands that remains in place despite winds or ocean currents. This ice does not drift.

Pack ice
Drifting sea ice that becomes a chaotic landscape of ridges and floes that vary widely in thickness over winter.

In the Northern Hemisphere as a whole, sea ice extent has declined in all seasons, and the open-water period has increased in areas that have ice cover only in winter **(Figure 3: Sea ice changes)**. Summertime ice volume has declined by as much as 82% between 1979 and 2023 for the Arctic as a whole. This major decline in ice volume reflects the significant loss of the thick multi-year sea ice **(Spotlight: Types of sea ice)**. This loss is not the same in every area of the Arctic. Canadian waters continue to harbour multi-year ice habitat. Over the last 10 summers, multi-year sea ice has declined by 7% in the northernmost area of the Canadian Arctic **(Figure 3: Sea ice changes)**. Gradual changes in sea ice can be seen. There are also years and decades that have rapid, strong decreases or increases.

Ocean areas are directly connected, yet unique areas are known. This includes the Beaufort Gyre which is a spinning, offshore ocean area that spans the deep Canada Basin in the western Canadian Arctic **(Figure 4: The Beaufort Gyre)**. The continental shelf is influenced by the Beaufort Gyre that connects to it. Studies since 2003 have tracked an accumulation of fresh water in the few hundred metres at the top of this gyre and an accumulation of heat in the sub-surface layer of water coming from the Pacific. This build-up happened over 26 years when the Beaufort Gyre spun counterclockwise more rapidly **(Figure 4: The Beaufort Gyre)**. The added weight of fresh water on top of the gyre pushes the lower Pacific layer of water up (an upwelling) and onto the shallower continental shelf of the western Canadian Arctic. This movement of saltier water toward shore was monitored for 30 years by mooring instruments near the seafloor on the continental shelf. Such a long data collection was needed to detect this change with certainty.

Dynamic ocean habitat is created by variability and change in both offshore and coastal waters. Temperature and salinity are key factors controlling the structure and suitability of ocean habitat for life. The small amounts of change measured in seawater of the western and eastern Canadian Arctic **(Figure 5: Canadian Arctic inflow and outflow)** is different from the larger changes observed over the same years in the Bering and Barents Seas. These other Arctic seas are receiving warmer waters from their neighbouring oceans.

Left: Multi-year-ice in Tuvaijuittuq. Photo: Pierre Coupel. Right: Walrus near Baffin Island. Photo: Mark Williams.

The Beaufort Gyre: collecting heat and fresh water in the ocean

FIGURE 4

The Beaufort Gyre is a large ocean area where the surface water spins in a circle

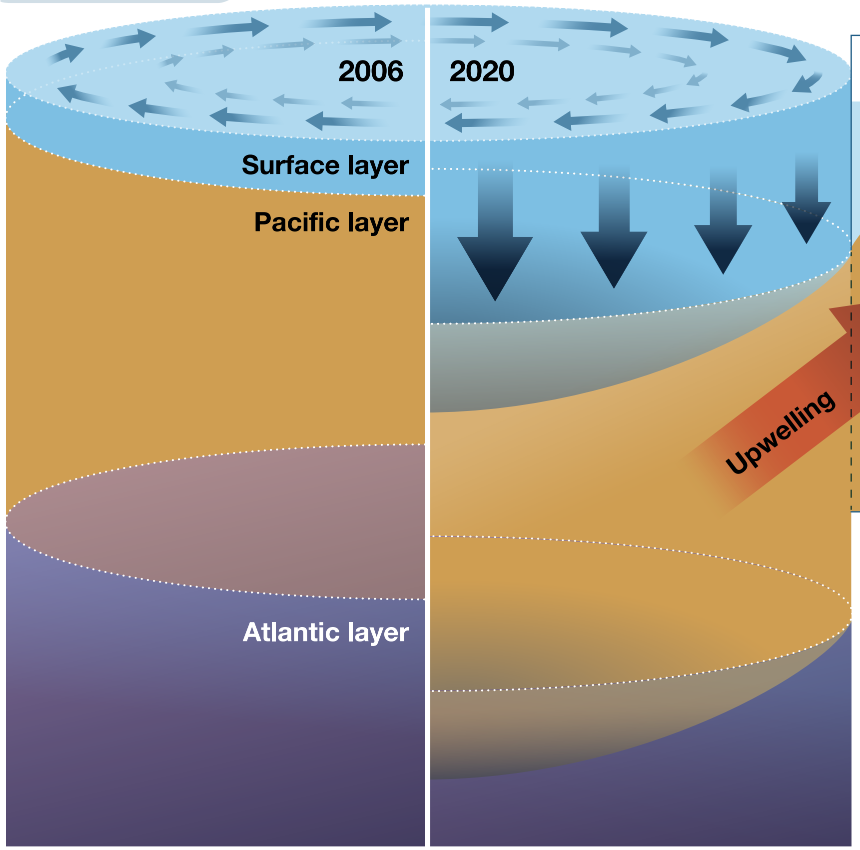
The Beaufort Gyre spins clockwise or counter-clockwise depending on wind patterns.

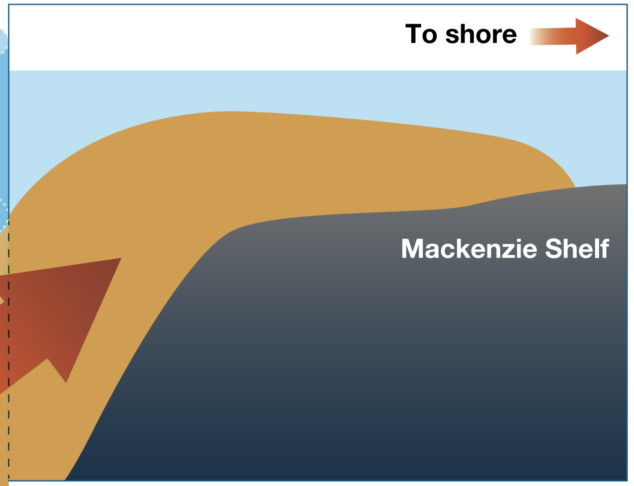
A faster clockwise spin causes fresh water from ice melt and rivers to accumulate near the surface of the Gyre, pushing the Pacific layer deeper.

Fresh water in the Gyre increased by about 50% from 2003 to 2008.

In the past, the spinning switched direction every 5–10 years. Winds have caused it to spin clockwise on average now since 1997.

If the spinning reverses direction, the accumulated fresh surface water will flow through Canadian Arctic waters to the Atlantic Ocean.

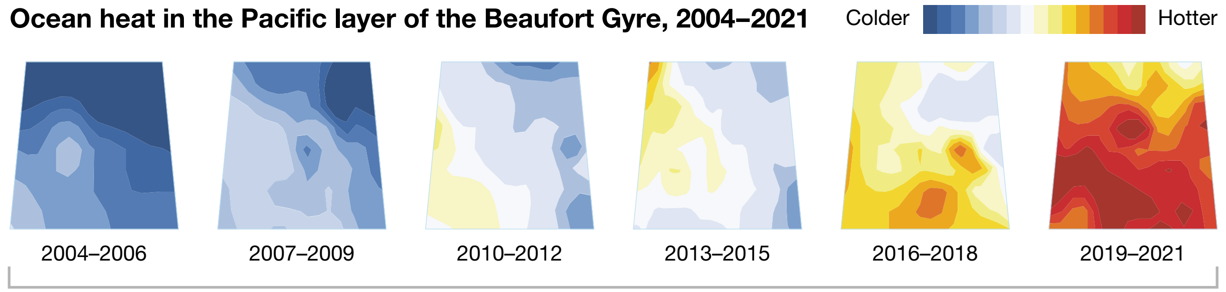




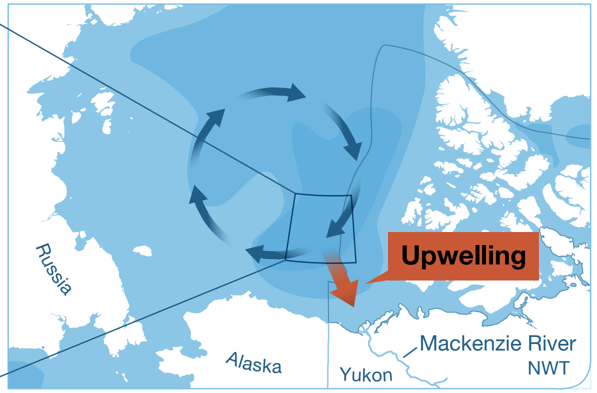
The extra surface waters forced the Pacific-layer waters out and up onto the neighbouring Mackenzie Shelf. This pushing of nutrient-rich waters toward the surface is called upwelling.

Upwelling measured on the Mackenzie Shelf (red arrow, below), hundreds of kilometres from the centre of the Gyre, has doubled over the last 25 years.

Ocean heat in the Pacific layer of the Beaufort Gyre, 2004–2021



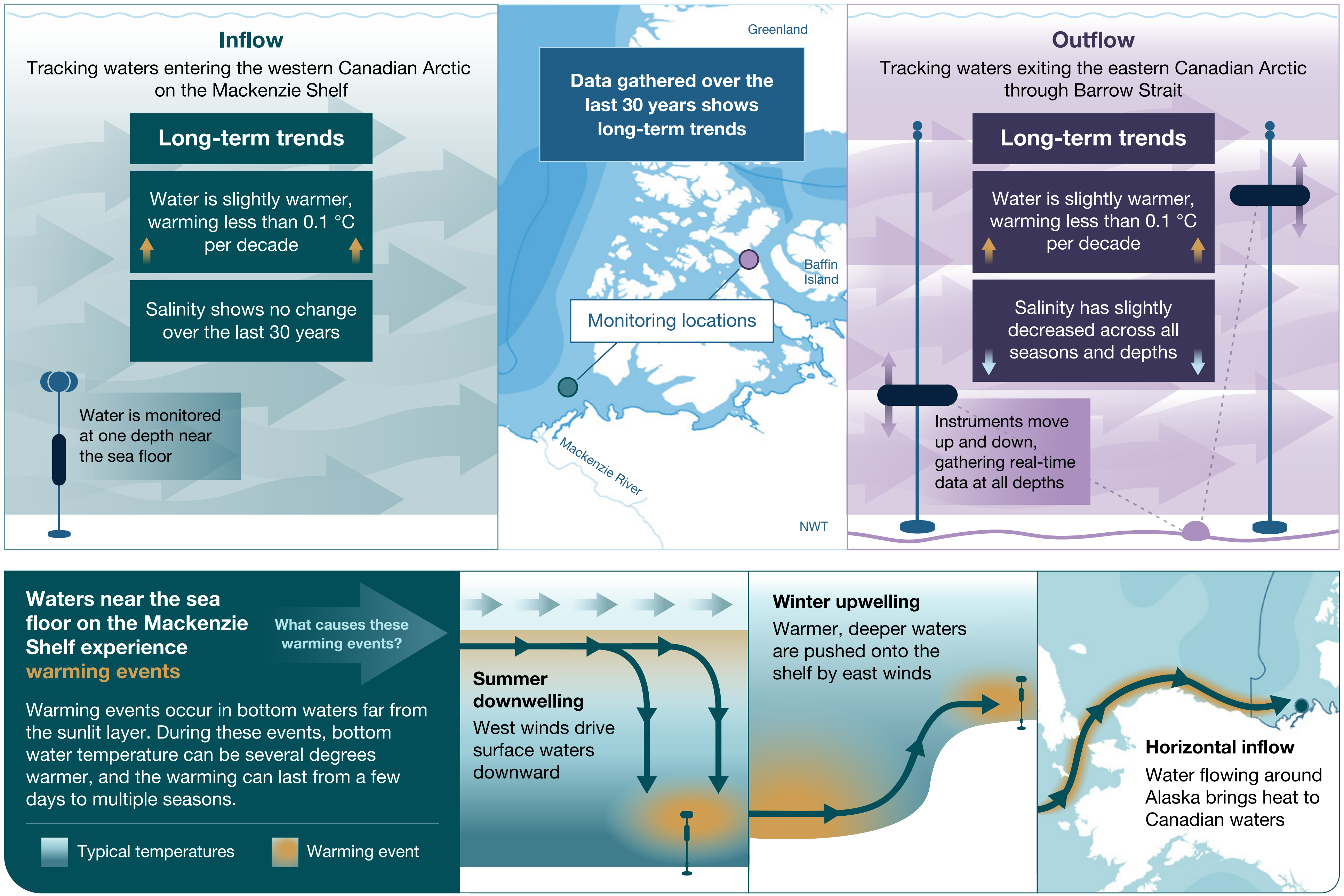
Since 2004, the average heat in the Pacific layer of the Gyre has increased from 250 to 850 million joules per square metre.



Canadian Arctic inflow and outflow: gathering data over time

FIGURE 5

We need data that is gathered consistently over a long period (20 years or more) to confidently identify change in ocean water



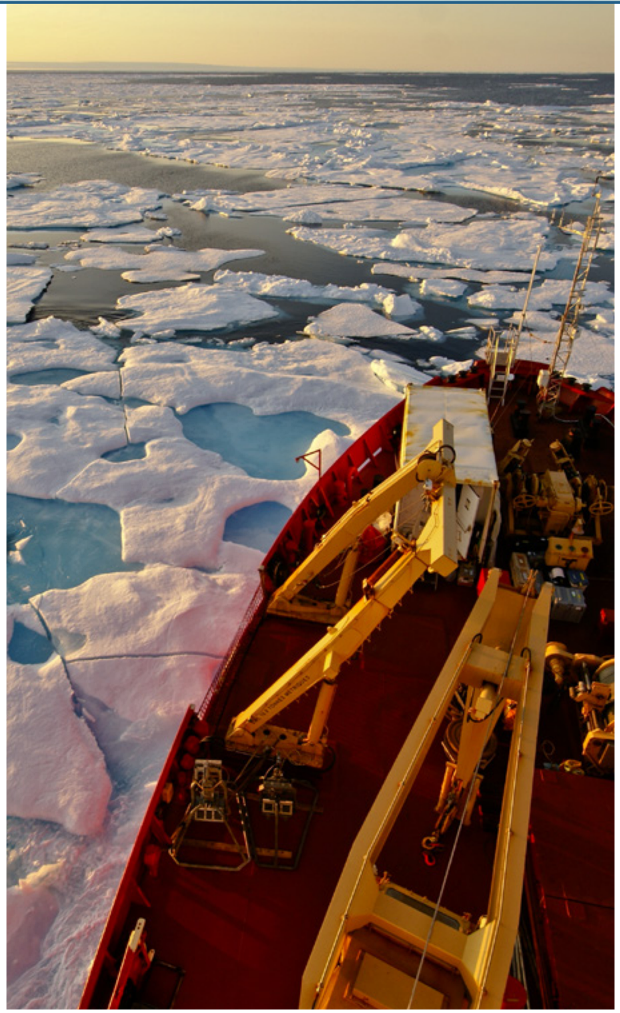
Updating expectations

New research shows there are some inconsistent and unexpected ways that marine ecosystems respond to natural variability or climate change.

New information has shown complex and sometimes unexpected responses of marine ecosystems to ocean variability or climate change. Unexpected ocean dynamics and species distribution are identified over time and across southern to northern locations.

Benefits from sea ice loss?

Shipping through Canada's Northwest Passage was expected to be easier with sea ice loss. However, comparing 1968–2006 and 2007–2020 showed that even with less multi-year ice (presence and growth) in the Northwest Passage, it will continue to be a shipping hazard for the foreseeable future. Expanded habitat for kelp and seagrass was also expected because of ice loss and other climate-related environmental changes, but expanded habitat has not yet been detected at the few Canadian sites with at least 10 years of data. Recent surveys of James Bay eelgrass affected by hydroelectric development and extremely warm 1990s conditions show ongoing loss. This also contradicts the current climate-related expansion of eelgrass habitat in other parts of the Arctic. In Canada, some potential opportunities from sea ice loss and Arctic warming are not necessarily quick or guaranteed.



Left: Eelgrass in James Bay. Photo: Alessia Guzzi. Right: Canadian Coast Guard Ship (CCGS) Amundsen, Beaufort Sea, Canada. Photo: Martin Fortier, ArcticNet.

Ringed seal on sea ice. Photo: Mark Williams.

Neighbours but different

Even in adjacent areas, we see changes that are not necessarily the same. Changes in zooplankton biodiversity have been documented in the Pacific and Atlantic Oceans. However, despite a strong connection to those waters, such changes have not been detected in the Canadian Arctic. The North Water and Lancaster Sound ice arches (Figure 3: Sea ice changes) are only a few hundred kilometers apart in the eastern Arctic. These ice arches are critical for polynya formation (Spotlight: Polynyas). The number of days each year that the arches were stable stayed similar for 20 years, and then in 2001–2022 their instability patterns changed. They are not responding the same way to forces from the atmosphere or ocean.

SPOTLIGHT

Polynyas

Polynyas are areas of thin ice or open water during the ice-covered period. Polynyas are productive habitats threatened by warming that alters sea ice, surface heat, and the amount of fresh water entering the Arctic Ocean. Changes in sea-ice movement revealed new, short-lived polynyas in Tuvaijuittuq (the Last Ice Area). The instability of expected polynyas such as Sarvarjuaq (the North Water) is increasing. Polynyas are at risk of being lost or seriously altered.

Large-scale comparisons

At a larger scale, trends across oceans and across the Canadian Arctic have not matched predictions. A recent study of seafloor biodiversity found that the Canadian Arctic Ocean has a higher diversity of seafloor invertebrates than Canadian Atlantic and Pacific waters do. This contradicts the widespread assumption that biodiversity declines the farther north one looks. Species important for the food web show some consistent trends in diversity and biomass, including zooplankton and Arctic cod. This consistency is unexpected in many marine ecosystems, especially given ongoing climate change impacts. In offshore waters, the composition of zooplankton communities is consistent across the entire Canadian Arctic, including Hudson Bay. The communities are all dominated by energy-rich species of copepods. Recent ship-based measurements (hydroacoustics) in offshore habitats across the entire Canadian Arctic also indicate stable trends in Arctic cod biomass. However, variability from one year to the next shows that the timing of sea ice break-up can influence Arctic cod biomass, especially in Baffin Bay.

Other rare ocean conditions can be identified when the Canadian Arctic is compared to other Arctic regions or world oceans. This includes conditions related to ocean chemistry (Spotlight: Ocean acidification extremes) and the presence of old, thick sea ice in the Tuvaijuittuq Marine Protected Area north of Ellesmere Island. There is more old sea ice in that area than anywhere else in the entire Arctic (Figure 3: Sea ice changes).

No ocean warming trend was found in the Eastern Beaufort Sea, according to satellite data of summer sea-surface temperatures (2003–2019). That finding seems uncommon or counter-intuitive,

Spotlight Infographic

given that Arctic air temperatures are rapidly warming. Still, important change did occur. The surface waters warmed significantly earlier in the year, over the time studied. That affected the amount and timing of phytoplankton growth. This example demonstrates that assessing a single trend may not verify whether ecosystem change is happening or not. A trend may also go undetected because there is not enough data for many parts of the marine ecosystem.

Source or sink?—No one answer

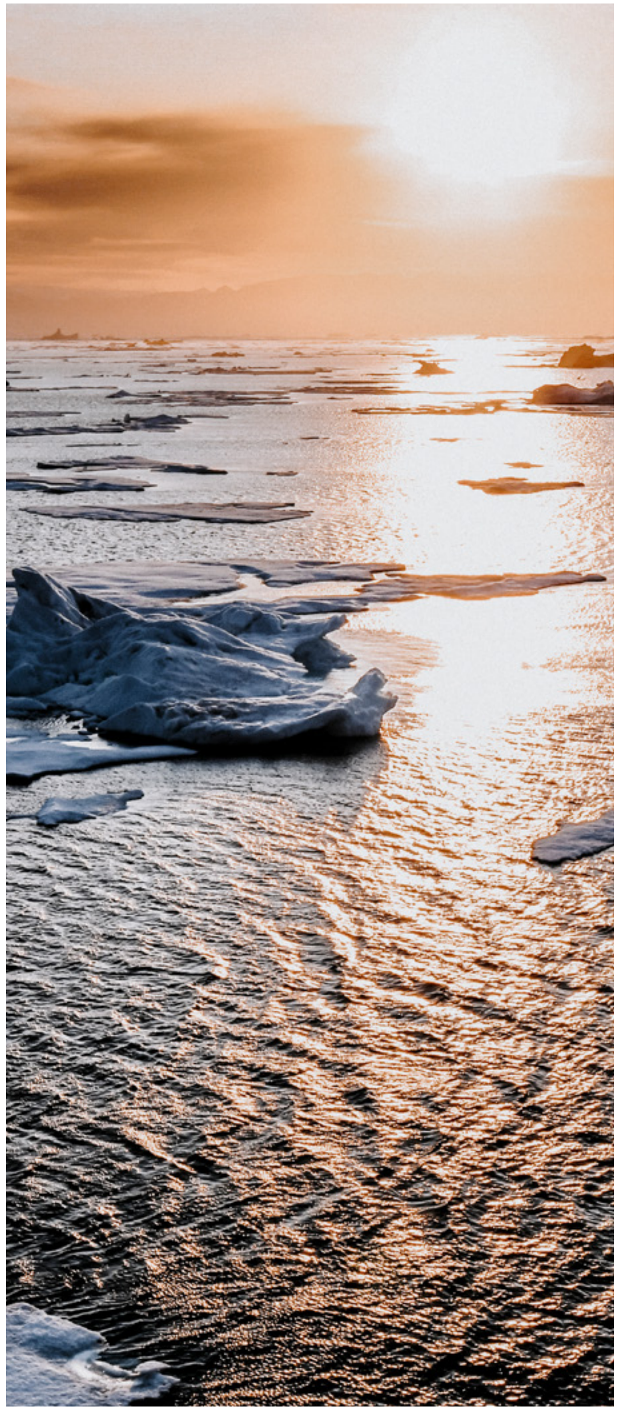
The issue of data availability is particularly important for understanding how oceans interact with carbon dioxide (CO_2) in the atmosphere. Oceans are critical for controlling CO_2 levels in the atmosphere to stabilize the climate. Is Canada's Arctic Ocean a CO_2 sink or a source of CO_2? If it is a sink, the CO_2 moves from the atmosphere into the ocean. If it is a source, the CO_2 is released from the ocean into the atmosphere. Improved data coverage reduced uncertainty in answering this question. The new data highlights how the answer depends on the season and on the physical structure of the ocean (Figure 6: Source or sink: CO_2 in Arctic waters).

SPOTLIGHT

Ocean acidification extremes

Ocean acidification is a condition where the ocean becomes more acidic. The atmosphere has increased CO_2 levels due to human activity. When that CO_2 dissolves in ocean water, it forms a weak acid. This harms the shells and skeletons of marine organisms and interferes with normal chemical reactions and processes. However, in certain regions, other processes influence the acidity of the ocean water.

Waters below 2000 m stay in Baffin Bay for a very long time — 360 to 690 years. The organic matter on the seafloor also stays and consumes oxygen when it breaks down, causing CO_2 to build up. This leads to extreme acidification in these deep waters. In contrast, a steady increase in acidification is not detected in the waters flowing out of the Arctic into western Baffin Bay and Davis Strait. That is a rare condition for offshore ocean waters. Fresh water from rivers, sea ice, glacier melt, and high Arctic coastal water enter Baffin Bay and Davis Strait. Fresh water input usually makes ocean acidification worse. In this region, it is the varying freshwater content in the seawater rather than rising CO_2 levels that controls the state of ocean acidification. The Baffin Bay waters emphasize how important it is to identify processes that contribute to extreme and uncommon acidification in the Canadian Arctic.

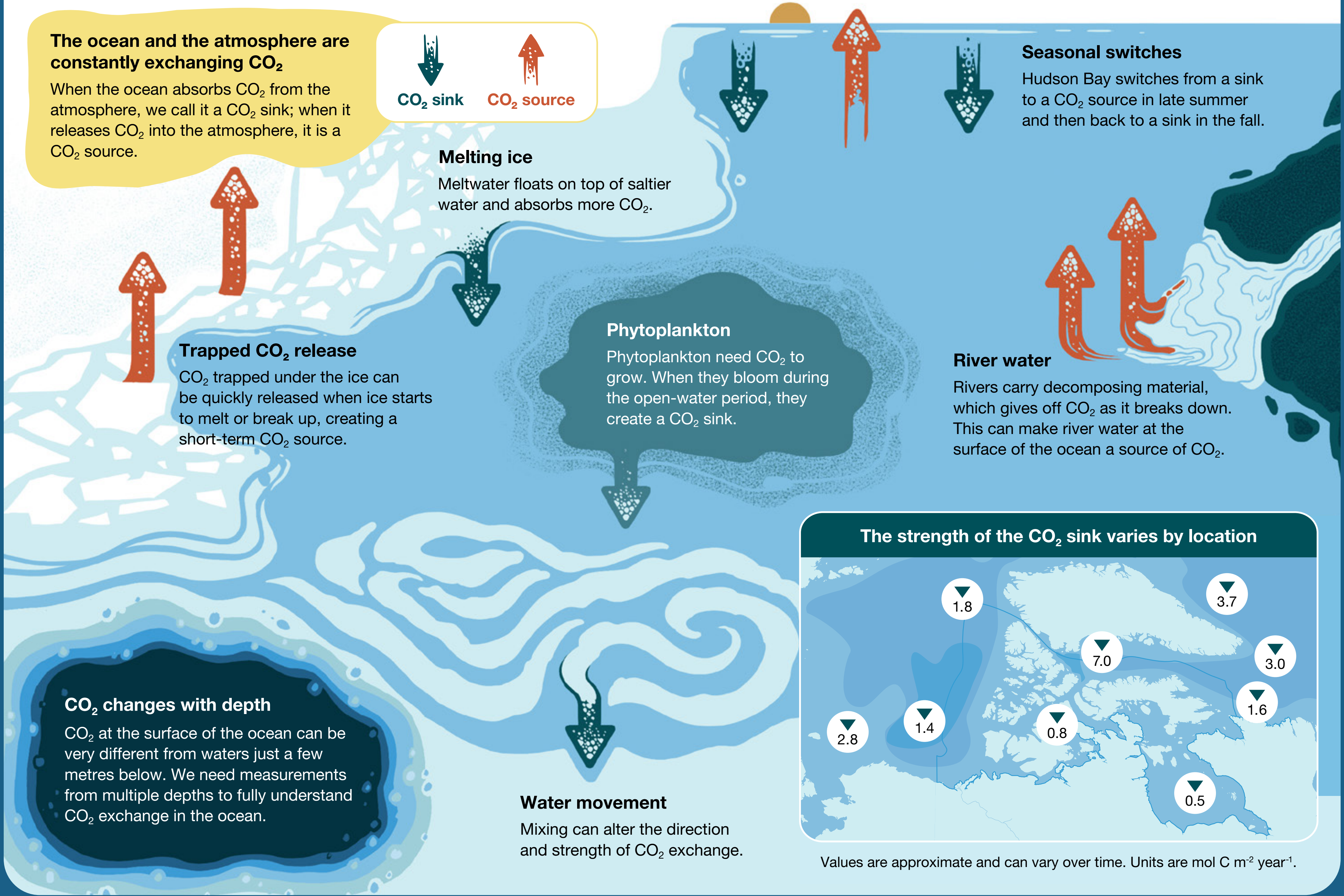


Coastal waters as sea ice breaks-up and melts. Photo: Getty Images.

Source or sink: CO_2 in Arctic waters

FIGURE 6

Limited data shows that Canadian Arctic waters are a sink for CO_2 — but not all the time. We need more information to understand the full picture.



Values are approximate and can vary over time. Units are mol C m^{-2} $year^{-1}$.

How species respond

New studies have led to a better understanding of how ocean habitat varies over seasons and years, and how that makes opportunities or challenges for some species.

Marine life is intimately connected to yearly cycles of habitat change including ice cover and open water, darkness and light, warming and cooling, and pulses of production that fuel the food webs. Long natural cycles (e.g., 10 years) and climate change can alter the

1. sea ice and ocean layer habitat,
2. chemistry and energy sources (nutrients) of the habitat, and
3. timing and connections between ocean and atmospheric processes, and between freshwater and marine habitats.

Habitat variability and change can influence the distribution of resources for species, when and how many offspring they have, how they feed and hunt, and where they go. Recent research showed that some species might adapt to habitat changes, at least in the short term.

Warming: ice and river habitat change

Algae growing on the bottom of sea ice is an important early food source. Many zooplankton, small invertebrates and fish can eat the ice algae as it grows. When the snow and ice melt, the algae released from the ice can be quickly eaten by grazers in the water and by invertebrates on the seafloor. With changing sea-ice habitat, the availability of ice algae will also change. Zooplankton and seafloor invertebrates do eat a variety of things, but it is not known how having less access to ice algae will affect the quality or diversity of seafloor invertebrates.

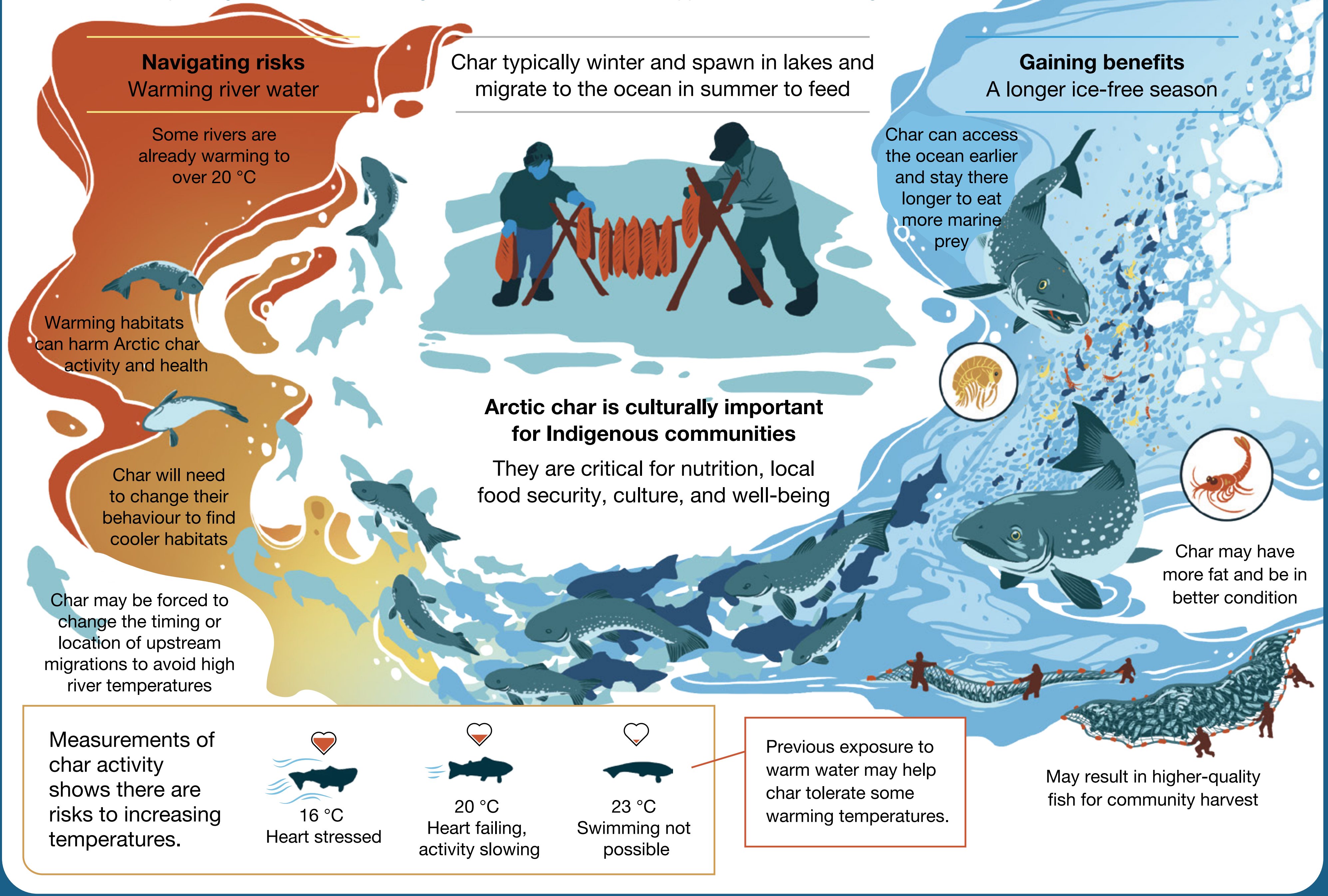
It is also hard to predict how habitat change caused by warming will affect culturally important species such as Arctic char **(Spotlight: Arctic char, did you know?)**. Different responses could be seen among individuals and whole populations as their environment changes in multiple ways **(Figure 7: Responses of Arctic Char to habitat change)**. Sea ice change will continue to affect all marine habitats and links between food webs. Warming will also impact the suitability of habitat for species and overall biodiversity.

Sea ice collected near Iqaluit, Nunavut, showing the growth of ice algae. Photo: Usaaraq Jari Aariak, DFO.

Responses of Arctic Char to habitat change

FIGURE 7

Arctic char are responding to more than one change in their habitat. This creates opportunities and challenges.



SPOTLIGHT

Arctic char, did you know?

Arctic char are the only freshwater fish species found north of approximately 75°N latitude. That's north of Ellesmere Island!

Every community with access to Arctic char uses it for food.

The Canadian Arctic supports commercial and emerging Arctic char fisheries that employ Inuit.

Being a cold-adapted species could make Arctic char extra vulnerable to climate changes.

Top: Dolly Varden Char. Photo: Colin Gallagher. Bottom: Beluga in Igluligaarjuk (Chesterfield Inlet), Somerset Island, Nunavut, Canada. Photo: Getty Images.

Responses: Genetics and mobility matters

Low genetic diversity within a species can make that species less able to adapt to habitat change, especially if they cannot move to a different location. For example, eelgrass in James Bay has less genetic variability than eelgrass in the Canadian Pacific and Atlantic sub-Arctic. With low genetic diversity, the James Bay eelgrass has limited potential to adapt to habitat changes linked with warming, earlier ice break-up, and increased freshwater input.

In contrast, mobile species have more options to cope with habitat change. Some populations of beluga and bowhead whales have adjusted the way they dive to reach prey. Dive behaviour also changes in response to location within their range, time of year, and the amount of sea ice around them (**Figure 8: Diving in: learning about marine mammal habitat use**). Narwhal, once thought to be less flexible than other whales when migrating, have now been observed to delay their fall migration south because there is less sea ice in their habitat. In Hudson Bay, a colony of thick-billed murres shifted its habitat range to areas with less ice cover. These new areas still had cold enough waters for their prey that prefer ice-covered habitat. Flexibility in habitat use, especially in seasons when they need fatty food, can help marine predators cope with the impacts of climate change in the Arctic.

Large-scale changes to migratory patterns have not been seen in the Canadian Arctic, though marine mammals and seabirds have made local adjustments in response to habitat change. However, the presence of killer whale and sperm whales is increasing in the eastern Canadian Arctic. The whales can travel farther and stay in new areas because of sea ice loss and the longer open-water period.

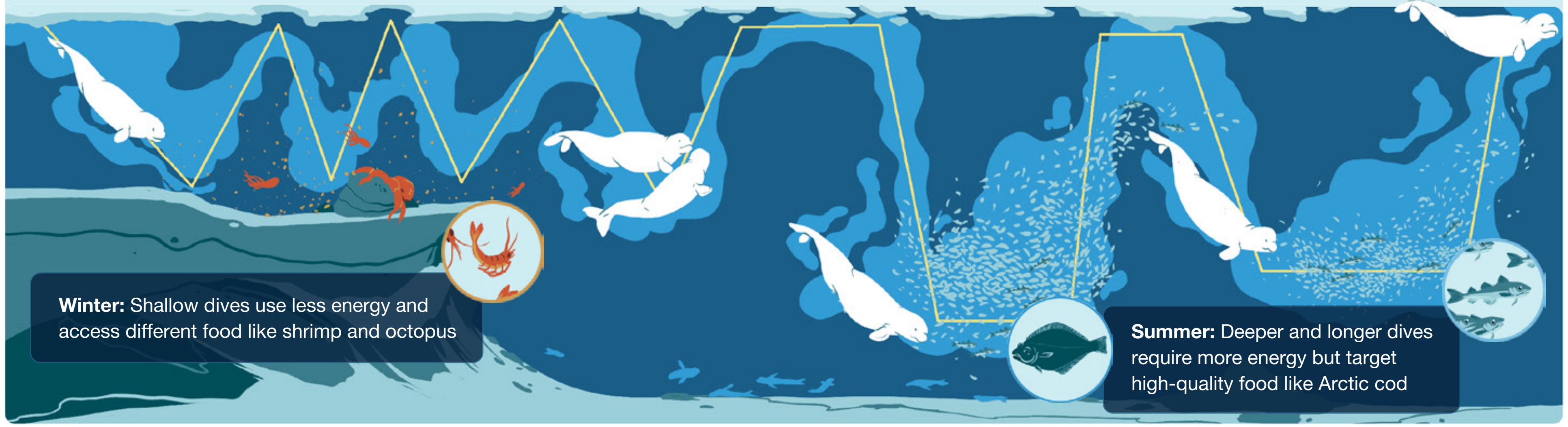
Diving in: learning about marine mammal habitat use

FIGURE 8

Beluga and bowhead whales change their movements in response to different habitat conditions. They use different dive patterns to search for different types of food. This flexibility means they can respond to changes in their habitats and the types of food that are available.

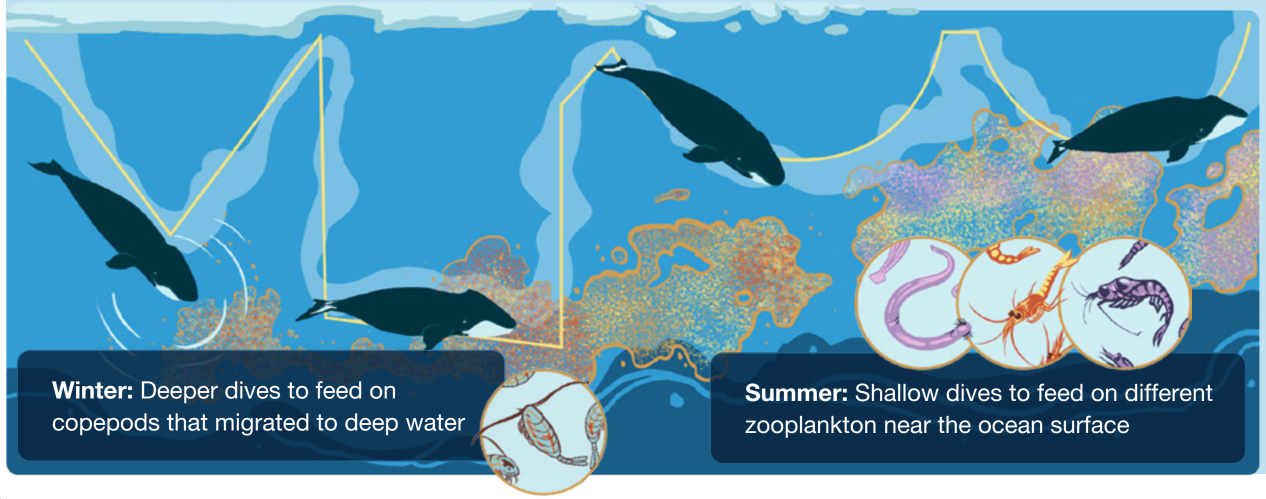
Beluga (Eastern Beaufort Sea population)

Belugas dive to feed, rest, move from place to place, and navigate through sea ice. They use many different patterns of dives depending on what they are doing.

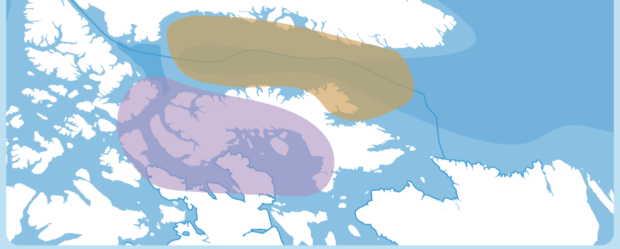


Bowhead (Eastern Canada–West Greenland population)

Bowhead whales dive mostly to feed. They use V-shaped dives to search for food.
They use either deep, square dives or shallow, U-shaped dives to target their prey and eat.



Bowhead whales change their dives to adapt to different habitats and locations



Canadian Arctic Archipelago

- Move long distances
- Use shallower dives
- Make more dives in summer and fall
- Feed on a mixture of zooplankton

West Baffin Bay

- Stay near one area
- Use deeper dives
- Make the same number of dives in all seasons
- Feed mostly on fat-rich copepods

Species stability and habitat use

There is improved knowledge about where species live, which habitats they prefer, and the diversity of species that live in Canada's Arctic waters.

New information actively describes the locations of species at different times and spatial scales. As we zoom into the Canadian Arctic, we consider three scales:

1. **Arctic-wide** — can include connections between the Arctic and other oceans
2. **Coastal** — such as shoreline waters shallower than 20 m
3. **Small** — such as a metre of water within a phytoplankton bloom

Evaluations of different species show how they might affect their environments and how stable these species are.

Arctic-wide scale

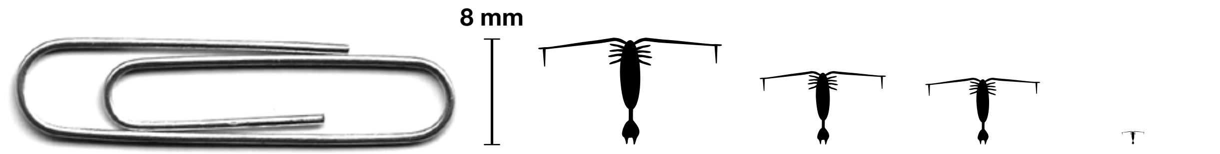
Studies spanning the entire Canadian Arctic have updated the knowledge of species distribution and diversity. For example, at over 400 stations across the Canadian Arctic, fatty zooplankton *Calanus hyperboreous* were found at 93% of the stations and *Calanus glacialis* were at 100%. Other smaller copepods (e.g., *Oithonia similis*) were also present at 93–100% of the stations (Figure 9: Relative size of some Arctic copepods). This means that important prey for marine fishes and bow-head whales are currently accessible throughout Canadian Arctic waters.

At this Arctic-wide scale, the diversity of invertebrates living on and in the seafloor has also been re-evaluated. A recent study found 1552 different types (taxa) of invertebrates, which is 560 taxa more than found before. Yet, this new assessment probably still underestimates seafloor biodiversity. Much is being learned about marine mammal, fish, and bird distributions during their seasonal movements.

Sun star, squid, and sea urchin collected from the seafloor of the western Canadian Arctic. Photos: Caity Allison, DFO.

For marine mammals, water depth plays a key role in where whales gather and how they use habitats to feed (Figure 8: Diving in: learning about marine mammal habitat use). The migration of marine birds can be measured over long distances with satellite tracking, lightweight geolocators, and small GPS devices. New tracking of marine birds identified long-distance connections to Antarctica (Arctic terns), Indian Ocean (long-tailed jaegers), Sea of Okhotsk (glaucous gulls), Gulf of Mexico (herring gulls), and multiple locations in the Pacific and Atlantic Oceans. Understanding these long-distance connections is necessary to examine potential effects of large-scale environmental changes and human influences on both Arctic breeding grounds and more southern wintering grounds.

Relative size of some Arctic copepods FIGURE 9



Coastal scale

In coastal areas, Indigenous Knowledge and community-led monitoring provides understanding of past and current species diversity and changes in marine mammal and fish distributions and health. In recent years, Arctic communities reported unusual species sightings. These sightings could show a gradual shift in a species' range, a rare species, or a species arriving because of a drastic shift in the ocean environment (Figure 10: Community observations: tracking coastal biodiversity).

Applying multiple ways of knowing enhances the understanding of unusual sightings and unexpected events. Indigenous Knowledge of past and current species provides insights into which occurrences are rare and unusual, versus those that are actually new. Community-led observations provide a better understanding of sperm whale sightings in Eclipse Sound since 2014 and bowhead overwintering in new areas. The sperm whale and bowhead sightings are linked to sea-ice change observed by the communities.

In coastal areas, the habitat preferred by Arctic char and similar species (e.g., Dolly Varden) is tightly linked to water temperatures and salinities levels that best support physical performance (e.g., activity and digestion) and their prey.

New information indicates that individual Arctic char can migrate within ice-covered rivers and to marine waters in winter. Fish from the Coppermine River moved up to 18 km offshore under the sea ice (Kitikmeot region of Nunavut) where some of the lowest Arctic char body temperatures were recorded. This previously undocumented winter movement shows that rivers can be important connections between freshwater and marine ecosystems year-round, not just after ice melt.

Left: Frank Dillon holding a chum salmon at the Big Fish River (Yukon). Photo: Colin Gallagher, DFO. Right: Bowhead whale. Photo: Justine Hudson.

Small scale

At very small scales, hi-resolution underwater video (Spotlight: Marine snow) revealed how and when individual phytoplankton cells begin sticking together into groups that then sink. This video technology showed that copepod zooplankton follow those groups, feeding on them rather than individual cells that stayed closer to the surface. This detailed description of species interactions helps to understand how and when energy is transferred at the base of the marine food web.

Impacts and stability

Some new knowledge about species suggest they could impact their ecosystem. Harmful algal blooms that led to toxins in seafloor invertebrates (i.e., amnesic and paralytic shellfish toxins) were found in the western Canadian Arctic. The toxin levels were very low, and those invertebrates are not harvested by local communities. It is not yet known if harmful algal blooms are becoming more common in the Canadian Arctic.

Communities keep monitoring salmon in the Canadian Arctic. The first capture of a juvenile chum salmon near the Canada/USA border (Kaktovik, Alaska) confirms spawning in the North American Arctic. Consequences and possible opportunities of more salmon in Arctic rivers remain uncertain for other fish and the people that depend on them.

SPOTLIGHT

Redfish resurgence

Greenland halibut and two shrimp species (northern and striped shrimp) are commercially fished in the Canadian Arctic. Since 2020, commercial catches of shrimp in Davis Strait included bycatch of many juvenile redfish. Fishing gear was changed to reduce this bycatch but separating the juvenile redfish and shrimp is difficult because they are similar in size.

It is not known why some years have very high numbers of redfish in Davis Strait. When this happens, redfish feed on food that shrimp, Arctic cod and other species also use. Redfish can also eat commercial shrimp species. The competition and predation caused by the redfish impacts the entire food web — all the way up to whales and birds. The resurgence of redfish could also negatively affect the shrimp and Greenland halibut fisheries.

Striped shrimp. Photo: Claude Nozères, DFO.

There is not enough long-term population data to scientifically rank the conservation status of most marine species in Canada's Arctic. Two species of marine birds are critically imperiled: the black guillemot and ivory gull. For marine mammals, the most recent inventory was for Eastern Beaufort Sea beluga whales, which found a stable population of 38 000. Marine mammal population counts generally happen every 5 years, or longer, for a specific population. But every year, commercial fish and shrimp stocks are monitored in Baffin Bay, Davis Strait and eastern Hudson Strait. Those show healthy populations of Greenland halibut and northern and striped shrimps, although the increase in juvenile redfish (Spotlight: Redfish resurgence) could threaten shrimp by eating them and competing for food.

SPOTLIGHT

Marine snow

Hi-resolution underwater images show the seasonal evolution and export of particles that form during and after phytoplankton blooms in Baffin Bay. Phytoplankton cells and debris from the decomposing algae stick together into particles. These particles falling down through the water look like snow. The new hi-resolution images show that the number and shape of particles change over time — from ice cover in winter to ice break-up in spring and open water in summer. This can explain why zooplankton move to use different parts of their habitat as they access resources in the marine snow.

Community observations: tracking coastal biodiversity

FIGURE 10

Indigenous Knowledge over generations provides insights to determine if a species is new to an area, or just rare and not yet documented.

Arctic communities report unusual sightings of species far from the areas where they are usually seen. Community harvests are important for documenting these species.

Photo: Matt Gilbert.

Community monitoring is tracking the expansion of salmon in the Canadian Arctic. More species of salmon are found in their harvest (pink salmon shown here).

Photo: Pakak Picco.

Communities across Inuit Nunangat use social media to connect knowledge by sharing observations.

Photo: Usaaraq Jari Aariak.

Rare events like salmon sharks outside their usual habitat suggest temporary changes to connections between ocean regions.

Photo: Warren Metcalf/Shutterstock.

Known distribution for each species   Location of sighting

Spotlight   Infographic

Understanding how ecosystems work

There is now a deeper scientific understanding of how ecosystems work and what can influence the activity and survival of some marine species.

Understanding the many steps that cause change in the ocean is essential for ecosystem management. In recent years, interactions between species and the environment were investigated across food webs and regions. This led to better descriptions of expected responses to change.

Coastal view near Qikiqtarjuaq, Nunavut. Photo: Getty Images

Ecosystem controller: The Sun

The Sun and sea ice play a major role in controlling Arctic marine food webs. At some locations, the amount of daylight changes from none to all day during an Arctic year **(Figure 11: Where can you find the midnight sun?)**. The food web's response to the return of the Sun is fast. The transfer of sunlight through sea ice and into the ocean controls where and when ice algae and phytoplankton grow. Their growth provides the energy that supports most of the food web. Snow that falls on the ice can block the transfer of sunlight needed to start growth after the dark winter. New research from Baffin Bay shows that 100 times more light can pass through the ice in just two weeks once the snow begins to melt.

The ocean surface habitat quickly comes to life under the remaining snow and ice. But if enough new snow falls, sunlight is blocked and the new growth stops suddenly. With enough sunlight, the phytoplankton population quickly grows, providing food for zooplankton.

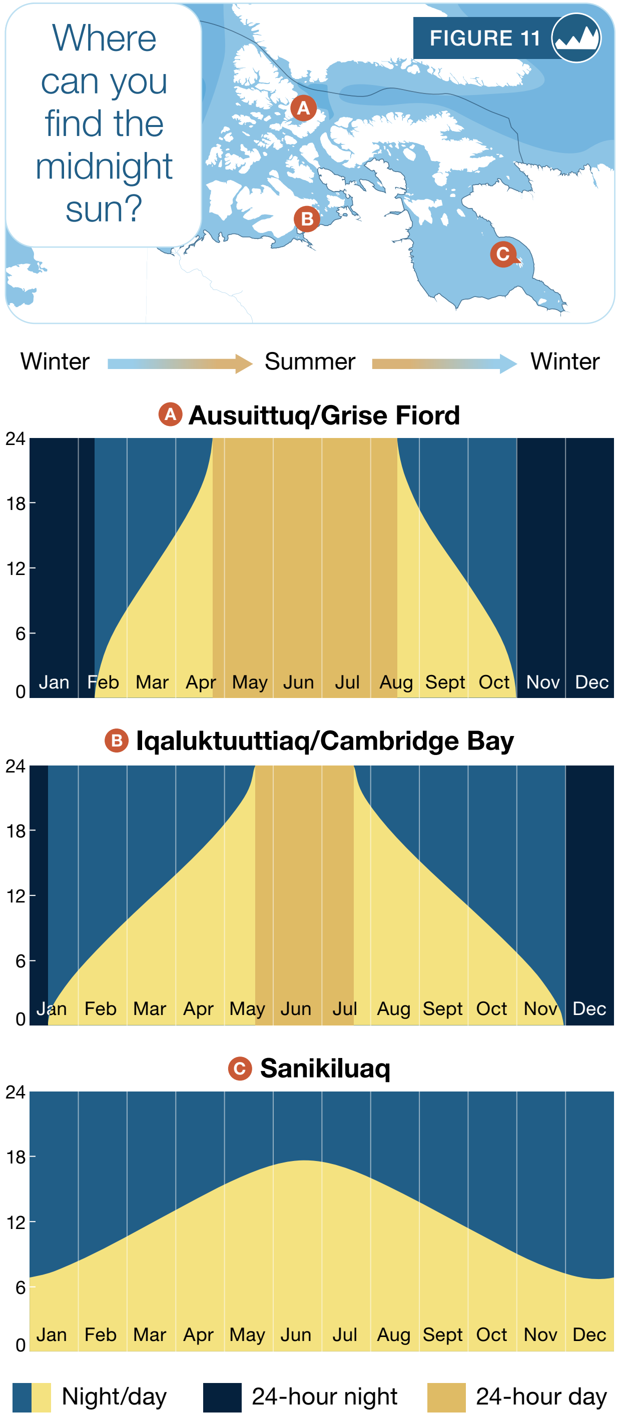
Cycles of sunlight cause many Arctic zooplankton and fish to migrate up and down in the water column each day to avoid being seen by predators. They transfer food web energy with them as they move vertically. New research from the western Canadian Arctic showed that part of beluga migration is linked to cycles of sunlight. In the fall when the Sun once again sets in the evening, beluga show distinct sun-related movements in water deeper than 700 m: shallower dives when darker and deeper dives in bright daylight.

Zooplankton from the Canadian Arctic: copepods and arrow worms. Photo: Alexis Burt.

Ecosystem controller: Sea ice

What happens to marine ecosystems when the clearance of sea ice is early? Considering responses to an earlier clearance of sea ice is necessary to understand more about how sea ice controls ecosystems. This change creates a longer open-water period. Across the Arctic, earlier ice clearance was expected to increase production at the base of the food web and benefit all. But that increase at the base has not yet been clearly documented in the Canadian Arctic. Ice clearance that is too early could limit benefits, research shows. It now looks like ice break-up before June raises the chance that zooplankton larvae will miss the best time to feed **(Figure 12: Ups and downs of cod and copepods)**. Consequently, less larvae develop into adults, and adult growth is low. This then reduces food for larval Arctic cod, limiting their development into adults. Ice-driven changes in the timing of food for zooplankton is not the only reason for a mismatch. Available food may not be healthy for the larvae. This occurred recently in Baffin Bay where the phytoplankton (*Pseudo-nitzschia*) appeared to release a toxin (neurotoxin domoic acid) that stopped the copepods from feeding, despite the good timing of the bloom **(Figure 12: Ups and downs of cod and copepods)**.

Sea ice is changing across the Canadian Arctic **(Figure 3: Sea ice changes)**, yet responses from one species can vary in different locations. In both Baffin Bay and the Beaufort Sea, the survival of larval Arctic cod into adulthood is affected by sea-ice concentration and water temperatures. In Baffin Bay, the timing of sea-ice break-up is strongly connected to the survival of Arctic cod larvae. The same strong connection is not found in the Beaufort Sea (western Canadian Arctic) even though the ice break-up has changed by a month or more **(Figure 12: Ups and downs of cod and copepods)**.



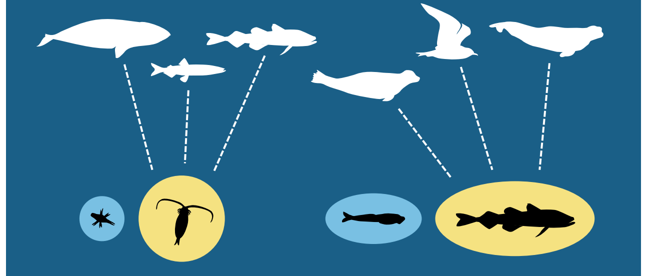
Ups and downs of cod and copepods

FIGURE 12

The survival of young copepods and Arctic cod depends on multiple conditions in their habitat. Survival to adulthood is highly variable between years.

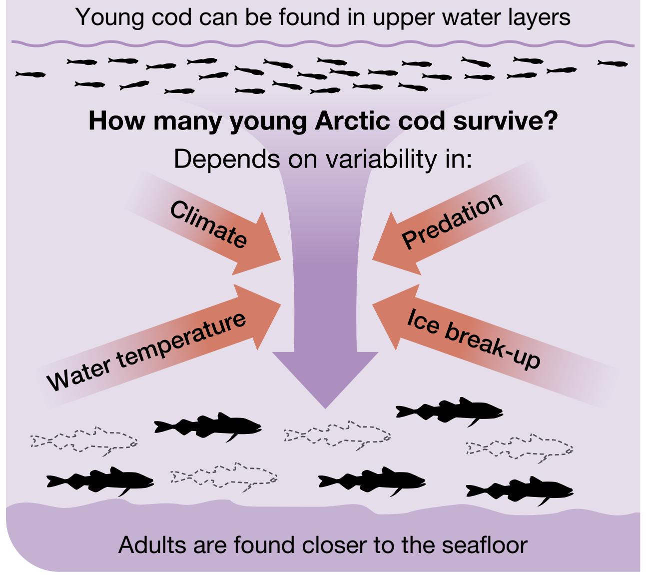
Arctic cod and copepods are called **forage species**.

They are important food for many fish, marine mammals, and birds



Larger, more nutritious adults — not younger life stages — are preferred by large predators

It takes more than one year for an adult **Arctic cod** to develop from an egg.

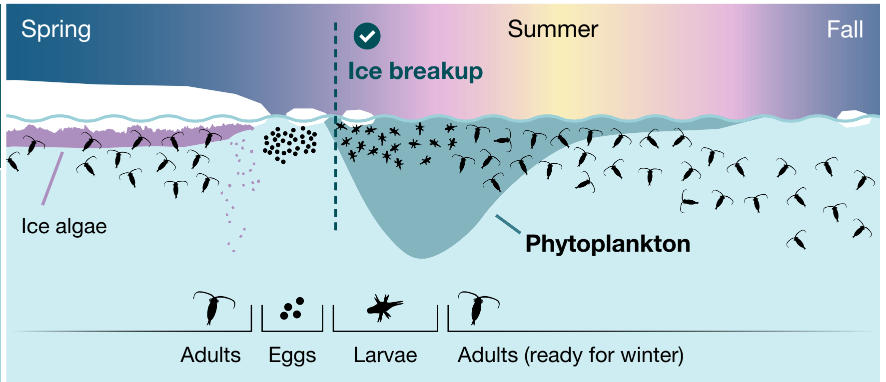


Copepods grow from eggs and have many young life stages that look different than adults. Some adult copepods migrate to deep water for winter.

Copepod larvae need the best access to food: the first part of a phytoplankton bloom.

Match

Larvae are developed enough to feed on the best part of the phytoplankton bloom.
More larvae grew into adults.

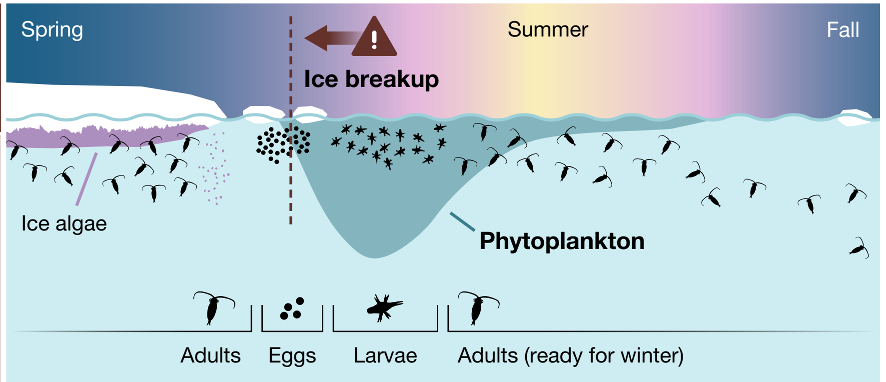


Pressure: Timing

Early ice break-up, earlier phytoplankton bloom.

Mismatch

In the Beaufort Sea, the larvae were not developed enough to benefit from the best part of the phytoplankton bloom.
Fewer larvae grew into adults.

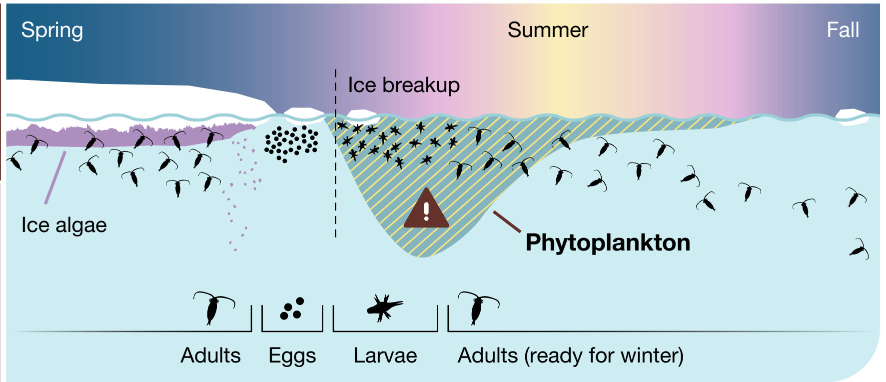


Pressure: Unfavourable food

Larvae are developed enough to use the bloom—the timing is right. However, the phytoplankton species are not beneficial.

Mismatch

In Baffin Bay, a bloom of diatom phytoplankton potentially released toxins and were not eaten by the copepods.
Fewer larvae grew into adults.



Ecosystem controller: Nutrients

Nutrients (e.g., inorganic nitrogen, phosphorus, silica) provide the fuel for the base of the food web. How nutrients are distributed across the Canadian Arctic was recently studied, updating key understanding about nutrient supply. For example, it is now understood that waters originating from the Atlantic Ocean supply up to 25% of the nutrients to the Canadian Arctic Archipelago. The previous estimate was only 5%. In coastal areas, glacial meltwater brings nutrients to the northeastern Canadian Arctic in two ways: it directly supplies micronutrients such as iron and manganese, and its cold, dense meltwater sinks, pushing up water from the deep with nutrients that phytoplankton use **(Figure 13: From the land: nutrients and carbon entering the ocean)**.

Organic carbon in the water is also a key marine nutrient. Two types of organic carbon are important for the food web. If this carbon is smaller than a speck of dust, it is called dissolved carbon. Microbes (e.g., bacteria) or pieces originally from a living organism represent the second type: particulate carbon. More is now understood about mechanisms controlling the supply of both carbon types from rivers, land and the ocean. Rivers can supply large amounts of organic carbon to coastal and marine food webs. Long-term trends (e.g., 1998–2019) from the Mackenzie River area show a significant increase in both types of carbon in late summer. This is likely explained by inputs from thawing permafrost **(Figure 13: From the land: nutrients and carbon entering the ocean)**. Consequently, thawing permafrost can be an important factor in understanding the transfer of carbon to the marine environment. The transferred carbon does not always stay in the dissolved or particle form, some of it is changed to CO_2. Slow-flowing permafrost debris has been found to release over three times more CO_2 to the atmosphere than the debris from a coastal cliff can when it suddenly collapses. The amount of CO_2 released by eroding permafrost depends on the type of erosion and how long debris stays close to shore.

Left: Coastline of Somerset Island, Nunavut. Photo: Mark Williams. Right: Arctic char habitat in the Yukon North slope. Photo: Colin Gallagher.

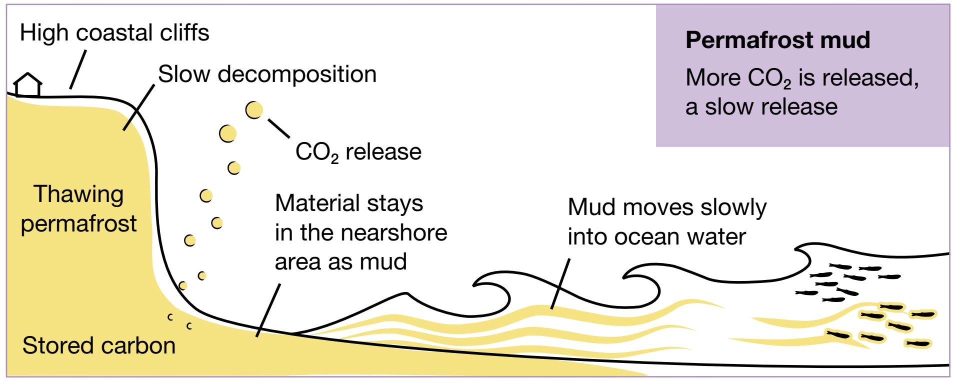
From the land: nutrients and carbon entering the ocean

FIGURE 13

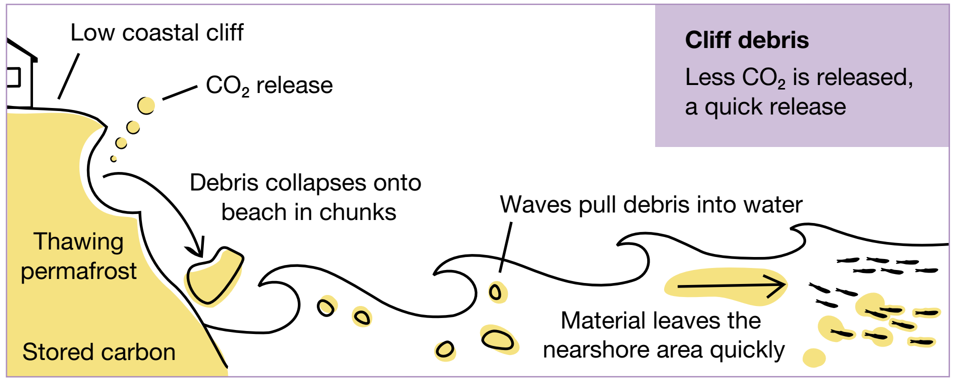
Melting glaciers and thawing permafrost both provide nutrients and carbon for the ocean. Their contributions influence food webs and CO_2 exchange in different ways.

Western Arctic: nearshore permafrost thaw

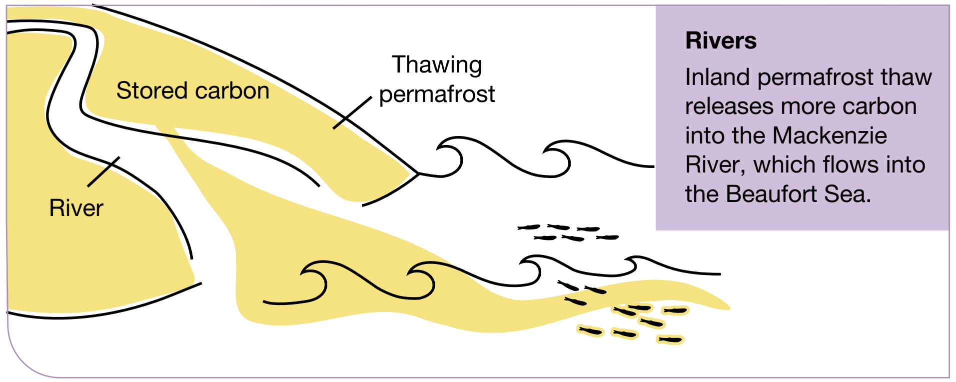
Permafrost thaw is increasing, bringing more carbon to ocean waters.



Permafrost mud
More CO_2 is released, a slow release



Cliff debris
Less CO_2 is released, a quick release



Rivers
Inland permafrost thaw releases more carbon into the Mackenzie River, which flows into the Beaufort Sea.

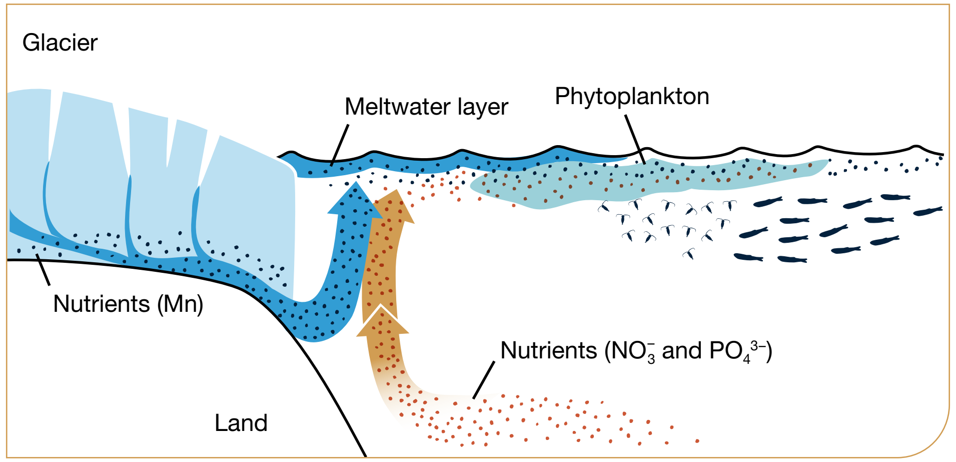
Eastern Arctic: glacier meltwater entering the ocean

Glacier melt entering the ocean below the surface supplies nutrients in direct and indirect ways.

Baffin Island, Nunavut. Photo: Malcolm Schuyl / Alamy.

Direct
Glacier melt carries micronutrients like manganese (Mn). These nutrients can be tracked far from the glacier itself.

Indirect
Glacier meltwater rises up, carrying ocean nutrients like nitrogen (NO_3^-) and phosphate (PO_4^{3-}) to the surface. Phytoplankton can use these nutrients.



Conclusion

Canada's Oceans Now: Arctic Ecosystems, 2023 shares major advancements in the understanding of how marine ecosystems function and their status in Canada's Arctic. New insights continue to highlight the importance of understanding physical environmental conditions and the base of the food web. This is needed to explain changes in species and how ecosystems function.

This report emphasizes that it is unwise to make general statements about a specific change or status indicator. To ensure proper understanding of an issue, the specific place and time that it relates to should be taken into consideration. There continue to be significant gaps in knowledge as information is not equally available for all locations and communities. However, our collective understanding is improving with the respectful inclusion of multiple ways of knowing and incorporation of different data collection methods and research from various disciplines. Collaborative programs continue to build new and better understandings of species and the ecosystems in which they live.

Aurora Borealis over Iqaluit. Photo: Fiona Paton/Flickr.

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