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THE ARCTIC OCEAN:

LOOKING BELOW THE SURFACE

COVER: A Clione limacina, also known as a sea butterfly or sea angel, swims in shallow waters beneath the Arctic ice in the Beaufort Sea, Alaska.

Photo: Kevin Raskoff, Hidden Ocean 2005 Expedition: NOAA Office of Ocean Exploration.

CONTENTS: Greenland shark, Baffin Island, Canada.

Photo: © National Geographic Stock / Nick Caloyianis / WWF

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Editor-in-chief:
Andrea Norgren,
andrea.norgren@wwf.se

Managing editors:
Sarah MacFadyen,
sarah@sarahmacfadyen.com
Patti Ryan,
patti@southsidecommunications.ca

Web and social media:
Ashley Perl,
ashley.perl@wwf.se

Design and production:
Film & Form/Ketill Berger,
ketill.berger@filmform.no

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The Circle 4.2022

THE ARCTIC OCEAN: LOOKING BELOW THE SURFACE

EDITORIAL

Convention season is over—now let's get to work

THE ARCTIC OCEAN'S express journey into the Anthropocene Epoch was marked by some notable global conferences this past fall. There were high and low points—and for better or worse, now it's time to turn the resulting agreements into action.

First, the good news: on December 19, 2022, the 15th Conference of the Parties (COP15) to the UN Convention on Biological Diversity concluded with a sweeping agreement by about 190 countries to halt and reverse nature loss within the next seven years. It is difficult to overstate its significance: this long-awaited achievement is critical for nature and our own survival.

But what does it mean for the Arctic?

Countries agreed to preserve 30 per cent of the Earth's land and seas by 2030, which means the existing protected and conserved areas across the Arctic Ocean must increase about four-fold. The "30 x 30" target is ambitious, but there can be no wavering. Networks of such areas are critical for securing the resilience of marine biodiversity and ecosystems in the face of a rapidly changing ocean. These ambitions can only be achieved if implementation considers the rights and needs of Arctic Indigenous Peoples and the contributions of all Arctic Ocean users.

WWF is working to meet this challenge with ArcNet: an Arctic Ocean Network of Priority Areas for Conservation. ArcNet is designed to address the conservation needs of Arctic spaces and species and improve ecological connectivity while inviting collaboration, supporting co-production, and accelerating implementation.

Another positive moment occurred this fall with the successful inaugural Conference of Parties to the Central Arctic Ocean Fisheries Agreement.

Walrus rest on a chunk of pack ice during a spring break-up in the Chukchi Sea near Alaska.

Photo: © naturepl.com / Steven Kazlowski / WWF

Arctic countries that are party to both COP15 and COP27 must now ask themselves how the disappointing lack of necessary climate ambition will affect their commitment to halt the extinction of species under the Global Biodiversity Framework.

This ground-breaking agreement commits Arctic and non-Arctic fishing nations to a precautionary approach to fishing in almost three million square kilometres of international waters in the Central Arctic Ocean as melting sea ice makes the area more accessible.

The single-sector agreement strengthens Arctic Ocean governance and bolsters the resilience of biodiversity. But it must also be seen as a first step towards establishing integrated and equitable institutions that will sustainably manage the 70 per cent of Arctic sea and land areas that are not conserved for nature.

Unfortunately, other news this fall on the climate crisis front was much less positive. The Paris Agreement's mission to limit global warming to 1.5°C is in jeopardy—and we are rapidly running out of time to avoid the loss of the Arctic's unique multi-year sea ice ecosystem and associated biodiversity. Yet countries attending the 27th Conference of the Parties to the UN Framework Convention on Climate Change in November made almost no progress on committing to necessary and ambitious greenhouse gas emission reductions.

Arctic countries that are party to both COP15 and COP27 must now ask themselves how the disappointing lack of necessary climate ambition will affect their commitment to halt the extinction of species under the Global Biodiversity Framework.

This issue of *The Circle* touches on an array of challenges facing the Arctic Ocean now—from acidification to plastic waste to melting glaciers and more. At the same time, researchers are studying the ocean's chemistry, mapping its floor and monitoring new species.

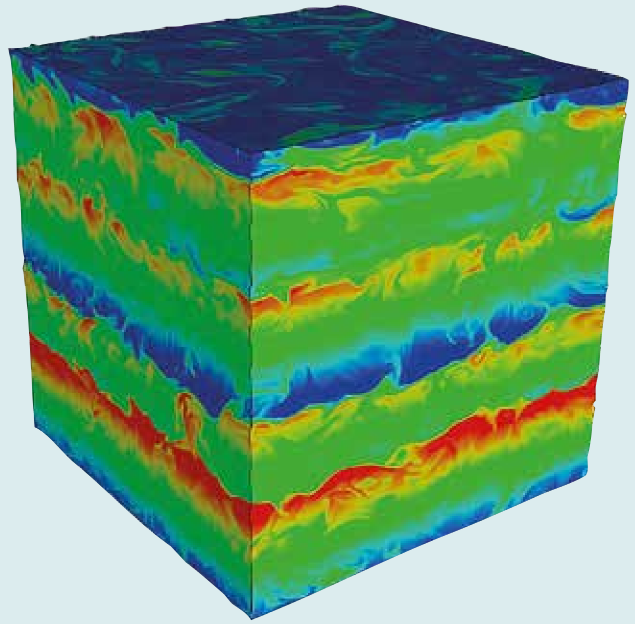
Those who are working to understand and conserve the Arctic Ocean are in a race against time. With international agreements and targets secured after a busy fall of negotiating, it's time to get started on implementation. ●

MARTIN SOMMERKORN is head of conservation with the WWF Arctic Programme.

IN BRIEF

MYSTERY SOLVED

Researchers demystify temperature and salinity staircases in the Arctic Ocean



A simulation depicts the strongly defined changes in temperature and salt that form staircase-like structures within the Arctic Ocean.

Image source: Ma, Yuchen and Peltier, W.R. (2022). Thermohaline-turbulance instability and thermohaline staircase formation in the polar oceans. *Physical Review Fluids*, 7(8). https://doi.org/10.1103/PhysRevFluids.7.083801

RESEARCHERS HAVE KNOWN about temperature and salinity "staircases" in the oceans since the 1960s—but until recently, it wasn't clear how they were created.

Common in many regions, these staircase-like ocean structures contain a mix of warm salt water and cooler fresh water. They are characterized by step-like layers with vertical temperature and salinity profiles that can range from tens to hundreds of metres in thickness.

In a study published in *Physical Review Fluids*, a team of researchers from the University of Toronto reported discovering "a new mechanism of hydrodynamic instability" that offered insights into how these thermohaline staircases form. The theory is that they assemble spontaneously when the turbulent intensity determined by the buoyancy Reynolds number (a measure that describes turbulent mixing in the open ocean's stratified environment) is weak enough.

Understanding thermohaline staircase formation in the Arctic Ocean could shed more light on the causes and consequences of rapid sea ice loss amid the climate crisis. It could also contribute to global warming projections and inform efforts to slow sea ice loss because the staircases amplify the flow of heat from the ocean into the overlying sea ice.

LIFE ON THE SEAFLOOR

Hidden phytoplankton could alter the carbon cycle

SCIENTISTS THOUGHT THEY understood what happened to microscopic algae after they bloomed on the surface of the Arctic Ocean each spring: the algae sank to the seafloor where, without light, they stabilized or died.

But recently, University of Tokyo researchers discovered that phytoplankton may be capable of blooming at the bottom of the Arctic Ocean. The researchers hypothesized that in shallower Arctic marine areas that are no longer covered by sea ice in summer, sunlight can reach the bottom of the ocean, triggering the blooms.

To test this theory, they re-created seafloor temperature and lighting conditions in the Chukchi Sea before incubating sediment samples for 24 days. Microscopic algae bloomed in the samples even when the irradiance was only 1 per cent of what is normally found on the water's surface.

Phytoplankton are a critical element in the Arctic food web whose dynamics affect the ecosystem. Phytoplankton also affect the carbon cycle because they remove carbon from the environment when they grow. If primary production is indeed taking place on the seafloor, the implications could be significant.

The scientists hope to study additional shelf areas and collaborate with ecosystem modellers to get a more precise understanding of the blooms' distribution and impact.

SINKING AND SHRINKING

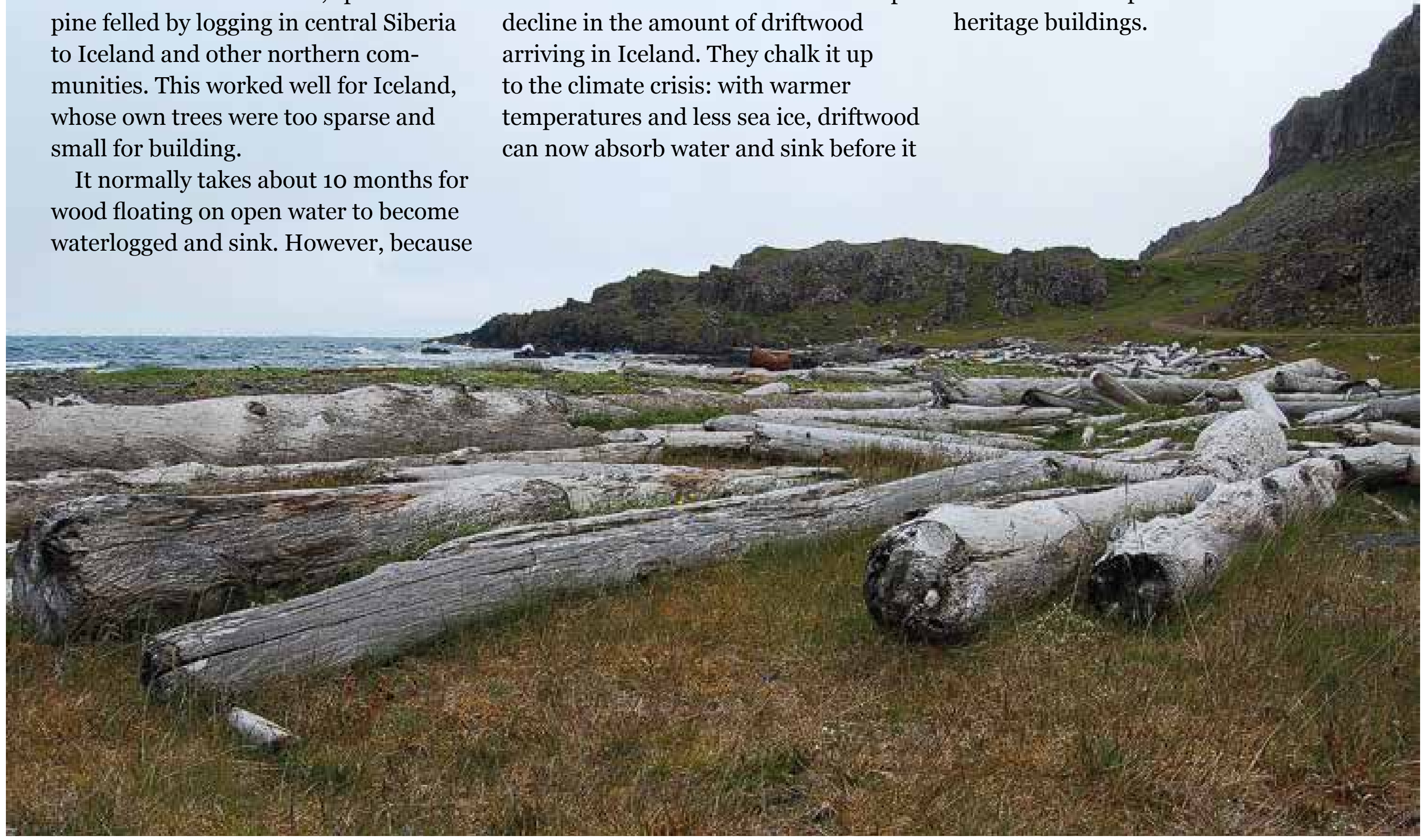
Iceland's disappearing driftwood

A STEEP DECLINE in the amount of driftwood arriving on Iceland's shores is bringing the country's culture and history into the climate conversation. Like a natural conveyor belt, sea ice once carried trees such as larch, spruce and pine felled by logging in central Siberia to Iceland and other northern communities. This worked well for Iceland, whose own trees were too sparse and small for building.

It normally takes about 10 months for wood floating on open water to become waterlogged and sink. However, because the Arctic Ocean experiences freezing and thawing cycles, timber could drift for lengthy periods in the Arctic waters without soaking up water, eventually washing up on shore as driftwood.

But researchers have noticed a steep decline in the amount of driftwood arriving in Iceland. They chalk it up to the climate crisis: with warmer temperatures and less sea ice, driftwood can now absorb water and sink before it reaches Iceland's shores. Based on simulations, it's possible that by 2060, no driftwood at all will make the journey.

Although modern Icelanders no longer rely on driftwood for lumber, they still use it in sculptures and to restore heritage buildings.



UNDERWATER NOISE

New study finds invertebrates' activities may be altered by noise

MARINE INVERTEBRATES ON the seafloor—such as mussels, crustaceans and worms—continually change the sediment they live in by burrowing, feeding, aerating and fertilizing it. These activities contribute to nutrient cycling in the ocean and affect the amount of carbon from dead organic matter that is stored in the seafloor.

But a new study led by the Alfred Wegener Institute for Polar and Marine Research suggests that noise caused by human activities is subjecting these organisms to increased stress that could alter their activities. This could affect important marine ecosystem functions, including food availability for organisms higher up in the food web, such as fish, and in the Arctic, bearded seals and walrus.

The study looked at how crustaceans, mussels and worms respond to low-frequency noise and how frequently and intensively they can transform and break down sediment during noise exposure. The researchers concluded that human-made noises could stop seafloor invertebrates from cultivating and restructuring sediments.

Understanding how human activities affect organisms on the seafloor is important because as the Arctic warms, the amount of human activity in the area—and the noise that goes with it—will continue to increase.

A pelagic pteropod, also known as a sea butterfly or sea angel.

Ocean chemistry

MELTING SEA ICE IS ACIDIFYING THE ARCTIC OCEAN

A warmer climate has caused significant amounts of sea ice in the Arctic Ocean to melt over the past few decades. Without an ice barrier between seawater and air, the ocean can rapidly absorb CO2 from the atmosphere. As **WEI-JUN CAI** and **ZHANGXIAN OUYANG** explain, this process lowers the pH of the ocean's surface water—and it is unfolding three to four times more quickly in the Arctic Ocean than in other oceans, threatening all forms of life.

ONCE PERENNIALLY ICE-COVERED, increasingly large areas of the Arctic Ocean are now ice-free for longer periods. With the loss of its "ice cap," the ocean's fresh and carbon-deficient surface water is exposed to increasing atmospheric CO_2, which it absorbs.

You might think this process could mitigate climate change. It does—but it also reduces both the pH level of the water and the saturation state of aragonite (a carbonate mineral) in the seawater, causing acidification.

Aragonite is produced by tropical and cold-water corals, pteropods and some molluscs. An ocean's aragonite saturation state is a measure of carbonate ion concentration, so it is commonly used to track ocean acidification. When the saturation state falls below 3, these organisms become stressed. Below 1, shells and other aragonite structures begin to dissolve. For years, we were not able to quantify how quickly seawater pH and aragonite would decline in the Arctic Ocean because of the scarcity of observations in this remote area. But now we have some clues.

When we first saw the preliminary results derived from a compiled dataset from 47 Arctic research cruises from 1994 to 2020, we were stunned: the data revealed that seawater pH can decrease at the swift rate of about 0.1 unit per decade in the ice-free Central Arctic Ocean—a rate much faster than in other oceans. It took more than 100 years for the pH in the Atlantic, Pacific and Indian oceans to drop by 0.1 unit. How is it possible that this could happen in the Arctic Ocean within just two and a half decades? What caused it? Could we trust our results?

> It took more than 100 years for the pH in the Atlantic, Pacific and Indian oceans to drop by 0.1 unit. How is it possible that this could happen in the Arctic Ocean within just two and a half decades?

THREE CONNECTED PROCESSES

With rigorous analysis, we validated the rapid rates of decline in seawater pH and aragonite saturation state in the Arctic Ocean. We found that the declines were significantly associated with the decrease in sea ice extent.

Simply speaking, there are three processes behind how melting sea ice controls and accelerates acidification in the Arctic Ocean.

First, after the air-sea barrier disappears, the carbon-deficient water under the sea ice is exposed to the atmosphere and can rapidly take up CO_2.

Second, the relatively lighter meltwater forms a stable layer at the top of the ocean that does not easily mix into the deeper waters. As a result, the CO_2 absorbed from the atmosphere accumulates and concentrates in the surface water.

And last but not least, the comparatively fresh (less salty) sea ice meltwater changes the chemistry of the seawater by diluting the carbonate ion concentration. A lower carbonate ion concentration indicates a lower buffer capacity for neutralizing CO_2 molecules. This is why pH decreases more quickly in sea ice water that has been diluted by meltwater than it does in normal seawater.

A THREAT TO FOOD WEBS, BIODIVERSITY AND FOOD SECURITY

Given expectations that both temperatures and sea ice loss will continue to increase, the lower pH and decreased aragonite saturation state in the summer Arctic Ocean may cause more severe acidification. This would be bad news for Arctic sea life, food webs, ecosystems and Indigenous Peoples.

For example, researchers know that sea butterflies are already struggling in acidifying polar oceans. A type of mollusc that is a "canary in the coal mine" for ocean acidification, a sea butterfly has an aragonite shell (which forms from calcium and carbonate ions) that will start to dissolve in corrosive waters (those with low pH and aragonite saturation state under 1).

Because sea butterflies are a key species in Arctic food webs and an important food source for fish and whales, their impairment may cascade throughout marine food webs, impact the diversity of species, sabotage marine ecosystems, restructure relationships between predator and prey in the ocean, and threaten Indigenous Peoples' food security.

Unfortunately, we are far from having a complete understanding of all the consequences that are likely to be induced by the rapid declines in pH and aragonite saturation state for the Arctic ecosystem. A recent model study predicted that the synergetic effect of earlier seasonal ice melting and amplified atmospheric warming in the summer will accelerate summer ocean acidification by the end of the century, not only in the Central Arctic Ocean but also in the shelf seas, which are key harvesting areas for Arctic fisheries.

Does all life in the Arctic Ocean have time to adapt to such rapid increases in acidic conditions? Sadly, we suspect that many shell-building organisms do not. ●

UNDERSTANDING THE SCIENCE

pH is a measure of how acidic or basic water is. Decreasing pH indicates increasing acidity.

A drop of 0.1 pH units in surface ocean waters may not sound like much, but the pH scale is logarithmic. The 0.1 decline represents an increase in acidity of about 30 per cent.

WEI-JUN CAI is a professor at the University of Delaware in the United States who studies the carbon cycle and biogeochemical dynamics in the Arctic Ocean.

ZHANGXIAN OUYANG is a post-doctorate researcher at the University of Delaware who works with Cai.

We started with this simple science question: "How much are the oceans melting away Greenland's ice from below?"

JOSH WILLIS is a climate scientist at NASA's Jet Propulsion Laboratory in California, US. He is the lead scientist for the Oceans Melting Greenland (OMG) project.

Photo: NASA/OMG.

Mapping the sea floor

OMG, GREENLAND'S OUTLET GLACIERS ARE MELTING FROM BELOW

The outlet glaciers of Greenland's ice sheet are disappearing at an alarming rate. In fact, they are melting six or seven times faster today than they were 25 years ago. If they were to melt completely, they would raise the world's sea levels by more than six metres—a distressing figure, considering that a rise of just one centimetre can erode three feet of coastline. But the question that remains unanswered is: Just how fast are they melting?

Over the past six years, **JOSH WILLIS** and a group of NASA scientists have been working hard to answer this question. Willis started the Oceans Melting Greenland (OMG) project to better to understand what role the Arctic's warming seas are playing in the melting of Greenland's outlet glaciers. As he told *The Circle*, some of their findings were surprising.

When we think of NASA, we don't usually think about oceans. Why is NASA studying Greenland's glaciers?

We often think of NASA as the agency looking to the stars. But actually, NASA spends a lot of its time, budget and energy looking at our planet to understand how it is changing. So we have satellites that tell us things like how much ice Greenland is losing, and others that tell us how the sea levels are rising as a result. But until recently, we were missing a piece of the puzzle that has to do with how the oceans are eating away at Greenland's ice from beneath.

What were you trying to figure out with this project?

Well, we started with this simple science question: "How much are the oceans melting away Greenland's ice from below?" We know the atmosphere is warming because of human interference with the climate, but the oceans are warming too. As those oceans warm, sea levels rise and interact with ice sheets and glaciers.

When we started OMG, we knew the oceans would probably be important, but we didn't know how widespread this activity was around Greenland. We came up with this idea to try to measure the oceans all the way around Greenland, then couple those results with measurements of the ice all the way around Greenland. We figured that if we watched the ocean and ice change from one year to the next, over time we would get a sense of how the oceans are affecting the ice.

How did you go about measuring those things and answering that question?

During the summer, sea ice around Greenland retreats and leaves the water open, so we were able to fly over and drop sensors down. We dropped about 250 every year. The sensors fall down ➤

Animation: How a Glacier Melts

through the water, measuring temperature and salinity as they go, and radio that data back to the airplane. Using these sensors, we were able to map out how the water temperature was changing all the way around Greenland from one year to the next. That was our main tool.

We also flew a radar around the edge of Greenland to measure how the ice was changing. But we needed to understand what role the shape of the sea floor might be playing, so a lot of what we did in the first couple years involved mapping out the sea floor so we knew the pathways where the water could reach the ice.

What were the most significant things you learned in the six years of the project?

Well, one of the real surprises at the very beginning was regarding a glacier called Jakobshavn, which is the biggest in Greenland in terms of how much ice it discharges. This glacier had been steadily retreating for more than 20 years. But when we first started OMG, it suddenly reversed its retreat and started getting thicker.

To understand why, we looked at the oceans first, and it turned out that a sort of temporary cooling signal had made its way up onto the shelf and into the fjord of this glacier. This cooler-than-normal water was enough to reverse the glacier's retreat temporarily. Since then, the glacier has started to retreat again, and we have observed warmer temperatures. But the fact that the ocean could have such a profound and quick influence on a glacier was a complete surprise to us.

How are you using this information now?

What we really figured out was that understanding the ocean is important if you want to predict what ice sheets and glaciers are going to do. But our ability to predict how fast the ice is going to melt is lagging behind the reality of the melting. What we're doing now is trying to build some longer-term ocean measurements so people can improve their predictions of the ice melt. We're also trying to use the information to decide where to keep measuring these ocean waters.

Why should people around the world care how quickly Greenland is melting?

What happens in Greenland doesn't stay in Greenland: ice loss there affects sea levels and coastlines all around the world. Greenland is now the single largest source of sea-level rise. In just the last 15 or 20 years, it has lost enough ice to raise global sea levels by one centimetre. That may not sound like a lot, but that's three feet of beach loss on most beaches around the world. ●

HFO must go

BLACK CARBON PUTS SHIPPING ON A COLLISION COURSE WITH THE CLIMATE

Data from 2015 to 2019 indicate an 85 per cent increase in black carbon emissions.

Global shipping is the world's sixth-largest source of greenhouse gas emissions. Black carbon, mainly from heavy fuel oil (HFO) used by some ships, contributes a fifth of these climate-warming emissions. **ANDREW DUMBRILLE** explains why HFO has to go—and why the International Maritime Organization and Arctic states need to ban it.

BLACK CARBON IS generated from the incomplete combustion of HFO in ship engines. Emitted from ships' exhaust stacks, it is the world's most polluting and hazardous fuel. When released in the Arctic, some of it lands on surfaces like snow and ice, absorbing sunlight and increasing temperatures—and accelerating local warming through ice and snow melt. Normally, snow and ice reflect heat back to the atmosphere. Reduced amounts of snow and ice (thanks in good part to the impacts of black carbon) diminish this effect, hindering the Arctic's ability to help regulate the climate. As the saying goes, what happens in the Arctic doesn't stay in the Arctic.

IMPACTS ON PEOPLE

There are immediate human health consequences from exposure to black carbon emissions, including coughing or breathing difficulties, heart problems, aggravated asthma, and premature death in people with heart or lung disease.

Health problems like these compound the hardships that Arctic communities and Indigenous Peoples are already experiencing from the impacts of the climate crisis. For example, snow and ice are at the centre of Inuit culture, and as they diminish—compromising infrastructure and altering ecosystems—it becomes harder for these communities to maintain their ways of life.

Yet Arctic shipping is on the rise. The Arctic Council's Protection of the Arctic Marine Environment Working Group recently found that from 2013 to 2019, there was a 25 per cent increase in the number of ships in the area and a 75 per cent increase in the distances travelled. Perhaps unsurprisingly, data from 2015 to 2019 indicate an 85 per cent increase in black carbon emissions.

There is hope, though: a recent study from the International Council on Clean Transportation modelled five transit routes through the Arctic and found that if ships switched from HFO to cleaner-burning distillate fuels (similar to diesel), black carbon emissions would fall by 50 to 80 per cent. Cleaner fuels are available worldwide, are already being used in some marine fleets, and can be used without the need to retrofit ships.

TIME TO ACT

So why aren't ships switching from HFO to cleaner alternatives? We can trace the answer back to the International Maritime Organization (IMO).

Given the nature of international trade and vessel traffic, rules to reduce emissions and pollution from ships need to be set globally—and the IMO is the body in charge of doing this. However, the most recent round of negotiations at the IMO did not result in an effective HFO ban. As of July 1, 2024, only 30 and 16 per cent of the HFO carried and used in Arctic waters, respectively, will be prohibited.

To strengthen the HFO ban and more effectively reduce black carbon emissions, the responsibility now rests with Arctic states. Progressive states could ban all HFO carriage and use and mandate a switch to cleaner-burning distillate fuel in their waters. Norway has taken a similar approach in its state waters near Svalbard, so we know it can be done.

We are all familiar with the concept of a catastrophic tipping point in the climate crisis. The Intergovernmental Panel on Climate Change Sixth Assessment Report found that the maritime industry, global supply chains and the infrastructure on which they depend are particularly exposed to climate shocks, extreme weather, sea-level rise, and environmental disruption caused by the climate crisis. Forcing the elimination of HFO use is a necessary step forward for northern communities, the world's climate systems and the maritime industry itself—a rare win–win–win climate solution. ●

ANDREW DUMBRILLE has 25 years' experience working with Canadian and international environmental NGOs and at forums such as the Arctic Council and International Maritime Organization. He is an advisor to the Clean Arctic Alliance and Inuit Circumpolar Council.

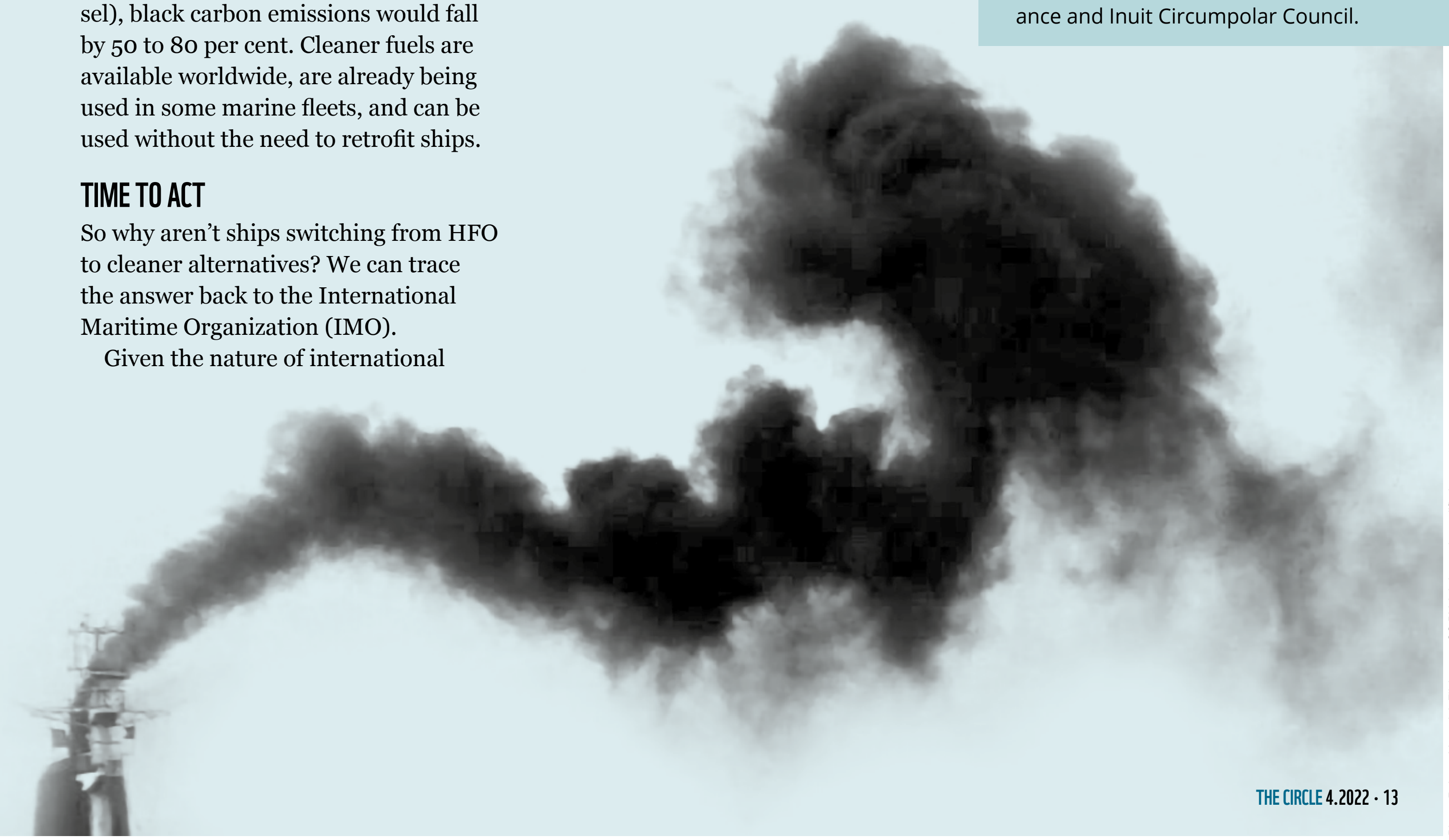


Photo: Roberto Venturini, Flickr.com, CC BY 2.0, image is modified

Photo: Evgeny Podolskiy

Evgeny A. Podolskiy and other scientists have studied Bowdoin Glacier in Greenland to understand changes in its calving behaviour.

Like many other glaciated areas worldwide, the Greenland ice sheet is losing mass, and this loss is contributing to sea-level rise.

Underwater thunder in Greenland

WHAT THE SOUNDS OF ICEBERG CALVING CAN TELL US

Researchers are trying to better understand the impacts of accelerating ice-mass loss on the Arctic and global environment. As **EVGENY A. PODOLSKIY** explains, monitoring iceberg calving is an essential part of this work. Recordings of the sounds of calving are yielding insights into ice dynamics and posing questions about how Arctic wildlife cope with all this sound.

WHEN YOU'RE TRYING to drop an underwater microphone next to the calving front of an ocean-terminating glacier, you have to be ready to move quickly. No one can predict when the calving might occur, but when it does, it can trigger a massive "tsunami" wave. This hazard is common in cold regions, and many explorers have faced it, including Charles Darwin, who almost lost the boat he needed for his return to the *Beagle*.

Like many other glaciated areas worldwide, the Greenland ice sheet is losing mass, and this loss is contributing to sea-level rise. This is happening not only because of intensified melting, but also due to the mechanical loss of ice from more than 200 outlet glaciers—valley glaciers that originate in ice sheets, ice caps and ice fields. Such losses, known as calving, are caused by the formation of crevasses and the collapse of icebergs into the sea.

Even though iceberg calving takes place in remote areas, Inuit are familiar with it and take it seriously. For example, in our research area in northwest Greenland, local Inuit will rush to protect their boats if they hear rumbling from massive glaciers several kilometres away. From experience, they know that destructive ocean waves may arrive minutes later.

Melting and mechanical loss of ice from more than 200 outlet glaciers in Greenland is diminishing the Greenland ice sheet and contributing to sea-level rise.

Photo: Evgeny Podolskiy

LISTENING IN TO THE SOUNDS BELOW

The dramatic calving process, which can involve cubic kilometres of ice, generates sound waves in the air, in solid earth and underwater. This means scientists can use microphones, seismometers and hydrophones to obtain valuable information, including the estimated sizes of calved icebergs. This research is still in its infancy, given that it has been going on for just 15 years. But as a scientist, I find calving sounds to be a fascinating acoustic phenomenon.

Sound waves can propagate for thousands of kilometres underwater. Still, it's important to be as close to the source as possible to record clear sound. Otherwise, the ocean can distort and filter the original sound through reflections, refractions, scattering and absorption.

This means that to record calving sounds effectively, we need to get dangerously close. We drop our instruments to the bottom of a glacier fjord a few hundred metres deep—and flee. Weeks or months later, we summon our instruments to the surface using an acoustic command. Later, on a computer, we can explore an underwater cacophony of sounds composed of characteristic iceberg booms, degassing icebergs, boats and marine mammals.

A MEMORABLE SOUND EXPERIENCE

I was particularly surprised on one occasion by recorded calving sounds that lasted almost half an hour and were so loud that colleagues from neighbouring laboratories and floors thought an earthquake was happening as I replayed it.

There are two main types of calving events: "small" (where the calved ice is less than 100,000 cubic metres in volume) and "large" (where the volume can reach a few cubic kilometres). The former events usually involve ice falling from a high ice cliff into the water. This causes cavitation—the collapse of a large air pocket formed by plunging ice—and generates a particular type of sound. The latter events involve the full-depth calving of gravitationally unstable icebergs that capsize after detachment and smash into the newly formed ice cliff hard enough to generate seismic waves that can be detected thousands of kilometres away. This is happening more frequently now because of climate change.

Our analysis of the sound of a large calving suggested that glaciers can generate the loudest underwater sounds in the entire Arctic Ocean. This volume places calving in Greenland in the same category as the most powerful natural sounds possible in the ocean after undersea volcanic eruptions and earthquakes.

EFFECTS ON WILDLIFE

Earlier studies reported that disintegrating tabular icebergs near Antarctica were also extremely loud and could be "heard" thousands of kilometres away, equivalent to noise from more than 200 supertankers. Yet no one wondered how such a powerful sound might affect animals in the region.

For example, in summer, seals and narwhal may stay close to the calving fronts of Greenlandic glaciers. To estimate the risk of auditory injury to them, we analyzed the sound of calving using recognized technical guidance from the US National Marine Fisheries Service. To our surprise, we found that calving likely does have detrimental effects on the hearing of marine mammals who live close to the calving front.

We still don't know how animals respond to calving sounds. For now, we can only conclude that the risk of hearing loss must be a worthy trade-off for the benefits of remaining in what seem to be some of the noisiest places in the ocean.

EVGENY A. PODOLSKIY is an associate professor with the Hokkaido University Arctic Research Center in Japan who studies passive seismo-acoustic observations of polar glaciers and animals.

Protecting Arctic waters

IS THE IMO'S POLAR CODE FIT FOR PURPOSE?

WWF has a vision for improving the International Maritime Organization's International Code for Ships Operating in Polar Waters. **SIAN PRIOR** outlines a short history of the code and explains some of the key challenges and gaps in implementing it.

> As Arctic sea ice has diminished, interest in shipping in the Arctic and Antarctic has grown—and so have the threats and risks associated with this activity, including black carbon emissions, waste discharge, underwater noise and oil spills.

MORE THAN 15 years ago, the *MS Explorer* ran into hard ice while cruising in the Antarctic peninsula and started taking on water. Fortunately, the 154 passengers and crew made it onto lifeboats and were rescued by another cruise ship before the ship sank.

This was just one of a spate of shipping accidents in the Arctic and Antarctic that led the International Maritime Organization (IMO) to begin developing a new code to ensure that ships operating in polar regions would do so safely and with minimum impact on ecosystems. The International Code for Ships Operating in Polar Waters, better known as the Polar Code, took effect in January 2017 and applies to cargo ships weighing 500 gross tonnes or more and all passenger ships.

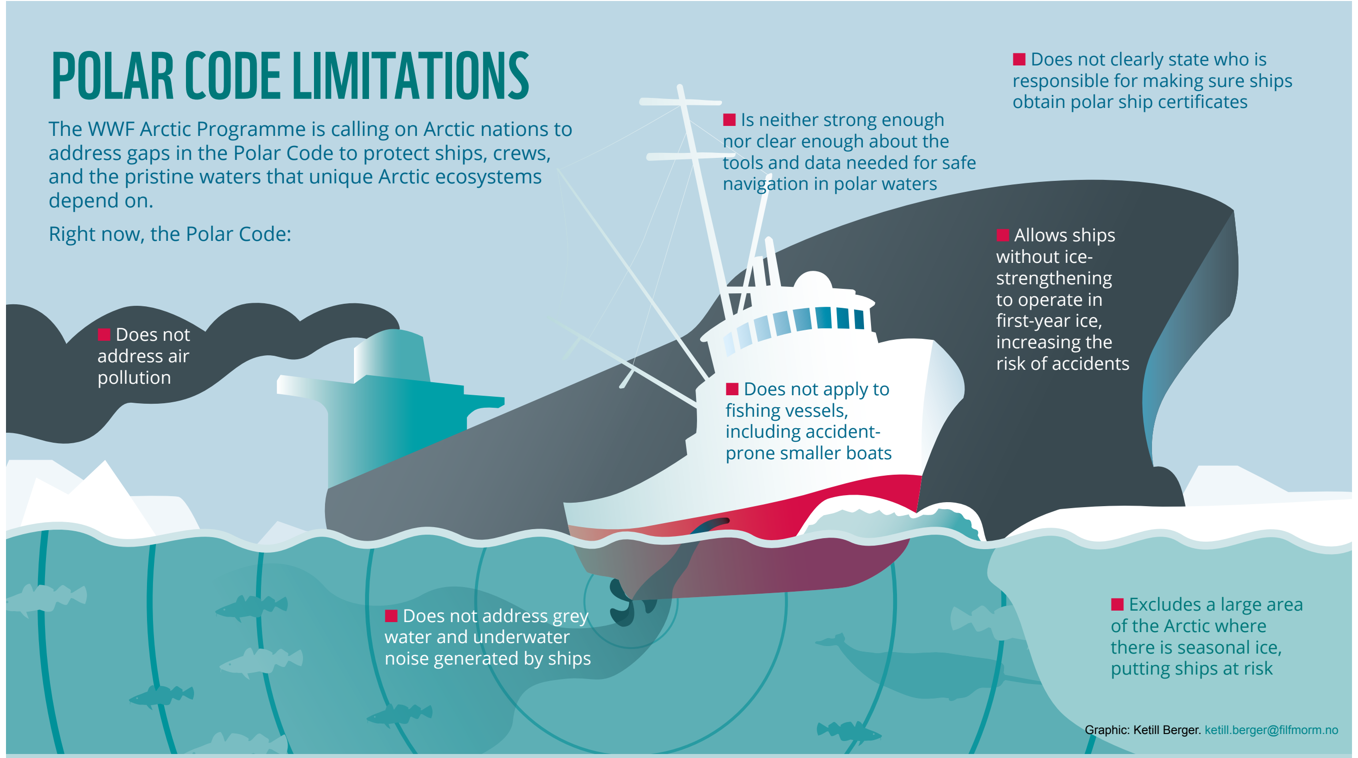
Since the Polar Code was adopted, attention has turned to the need to extend safety measures to fishing vessels, cargo ships weighing 500 gross tonnes or less, and pleasure yachts (essentially, all non-SOLAS vessels, meaning those not covered by the Safety of Life at Sea Convention). The IMO recently adopted guidelines on safety for fishing vessels and pleasure yachts and is due to adopt new measures on navigation and voyage planning, which will take effect starting in January 2026.

ENSURING REGULATION KEEPS PACE WITH SHIPPING

But over the last decade, as Arctic sea ice has diminished, interest in shipping in the Arctic and Antarctic has grown—and so have the threats and risks associated with this activity, including black carbon emissions, waste discharge, underwater noise and oil spills. Between 2013 and 2019, the number of ships operating in the Arctic increased by 25 per cent and the distance they travelled increased by 75 per cent. Most are fishing vessels, but there are also more oil tankers and bulk carriers (exporting mining ores) in the Arctic. The distance sailed by bulk carriers has risen by as much as 160 per cent.

In 2021, WWF's Arctic Programme commissioned a review and analysis of the experience gained since the Polar Code was implemented. The aim was to assess the challenges experienced in implementing the code and identify gaps in the code. The analysis identified a wide range of challenges and gaps in ➤

The Norwegian high-latitude cruise ship, Fram, *on the west coast of Svalbard.*



For more details about WWF's priorities for ships operating in the Arctic, see our Review of Perceived Gaps and Challenges in the Implementation of the Polar Code.

areas like certifying ships that operate in polar waters, validating the guidance to determine the safety of ships in various ice conditions, and accessing data about ice conditions, air temperatures and hydrography. The review also uncovered a number of challenges related to voyage planning.

QUESTIONING WHETHER THE POLAR CODE DOES ITS JOB

Given that polar shipping is likely to keep increasing, it is clearly time to consider whether the Polar Code is still fit for purpose. Although it's important to address all the issues, WWF has identified priority areas where stronger regulations would benefit Arctic wildlife and communities. These include making improvements to polar voyage planning, expanding the code to cover all vessels, and eliminating all polluting discharges—including atmospheric emissions—in polar environments.

WWF has created a variety of resources to support polar voyage planning. It has also developed a blueprint for a network of priority areas for protection. Work is underway to review and overhaul its Mariners' Guides, with updated versions due to be published in 2023. Other work focuses on introducing mandatory and voluntary shipping measures at the domestic level.

But more action is needed within international frameworks, including at the IMO.

TIME FOR ACTION IS HERE

The single most urgent need is for a thorough review of the challenges of implementing the Polar Code. The review should pinpoint where amendments or improvements to the code are needed and address gaps in polar protection. The findings from WWF's work on this issue could support such a review.

Secondly, there is a need for better awareness of the importance of voyage planning in polar waters, not to mention better guidance. Access to data about ice conditions, temperatures, hydrographics, marine mammal populations and migration routes needs improving. In addition, safety measures that are routinely applied to passenger and cargo ships must apply to all vessels in polar waters, especially fishing vessels, which make up a large component of the Arctic fleet.

Finally, all polluting discharges and emissions from ships in Arctic waters should be eliminated, particularly those that accelerate the climate crisis, such as black carbon.

Arctic shipping is increasing, and every incident could have irreversible consequences—so the time to make changes to the Polar Code is now. These changes could go a long way toward protecting the fragile Arctic marine environment and the wildlife and communities who call it home. ●

SIAN PRIOR is a freelance marine science consultant who specializes in advocacy and campaigning for coalitions of marine environmental non-governmental organisations.

Can we turn off the tap on plastics?

WADING THROUGH THE PLASTIC PROBLEM IN THE ARCTIC OCEAN

For more than 10 years, **MELANIE BERGMANN** has been studying plastics in the Arctic Ocean. It all started when the deep-sea scientist began looking at species on the Arctic Ocean's floor and noticed a startling abundance of plastics and other human-made debris. This discovery kicked off her quest to find out where it was all coming from—and what impact it was having.

Since 2002, she and a team of researchers at the Hausgarten Ocean Observatory have been using a towed camera system to track debris on the deep-sea floor off the west coast of Svalbard—and what they've found is concerning. In just 13 years, the quantity of debris on the seabed has increased sevenfold—even 30-fold at the northernmost station. As she tells *The Circle*, plastic pollution is putting added stress on Arctic marine ecosystems, and it is time for the world to take concrete steps to stop it. ➤

Photo: Deonie Allen

I've seen bears with ropes around their necks, and plastic items have been found in their feces. About 91 per cent of northern fulmars (seabirds) in Svalbard have plastics in their stomachs, and it's been found in other seabird species as well as in Greenland shark, which can live for 500 years.

MELANIE BERGMANN is a senior scientist at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research in Bremerhaven, Germany. She recently cowrote a report commissioned by the WWF on the impacts of plastic pollution on the world's oceans.

How big a problem are plastics and microplastics in the Arctic Ocean?
It's like in the rest of the world—it's ubiquitous. Everywhere we look, we find it. In some areas of the Arctic, the concentrations are as high as they are in less remote areas, and sometimes higher. For instance, the amount that we found on the sea floor was similar to that found in surveys done off the coast of Barcelona. This shows that there's a real problem, especially when you think about how few people live in Svalbard compared to Barcelona.

What kinds of plastic and other debris are you finding in these remote areas?
Much of it is just fragments, like bits of plastic film. It could be from plastic bags or fisheries. We also find bits of rope and glass. Glass is important because it sinks directly to the seafloor, indicating local disposal. Until 2013, it was legal to dispose of glass in the Arctic. It's not anymore, but it can be hard to tell if the debris is old or new. On beaches, most of what we find is from fisheries.

Do we know where all this litter is coming from?
We recently conducted a study where we asked citizen scientists in Svalbard to send us the litter they collected. We looked at every item to see if we could find a label or anything that would indicate where things were coming from. Only one per cent of the items showed signs of their provenance because most were from fisheries—and nets don't have labels.

But 48 per cent of the items that did have labels originated from Russia and Norway, which are Arctic states. In fact, about 65 per cent came from European Arctic states, while another 30 per cent came from Europe, and the remaining five per cent came from very distant places like the US, Canada, Brazil and Argentina. Of course, some of it could have come from ships from those countries operating in the region.

Can we ever really know where all this plastic in the Arctic is coming from?
I think the emerging consensus is that it's coming from both local and faraway sources. As Arctic sea ice melts, we are seeing more and more human activity in the area, including hydrocarbon exploration, tourist cruises and shipping. The number of fishing vessels in the area has doubled and the number of cruise tourists has tripled. The number of ships calling at Svalbard increased tenfold between 2000 and 2014. I think the very presence of more ships in this part of the world means we will see even more plastic ending up in local waters, whether it is dumped intentionally or not.

And then there are airborne microplastics, which are carried to the Arctic by winds from various directions. We took snow samples on ice floes in Svalbard and found considerable concentrations. This is important because air moves much faster than water. Particles can travel thousands of kilometres in a matter of days.

How does all this plastic affect species, especially those in the Arctic Ocean?
This is something that we know little about. We do know that polar bears ingest and get entangled in plastic. I've seen bears with ropes around their necks, and plastic items have been found in their feces. About 91 per cent of northern fulmars (seabirds) in Svalbard have plastics in their stomachs, and plastics have been found in other seabird species as well as in Greenland shark, which can live for 500 years.

We've also found it in zooplankton. That finding indicates that plastic has infiltrated the base of the food web. But to find out whether harm is being done, we would need to run experiments—and doing experiments with Arctic animals is not a trivial exercise. However, there is no reason why Arctic species should be less vulnerable to the effects of plastic than their relatives elsewhere. Quite the opposite, because they also have to deal with other severe changes as the climate heats. According to some recent studies, temperatures are rising four times faster in the Arctic compared to the global average.

> We've seen eight per cent growth in plastic production annually, and already our systems in the developed world cannot cope. Still, countries can act before there's a UN treaty in place. We don't have to sit there and twiddle our thumbs.

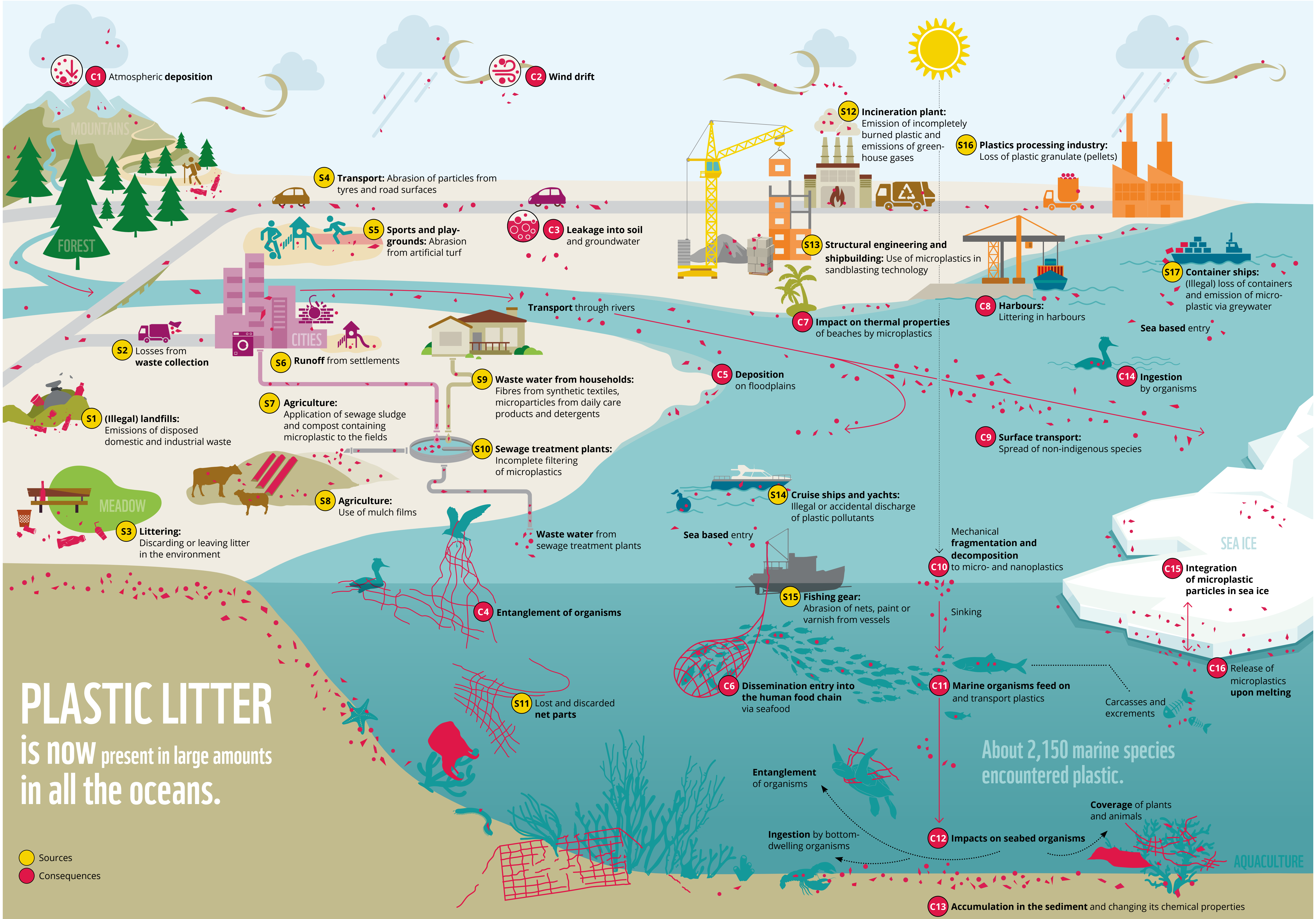
A tourist picks up plastic waste on the shore of Amsterdamøya, a small island off the coast of Svalbard.

Photo: GRID-Arendal resources library, Peter Prokosch, CC BY-NC-SA 2.0

If these plastics and microplastics are reaching such remote areas, what can be done?
We need to turn off the tap. I have big hopes for the UN Treaty on plastic pollution, which will be negotiated over the next two years. I hope it will contain measures to reduce the production of plastics in the first place. That decrease must be at the heart of any mitigation measures because we've seen eight per cent growth in plastic production annually, and already our systems in the developed world cannot cope. Still, countries can act before there's a UN treaty in place. We don't have to sit there and twiddle our thumbs.

What can be done in the Arctic region itself?
I think we have to reduce waste disposal from fishing boats. For instance, we could implement a one-fee system in the region: when ships come into port, instead of paying by the kilogram to dispose of waste, they would just pay a single fee no matter how much they bring. This would discourage them from dumping it at sea. Gear-marking schemes and education could also help.

And Arctic communities need better waste management systems. For example, in Greenland, Russia and a couple of other Arctic countries, there are open landfills on beaches in some areas. We should also improve sewage treatment in these areas, because even if there aren't a lot of people living there, if everything goes into the ocean unfiltered, it adds up. ●



MOUNTAINS
FOREST
CITIES
MEADOW
SEA ICE
AQUACULTURE
C1 Atmospheric deposition
C2 Wind drift
S4 Transport: Abrasion of particles from tyres and road surfaces
S5 Sports and playgrounds: Abrasion from artificial turf
C3 Leakage into soil and groundwater
S12 Incineration plant: Emission of incompletely burned plastic and emissions of greenhouse gases
S16 Plastics processing industry: Loss of plastic granulate (pellets)
S13 Structural engineering and shipbuilding: Use of microplastics in sandblasting technology
S17 Container ships: (Illegal) loss of containers and emission of microplastic via greywater
C8 Harbours: Littering in harbours
C7 Impact on thermal properties of beaches by microplastics
Sea based entry
Transport through rivers
S2 Losses from waste collection
S6 Runoff from settlements
S9 Waste water from households: Fibres from synthetic textiles, microparticles from daily care products and detergents
C5 Deposition on floodplains
C14 Ingestion by organisms
S7 Agriculture: Application of sewage sludge and compost containing microplastic to the fields
S1 (Illegal) landfills: Emissions of disposed domestic and industrial waste
S10 Sewage treatment plants: Incomplete filtering of microplastics
C9 Surface transport: Spread of non-indigenous species
S8 Agriculture: Use of mulch films
S3 Littering: Discarding or leaving litter in the environment
S14 Cruise ships and yachts: Illegal or accidental discharge of plastic pollutants
Waste water from sewage treatment plants
Sea based entry
Mechanical fragmentation and decomposition
C10 to micro- and nanoplastics
C15 Integration of microplastic particles in sea ice
C4 Entanglement of organisms
S15 Fishing gear: Abrasion of nets, paint or varnish from vessels
Sinking
C16 Release of microplastics upon melting
C6 Dissemination entry into the human food chain via seafood
C11 Marine organisms feed on and transport plastics
Carcasses and excrements
S11 Lost and discarded net parts
PLASTIC LITTER
is now present in large amounts in all the oceans.
About 2,150 marine species encountered plastic.
Entanglement of organisms
Coverage of plants and animals
Ingestion by bottom-dwelling organisms
C12 Impacts on seabed organisms
C13 Accumulation in the sediment and changing its chemical properties
Sources
Consequences

Áslat Holmberg grew up fishing salmon with nets. Like others in Finland's northernmost municipality, he has been coping with the impacts of a ban on salmon fishing intended to help stocks recover.

Photo: Áslat Holmberg

Disappearing salmon

A DECLINE IN SALMON STOCKS IS AFFECTING THE SAAMI WAY OF LIFE

Fishing restrictions in the small town of Ohcejohka (Utsjoki)—Finland's northernmost municipality—are affecting food security in the region along with the ability of Saami elders to pass along their traditional knowledge. A salmon fisher and teacher from the village of Njuorggán (Nuorgam) in the municipality of Ohcejohka, **ÁSLAT HOLMBERG** is also president of the Saami Council and a former member of the Saami parliament of Finland. *The Circle* asked him to describe the situation for the 1,200 people who call Ohcejohka home. ➤

Most of us grew up with the idea that salmon are the core of our food security. Its absence means a key food source is now "off the menu," so to speak. It is also having huge economic and cultural impacts.

I'M WHAT YOU WOULD CALL a traditional fisher, which means I fish with nets. I grew up fishing salmon in the Deatnu (Teno) River near Ohcejohka and knowing there would always be salmon in our freezers. Salmon is a building block of my culture.

But our access to salmon changed in 2017, when the Finnish and Norwegian governments shortened the fishing season and limited the number of days we could fish on the Deatnu River. This decision was made in response to diminishing salmon stocks.

> As a person who relies on salmon and is personally connected to the ocean, I find the future very worrying.

WHERE DID ALL THE SALMON GO?

It's not clear what caused the decline, but it's likely that climate change is a key driver: some of the stocks that salmon feed on may have migrated further north due to warmer waters. In the Finnish side of Sápmi, the average temperature has risen by more than 2°C over the last century or two. It's also possible that the salmon can't find enough food and are just not returning in the same numbers.

But it's interesting that the number of juvenile salmon in the river has not declined as steeply as the number of returning salmon. What that tells us is that they are just not coming back. Atlantic salmon almost always come back to the river where they spawn—so it's likely they are not surviving their ocean migrations. We don't know why.

In any case, in 2021, a total fishing ban was imposed, and it is still in place, so we have not been able to fish salmon at all for two summers in a row. The ban applies to the Deatnu River, its tributaries, estuaries and the Finnmark sea areas from May to December. And the authorities have proposed extending the ban again next summer.

CONSEQUENCES FOR SAAMI PEOPLE

This has huge impacts for Saami in the area. Most of us grew up with the idea that salmon are the core of our food security. Its absence means a key food source is now "off the menu," so to speak. It is also having huge economic and cultural impacts.

Ohcejohka used to be a popular destination for tourists who wanted to try salmon fishing. But for two summers now, the tourists have not shown up. It's estimated that we are losing about five million euros per year due to the ban. This has driven the municipality into a grim situation where it doesn't have the money it needs to fund some of its basic needs.

Culturally, our traditional knowledge is tied to fishing, and when you're not able to fish, you can't transfer that knowledge. For example, net fishing requires knowledge about how to fish, when to fish, what kind of equipment to use, how to repair that equipment, and even how to make the equipment in the first place. If we can't fish, we can't pass this knowledge along to the next generation.

And given the age of some of our elders—my father will turn 90 next summer—even two summers is a long time. Not enough youth have had the chance to acquire these skills, so every year that goes by is valuable in terms of learning from the older generation. The declining salmon stocks and resulting bans threaten the continuation of our culture and the knowledge it contains.

A COMPLEX PROBLEM—AND A RIGHTS DISCUSSION

But even our traditional knowledge does not really help us understand the root of the problem. That's because the biggest changes have happened in the ocean, not in freshwater—and the ocean is an immensely complex ecosystem. Of course, we could still propose management strategies, like quotas on the fishing of species that salmon feed on or tighter regulations for the salmon farming industry, which is the number one threat to wild salmon. Indigenous knowledge also tells us that increased fishing and hunting of salmon predators would help. But other than that, it comes down to mitigating the effects of climate change.

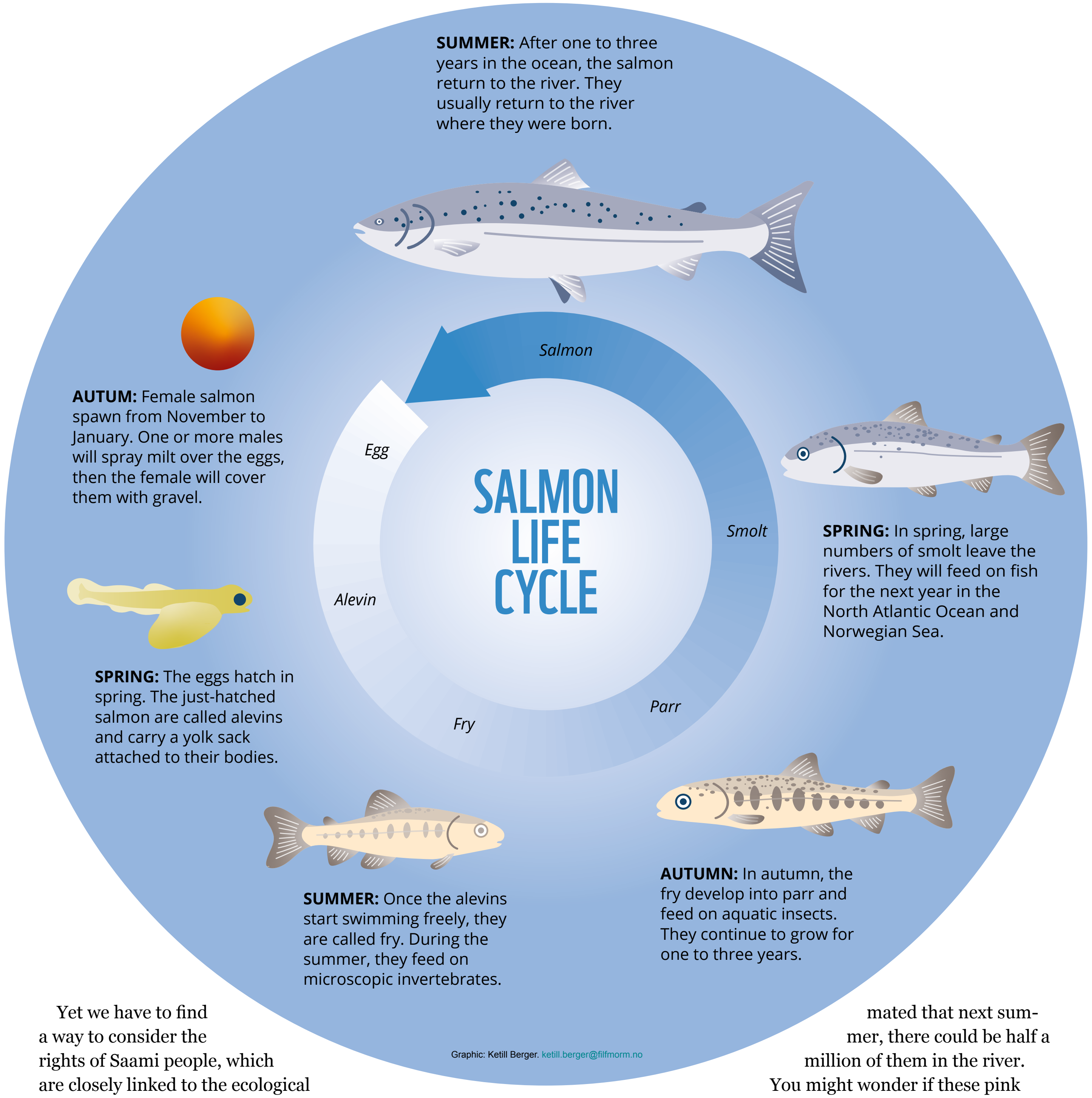
A DECLINE AND AN INVASION

- Atlantic salmon are born in streams and rivers and migrate out to the open sea, returning to freshwater again to reproduce.

The Deatnu River near Ohcejohka (Utsjoki) flows into the Arctic Ocean and has traditionally been one of Europe's largest salmon rivers. But in recent years, there has been a devastating and poorly understood decline in the salmon population in the region.

Meanwhile, invasive pink salmon have begun showing up by the thousands, setting off alarm bells. The fish were first introduced in the 1950s by Russian researchers, who released them on the Kola Peninsula. The salmon spread moderately at first, but their population in the Deatnu River exploded in 2019 and 2021. These salmon are now found along major parts of Norway's coast, but the situation is most serious in the east Finnmark region.

Map: Ketill Berger. ketill.berger@filfmorm.no



Graphic: Ketill Berger. ketill.berger@filfmorm.no

Yet we have to find a way to consider the rights of Saami people, which are closely linked to the ecological situation. Salmon is fundamental to us as a food source, so we need to look for ways to maintain our knowledge and culture despite the dire situation. One approach could be to look at the types of salmon stocks in the watershed, see which ones are doing better than others, and figure out what amount of fishing could be allowed for the healthier stocks. We should also be looking at ways to strengthen the environmental conditions for the salmon, both in the freshwater and the sea.

Compounding the problem, we are also now dealing with an invasive species. Pink salmon (also known as Pacific or humpback salmon) have essentially overtaken the river—last summer, there were four times more pink than Atlantic salmon. This changes the very nature and composition of the river, including its nutritional load, because pink salmon die after spawning, and it's estimated that next summer, there could be half a million of them in the river.

You might wonder if these pink salmon could not become a food source for us. Perhaps that could be one way of adapting, but we have not been able to try because of the fishing ban. I've heard that next summer, some amount of pink salmon fishing may be allowed—but the challenge is that the same equipment used to catch them would also catch Atlantic salmon.

As a person who relies on salmon and is personally connected to the ocean, I find the future very worrying. ●

Canadian scientist Amanda Savoie collected kelp samples during a dive in the Arctic Ocean near Cambridge Bay, Nunavut, Canada.

Photo: Roger Bull © Canadian Museum of Nature

As ocean temperatures warm, the distribution of some kelp species will likely expand, but that of others, like the Arctic kelp *Laminaria solidungula*, will shrink as suitable habitat is lost. The effects that these changes will have on the marine ecosystem are still unknown.

Seaweed biodiversity and ecology

DIVING INTO ARCTIC SEAWEED

Did you know that Canada has the world's longest coastline? Including all three coasts and islands, there are 243,042 kilometres of coastal habitat. This coastal zone is one of the most productive habitats on Earth—but it is also among those most threatened by human activity and the climate crisis. **AMANDA SAVOIE** describes a project that is gathering baseline data about Arctic seaweed to help scientists understand future changes.

Photo: Roger Bull © Canadian Museum of Nature

Seaweed is a critical part of the marine ecosystem, but much remains unknown about seaweed ecology in Canada.

ALL ALONG CANADA'S COASTLINE, from the Atlantic to the Pacific to the Arctic oceans, seaweed thrives in the intertidal and shallow subtidal zones. This includes the Canadian Arctic—a difficult place to live for marine organisms, with sea temperatures as low as –1.5˚C and harsh ice scouring in the colder months. Yet throughout the Arctic, massive forests of seaweed flourish just below the water's surface. As a seaweed researcher (also known as a phycologist), I study where seaweed species are found, how many species exist, and how they interact with one another.

But what exactly is seaweed?

Seaweed is a type of algae—a large group of photosynthetic and aquatic organisms that are responsible for up to half of the world's primary production (creation of new organic matter). It is a critical part of the marine ecosystem, yet we still have a lot to learn about seaweed biodiversity and ecology in Canada.

ESTABLISHING BASELINE DATA

Despite their abundance, Arctic seaweed species are particularly understudied. This past summer, I travelled to Cambridge Bay, Nunavut, in the western Canadian Arctic, with a team ➤

Photo: Roger Bull © Canadian Museum of Nature

Once a seaweed sample has been dried, pressed and labelled, it can be used by researchers for hundreds of years.

of collaborators to start a new research programme studying seaweed biodiversity and ecology. We were based out of the Canadian High Arctic Research Station, which opened recently to facilitate research in the western Arctic.

Very few seaweed surveys have been conducted in the western Canadian Arctic. The last one was done by a phycologist near Cambridge Bay in the 1960s. As the ocean warms due to the climate crisis, we expect to see changes in species diversity, biomass and distribution. But without baseline information, it will be impossible to detect these changes. Although changes due to warming ocean temperatures are already happening, one of the main goals of our project is to establish a baseline dataset that will allow us to document and understand future changes.

We packed our SCUBA gear knowing we would need to dive to search for seaweed, given that not much lives in the intertidal zone in Cambridge Bay in the colder months, when thick sea ice scours the coastline. Luckily, we were working with an experienced local guide, John Lyall Jr., who took us out on his boat, the *Ugyuk*. John's experience and knowledge were critical to our success. With his help, we found several large patches of seaweed right away.

EXPLORING ARCTIC KELP FORESTS

We were particularly interested in kelp, a type of large brown algae that can form huge forests in Arctic waters, so we were delighted when we spotted some on our first day out diving with John. Kelp forests are an important habitat, providing refuge for fish and invertebrate species and supporting pelagic and benthic biodiversity. At first, we weren't sure if there would be much kelp to be found around Cambridge Bay. As ocean temperatures warm, the distribution of some kelp species will likely expand, but that of others, like the Arctic kelp *Laminaria solidungula*, will shrink as suitable habitat is lost. The effects that these changes may have on the marine ecosystem are still unknown.

SCUBA diving in the Arctic Ocean is a spectacular experience. The water temperature was around 2˚C, so dry suits were a must. But this cold water was also crystal clear, and along with the seaweed gardens, we were also treated to views of beautiful sea life. My personal favourites (aside from the seaweed, of course) were the sea angels (*Clione limacina*, a type of pelagic gastropod) that floated in the water column all around us as we descended to the sea floor. We also saw colourful sea cucumbers, anemones, sea stars, fish and even some bright red soft corals.

Part of our work involved collecting samples to take back to the herbarium at the Canadian Museum of Nature for identification. A critical resource for studying biodiversity, an herbarium is like a library filled with dried plant, lichen and algae samples. Once a specimen has been dried, pressed and properly labelled, it can be used by researchers for hundreds of years. To press seaweed species, we float them out in a tray of water and press them onto thick paper, making arrangements that sometimes look more like art than science. We also take subsamples for DNA, which can help identify trickier species.

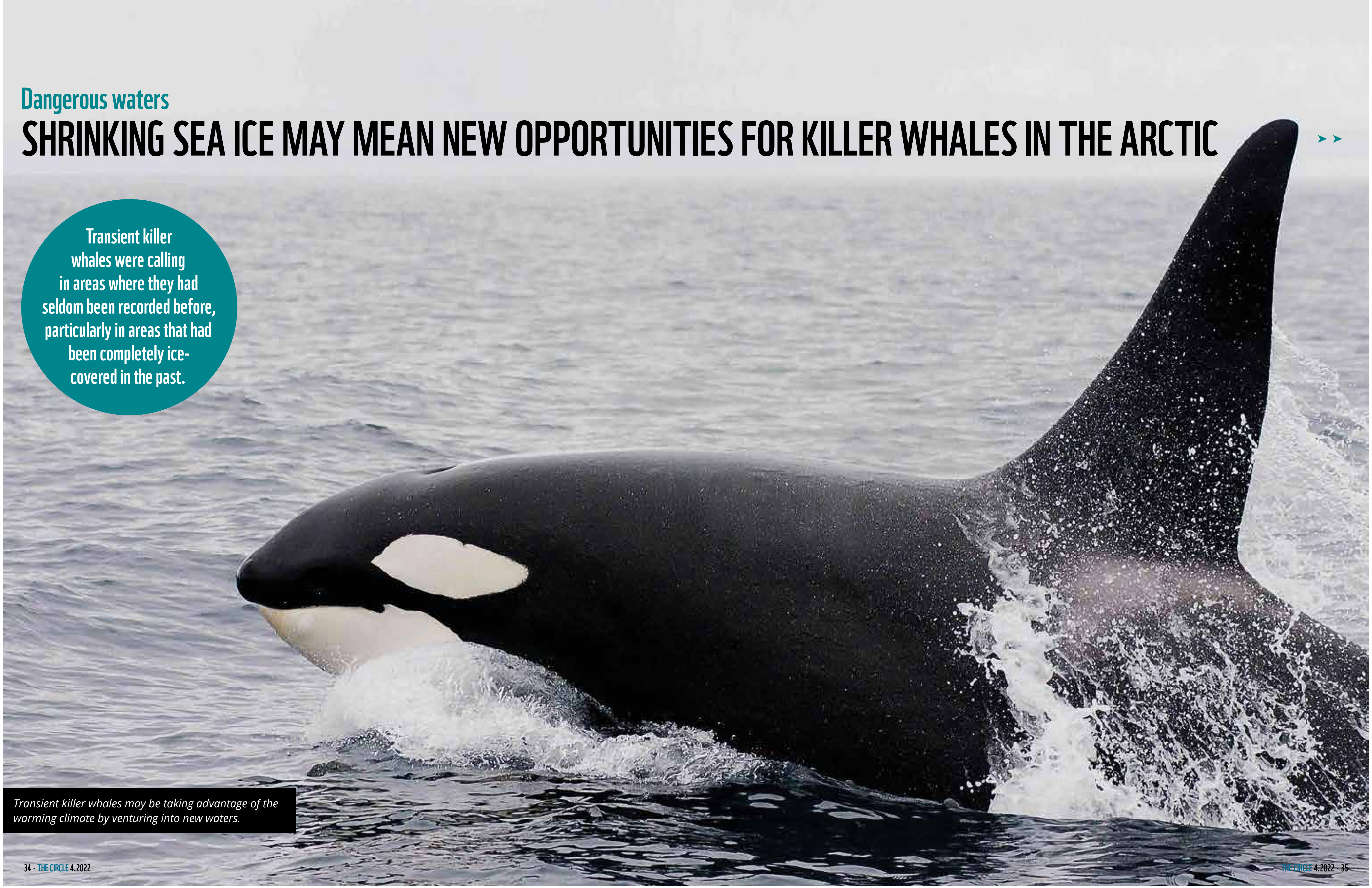
This was the first year of a multi-year survey, and we were delighted to have had such a successful trip. Although the waters of Cambridge Bay are cold for diving, the community is warm and welcoming, and we are grateful to everyone who helped make our seaweed survey a success. ●

Photo: Roger Bull © Canadian Museum of Nature

AMANDA SAVOIE is a Canadian phycologist and director of the Canadian Museum of Nature's Centre for Arctic Knowledge and Exploration.

Dangerous waters

SHRINKING SEA ICE MAY MEAN NEW OPPORTUNITIES FOR KILLER WHALES IN THE ARCTIC



Transient killer whales were calling in areas where they had seldom been recorded before, particularly in areas that had been completely ice-covered in the past.

Transient killer whales may be taking advantage of the warming climate by venturing into new waters.

Photo: NOAA


Brynn Kimber and team at work in the Bering Sea.

Photo: Catherine Berchok (NOAA/MML).

Transient killer whales typically only call after they have made a kill. Their prey—other marine mammals—listen closely for these efficient and capable predators, hoping to avoid encounters. In the Alaska Arctic, sea ice has historically kept killer whales at bay. But as **BRYNN KIMBER** writes, the triumphant calls of transient killer whales are sounding more and more frequently in Alaska as the Arctic warms and sea ice melts.

FOR RESIDENT ARCTIC species, such as the bowhead whale, there is safety in sea ice: it protects them from killer whales. Killer whales are one of the only animals (aside from humans) who hunt bowheads, but they lack the bowheads' ability to break through sea ice to create vital breathing holes.

Frozen areas offer refuge and protection for bowheads and other Arctic species. But as climate change warms the Arctic, sea ice is melting—and some icy areas that were once safe are now characterized by open water and danger. Based on their growing acoustic presence in areas where they were once rarely seen or heard, transient killer whales may be taking advantage of these changes.

EAVESDROPPING ON WHALES

Passive acoustic monitoring is an invaluable tool that scientists can use to detect the presence of marine mammals, especially in remote areas that are difficult to access, such as the ice-covered Arctic. Many marine mammals make distinct calls that enable us to identify them. When we pick up these calls on moored recorders, we can assess marine mammals' locations throughout the year.

Since 2008, the Marine Mammal Laboratory at the National Oceanic and Atmospheric Administration's Alaska Fisheries Science Center has been building a dataset from more than 20 recorders used year-round in Alaska waters. This dataset provides a look at how the acoustic presence of animals varies from year to year. The data can be used for a variety of purposes, including tracking migration patterns and observing changes in animal movements over time. In an area such as the Arctic, which is undergoing rapid change due to rising temperatures and decreasing sea ice, this can provide a vital look into how species distributions might change with ecosystem shifts.

When I analyzed these recordings, one such shift jumped out: transient killer whales were calling in areas where they had seldom been recorded before, particularly in areas that had been completely ice-covered in the past.

When I looked more closely, three distinct patterns emerged. First, killer whales were arriving at the Bering Strait—the southern entrance to the Alaska Arctic Ocean—earlier and earlier in the spring, just after the ice disappeared each year. Second, they were lingering in the area longer and more consistently than they had before. And third, they were being detected in areas where they had seldom been detected before, including far up in the Chukchi Sea, much further north than historically recorded.

HOW ARE TRANSIENT KILLER WHALES DIFFERENT FROM OTHER KILLER WHALES?

■ There are three ecotypes of killer whales: transient, resident and offshore. They have different foods, social structures, languages, behaviours, home ranges and appearances, and are not known to interbreed.

In fact, killer whales are known to have populations that are genetically segregated because of social and cultural differences rather than owing to geography—in other words, individual cultural groups have become genetically distinct. Genetic evidence has revealed that the transient and resident orca populations have not shared a common ancestor for at least 750,000 years.

While some resident killer whales feed mainly on fish and squid—and offshore killer whales feed on fish and sharks—transient killer whales are mammal hunters who have evolved to be expert predators of seals, sea lions, porpoises, dolphins and even other whale species.

IMPACTS ON ECOSYSTEMS AND COMMUNITIES

Killer whales are efficient predators that are capable of significantly impacting the populations of their prey. If the increased acoustic presence of killer whales means more overlap with Arctic species, such as bowhead whales, beluga whales and various seal species, this may indicate increased predation, which could affect population numbers for these prey species. In addition to direct predation pressure, there is also concern that the mere presence of killer whales might cause significant stress to these prey species, potentially altering their foraging and reproductive behaviours.

Not only could increased pressure from predation negatively affect endemic Arctic species—it may also affect Indigenous Peoples in Alaska who rely on subsistence hunting to maintain their way of life. The species that would be most vulnerable to disruptions caused by transient killer whales—bowhead whales, belugas and seals—are the same ones that Alaska Native hunters rely on to feed their communities.

Unfortunately, the increased presence of killer whales is just one result of climate change that could affect both the people and animals living in the Arctic. As the ocean warms and sea ice melts, it's important for scientists, citizens and organizations to monitor how the ecosystem is changing and figure out how best to manage it. ●


BRYNN KIMBER is a bioacoustics specialist and a senior analyst on the Marine Mammal Laboratory's acoustics team at the National Oceanic and Atmospheric Administration's Alaska Fisheries Science Center.

MEANWHILE IN GREENLAND...

■ According to a study published recently in *Global Change Biology*, declining pack ice in coastal areas of southeastern Greenland may be irreversibly changing the marine ecosystem in the area. Scientists have observed an increase in the numbers of humpback, fin, killer and pilot whales as well as dolphins in the area. At the same time, there have been fewer narwhal and walrus.

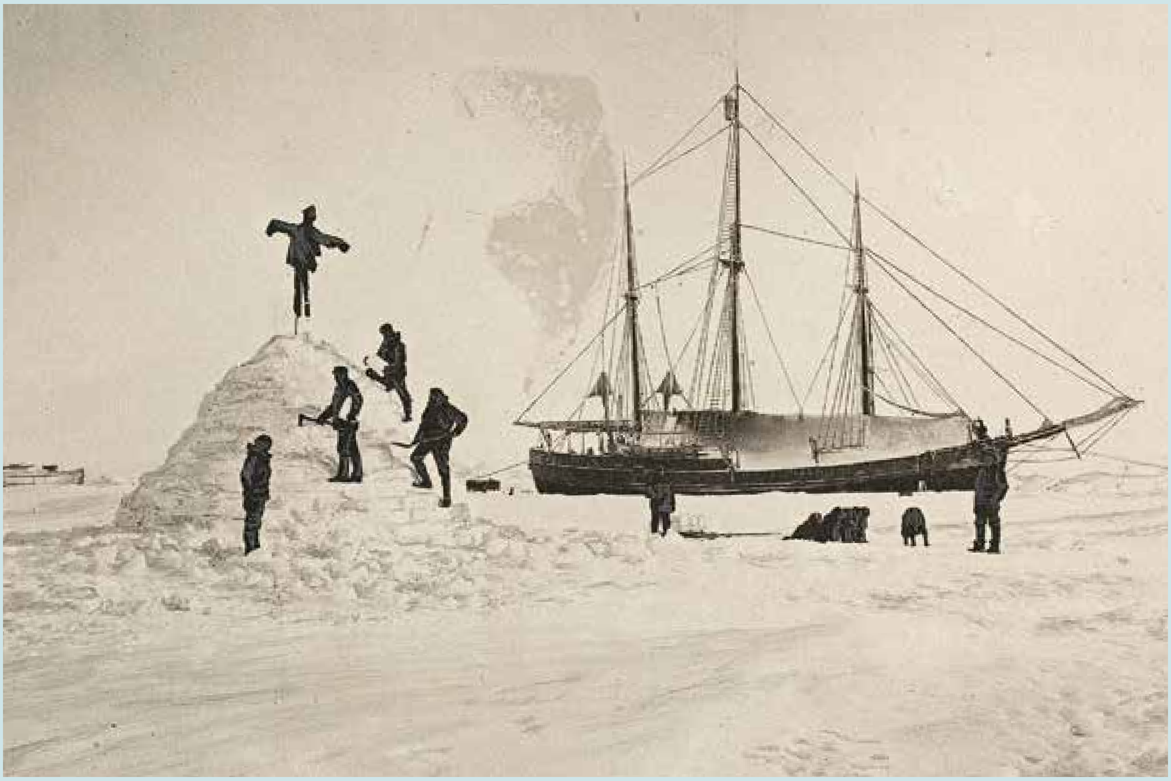
The sub-Arctic ecosystem off the coast of southeastern Greenland has long been characterized by sizeable amounts of drifting pack ice. But over the past century, the area has grown more temperate, with warmer ocean temperatures and less sea ice. These changes are attracting large numbers of whales and other new species.

The study estimates that the new cetaceans in the area may be responsible for consuming 700,000 tons of fish and more than 1.5 million tons of krill species.

The findings may indicate a tipping point (known as a regime shift) in the marine ecosystem, with potentially cascading effects.

THE BACK PAGE

Making history on the Arctic Ocean



The *Fram* sailed away from Bergen, Norway, on July 2, 1893 bound for the Arctic Ocean. Led by Norwegian explorer Fridtjof Nansen, the expedition aimed to reach the North Pole by tackling the Arctic Ocean's east-west current. Although the ship never reached its intended destination, the expedition set a record for travelling the furthest point north—and paved the way for future explorers to embark on their own North Pole expeditions. (Photo courtesy of The Fram Museum.)