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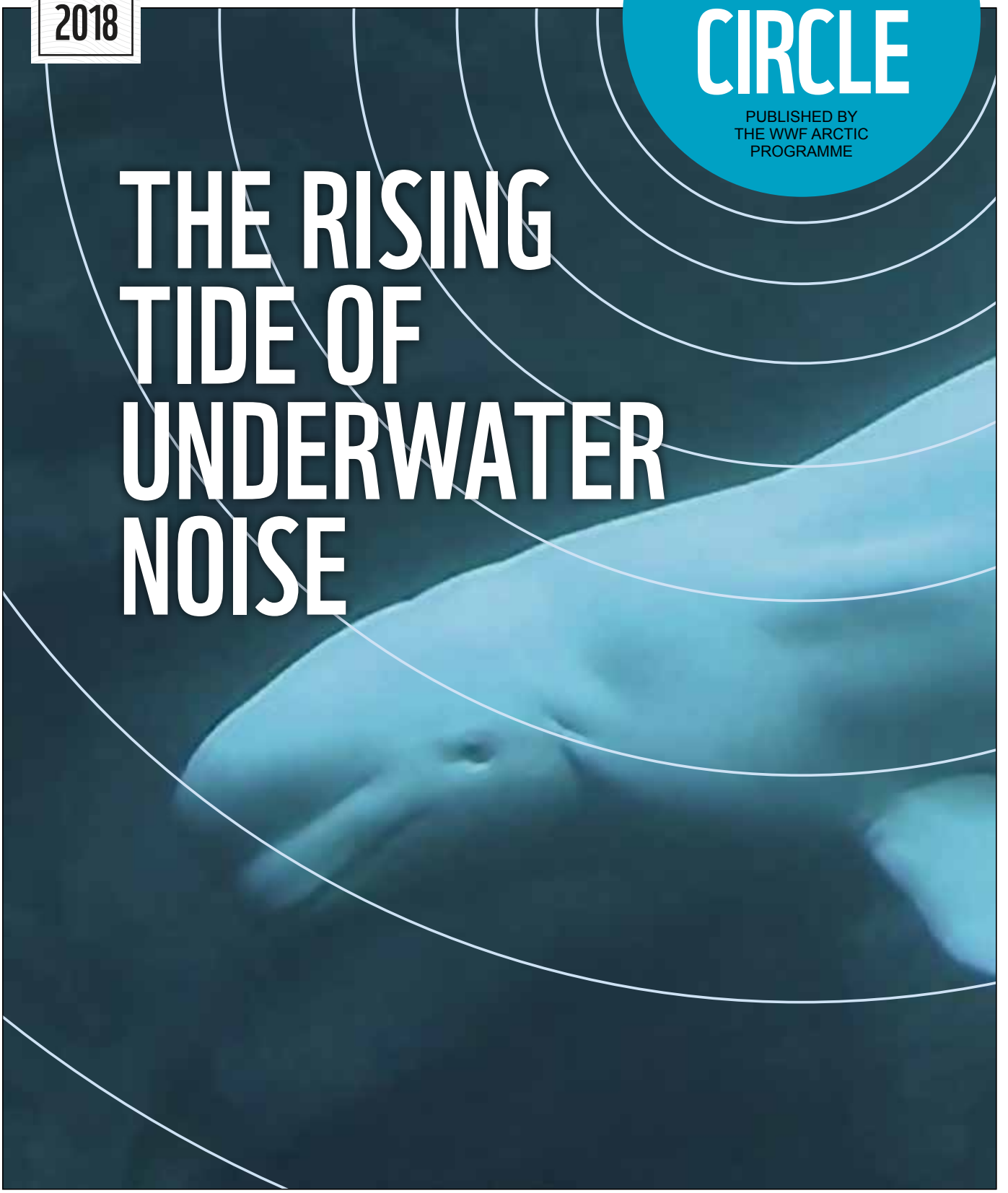
THE RISING TIDE OF UNDERWATER NOISE



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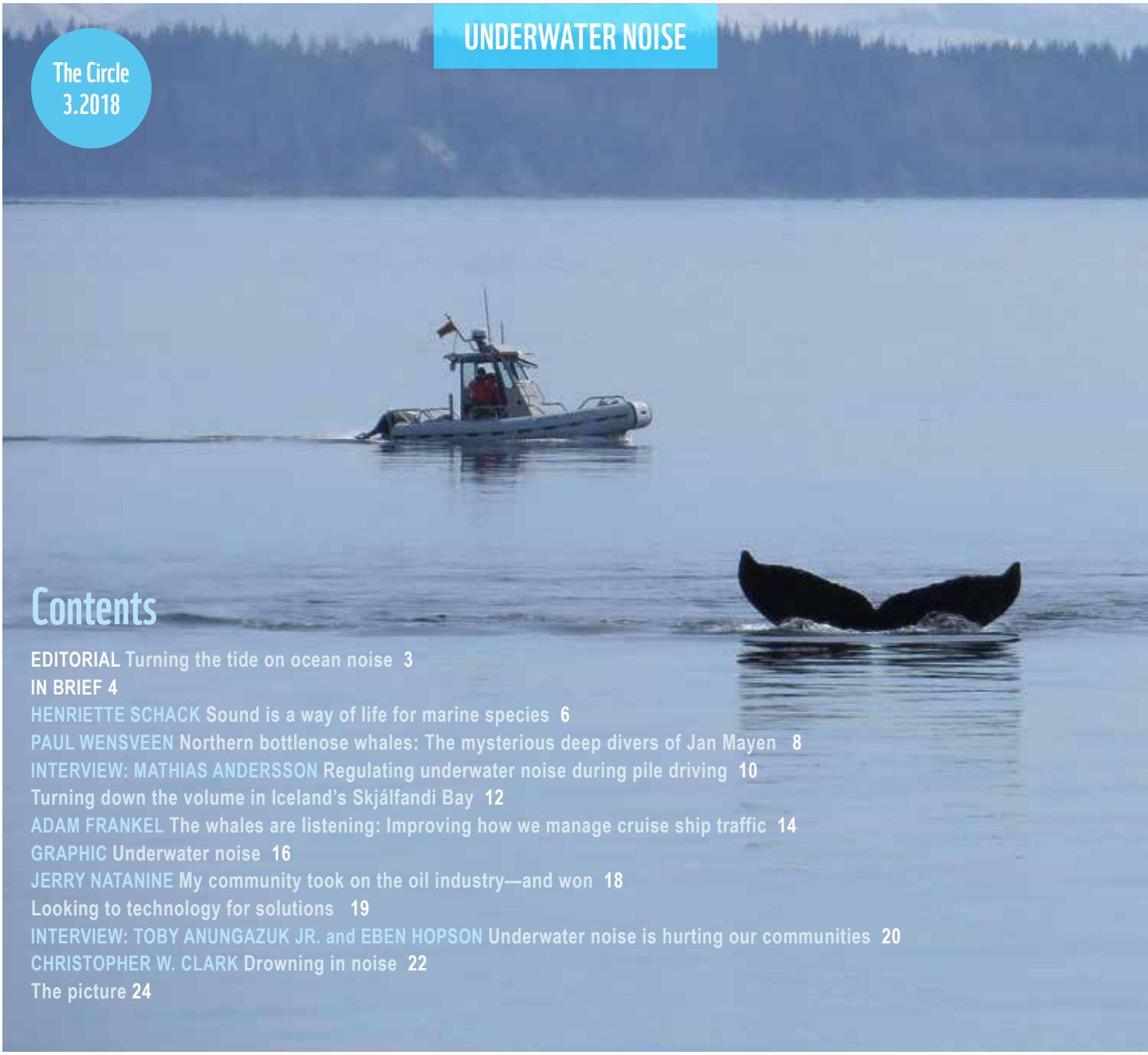
UNDERWATER NOISE



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COVER: Beluga whale.
Photo: Greg Hume

ABOVE: Humpback whale, Alaska.
Photo: National Park Service whale biologists under the authority of scientific research permits issued by the National Marine Fisheries Service.

EDITORIAL

Turning the tide on ocean noise

THE OCEANS are filled with natural sounds—but also, increasingly, by human-made noise. There is probably no ocean left in the world that is not affected by noise from industry, shipping or military sonar.

Until recent years, the Arctic was one of the last refuges from such noise. But new access made possible by climate change is increasing both shipping traffic and fossil fuel exploration. The Arctic Sea may soon become a noise-filled basin like all the others, with the same unfortunate impacts on marine life and local communities.

Most ocean life relies on natural sound for vital life functions, using it to communicate with each other, find prey, find mates, detect predators, orient themselves and sense their surroundings. Ocean species are not adapted to anthropogenic noise, and can be injured or killed by elevated and prolonged levels when these basic life functions are compromised.

Studies have shown that ocean noise events can cause fish catch rates to drop substantially, with larger fish leaving the area. By-catch rates increase as fish abundance decreases in the presence of noise. Across the world, unchecked propagation of ocean noise is undermining efforts to achieve healthy, sustainable oceans and restore fish stocks—a priority established in the 2030 Agenda for Sustainable Development. The implications for human livelihoods and food security are serious. Other industries are likely to be affected as well, such as tourism, which includes the multi-billion-dollar whale-watching industry.

There is growing international consensus on the need to address this pressing issue. A number of multilateral environmental agreements have yielded resolutions about regulating ocean noise, including the Convention on Migratory Species, which recently released international Guidelines on Environmental Impact Assessment for Marine Noise-generating Activities.

It is crucial that we consider ocean noise across ocean management. Implementing fish stock restoration measures, such as "no fish" zones, may not be enough if fish mortality, health and behaviour are compromised by noise-generating activities. Similarly, networks of marine protected areas (MPAs) can be effective means of protecting marine life—but without buffer zones, noise flows freely into these areas and devastates the species MPAs are meant to protect.

We must mainstream the consideration of ocean noise and include it in all ocean management decisions, including those in the Arctic. This means assessing the best available scientific evidence, establishing the best practice standards, and enacting ecosystem-based management and the precautionary principle throughout Arctic processes.

THE ARCTIC NEEDS OUR INTERVENTION NOW, BEFORE TOO MUCH DAMAGE OCCURS.

Ocean noise travels vast distances. Its transboundary nature must be managed globally. The Arctic needs our intervention now, before too much damage occurs.

The good news is that momentum to regulate ocean noise pollution is growing with the UN Open-ended Informal Consultative Process on the Oceans and the Law of the Sea. The Convention on the Law of the Sea (UNCLOS) is dedicated to ocean noise this year. There will also be an opportunity to include ocean noise in the first intergovernmental conference for the legally binding agreement for the high seas under UNCLOS.

I believe that if there is political will, we can turn the tide on ocean noise. ○

SIGRID LÜBER is the founder and president of OceanCare and co-chair of the Joint Conservation of Migratory Species of Wild Animals (CMS)/ Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS)/ Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) Noise Working Group.

STUDYING FISH BEHAVIOUR

New research shows underwater noise harms fish

A NEW STUDY has found that noise from human activity affects the ability of fish to survive.

A collaborative research team at the University of Victoria, Canada analyzed 42 studies from around the world on the effects of underwater noise on fish behaviour and physiology. Their meta-analysis, published in Global Change Biology, found that anthropogenic noise was the most compromising factor in the ability of fish to forage, reproduce and avoid predators.

The research team, led by University of Victoria fish ecologist Francis Juanes and doctoral student Kieran Cox, concluded that when subjected to underwater noise, most fish species become stressed and have difficulty hearing.

The study notes that marine ecosystems could face dire consequences if ocean noise continues its current trajectory. Unlike on land, the problem will not be solved by simply creating marine protected areas, since sound travels through water more easily than through air. Noise in the open ocean has increased steadily since the 1950s.

MUSICAL WHALES

Study finds bowhead whales use "complex singing" to mate

IN APRIL, University of Washington oceanographer Kate Stafford published a study in Biology Letters revealing that critically endangered bowhead whales near Greenland make highly complex "singing" sounds to find and attract mates.

The whales—which can weigh 75 tonnes and live for two centuries—make few sounds when not searching for mates, but sing 24 hours a day through the breeding season from November to April. During that time, the whales mainly live in darkness under pack ice.

Stafford's findings are the result of years of study in the Fram Strait, a deep-water passage off the east coast of Iceland. Before the study, it was assumed that bowhead whales' "singing" was like that of humpback whales, where all members of a population sing a similar song. But Stafford found that bowhead whales improvise, and compares their communication to a kind of freeform jazz.

Participants in the 2017 Students on Ice expedition overlook Ilulissat Icefjord in western Greenland.

Photo: Martin Lipman, SOI Foundation

THE QUEST FOR ARCTIC OIL

Norway pushes east in Barents oil exploration

THE NORWEGIAN government plans to expand oil drilling in the Norwegian and Barents seas. In May, the country's minister of oil and energy, Terje Søviknes, announced 103 new oil exploration blocks—47 in the Norwegian Sea and 56 in the Barents, including new blocks in the eastern Barents, closer to Norway's maritime border

RESEARCH AT SEA

Students on Ice Arctic expedition sets sail

THIS SUMMER, 120 youth from across the globe will board the *Polar Prince*—a 67-metre (220-ft) research icebreaker—to travel from western Greenland to the Canadian high Arctic.

Since 2000, Students on Ice (SOI) has led the annual Arctic expedition to provide insight into the dynamics of climate change, traditional knowledge, scientific research, policy and other important Arctic and global topics. The trip brings together Indigenous and non-Indigenous youth and staff as well as scientists, elders, artists, historians and leaders.

The 2018 expedition sets sail from Kangerlussuaq, Greenland on July 25, 2018. It will cross the Davis Strait and travel through the eastern entrance of the Northwest Passage before ending up in Resolute Bay, Nunavut in early August. This year, the focus will be on the UN Sustainable Development Goals (SDGs) and how youth can apply the goals in their daily lives and communities.

with Russia. An oil exploration block is typically an area of thousands of square kilometres awarded to oil drilling and exploration companies by a country's government.

A substantial drilling campaign in the Barents last summer failed to turn up new potential commercial oil fields, but Norway's petroleum industry remains undeterred. The country's minister of oil and energy defended the activity by saying new oil discoveries create jobs and revenues.

The news disappointed WWF and a variety of global environmental organizations, some of whom called the plans irresponsible and pointed out that Norway is already the world's seventh-largest exporter of fossil fuels.

Sound is a way of life for marine species

Photo: Christopher Michel

Photo: Gabriel Barathieu

Top: Russian icebreaker 50 Let Pobedy *(50 Years of Victory); bottom: sperm whale and calf.*

In an underwater environment where light is often limited, the acoustic soundscape holds key information for many marine organisms, including those who migrate over great distances in search of food and mates. But as HENRIETTE SCHACK notes, with human activities increasing in the Arctic, the soundscape is changing—and the effects could be substantial for animals and humans alike.

CLOSE YOUR EYES and try to imagine the sounds of the Arctic: Ice creaking as it moves with the wind and the currents. Continuous fizzing of bubbles released from melting ice. Sudden, loud cracks from breaking icebergs. And in the background, the whistles and calls of belugas and narwhals, the songs of bowhead and fin whales, and the barks, yelps, chirps, knocks, trills, moans and grunts of ringed seals, bearded seals and walruses.

All of these diverse sounds have long combined to form the Arctic orchestra. Newer to the auditory scene are man-made sounds—many of which directly interfere with naturally occurring sounds in both frequency and intensity.

Marine mammals depend on acoustic information to survive. Precisely what information they use, and how they use it, is still a mystery—but our understanding of their senses has been developing steadily through decades of research. For example, we now know that toothed whales, like belugas and narwhals, emit intense high-frequency clicks and use the echoes reflected by prey to locate and eventually capture it. They also use echoes to avoid obstacles. This is known as echolocation. Baleen whales, such as bowhead and fin whales—as well as pinnipeds—use their hearing to communicate with each other and most likely also for orientation and navigation.

How do various species of marine mammals respond to anthropogenic noise?

Scientific studies have shown that noise from human activities can affect marine mammals in various ways:

- Some whale species have been observed compensating for noise by calling or singing more loudly, shifting their signals up in frequency, calling more often or simply going quiet until the noise has passed.
- Many studies have found that noise can cause behavioural changes, such as flight and avoidance.
- Narwhals and belugas have both been observed reacting to noise from icebreakers at long ranges—but where belugas would flee and call to each other in alarm, narwhals seemed to stop calling and sink down in the water column instead.

How and when animals change their behaviours to cope with noise depends on a wide variety of factors. Existing ambient noise levels and the animal's proximity to a sound source are two important ones. With greater levels of ambient noise, animals must be closer to other members of their species to hear them. Ice conditions can also change how animals react. Factors such as age and sex—and what the animal is currently doing, like foraging—can also play a role.

As ice-free periods in the Arctic become longer and more frequent, shipping and exploration for oil and gas are increasing. Shipping is expected to expand considerably in the coming decades. The consequence could be a substantially altered Arctic soundscape. Noises from container ships, cruise ships and icebreakers overlap in frequency with the known or presumed hearing range of many marine mammals, as well as with sounds produced by these animals, interfering with their ability to communicate, navigate, forage, mate and defend themselves. As well, the high-intensity noise of oil and gas exploration has the potential to cause hearing loss in marine mammals. Exposure to intense noise, like that from seismic surveys, or longer exposure to lower levels of noise, can cause temporary or permanent hearing loss in animals and may cause changes in stress hormone levels.

PRECISELY WHAT ACOUSTIC INFORMATION MARINE MAMMALS USE, AND HOW THEY USE IT, IS STILL A MYSTERY—BUT WE KNOW THEY DEPEND ON IT TO SURVIVE.

HENRIETTE SCHACK is a freelance environmental consultant in Denmark who specializes in risk and impact assessments of underwater noise and marine organisms.

Underwater noise has long been a concern regarding marine mammals. New studies are constantly contributing pieces of the puzzle, but exactly how changes in the Arctic soundscape will affect marine mammal populations is still just guesswork.

What is clear is that the time for preventive action is now. With human activities still at relatively low levels in the Arctic, we have a unique opportunity, through careful marine spatial and temporal planning, to shape how we utilize the area. If we make the right decisions now, we can preserve the harmony of the Arctic's underwater orchestra in a way that benefits animals and humans alike. ○

Northern bottlenose whales:

The mysterious deep divers of Jan Mayen

In the early 2000s, mass strandings of beaked whales during military exercises in temperate and tropical waters put the issue of navy sonar and marine mammals on the map. As PAUL WENSVEEN tells us, recent research expeditions to Jan Mayen, a Norwegian volcanic island in the Arctic Ocean, suggest northern bottlenose whales—the beaked whales of the Arctic—are also very sensitive to underwater noise.

AGAINST THE DRAMATIC backdrop of Jan Mayen's glacier-covered volcano, Beerenberg, a group of four northern bottlenose whales surfaces to breathe. The animals have been diving for almost an hour, reaching depths of more than 1,500 metres. In this otherworldly environment where sunlight does not penetrate, the whales rely on their hearing and ultrasonic clicks to find food and stay in contact with each other. The clicks function as an acoustic flashlight.

Suddenly, an unusual sound is produced near the surface of the sea several kilometres away from the whales. The sound is barely audible to them at first, but it repeats every 20 seconds and grows louder each time. Curious by nature, the animals stop foraging and move in the direction of the source. Soon, however, the synthetic sonar sound is loud enough to provoke a large-scale avoidance response. Many whale groups in the area travel dozens of kilometres away from the source of the noise, and only return to their normal feeding behaviour hours later.

This scenario is based on actual events observed during an experiment in 2013 near the remote island of Jan Mayen (71° N), located on the North Atlantic ridge; the sonar sounds were being played by researchers. The results of subsequent experiments in 2015 and 2016 suggest that the whales' avoidance response was not a fluke. The scientists who were lucky enough to study these magnificent animals used controlled playbacks and careful monitoring along with on-animal tags and passive acoustic receivers. The sonar sounds they played for the whales were softer than real sonar and played for shorter periods. The concern is that actual sonar operations many lead to even longer and larger-scale behavioural responses than those observed.

PAUL WENSVEEN is a University of Iceland researcher focusing on the impacts of noise on marine mammals. He is also a member of the "3S Project," an international research consortium studying the effects of navy sonar on cetaceans.

Photo: Eirik Grønningsæter

Photo: Miguel Neves dos Reis

Photo: Saana Isojunno

Little is known about northern bottlenose whales: they spend minimal time on the surface, dive to depths of more than 1,000 metres, and can disappear for an hour or two at a time.

EXTREME LIFESTYLE MAKES BOTTLENOSE WHALES HARD TO STUDY

We know very little about northern bottlenose whales because they spend only minutes at the surface and often dive to depths greater than 1,000 metres, disappearing for up to an hour at a time. Dives lasting as long as two hours have been reported. However, it is believed that populations are still recovering from the whaling era. While only one report of a sonar-induced mass stranding involved a northern bottlenose whale, other forms of disturbance may be more concerning from a conservation viewpoint.

The northern bottlenose whales of Jan Mayen are representative of other beaked whales living in areas without frequent exposure to sonar, so they provide an important case study. The evidence suggests that beaked whales near navy training ranges respond less to distant and predictable sound sources than to close and unpredictable ones at the same decibel level. From this, we infer that they may have learned to tolerate certain noise exposures based on previous experience. But this might not be the case for whales that have spent much of their lives in the largely pristine acoustic underwater environments of the Arctic, such as narwhals and northern bottlenose whales, which both seem highly sensitive to man-made noise.

RESEARCHERS THINK BEAKED WHALES REGULARLY EXPOSED TO PREDICTABLE NOISE MAY LEARN TO TOLERATE IT. BUT THIS MAY NOT BE THE CASE FOR BOTTLENOSE WHALES THAT HAVE SPENT THEIR LIVES IN THE LARGELY PRISTINE ACOUSTIC UNDERWATER ENVIRONMENTS OF THE ARCTIC.

Navy operations and oil and gas exploration both rely on sound to "see" under water, and this is unlikely to change any time soon. The North Atlantic Treaty Organization (NATO) is also showing renewed interest in the Greenland–Iceland–UK gap, and the Arctic is strategically important in anti-submarine warfare. In addition, climate change is likely to lead to increases in oil and gas exploration and heavy shipping in the Arctic. Given the scale of the challenges ahead—and the difficulties involved in studying marine mammals—all stakeholders need to continue to work together to minimize the impact of man-made noise in the area and protect the marine mammals that live there.

Jan Mayen is a Norwegian volcanic island in the Arctic ocean.

Regulating underwater noise during pile driving

Pile driving generates some of the most disruptive underwater noise. We asked MATHIAS ANDERSSON, a Swedish fish ecologist and bio-acoustician with the Swedish Defence Research Agency, about the current state of pile-driving regulation around the world. Andersson has been studying the impact of sound on marine life for a decade and recently published *A framework for regulating underwater noise during pile driving*, an extensive review of scientific literature on underwater noise from pile driving and its effects on marine life.

Pile driving involves repeatedly pounding long pipes into the ocean floor to support structures.

PILE DRIVING involves repeatedly pounding long pipes—made of wood, steel or reinforced concrete—into the ocean floor to support other structures, such as bridges, piers or turbines. To drive the piles down, a hydraulic hammer strikes their tops repeatedly at a rate of once per second. Depending on the project, it can take up to 5,000 strikes per pile. The noise can reach levels high enough to disturb, injure or even kill some marine animals.

What is pile driving used for, and why is it necessary?

Pile-driving is a well-established method of building a structure on the sea floor. For example, if you want to build a wind turbine, you can hammer the metal piles down to 30 or 40 metres depth and the structure will be quite stable. Any time you want to attach something to the sea floor, pile driving is the solution. It has probably been used to build most harbours in the Arctic. The downside is it makes a lot of noise in the water.

What sort of regulation is there around pile driving?

It is mixed—some countries are quite progressive, others less so, and there is no single international agreement. Taking Sweden as an example, environmental law here says you should use the precautionary principle: if the effects of an activity are unknown, you shouldn't do it. As well, steps need to be taken to minimize the impact on species that are on the International Union for Conser-

"Finding a worldwide solution will never happen because there are simply too many regional differences in terms of species and activities," says Swedish fish ecologist and bio-acoustician Mathias Andersson.

Photos: FOI, Swedish Defence Research Agency

Photo: Swedish Defence Research Agency (FOI)

vation of Nature (IUCN) red list, such as the harbour porpoise. Sweden has signed various international treaties, like the HELCOM (Baltic Marine Environment Protection Commission) treaty and the OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic). But there is no single global agreement when it comes to pile-driving noise and animals.

Should we have something more unified among countries?

In my view, no. I think each nation needs to deal with its own issues. Finding a worldwide solution will never happen because there are simply too many regional differences in terms of species and activities. How far and how quickly sound travels in water depends on local conditions as well. A generic threshold wouldn't be helpful.

One multinational initiative we do have is the International Council for the Exploration of the Seas (ICES) impulsive noise events registry. It's not regulatory, but it supports HELCOM and OSPAR by collecting data on events like pile driving, controlled explosions and other activities to increase knowledge of trends in underwater noise. It will also be used in the future to evaluate the pressure of impulsive sound on the marine environment, according to the EU's Marine Strategy Framework Directive (MSFD). In this work, a threshold for noise will be developed, not with regards to individual piling activity but in terms of the cumulative impact on a regional scale.

Which countries are most progressive when it comes to regulating pile driving to protect marine species?

I would say in terms of mitigation techniques, the leaders are Germany, the UK, the Netherlands, and to a slightly lesser extent, Denmark—and because they're ahead in mitigation, it's also natural for them to have more developed regulations. Here in Sweden, we have just one big offshore wind farm and three small ones, so there hasn't been a big debate, though pile driving also occurs in the construction of harbours here.

Are there new technologies that can make pile driving less disruptive to marine life?

Yes, several. One approach is to use cofferdams, which involves placing the piles inside tubes to help keep the noise from travelling. Or you can have a bubble curtain around the pile driving, which involves a hose at the bottom that releases bubbles into the water, or you can erect nets with plastic bubbles. Another approach is to alter how you hammer: if you hammer more forcefully, the work will go more quickly, but it will be louder. If the maximum sound level is more important than the duration, you can hammer more softly—but it will take more strikes and more time to get it done. The choice depends on what local species you want to protect. That's a good example of why it's so difficult to come up with a global or even a national strategy.

IN PILE DRIVING, A HYDRAULIC HAMMER STRIKES THE TOPS OF THE PILES AT A RATE OF ONCE PER SECOND, AND IT CAN TAKE UP TO 5,000 STRIKES TO FINISH ONE PILE. THE NOISE CAN REACH LEVELS HIGH ENOUGH TO DISTURB, INJURE OR KILL SOME MARINE ANIMALS.

If these mitigation strategies exist, why aren't they used more often?

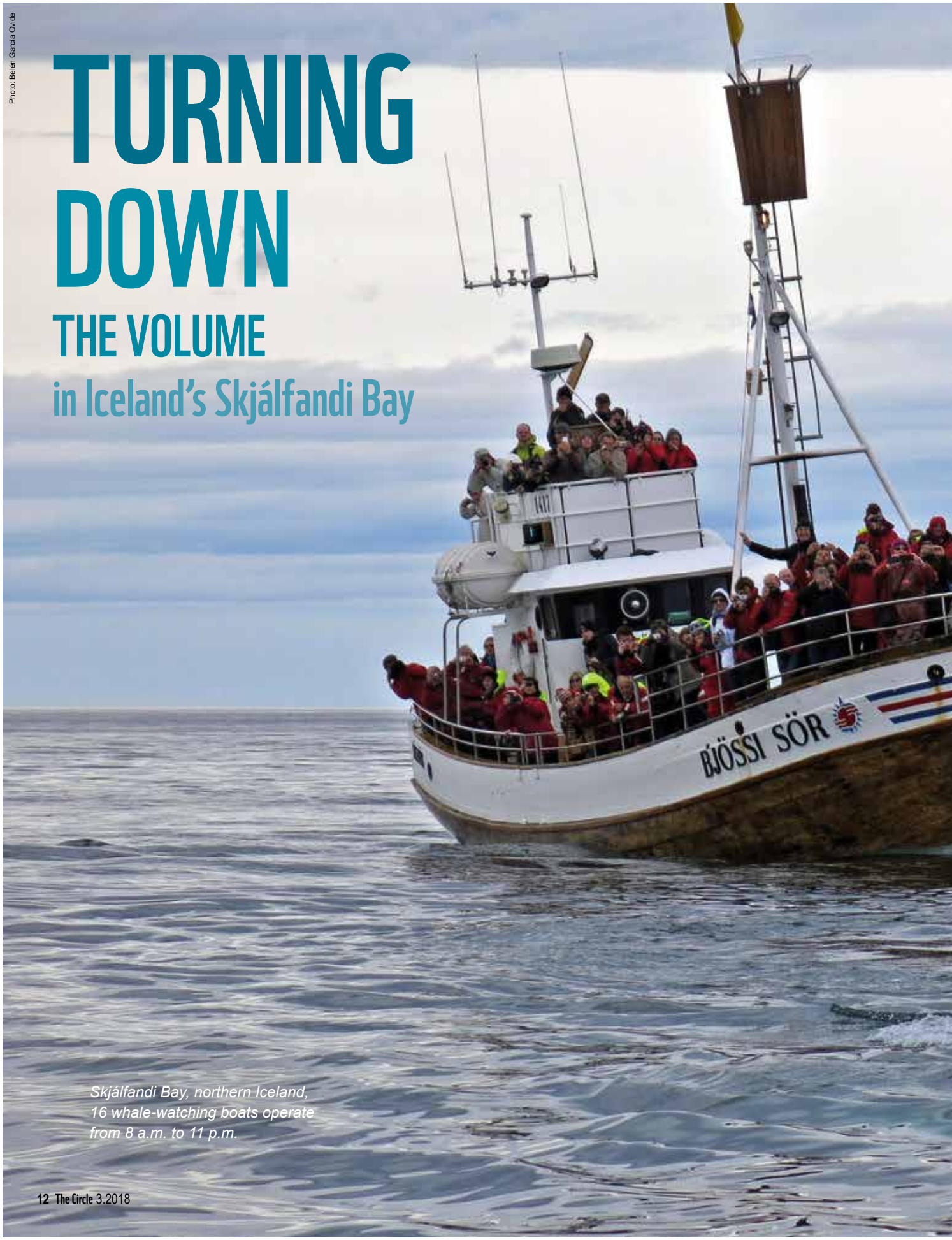
Mitigation costs money—for example, it can make construction take longer—so there has to be an incentive for industry. We can learn from Germany: it set a very strict threshold for injury of the harbour porpoise, in terms of sound level, and industry was not able to comply right away. But after a few years of research and technical development, companies now have the technology to comply with the set threshold. I think the lesson is that if a government is going to set a high standard, it has to be willing to help pay for some of it. ○

■ You can download a copy of Andersson's research report at: www.naturvardsverket.se/Om-Naturvardsverket/Publikationer/ISBN/6700/978-91-620-6775-5/.

Photo: Belén García Ovide

TURNING DOWN THE VOLUME

in Iceland's Skjálfandi Bay



Skjálfandi Bay, northern Iceland, 16 whale-watching boats operate from 8 a.m. to 11 p.m.

Nestled on the eastern edge of Skjálfandi Bay in northern Iceland, the picturesque town of Húsavík is known as one of the best places in Europe to get a close-up look at whales. In fact, you have a better chance of seeing a whale in Húsavík than any other place in Iceland. Because of the bay's thriving ecosystem—teeming with plankton—humpbacks, minke and blue whales come here to feed from May to October before heading south for the winter to mate. But is the town's thriving whale-watching industry distressing these magnificent mammals?

WHALE-WATCHING BOATS first began setting sail from Húsavík's picturesque harbour in 1995. But Iceland's recent tourism boom has resulted in growth in the whale-watching industry—and the number of ships in Skjálfandi Bay.

"When I moved here in 2014, there were only two whale-watching companies," says Belén García Ovide, a Spanish marine biologist who has worked as a whale-watching guide and studies the impact of noise on Húsavík's whales. "This year, we can see four different companies and 16 whale-watching boats operating from eight in the morning to 11 at night. So it is non-stop for the whales."

While working as a guide, García Ovide says she began to wonder what effect the increased boat traffic from tours was having on the whales, and decided to make it the focus of her research.

"We put some tags on the humpback whales and saw a reduction in their foraging activity when the whale-watching boats approached them, compared with when they were far away," she explains. "We also found the whales were diving deeper when they were exposed to higher noise intensity."

Her concern is that the increased noise from tourist boats is driving the whales out of their foraging areas and causing them to be stressed and expend extra energy during the critical feeding season. This could mean they might not find enough food during the summer months, making it difficult for them to reach their breeding grounds. She is looking to work with all of Húsavík's whale-watching companies to ensure they take concrete steps to limit underwater noise in the bay. She points to the town's whale-watching pioneer, North Sailing, as an example of how a company can do it properly.

When it launched its first two boats over 30 years ago, the company made it a priority to have as little impact as possible on the whales and their environment. ➤

Photo: North Sailing

The Opal is one of two boats operating in Skjálfandi Bay that uses wind power to charge its electric engine.

"We've tried for a responsible approach to nature, in terms of guidelines on how we approach the animals in their environment. We've also tried to curb fuel consumption and noise by keeping speeds down, so we are not pushing the engines or propeller too hard," says North Sailing's co-owner Heimir Harðarson.

North Sailing has also worked with other Icelandic and Nordic partners to develop a new electrical system that allows wind power to charge their boats' electric engines. So far, the company has installed the system on of two of its nine whale-watching ships, *Opal* and *Andvari*.

Photo: North Sailing

Marine biologist Belén García Ovide taking boat noise recordings in Skjálfandi Bay.

"The system was designed to create a relatively noise-free boat, as long as you drive it sensibly. Because even with an electric boat, the propeller will make some noise," says Harðarson. "The next step is designing the propeller with that in mind." According to Harðarson, North Sailing is the only company in Skjálfandi Bay taking such steps to reduce the noise its boats create—and lessen their impact on the whales in the bay.

For her part, García Ovide wants to see more companies take steps to design their boats to be quieter, more efficient and eco-friendly, and to monitor noise levels in the bay and the potential effects on the whales.

She also plans to turn her attention to cruise ships, which are an increasingly common sight in Skjálfandi Bay.

"We are interested in these big ships because there are more coming every year. Some of them are generating a lot of noise in the bay, and we can actually see the whales getting crazy when they approach," she says. "There is no specific track the cruise ships have to follow—they just come into the middle of the bay. They often disturb the smaller boats as well as the whales. We would like to do something about it." ○

The whales are listening:

Improving

Sound is the one sensory medium that travels well through water—and biologists like ADAM FRANKEL are learning how critical it is to animals ranging from mollusks to baleen whales. His research reveals that slowing cruise ships down and altering their schedules may be two of the best ways to ensure whales can communicate properly.

I FIRST BEGAN to investigate the critical role that sound plays for ocean life almost 25 years ago. In July 1984, I arrived in Glacier Bay, Alaska, to study the effect of cruise ships on humpback whale behaviour. Fast forward 30 years: I am now an acoustic biologist focused on marine mammals, and have studied a wide variety of dolphin and whale species from Barrow, Alaska to Kaikoura, New Zealand. Managing and mitigating the impacts of vessels on humpback whales is important for Glacier Bay National Park (GBNP), and was the focus of a research project I worked on recently with Christine Gabriele, the chief humpback whale biologist for Glacier Bay.

Our project used software to simulate whale and vessel movement in the bay and predict both vessel noise levels and the amount of "quiet" time whales likely experience. The software measured the cumulative sound exposure level (CSEL), or total amount of noise, a whale is exposed to over an entire day.

We found that cruise ship speed was the dominant factor in how much noise

how we manage cruise ship traffic

Photo National Park Service whale biologists under the authority of scientific research permits issued by the National Marine Fisheries Service.

the virtual whales were exposed to. In fact, the median CSEL values from two slow ships were lower than from just one fast ship. We also found that even though slower cruise ships produce longer exposure times, they generate lower CSELs—three times lower than fast cruise ships. Synchronizing cruise ship arrival times had little effect on CSEL, but it did create longer quiet periods that could benefit whale communication.

This research tells us that slowing existing ships and altering their schedules are two of the easiest ways to mitigate the effect of noise on whales. Slowing ships would also increase fuel efficiency, reduce the probability of ship strikes, and decrease the amount of air pollutants produced.

The shipping company Maersk has taken a positive step by starting a radical retrofit program that has not only decreased the cost per container by 15 per cent, but also reduced the sound output of its ships by half (6 dB). We already know that the physical condition of vessels also affects their sound output. For example, damaged propellers and barnacle-encrusted hulls make for louder ships.

We need to find more ways to encourage shipping companies to take on initiatives like this. The International Maritime Organization has pledged to reduce ship noise levels, but the goals and guidelines are voluntary. As an incentive, the Canadian ports of Vancouver and Port Rupert reduce berthing fees for certified quiet ships. Initiatives like these may be a productive way forward, since they can help reduce shipping impacts and make economic sense as well.

SLOWING EXISTING SHIPS AND ALTERING THEIR SCHEDULES ARE TWO OF THE EASIEST WAYS TO MITIGATE THE EFFECT OF NOISE ON WHALES.

Overall, our study demonstrated how changes in vessel configuration and operation can benefit shipping companies and positively affect the ocean's acoustic environment. Given the increasing numbers, sizes and speeds of commercial ships, such changes are urgently needed. The stakes will get higher as Arctic ice retreats. The more we can do to preserve the underwater sound environment, the better the world will be for the whales that rely on sound in their daily lives. ○

ADAM FRANKEL is a senior bioacoustician with Marine Acoustics, Inc. and a founding member of the Hawai'i Marine Mammal Consortium.

UNDERWATER NOISE

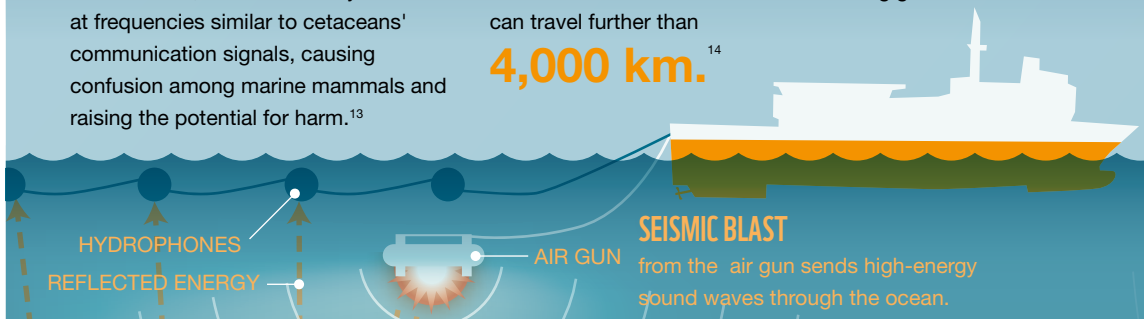
Oceans cover more than 70% of the planet.[1] The Arctic Ocean was a natural "acoustic refuge" for marine animals until recently because of thick ice cover for much of the year.

OIL AND GAS

Oil and gas exploration uses seismic air guns that are 6-7 orders of magnitude louder than the loudest ship sounds. Also, the sounds they emit are at frequencies similar to cetaceans' communication signals, causing confusion among marine mammals and raising the potential for harm.[13]

Ships equipped with air guns fire every 10-12 seconds for weeks or months and the sound can travel further than **4,000 km.**[14]

According to a 2014 report, Inuit throughout the Arctic say seismic surveys are driving animals away from their hunting grounds.[15]



SEISMIC BLAST from the air gun sends high-energy sound waves through the ocean.

WHERE VESSEL NOISE COMES FROM

THE SCIENCE OF SOUND

Generally, sound travels about **4.5 TIMES FASTER** and 60 times further in water than in air. It can travel 1,500 metres/second—more than 15 football fields end-to-end.

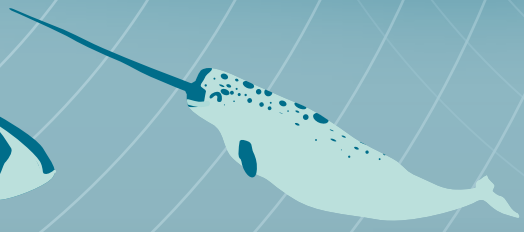
The underwater soundscape of the Arctic Ocean differs from that of temperate waters. For example, it is quieter in areas with short-fast pack ice and noisier in places with frequent ice cracking.[2]

In the Arctic, sound travels longer distances and closer to the surface compared with temperate oceans.[3]

Icebreaking ships in the Arctic have a different "noise signature" versus other vessels. Decibel levels rise when ships break ice.[3]

MARINE ANIMALS AND SOUND

Bowhead whales sing 24 hours a day in winter to woo mates.



East Greenland narwhals spend on average 27% of their time echolocating.[18]

MAJOR SOURCES OF UNDERWATER NOISE [6]

Pile driving and other offshore construction

Military activity

Seismic surveys

1. See https://www.nrdc.org/stories/ocean-pollution-dirty-facts.
2-4. WWF, *Underwater noise from Arctic shipping: Effects on marine mammals and a need for specific guidelines to safeguard biodiversity.*
5. See http://www.cbc.ca/news/canada/north/beluga-ear-research-1.3462069; study was conducted in Tuktoyaktuk (north of Inuvik in NT).
6. See https://www.sciencedirect.com/science/article/pii/S096456911500160X.
7. See http://www.visionproject.org/images/img_magazine/pdfs/international_shipping.pdf.
8. See https://www.nrdc.org/stories/ocean-pollution-dirty-facts.
9. As of March 2018. See https://www.arctictoday.com/canadian-arctic-shipping-traffic-nearly-tripled-25-years/.
10. See http://www.highnorthnews.com/dozens-of-vessels-violate-safety-rules-on-northern-sea-route/.

SHIPPING

60,000 commercial tankers and container ships are on the seas at any given time.[8]

90% of all goods travel by ship.[7]

The distance travelled by ships in the Canadian Arctic has nearly tripled over the past 25 years.[9]

Noise from ship traffic is doubling every decade. [12]

Arctic shipping traffic is expected to grow **4x** by 2025.[10]

In 2017, nearly **88 VESSELS** travelling the Northern Sea Route **VIOLATED SAFETY RULES**.[11]

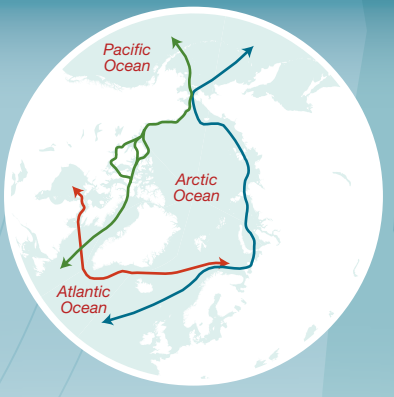
DRAG FROM POOR HULL MAINTENANCE

ENGINE AND ONBOARD MACHINERY

BOW/STERN THRUSTER

PROPELLER

CAVITATION



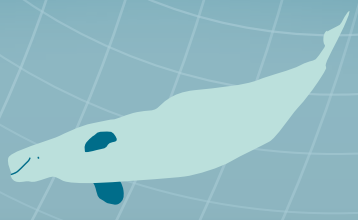
NORTHERN SEA ROUTE

THE NEED FOR PROTECTION

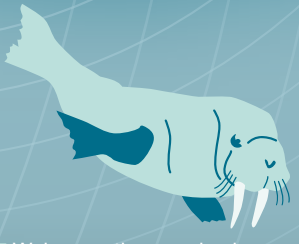
More than **3 billion** people depend on marine and coastal diversity for their livelihoods.[16]

Anthropogenic noise affects fish's ability to locate food, find mates, navigate, communicate and evade predators, and can cause commercial fish species to abandon their habitats.

Just **5%** of the world's oceans are designated as marine protected areas.[17]



Noise can damage beluga whales' hearing by causing a loss of hair cells in their ears.[5]



Walrus mothers and calves recognize each other by voice. Underwater noise can make it difficult for them to reunite using vocal cues if they get separated

Shipping and fishing boats

Sonar

Wind farms

Pleasure crafts

Graphic: Ketill Berger, Film & Form, filmform.no

11. See http://www.highnorthnews.com/dozens-of-vessels-violate-safety-rules-on-northern-sea-route/.
12-13. See https://e360.yale.edu/features/how_ocean_noise_pollution_wreaks_havoc_on_marine_life.
14. See https://www.nrdc.org/stories/ocean-pollution-dirty-facts.
15. See https://www.newsdeeply.com/arctic/articles/2016/02/19/marine-mammals-unsettled-as-arctic-noise-grows.
16. See https://www.un.org/sustainabledevelopment/blog/2016/12/more-than-5-per-cent-of-worlds-oceans-now-protected-with-more-commitments-underway-un-environment-wing/.
17. As of Dec. 2016. See https://www.un.org/sustainabledevelopment/blog/2016/12/more-than-5-per-cent-of-worlds-oceans-now-protected-with-more-commitments-underway-un-environment-wing/.
18. Blackwell, S.B, Tervo, O, Conrad, A.,Guldborg Hansen, R., Sinding, M., Heide-Jørgensen, M-P. (2017) Vocal behaviour of East Greenland narwhals. Society for Marine Mammalogy 22nd Biennial Conference on the Biology of Marine Mammals.

My community took on the oil industry–

Kangiqtugaapik (or Clyde River) is a picturesque community of roughly 1,000 people on the east side of Baffin Island in Nunavut, Canada. The area is home to various sea mammals, including different species of seal, whale and water fowl. But as JERRY NATANINE explains, in 2011, the small community's way of life, food supply and livelihood were threatened—so the town fought back.

LIKE MANY other Inuit communities, most of Kangiqtugaapik's healthy food still comes from the sea. Hunting seals, whales and waterfowl, and fishing for char, are incredibly important to our physical and cultural health. Kangiqtugaapik also benefits from a thriving commercial fishery that provides employment and financial revenues to several communities in the Baffin Island region. We very much depend on the animals and birds that live in and migrate to our area.

In 2011, a consortium of geophysical companies applied to conduct seismic surveys in Baffin Bay and Davis Strait. Seismic surveys are used by oil and gas companies to identify potential oil and gas deposits. This would have meant blasting very loud sounds into the water near Kangiqtugaapik—so loud they would have penetrated the ocean floor. There is evidence from many parts of the world that seismic blasting can harm marine mammals and disrupt fisheries.

During an environmental assessment of the application, there was wall-to-wall opposition from Nunavummiut. Through petitions, letters and resolutions, we made it very clear we did not support the proposed surveys. Both of our Inuit organizations—Nunavut Tunngavik Incorporated and the Qikiqtani Inuit Association—passed resolutions opposing the surveys. The Baffin Mayors Forum, a meeting of all of the mayors from Baffin Island, did the same.

We were against the proposal for three main reasons. First and foremost, we were very worried about the effect seismic testing might have on our hunting way of life. We worried that the noise could harm many parts of the ecosystem, from the big sea mammals like whales all the way down to the tiny plankton. Secondly, the companies did a horrible job of consulting with us. They couldn't answer our most basic questions about potential impacts to the environment, and gave us absolutely no reason to trust them. Finally, they were not offering substantial benefits to our community. The companies would not agree to hire any permanent Inuit employees or share revenues.

> THE SUPREME COURT RULING MADE IT VERY CLEAR THAT INUIT MUST BE CONSULTED EXTENSIVELY WHERE OFFSHORE DEVELOPMENT IS CONCERNED.

We quickly realized this was not "development" they were proposing. It was exploitation.

Despite our objections, the surveys were approved in the summer of 2014. At the time, I was mayor of Kangiqtugaapik. Our Hamlet Council and

JERRY NATANINE is an Inuk from Kangiqtugaapik (Clyde River), Nunavut, and is the town's former mayor. He is currently president of the Clyde River Hunters and Trappers Organization.

Photo: Greenpeace

Photo: Jack Iqaqrialuk

—and won

Hunters and Trappers Organization agreed we should keep fighting and stand up for ourselves and the animals we eat. We approached our Inuit organizations, the Government of Nunavut, our federal Member of Parliament, and several environmental groups. However, none of them were willing or able to help us continue our fight.

We ended up finding help in the most unlikely of places—from Greenpeace, a group that had been detested in Nunavut for decades. Many Inuit are still very angry with the organization because of its anti-sealing campaign in the 1970s and 1980s. The European boycott on sealskins impoverished our communities. But with nowhere else to turn, we decided to make common cause with an old enemy.

With funding from Greenpeace and a lot of volunteer work from many people, we challenged the seismic surveys in court. The next few months of my life were a blur. I will never forget how frantic we were as we rushed to submit our application to the courts. With a deadline only a few days away, and our lawyer's wife going into labour, it was an emotional and exciting time for all of us.

The Federal Court of Appeal dismissed our case, but we didn't give up. We appealed to the Supreme Court of Canada and won. The Supreme Court ruling made it very clear that Inuit must be consulted extensively where offshore development is concerned. By uniting as a community, and by working with our former enemy, we defeated a threat to our well-being and established an important precedent for Inuit rights. ○

This article was written with the assistance of Warren Bernauer, a graduate student at York University in Toronto, Canada who worked closely with Jerry Natanine during Kangiqtugaapik's battle against proposed oil and gas exploration.

Looking to technology for solutions

Oil and gas exploration is happening throughout the Arctic. With increased sea ice melt due to climate change, the pressures to allow even more industrial activity will only increase, leading to more and more noise in underwater environments. A global water and environment firm has developed software for the oil and gas industry to mitigate those harms—but could the tool ultimately make matters worse?

NEW TECHNOLOGY designed to help industry avoid marine animals in Arctic oceans has promise, but may be a double-edged sword.

The technology—software known as MARAMBS (for Marine Animal Ranging Assessment Model Barents Sea)—was developed by DHI, a global firm specializing in technological solutions for water environments, and co-funded by the Research Council of Norway. It mimics the behaviour of various species in the marine environment and models their responses to stresses like underwater noise. The idea is to help oil and gas exploration companies avoid contact with them. In theory, the tool could also be used by regulators or any organization planning protected areas.

"We use the technology to simulate the movements of birds and marine mammals in the Barents Sea," explains Mads Madsen, an ecological and water modelling expert with DHI.

Madsen, who specializes in spill risk assessment during offshore oil and gas activities and manages the MARAMBS project at DHI, developed the software with Dr. Frank Thomsen, a DHI scientist whose research focuses on the sounds made by killer whales and the impacts of human-made noise on whales.

The idea behind MARAMBS is to understand and assess the impacts of human activities on ocean life, including whales and fish, as industry increases in the marine Arctic. The problem with conventional risk assessments is that they are "static," says Madsen—meaning they don't factor in how marine animals change locations. "But we know that marine life is mobile and moves in relation to environmental variables and human impacts," he explains. "Simulating these movements is at the heart of MARAMBS."

MARAMBS can help identify risks earlier and more accurately compared with older technologies, so industry can take more focused management measures. Madsen says operators in the Barents Sea can use the technology's Web-based data portal to plan their activities in the most environmentally friendly manner possible, while research organizations can use it to gather data on marine life.

Data from the MARAMBS project cover the entire Barents Sea as well as parts of adjacent seas, and are available on an hourly, daily or period average basis. Madsen says this allows offshore operators planning activities in a specific area to extract information on the presence and density of species for the relevant activity period.

MARAMBS doesn't currently report on the presence of marine animals in

real time. Its species density maps use hindcast metocean data—historical data derived from a blend of meteorology and physical oceanography conditions like winds, waves and climate. An underlying assumption of the technology is that marine animals' movements and migrations are largely influenced by an area's stable physical conditions—such as currents, salinity and temperature—and can therefore be predicted with reasonable accuracy.

The obvious issue with the existing premise of the technology is that while the goal of MARAMBS is to protect marine wildlife, it also supports the oil and gas industry. It won't reduce industrial activity or development overall—and oil and gas development is hastening climate change, whose effects are felt most intensely in the Arctic.

Nils Harley Boisen, a WWF advisor for Arctic and northern areas, says while technologies like MARAMBS are often branded as tools to help the environment, the problem is they tend to be used as a justification for opening up new oil and gas exploration areas.

"It can be a way for industry to 'de-risk' itself and justify expanding its activities by appearing to have a heightened regard for environmental conditions," says Boisen. "But in reality, it may not reduce the risk or likelihood of accidents happening."

A tool like MARAMBS could be powerful and useful in the right hands, says Boisen, who would prefer to see it used to define marine protected areas. For instance, researchers could test how effective the technology is in a variety of circumstances. But that would mean making the technology accessible to everyone, not just those who can pay.

"This is something environmental authorities should have in their toolbox rather than private companies," he argues. "Unfortunately, we view Norway's ambitions in the Barents Sea as an international door-opener for Arctic oil and gas."

If MARAMBS is indeed suited for broader applications, such as research, regulation and planning, perhaps industry will do the right thing and create the opportunity for more planet-friendly uses for it. ○

Two views, same news:

Underwater noise is hurting our communities

TOBY ANUNGAZUK JR. and EBEN HOPSON are from Alaskan towns almost 800 kms (500 miles) apart. They are also almost half a century apart in age. But they have at least one thing in common—their deep concern over what increasing underwater noise is doing to their communities.

TOBY ANUNGAZUK is a "young" elder who was raised in Wales, Alaska, the westernmost town on mainland North America. He spent much of his early life on the spring shore ice in a boat in the leads or floating around on floe ice.

Eighteen-year-old EBEN HOPSON is from the town of Utqiagvik, on the tip of Alaska, 480 km (300 miles) north of the Arctic Circle. The world he grew up in is much different—and noisier—than the world of Toby Anungazuk's youth.

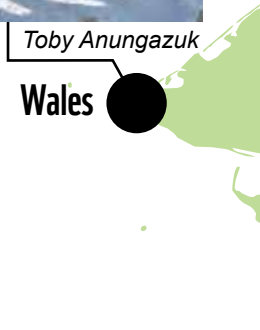
The two Alaskans share their views on underwater noise and its effects on the sea mammals that have long sustained their communities.

What does the term "underwater noise" mean to you personally?

TOBY: Well, I was born in 1955, and I grew up listening to the noises below the water because we relied on them for harvesting—it was very important to put food on the table for the year. If our parents could afford it, we ate one meal a week from a store. But we hunted in the spring and fall. The bearded seal would be making noise, so we would track it. We'd stick our oar or paddle in the water and when we heard a noise, we'd start spinning the paddle until we heard the loudest noise, and that's the direction we'd go.

EBEN: To me, underwater noise means the voice of the animals that we harvest and that sustain us. It means life to me, because without underwater sound, there wouldn't be any sign of life. The sound of the animals in the water—that means life for them and life for my people.

Toby Anungazuk



Eben Hopson

Utqiagvik

What experiences have you personally had listening to these sounds?

TOBY: In maybe 1963, when I was eight years old, I went out to chip the ice and one of the hunters had a boat. They grabbed the oar from the boat and stuck it in the water, and put the spear next to it. I was looking at him wondering because I couldn't really see anything. That was my first experience. I was fascinated by it.

Back in the early sixties, it was actually very quiet, so noises would carry a long way. Now there are generators for power, we have two different airlines that come once in the morning and once in the afternoon, flying to several different villages. Of course, there are also snow machines. So, it's a really big change.

EBEN: In 2016, I went out on the ice, off the shore here in the Bering Sea with a couple of scientists and they opened a hole in the pack ice and dropped a hydrophone in the water. When I first heard the sounds of the seals and whales in the water, that opened up a new world to me because until then, I didn't know what they sounded like in the water. That was really outstanding to me. It was pretty amazing to hear.

How concerned are you about the increase in underwater noise? What does it mean for your community, and for the belugas, bearded seals and other sea mammals that live there?

TOBY: When I was young, hunters could hunt from the ice edge. Early spring migration could be right off shore—all you really needed was a little scull to get seals. Now, to get that same amount of food, they have to go off shore in boats earlier in the spring.

What I'm very concerned about is the increased Arctic shipping. The sea mammals migrate north from Wales, from the northern Bering Strait, and then they go out into the ice. And now there are all these ships that never used to pass through there. If you listen, if you put the oar underwater, you'll hear a ship before you see it. It must be having an impact on the sea mammals that are feeding to gain weight, since it's their prime feeding time of the year and the ships are travelling through the prime feeding areas. The ships might drive them into areas where there is nothing to eat, and they're not going to gain weight. And of course, when the ships have the black smoke coming out, they're putting soot in there and if it's falling on ice, it's making the ice melt faster.

EBEN: In the past they used dog sled teams, so it was really quiet compared to now, with snow machines. The snow machines make a louder sound than a dog team does. When we were out on the ice in April of 2016, when the scientists dropped the hydrophones in the water, there was a snow machine about two miles away driving back into town from a whaling camp, and we heard that really clear on the hydrophone. If it had been a dog sled team coming back into town, we wouldn't have been able to hear it.

If they allow offshore drilling here in Alaska, the sounds of the oil rigs will scare off the animals, altering the migration routes they've taken for hundreds of thousands of years. We're depending more on oil for energy than any other power source. But there are hundreds of streams where we can hook up hydroelectric power plants, there is sun shining on the Earth where we can put solar panels to absorb the power, there is wind blowing every day all around the world and that wind can make power.

Being a native here in Alaska, where we depend on the ocean for food more than the grocery store, and knowing that the outside world is impacting our land for their benefit—that bothers me a lot, because it's where I live and where I was raised. If anyone wants to do anything to the land or the ocean, then they will have to put up a long fight with the Natives.

Drowning in noise

The Arctic is undergoing dramatic and radical changes, most obviously in the loss of sea ice and the associated rise in temperature. Some see these changes as opportunities for year-round commercial shipping and ready access to massive fields of oil and gas beneath the seafloor. This could also lead to acoustic industrialization—the loss of one of the most pristine marine environments on this planet—and threaten the Arctic's magnificent marine life. But as scientist CHRISTOPHER W. CLARK notes, one solution is to create acoustic sanctuaries: places that are still naturally quiet and in which noise-generating activities that perturb that quiet are forbidden.

A HUNDRED YEARS ago, whales and seals roamed the ice-cold waters of the Arctic without fear of seismic explosions from oil exploration or the growing roar of shipping traffic. Around this time, the commercial slaughter of bowhead whales ended, and the Arctic entered a period of relative acoustic tranquility. Whales and seals who were calves and teenagers during the First World War knew the sounds of that quiet ocean, learned to interpret the subtle roars of coastal currents and grew up to understand the tell-tale signs of shifting ice fields and summer calms. They used these cues to recognize opportunities for feeding or mating and to find safe places for giving birth. Listening to and producing sounds in an ocean with little human-induced noise was an essential tool for survival. Unfortunately, those days are long gone.

The natural acoustic soundscape has been blown apart by a crescendo of noise that drowns the calls and songs of whales and seals, that turns their quilted world of precise sound into acoustic static and renders their exquisite listening abilities useless.

Each of the marine mammals endemic to the Arctic has remarkable adaptations that provide distinct advantages for living in the Arctic's harsh environment. Many of these are associated with auditory perception and sound production. That is to say, Arctic marine mammals possess exceptional and delicate bioacoustic abilities. They "see" their underwater world through sound. This underscores the adaptive importance of listening to and producing sounds for survival.

WHALES AND SEALS WHO WERE CALVES AND TEENAGERS DURING THE FIRST WORLD WAR KNEW THE SOUNDS OF THE QUIET OCEAN, LEARNED TO INTERPRET THE SUBTLE ROARS OF COASTAL CURRENTS AND GREW UP TO UNDERSTAND THE TELL-TALE SIGNS OF SHIFTING ICE FIELDS AND SUMMER CALMS.

All Arctic whales and seals use passive and/or active acoustics for life's basic functions: communicating, detecting predators, foraging and navigating. So, for example, they can navigate by passively attending to the sounds of ice grinding, cracking, sliding and exploding, or by actively listening to the reverberations and echoes of their calls, songs and echolocation clicks off ocean ice features. We know from Arctic acoustic research that there are subtle differences in the acoustic environments of multi-year ice, young ice and open water, as well as myriad combinations of these conditions. All Arctic whales, even adult bowheads, can get trapped or die in ice, so there is clearly a selective advantage for specialized attributes that enable marine mammals to sense such threats. A naturally occurring ocean soundscape is essential for these mammals to take full advantage of their adaptations for listening to and producing sounds.

But today, the Arctic's acoustic environment is under siege from civilization's advancing progress. Seismic airgun explosions from surveys conducted off northern Greenland penetrate the coastal waters near Barrow, Alaska, 3,000 km away. The shipping route through the Northwest Passage is becoming readily available as multi-year ice melts, allowing nearly constant noise

Photo: IIP Photo Archive

Adult bowheads can get trapped in ice and die. They depend on acoustics for navigating.

from propeller cavitation.

There is no ambiguity about the reality of this rising tide of anthropogenic din. Yes, there are and will be disagreements about how much and how fast and what is biologically tolerable and what is not. But those are only points of debate along a continuum of threats that are unambiguously increasing the density and distribution of human noise.

Nor is there ambiguity about the extraordinary uniqueness of Arctic marine mammals' bioacoustic capabilities. There is still much we don't know, so there will continue to be scientific revelations about how well they hear and how remarkably they call, sing and echolocate. Those are beautiful waypoints along the trail of discoveries that could further demonstrate life's remarkable and seemingly endless inventiveness and capacity.

But pause for a moment and think about the implications of these two star-crossed trajectories: that is, marine life's continued existence and our exploitation of the Arctic's resources.

Back away as best you can from the temptation to slip into reductionism and determinism, and simply consider the overall situation: the Arctic environment is changing radically, both physically and biologically, in terms of temperature, ice, primary productivity and life. Humans are moving expeditiously to take advantage of the opportunities created by climate change. Will we take into consideration the lost opportunities for the life that's already there? What happens when Arctic life has nowhere to go? Do we care enough to change our ways of life to allow the Arctic's to continue?

Let's agree to leave the natural Arctic soundscape as we found it. Let's establish acoustic sanctuaries in which human noise-making activities are restricted, motorized vehicles are not allowed, and naturally occurring levels of noise are respected. We have learned that restrictions on human-made toxins lead to better lives. Let's apply this same principle to noise by restricting the release of noisy by-products that are harmful to marine life and to our future. I contend that the Arctic requires special attention in the form of protection: a moratorium on exploitation and the unambiguous recognition that its existence as a healthy, frozen, unaltered habitat is critical. ○

CHRISTOPHER W. CLARK is a research professor and senior scientist in the department of neurobiology and behavior at Cornell University.

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THE PICTURE

Kayaking in acoustic tranquility

Photo: National Museum of Denmark

Inuit kayaking at King Island, Alaska. This kayak is broader and more stable than the Greenlandic kayak and was adapted to the difficult waters in the Bering Strait. When kayaking, the Inuit wore clothing made of whale or seal intestines waterproofed with blubber. Waterproof clothing was a necessity for survival when sailing in bad weather and in case of capsizing. *Photograph from the 5th Thule Expedition, 1921 to 1924.*