# OCEANWATCH

## Spotlight

# Understanding Underwater Noise Pollution from Marine Vessels and its Impact on Whales, Dolphins and Porpoises

**Ocean Wise, Lance Barrett-Lennard** | *Whales in the path of a large container ship.*

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# Overview

From rustling leaves to the cacophony of city noises, sounds permeate the world all around us. We live immersed in sounds, as does all marine life. In fact, the underwater environment is filled with natural sounds, including the signals of the animals themselves. Sounds are very important for survival below the waves because light is quickly absorbed, making vision less important. Cetaceans[i] (whales, dolphins, and porpoises) have developed highly sophisticated means to use sound, relying on their sense of hearing for navigating, sensing their environment, finding prey, and communicating.

Noise, which is any interfering sound, can interrupt critical sound cues necessary for the daily life of marine mammals. Many human activities, including commercial shipping, oil and gas exploration and production, commercial fishing, and shoreline and underwater construction, produce high levels of underwater noise. Researchers now recognize that noise pollution is a serious threat to cetaceans and many other marine organisms and are studying how to mitigate its negative impacts.

Here, we summarize the negative impacts of vessel noise on cetaceans. We outline some basic principles of sound underwater and describe how cetaceans use sound so we can better understand why and how noise affects this group of marine mammals. We present four spotlights to highlight where cetacean populations have been impacted by noise pollution within North American waters, including narwhals in the Arctic, killer whales in the Pacific, right whales in the Atlantic, and belugas in the Gulf of St. Lawrence. Lastly, we present a list of recommended actions that can be taken to mitigate underwater noise.

[i] Cetaceans - the collective name for all whales, dolphins and porpoises. Cetaceans are subdivided into baleen whales or mysticetes, and toothed whales or odontocetes.

**Ocean Wise, Valeria Vergara** | *A pod of beluga whales at the water's surface in the Arctic.*

# Underwater noise pollution

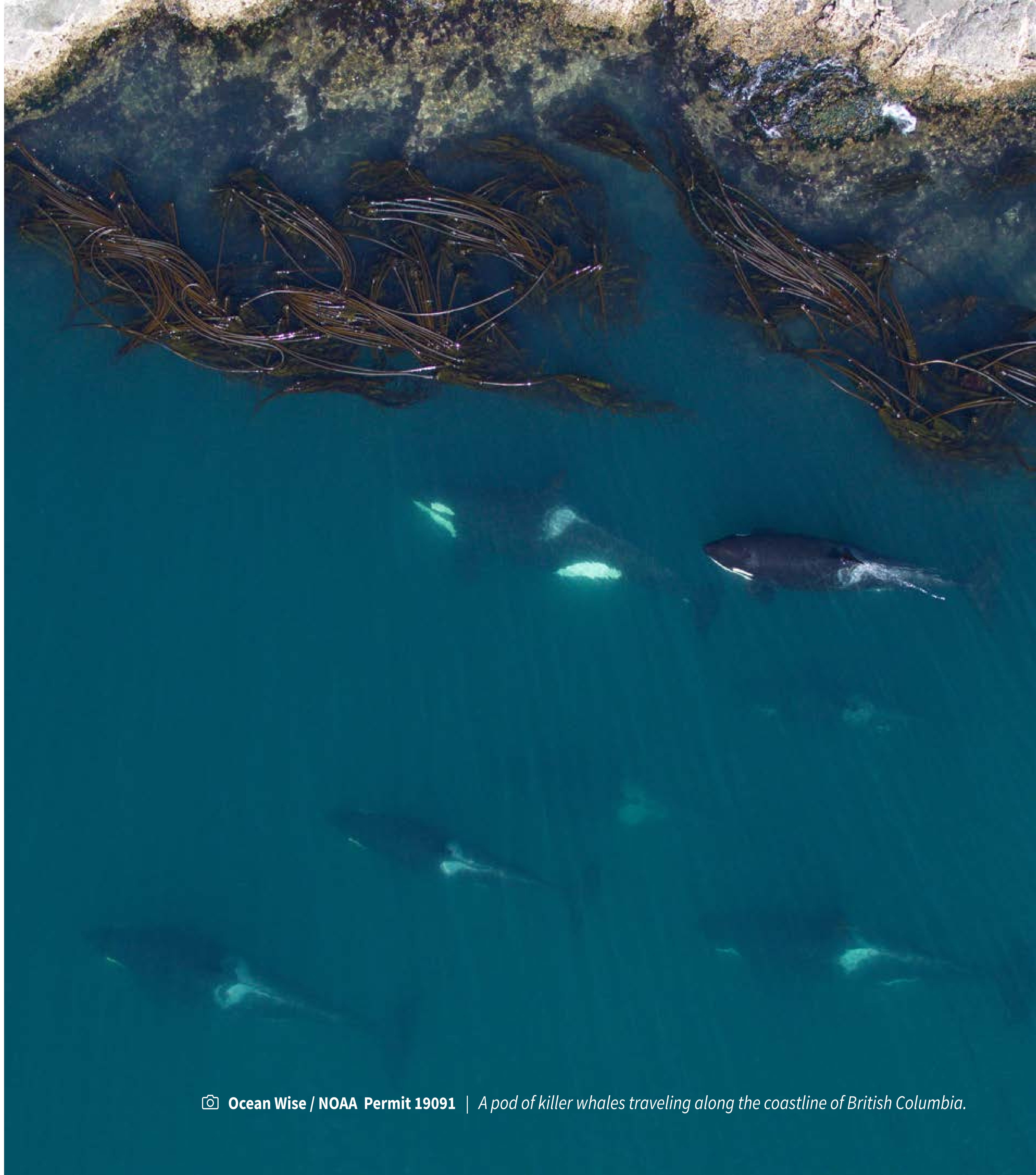
Noise pollution affects many marine species, from whales and dolphins to fish and invertebrates[ii]. The din of human-made noises in our oceans, produced by a wide range of activities such as marine construction and coastal development, resource exploration or extraction, military sonar, and boating and shipping, has become a pervasive threat to marine life, and a global conservation concern. In Canada, noise pollution has been recognised as an issue for more than 10 years. Researchers across many different organisations, including our own researchers at Ocean Wise, and at various levels of government, have been working together to better understand the harmful effects of noise on marine life, and to mitigate these impacts.

In the industrialized northern hemisphere, commercial shipping is typically amongst the predominant low frequency[iii] noise sources (below 1000 hertz, Hz)[iv], except for some Arctic areas.[1] Underwater sound created by smaller boats also contribute to a noisy underwater environment at higher frequencies, especially in coastal habitats.

A phenomenon known as propeller cavitation is one of the culprits. Cavitation occurs when a propeller spins quickly and creates thousands of tiny bubbles as the vessel moves through the water. When these bubbles collapse, they create a loud popping sound. The faster the propeller rotates, the more bubbles are formed, which is why cavitation noise is related to the speed of the vessel. Noise is also caused by a ship's propulsion machinery, and rotating gears and shafts.

From small recreational craft to large commercial ships, the number of marine vessels traveling the ocean is on the rise.[2] The commercial shipping fleet has been growing rapidly as a consequence of globalization, with four times as many ships at sea in 2014 compared to 1992.[3] Accordingly, increases in underwater low frequency noise levels have been documented in many regions of the world, at a rate as high as 3 dB (decibels)[v] per decade.[4] Because the decibel scale is logarithmic, a 3 dB increase in underwater noise is a doubling in sound intensity every decade.

[ii] Invertebrates - an animal lacking a backbone, such as mollusks, sea stars, octopuses, and others.
[iii] Low frequency - when we talk about the frequency of a sound, we refer to whether the sound is high-pitch or low-pitch (imagine keys on a piano). Because sound is essentially a pressure wave of vibrating molecules as it passes through a medium (such as air or water), frequency can be thought of as the number of cycles of a sound wave that travel past the ear in one second and is measured in hertz. High-pitched or high-frequency sounds have many more cycles per second, or hertz, than low frequency sounds.
[iv] Hertz (Hz)- a unit of sound frequency equivalent to one cycle of a sound wave per second.
[v] Decibel (dB) - a unit that measures sound amplitude, or the loudness or intensity of sounds. Because sound amplitude has a very large range, the dB scale is logarithmic. This means that the sound energy doubles for every 3 dB increase. A decibel represents a ratio between a measured pressure and a standard reference pressure at a standard distance, so that the loudness of a sound is described as a level above that reference pressure, much like sea level is used as reference level when we specify the height of a land mass. In water, the reference intensity is 1 micropascal (µPa).



**Ocean Wise / NOAA Permit 19091** | *A pod of killer whales traveling along the coastline of British Columbia.*

# UNDERWATER NOISE POLLUTION NEGATIVELY IMPACTS MARINE MAMMALS

**1**

In the Arctic Ocean, narwhals are especially vulnerable to increased vessel traffic.

**2**

In the Pacific Ocean, the ECHO program aids protection of southern resident killer whales.

**3**

When marine traffic was halted after 9/11, stress hormone levels decreased in North Atlantic right whales.

**4**

Underwater noise can prevent the reunion of separated beluga mother-calf pairs in the St. Lawrence Estuary.

Lance Barrett-Lennard, Ocean Wise | *Southern resident killer whales.*

## What is noise and what is sound?

Most of us have probably never considered the difference between sound and noise. A particular sound may be a noise to some but an important signal to others. Noise is essentially any unwanted sound. It interferes with the ability of marine mammals to hear acoustic signals that they rely upon, such as the calls between a mother and her calf, or the echolocation returning echoes from potential prey.

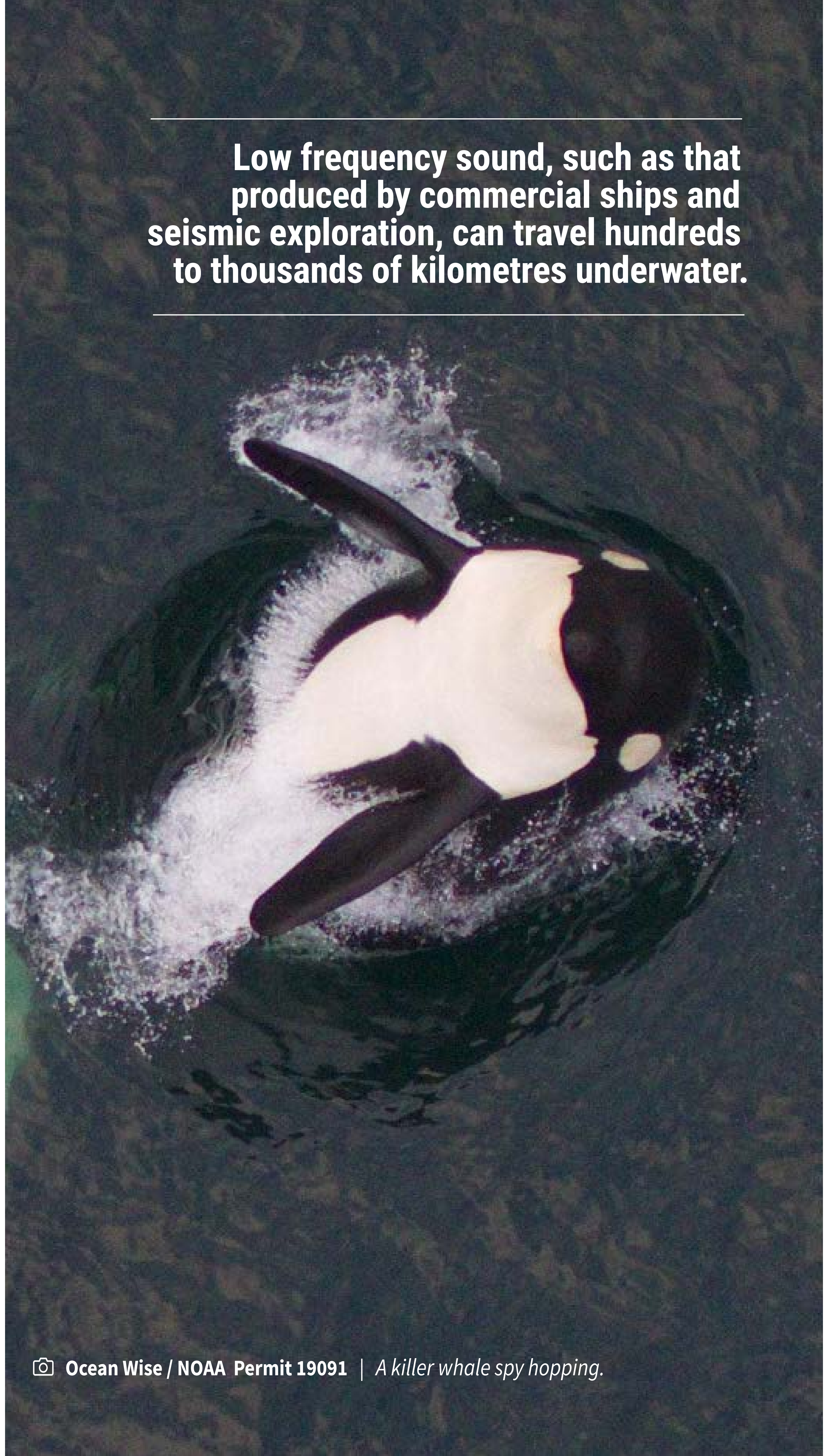
The underwater world is far from silent; it is filled with sound. Until around a century ago, the underwater sound surrounding marine animals in their environment, called a soundscape[vi], consisted of mostly natural sounds: waves, currents, rain hitting the surface, and the signals of the animals themselves, such as snapping shrimp, chorusing fish, and of course, whale sounds. However, human activities on the oceans have been increasing at a rapid rate. The noise made by these activities interferes with the ability of cetaceans to hear the sounds they rely on for survival.[5]

When we think about a noise, we tend to think about its loudness (measured in decibels, dB); its pitch or frequency (measured in vibrations per second or Hertz, Hz), and how often it occurs.[6] Commercial ships and seismic exploration conducted with air guns produce low frequency noise (between 50 and 150 Hz; and 5 to 90 Hz respectively). This noise might be continuous, such as that emitted from a ship's propeller, in which case it is referred to as non-impulsive; or intermittent, such as the noise produced by air gun blasts,[7] referred to as impulsive. These low frequency sounds can travel hundreds to thousands of kilometres underwater.[8] Over large geographical scales, shipping noise and air gun sounds can merge and become continuous background noise.

[vi] Soundscape - also known as the acoustic landscape, this is the collection of multiple sound sources that surround the receiving animal.
[vii] Approximately 1500 metres per second underwater compared to 340 metres per second on land.
[viii] Micropascals (µPa) - a measure of sound pressure.



**Low frequency sound, such as that produced by commercial ships and seismic exploration, can travel hundreds to thousands of kilometres underwater.**



Ocean Wise / NOAA Permit 19091 | *A killer whale spy hopping.*

## What is the difference between sound underwater and sound in the air?

Those of us who live on land know the difference between a yell and a whisper. We also know that if we move far enough away, we are unlikely to hear a sound any longer. But sound travels differently underwater than it does in air.

Sound is a pressure wave that creates oscillations that can travel through any medium, such as air or water. Because water molecules are more closely packed than molecules in the air (water is denser than air), they can more quickly transmit vibration energy from one particle to the next. This means that sound travels over four times[vii] faster underwater than it does in air.[6]

A direct comparison of sound levels, or measurements in decibels (dB), is not possible. A decibel is not a fixed unit of measure, like a meter or a gram. Any sound level provided in decibels is described as a level above a reference pressure measured in micropascals[viii] at a standard distance. Air and water have different reference pressures, leading to differences in perceived intensities, which needs to be considered to make meaningful comparisons between noise intensity in water and air. The reference pressure in air is 20 micropascals (µPa), while it is only one micropascal (µPa) in water. A sound that has the same effective intensity in air and in water would be 63 dB quieter in air. In other words, to convert a dB measurement in air to dB in water, we must add 63 dB.

## How do cetaceans use sound?

Underwater, sight is less efficient than on land. Underwater vision is not very useful for detecting anything beyond a few tens of meters, because light rapidly diminishes as it is absorbed by water. By contrast, sound travels very efficiently in water, moving faster and covering much larger distances than in air. It is therefore not surprising that cetaceans rely on sound for many aspects of their lives: to locate food, to navigate and sense their environment, to detect predators, and to communicate over short and long distances.

Sounds used for communication can serve a variety of purposes, such as keeping groups together, maintaining contact between mothers and their calves, attracting mates, coordinating group movements when foraging, and even as "names" of sorts, to identify themselves to others. The well-studied signature whistles produced by bottlenose dolphins[9] are an excellent example of the latter, while the dialects that killer whale family pods use are an example of sounds used for group cohesion.[10]

Different species produce sounds at different frequencies. Many toothed whales[ix], such as killer whales, belugas, and sperm whales, produce broadband[x] clicks for echolocation that extend to very high sound frequencies, and lower-frequency sounds that include whistles, chirps, grunts, and buzzes for communication. Other toothed whales, such as harbour porpoises, use very high frequency clicks (above 150,000 Hz) for both communication and echolocation.[11] On the other hand, baleen whales[xi] such as humpback, blue, or minke whales, which hear best at lower frequencies, tend to produce very low frequency sounds that travel long distances. Frequencies below 1,000 Hz[12] overlap with the main frequencies of the noise produced by large ships (Figure 1).

Different species also differ in their sensitivity to sounds. Marine mammals can hear sounds far beyond the human hearing range (which is 20 to 20, 000 Hz). The sound speed difference between air and water, in addition to low light conditions, likely fostered the evolution of hearing sensitivities across broader frequency ranges than those found in terrestrial mammals.[13] For example, most toothed whales can hear sounds between 200 and 100,000 Hz (and some species even higher), while large whales (baleen whales) can hear frequencies as low as 10 Hz. The frequencies of sound that an animal is sensitive to influences the kinds of noise it may be susceptible to.

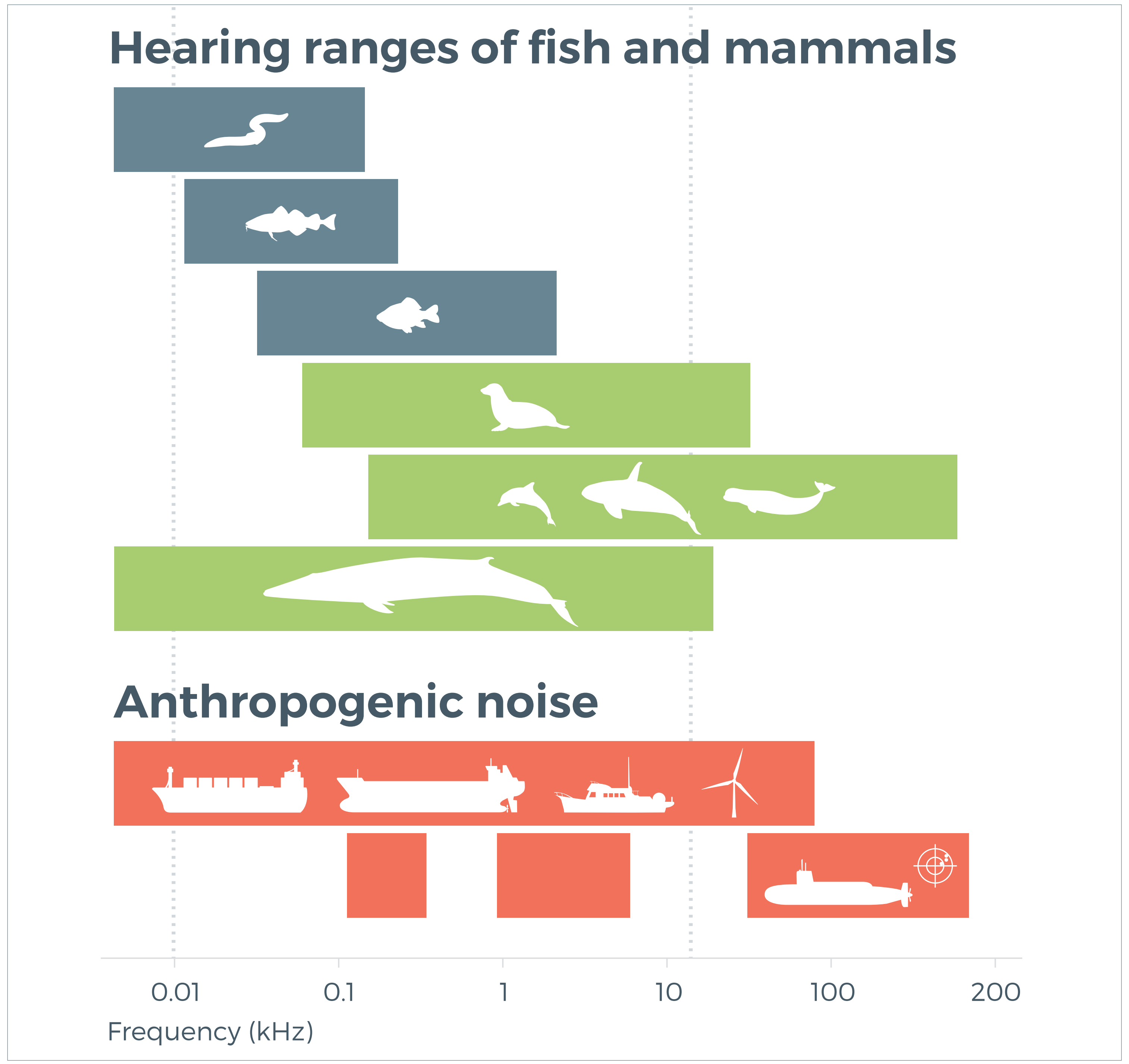



**Figure 1**. Range of frequency typically heard and produced by marine fish (blue blocks) and marine mammals (green blocks), compared to the range of frequency typically produced by certain human activities on the oceans (red blocks).

[ix] Toothed whales - also called Odontocetes, toothed whales include dolphins, porpoises, and all other whale species that possess teeth, such as killer whales or sperm whales.
[x] Broadband - sounds that have acoustic energy over a broad range of frequencies are known as "broadband" (such as ship propellers or airgun blasts), while sounds that encompass only a single frequency or a small range of frequencies are called "narrowband" (such as navy sonar).
[xi] Baleen whales - also known as mysticetes, baleen whales have baleen instead of teeth, which they use to filter their food, such as krill, plankton and small fish. Baleen whales include blue, fin, bowhead, humpback and minke whales.



**Cetaceans rely on sound for many aspects of their lives, such as locating food, navigating and sensing their environment, detecting predators and communicating.**

Ocean Wise / NOAA Permit 19091 | *Killer whale with her calf.*

## How does underwater noise impact cetaceans?

Underwater noise can have a variety of impacts on cetaceans, depending on the vocalization types and hearing sensitivity of the species, and the frequency, intensity, and duration of the noise. These impacts include auditory masking[xii], behavioural disturbance (ranging from simple annoyance to severe harassment responses), displacement from critical habitats, physiological stress, and hearing loss and trauma, which, in extreme cases, can lead to mass strandings and deaths (associated with some navy sonar exercises).

Vessel traffic, particularly commercial shipping, is an important contributor to noise pollution. One of the most pervasive problems with the kind of persistent noise introduced by vessel traffic is auditory masking, which occurs when noise interferes with an animal's ability to detect and recognize important sounds.[14,15]

For example, as toothed whales dive to chase their prey into deeper and darker water, their ability to use vision to follow prey declines, which is why they must rely on sonar signals – echolocation – to find and capture their prey. These echolocation signals are masked by underwater noise, so that a whale's ability to detect its prey becomes more difficult, and hunting success declines (Figure 2).

Many marine mammal species, including killer whales,[16,17] dolphins,[18,19] beluga whales,[20,21] and humpback whales[22] change how they communicate during noisy periods to increase their chances of successful communication. They may produce longer and louder calls, repeat a call, shift the frequency of a sound so that it does not overlap with the frequency of the noise (i.e., call at a higher pitch), or wait to call until the noise subsides. However, this comes at a cost. Making louder sounds and repeating calls uses more energy.[23] Having to constantly resort to altering their vocalizations may increase stress levels, reduce how efficiently they communicate, or increase the time that would normally be spent on other activities. If the noise levels are high enough and sustained over long periods, these strategies would not be effective, and the ability of the whales to communicate could be completely impaired.

Minke whales in the North Pacific communicate using so-called "boing" vocalizations, described as akin to a metallic frog call with the intensity of a chainsaw[24] (listen to a boing call here). Although their function is unknown, they are detected mainly during the breeding season.[24] In studying these calls, scientists observed that although minkes produced louder calls in noisy conditions, this increase in loudness was only marginal, and certainly not enough to fully compensate for the noise. This means that a long-distance boing call that could be used to communicate with other minke whales as far as 114 km away, could only be heard up to 19 km when noise levels, such as that from vessels, increased. This impairment to communication could have a severe impact on the health of minke whale populations.

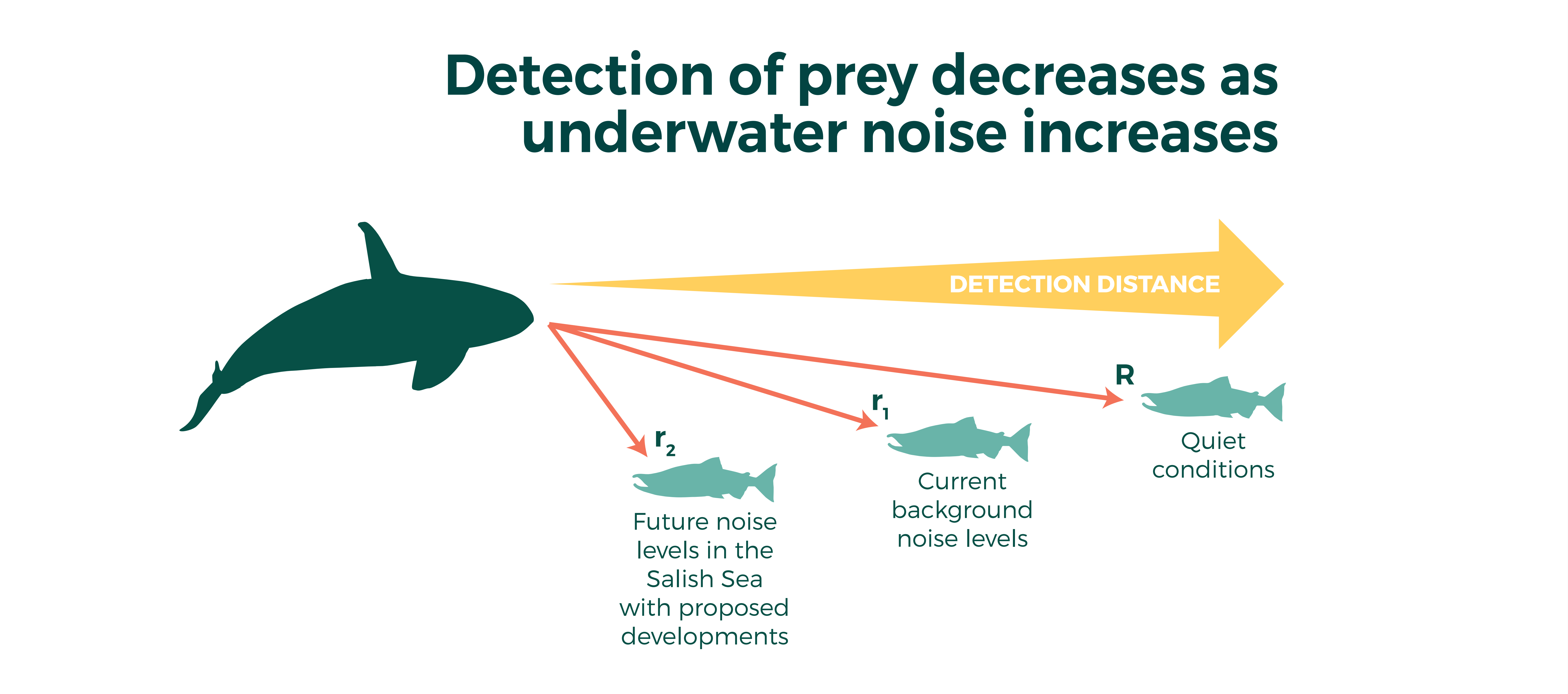



**Figure 2**. At different theoretical underwater noise levels, a whale's ability to detect prey becomes more difficult. R represents how far away a whale can detect prey when it is quiet; $r_1$ represents prey detection distance at current noise levels; $r_2$ represents the predicted prey detection distance if noise levels continue to increase from commercial shipping and other human activities.[5]

[xii] Auditory Masking - the interference of noise with an animal's ability to understand, recognize or even detect important sounds for communication, foraging, navigation, etc.

## Vessel class

The character of noise radiated by a vessel is known as its "noise signature". Some vessels are louder, and some are quieter. The frequency of noise produced can also differ depending on the vessel class and design (Figure 3). While vessel class plays a large role, the noise signature is also related to speed, length, draft/load, propeller pitch, shaft gear, and even maintenance. The differing acoustic outputs (e.g., loudness, frequency) from different vessels is important when considering acoustic masking. Signal masking occurs when the sound (e.g., a whale call) and the noise (e.g., from a vessel) are produced in the same frequency band, much as if they were playing on the same radio channel. If the sound and the noise occur in different frequency bands, it is as if they were playing on different radio channels and tend to overlap less, reducing any masking effect.

Large vessels, including container ships, ferries, cruise ships, and military vessels, generate noise at lower frequencies than smaller vessels. Low frequency sounds travel much farther underwater than high frequency sounds. Ship traffic, which has been steadily increasing over the last few decades, is responsible for the sustained rise in low frequency ambient noise in the 10 to 100 Hz range in many of the world's oceans.[4] Baleen whales, which use sound in the same frequency range as that emitted by large ships, are particularly affected by low frequency shipping noise.

However, at close range (i.e., less than 3 km) the noise from ships can be significant not only at low frequencies, but also at high frequencies (above 10,000 Hz).[25] Small pleasure craft are also loud at high frequencies, especially at high speeds. In fact, when travelling at high speed, all classes of vessels can emit noise at higher frequencies than that shown in Figure 3, because of propeller cavitation, described earlier.

This is important for smaller whales and dolphins that can hear those higher frequencies better than large baleen whales. The high frequency components of shipping noise at close range, and of small pleasure craft, can potentially mask the communication calls and echolocation clicks of many species, such as the endangered southern resident killer whales (SRKW).

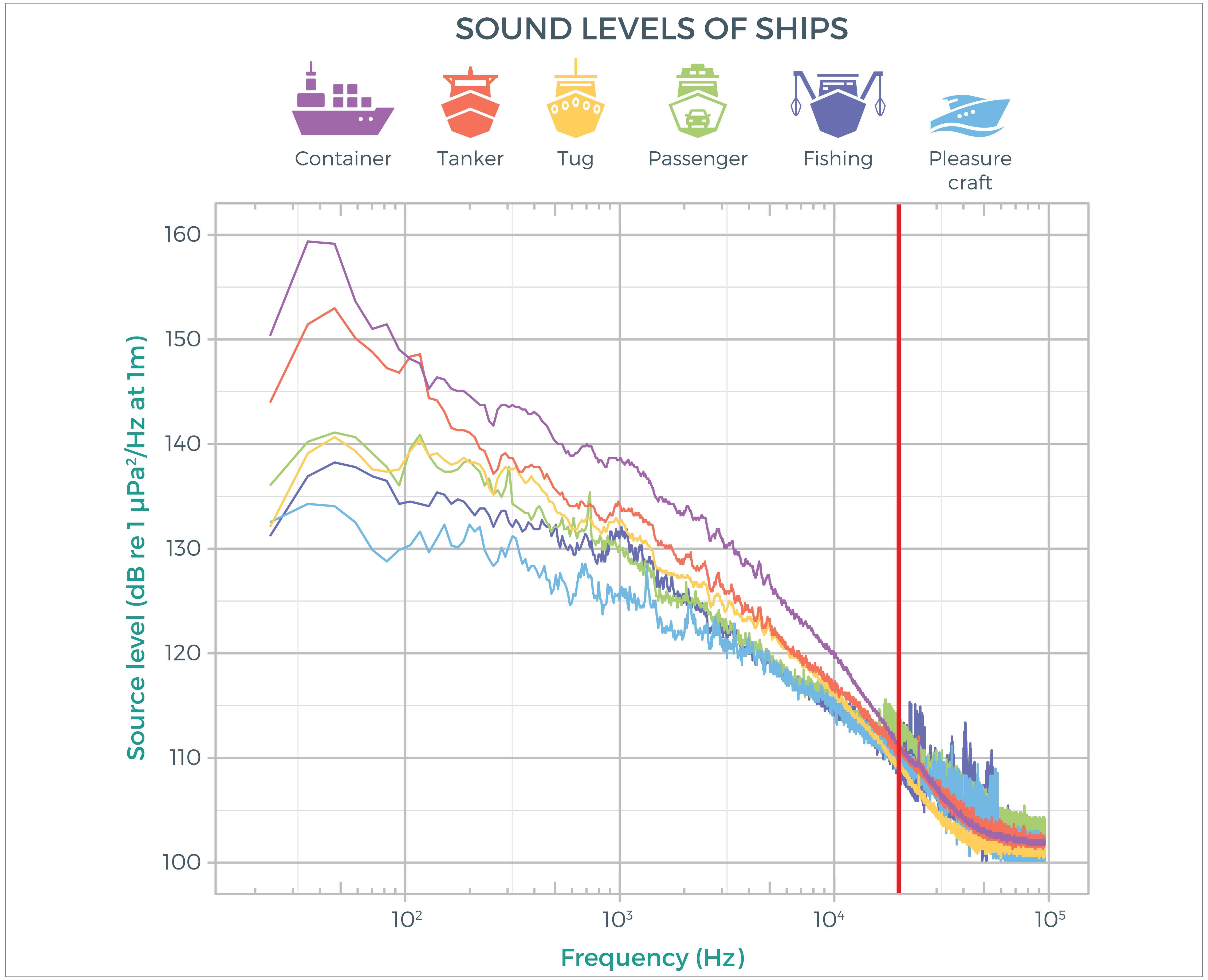



**Figure 3**. Different classes of vessel emit different median source sound levels over a range of frequencies (x-axis; Hertz [Hz] increases from left to right). The noise emitted by vessels is greater at lower frequencies (y-axis; decibels, 1 dB re 1 µPa/Hz at 1m)[xiii]. The red vertical line indicates 20,000 Hz, which is the upper hearing range for humans (range 20 to 20,000 Hz).[5, 25]

[xiii] Note: decibels (dB) are always relative to a reference pressure measured in micropascals (µPa) at a standard distance. The reference pressure for dB in water is re 1 µPa per hertz at 1 m (the standard notation for water).

# What factors alter underwater noise?

## Temperature, Salinity and Depth

In water, the speed of sound increases with temperature, salinity,[xiv] and depth (water pressure). Sound pressure waves often follow channels in the water, known as ocean sound channels. These channels can extend hundreds or even thousands of kilometres. They are determined by the depth of the lowest speed of sound – called the sound-speed minimum – which varies with temperature, water pressure and salinity. Deeper in the ocean, the temperature becomes cooler, slowing down the speed at which sound travels (Figure 4).[26] The sound speed minimum at a depth of 1000 metres is a deep sound channel, known as the SOFAR channel[xv], that allows sound waves to travel great distances.

However, in colder regions, such as the Arctic, the temperature is nearly uniform from the surface to the bottom. Because water pressure increases with depth, allowing sound to travel faster, sound speed is lowest near the surface. Thus, the polar equivalent of the SOFAR channel occurs nearer the surface. The Arctic sound channel allows sound waves to propagate farther distances at shallow depths compared to non-polar regions, by upward refraction[xvi] in the water towards the zones of minimum sound speed, and repeated reflection[xvii] from the surface.

Sound moving through water channels is a complex topic. Further reading can be found in the Resources section.

[xiv] Salinity - the effect of salinity is comparatively smaller compared to the effect of temperature and depth on the speed of sound.
[xv] SOFAR Channel - the Sound Fixing and Ranging channel, or deep sound channel, is a horizontal layer of water in the ocean where the speed of sound is at its minimum, facilitating low frequency sound waves to travel many thousands of kilometers.
[xvi] Refraction - a change in the direction of an underwater sound wave at an interface (i.e., where two media, such as water and sand, meet).
[xvii] Reflection - when a sound wave bounces off an object or surface.

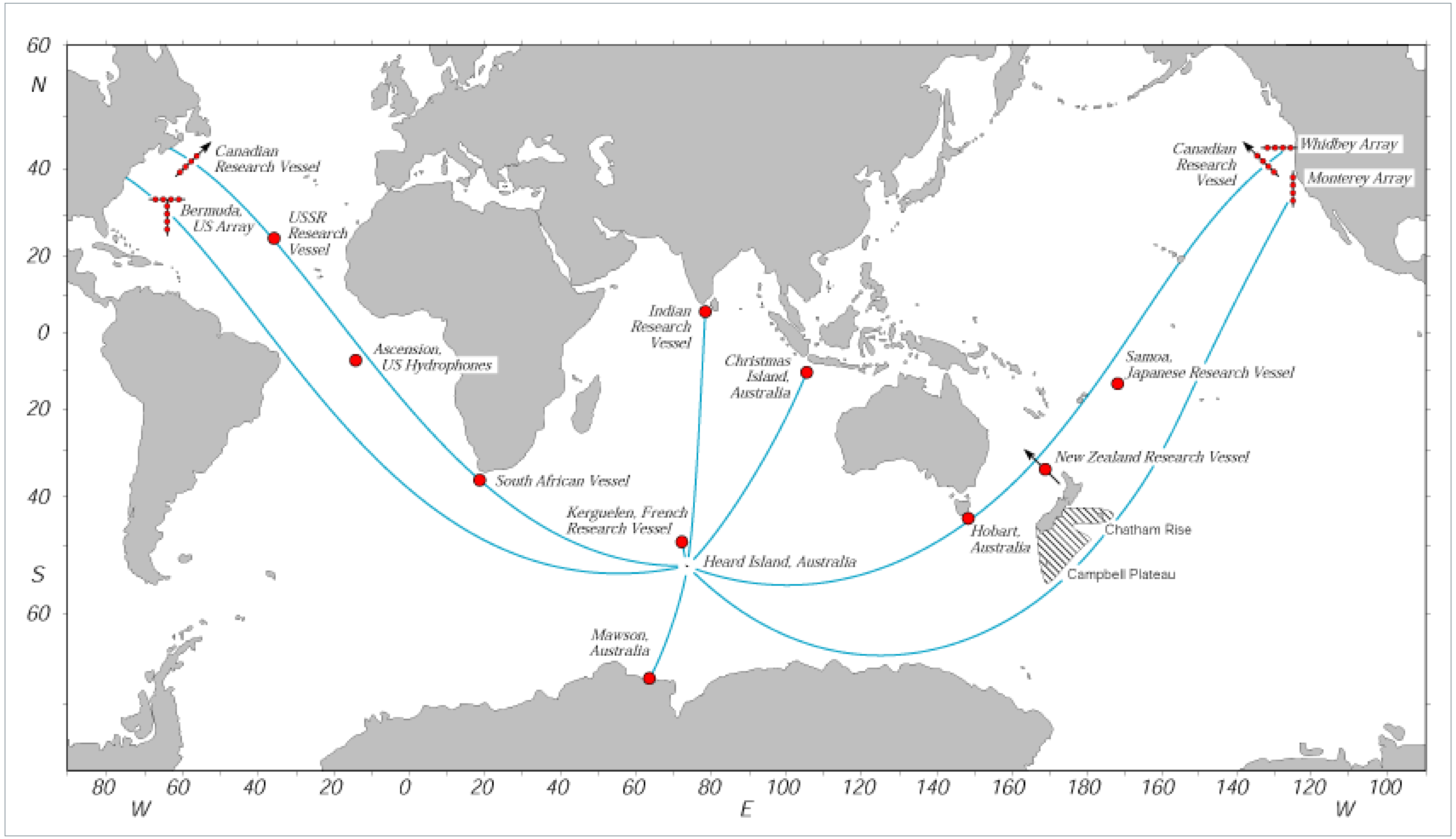



**Figure 4**. Low frequency sound can travel for thousands of kilometres. This is particularly true when sound is travelling through deep ocean channels, formed by changes in water temperature, differences in salinity, and increased pressure with depth. This map, from Munk et al. (1994) illustrates the results of an elegant experiment that demonstrated the ability of human-made acoustic signals to travel the world's oceans. The blue lines show the transmission distance of a signal that was broadcast at 57 Hz and detected at various receivers (red circles) throughout the world's oceans.[27]

## Substrate type

The ocean has many different substrates, such as sandy or clay bottoms, rocky cliffs, or coral reefs. Because sound is a pressure wave that creates oscillations that can travel through any medium, noise can also travel through solids via particle motion. The particles in solids are more densely packed together compared to in water or air, thus sound can transmit even faster through a solid (substrate) compared to a liquid (water) or gas (air) (Table 1) because the moving particles bump into neighbouring particles more easily.

Human activities, such as pile driving or drilling, can produce underwater noise from direct contact with the substrate.[28] By contrast, non-contact activities, such as shipping or sonar, can produce underwater noise indirectly by propagating into the substrate from the water. Additionally, activities taking place on land, such as coastal development or vehicle traffic, can produce underwater noise due to sound transmission via the substrate into the water column.[28]

When sound waves travel through a medium, such as water, they will change direction when interfacing with different layers such as those formed due to temperature or salinity differences, or when interacting with a solid medium, such as the sea bottom, or with the sea surface. This is known as refraction. At the interface with another medium, such as a sandy bottom, the sound wave will be reflected back to the medium from which it came – in this case, the water.[29] Some substrates can also absorb underwater sound energy, as well as water itself, which often contains sound-absorbing air bubbles.[28] This means that the patterns of sound propagation are often very complex and difficult to predict.

## How does climate change alter underwater noise?

Global warming is changing ocean soundscapes. The ocean acts as a significant carbon sink, absorbing vast amounts of atmospheric carbon produced by human activities. Carbon dioxide produces carbonic acid as it dissolves, increasing the acidification of the oceans (known as ocean acidification). A consequence of ocean acidification is that it lowers underwater sound absorption. More acidic seawater means that sound absorption of low frequency waves (between 100 Hz and 10 kHz) could decrease by 60% by the end of this century.[30] These low frequencies will thus be louder and able to travel further. More research is needed to understand where the noise hot-spots will be, as some areas will be affected more than others, and to what extent these changes may also allow marine mammals that use low frequency sounds to communicate over longer distances.

Perhaps the largest changes are seen in the Arctic. Despite natural ambient sounds that can be loud, such as those produced by ice fracturing due to wind, waves, or current, the Arctic has been considered, until recently, one of the quietest places on Earth. Natural ambient noise levels can be quite low under solid ice relative to other areas of the world, because the ice acts as a shield between the underwater environment and weather-related noise sources.[31] However, the Arctic is warming at nearly twice the rate as the rest of the planet, with dramatic changes in sea ice duration and distribution. Sea ice cover has decreased, and ice is forming later and breaking up earlier each season.[31–33] Without this ice buffer, natural ambient noise levels increase. Disappearing ice also means increased access and a longer season for a wide range of noisy human activities, particularly vessel traffic.

In the Canadian Arctic, ship traffic roughly tripled between 1990 and 2016, with much of that increase occurring in waters near Nunavut. This increase in Arctic shipping is introducing noise pollution to previously quiet areas, potentially affecting marine mammals that are already impacted by climate change. Monitoring noise levels in various Arctic areas together with shipping and marine mammal presence and abundance, is key to understanding the degree to which noise impacts marine mammals, and to better manage those impacts.

In the Arctic Ocean's Beaufort Sea, a warm channel at 50 – 80 m depth is now permanent rather than seasonal, due to ice melt. An additional warm layer around 200 m deep is completely new, formed as a result of heat flowing from the Pacific Ocean into the Arctic Ocean through the Bering Strait. A cold-water layer separates the two warm layers. Refraction happens at the boundary of each of those layers which means sound travels better within than across layers. These three layers form what is now known as the Beaufort Lens sound channel, which transmits sound extremely efficiently. Today, sounds, including noise from ships, travel nearly four times farther than over a decade ago.[34]

**Table 1** The speed (metres per second) that sound waves travel through different media (originally from JASCO Applied Sciences).[29]

| MEDIA | SPEED (M/S) |
|---|---|
| Air at 20°C | 343 |
| Salt water at 25°C | 1532 |
| Sand | 800 – 2200 |
| Clay | 1000 – 2500 |
| Sandstone | 1400 – 4300 |
| Granite | 5500 – 5900 |
| Limestone | 5900 – 6100 |

# Spotlight 1

## In the Arctic: Melting ice means more shipping

The Arctic is undergoing a profound transformation. How will marine mammals respond to these drastic changes? Which marine mammal species are most vulnerable to shipping traffic in a progressively ice-free Arctic? Researchers from the University of Washington and the University of Alaska Fairbanks attempted to answer these important questions. They examined a range of factors that influence the vulnerability of seven Arctic marine mammal species to vessel traffic in two increasingly navigable routes, the Northwest Passage and the Northern Sea Route.[35]

The study looked at 80 subpopulations[xviii] of beluga whales, narwhals, bowhead whales, ringed seals, bearded seals, walruses and polar bears. It found that just over half (42) of these subpopulations would be exposed to vessel traffic. Narwhals, belugas and bowhead whales, which are all sound-dependent species, were found to be the most susceptible to an increase in vessel traffic, with narwhals topping the list.

It is not surprising that narwhals were the most vulnerable. These Arctic whales live in the middle of shipping routes, have extremely traditional summering grounds, and are a notoriously shy species known to react strongly to disturbances. Because a large proportion of the world's narwhals live in Canada, understanding how an increase in vessel transits will impact this species will help us to devise effective mitigation measures.

[xviii] Subpopulations - a subset of a larger population.



**More than half of the marine mammal species living in the Arctic will be exposed to increases in vessel traffic. Narwhals are especially vulnerable.**

**Ocean Wise, Valeria Vergara** | *Narwhals swimming in Tremblay Sound.*

# Spotlight 2

## In the Pacific: Southern resident killer whales benefit from vessel slowdown

The Salish Sea in the Pacific Northwest, between southern British Columbia (Canada) and northern Washington (USA), is home to an endangered population of SRKW. The number of these iconic animals has sadly decreased to just 74 individuals. Noise and disturbance are one of the three main threats to their recovery, along with contaminants and reduced availability of chinook salmon, their main prey (see Resources for more information).

The Port of Vancouver's Enhancing Cetacean Habitat and Observation (ECHO) Program, developed to mitigate the threats to whales posed by shipping activities, commissioned a study to understand if slowing down vessels would be effective in reducing underwater noise levels.[36–38] A first-of-its-kind voluntary commercial vessel slowdown trial in Haro Strait, a "hot-spot" or area of high importance to SRKW, began in the summer of 2017. All vessels transiting a 16 nautical mile corridor (Figure 5) were asked to reduce their speed to 11 knots (the average speed for container ships is over 18 knots and over 13 knots for bulk carriers). Most commercial vessel pilots complied, an excellent example of collaboration.

Researchers used listening stations (passive acoustic monitoring stations that consist of underwater microphones/hydrophones connected to digital sound recorders) to monitor underwater noise levels in the area during the slowdown trials. The results were promising. The speed reductions resulted in reduced noise from all commercial vessel classes in most frequencies, and an overall reduction in underwater noise in nearby habitats (see Resources to find a link where you can hear the difference). Slowing ship speed is therefore an effective way to reduce underwater noise exposure from ships. The researchers used a simulation model based on these results to show that the whales would have fewer lost feeding opportunities and increased success finding food in their foraging habitat within the slowdown region.

The successful experiment was expanded in 2019 and 2020 to enlarge the slowdown area to include Boundary Pass and Haro Strait, both SRKW feeding areas. In 2019, 82% of large commercial ships participated in the slowdown initiative. At the time of writing (September 2020), the slowdown trials had been extended until October 31st 2020.

**Vessel slowdowns decrease underwater noise, reducing the negative impacts on marine mammals.**

**Ocean Wise, Lance Barrett-Lennard** | *Southern resident killer whale.*

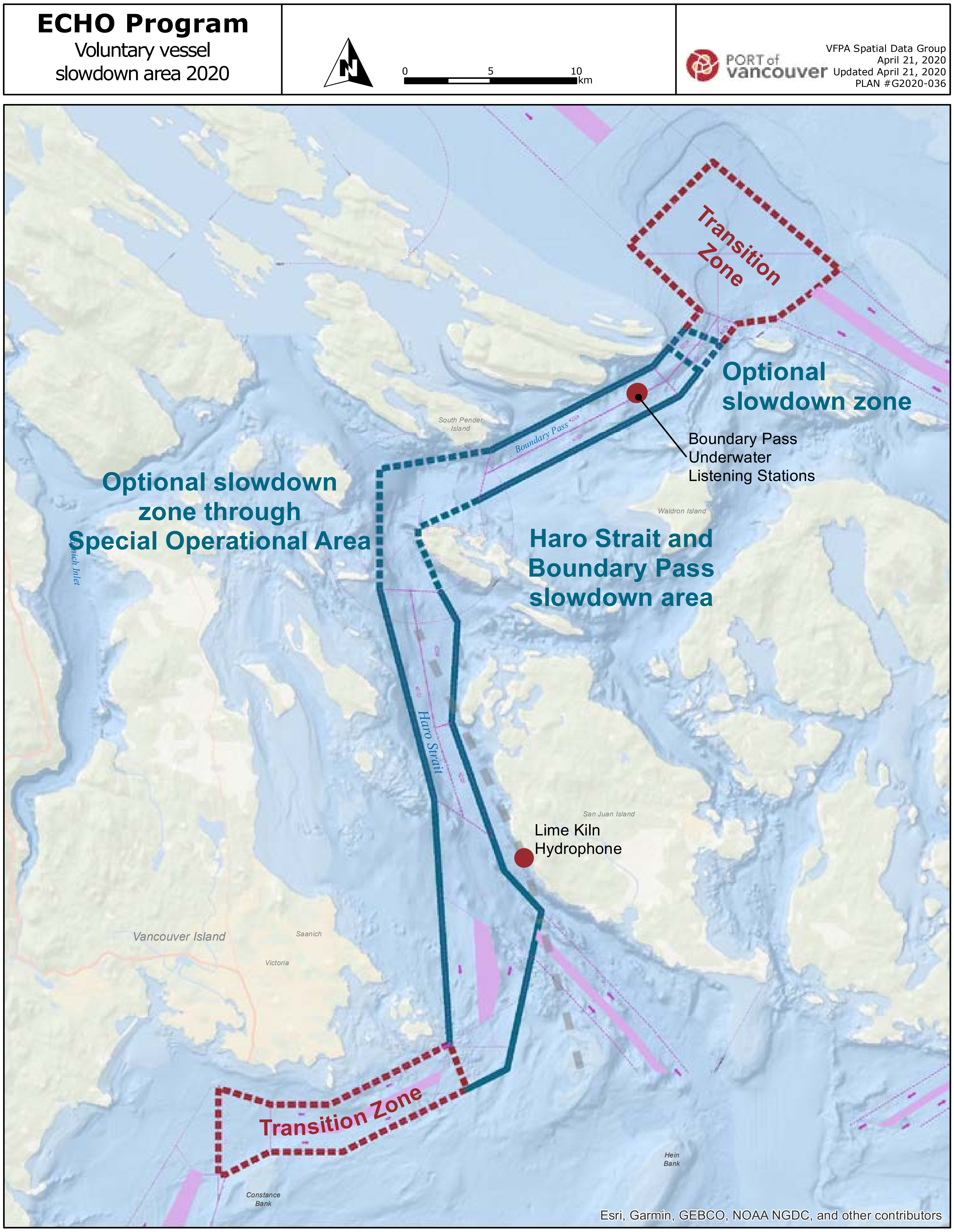



**Figure 5**. Vessel slow down area in southern resident killer whale habitat.[39]

# Spotlight 3

## In the Atlantic: Quieter oceans led to less stress

In September 2001, much of the coastal ocean around North America was quiet for the first time in decades. In the aftermath of the 9/11 attacks, all non-essential ship traffic came to a near-standstill along many shipping routes, due to security concerns. This provided a temporary pause in noise pollution, and a perfect unplanned experiment to show the link between underwater noise and stress in whales.

A research team led by New England Aquarium scientists paired data from two unrelated studies in Canada's Bay of Fundy.[40] The first study looked at endangered North Atlantic right whale social behaviour. It compared acoustic recordings from right whales collected before and after 9/11. The second study looked at health and reproduction of North Atlantic right whales and collected fecal samples (whale poop!) from right whales in the same area, during the same period.

The study found that the reduced ship traffic in the Bay of Fundy following the 9/11 events resulted in a sharp six-decibel drop in broadband underwater noise levels, with a notable reduction in frequencies below 150 Hz, the low frequencies emitted by ships and used by baleen whales to communicate. This drop in noise levels was associated with a noticeable decrease in the levels of the stress-related hormone glucocorticoid in feces samples of the whales. The whales were simply far less stressed than normal during these unusually quiet times.

The reduction in ship traffic and consequently underwater noise during 9/11 can be likened to what has been observed during the global COVID-19 pandemic, when air, road and vessel traffic all decreased. Researchers the world over have been measuring the concomitant reduction in noise. For example, locally, in the Strait of Georgia, the reduction in commercial shipping traffic into the Port of Vancouver lead to a decrease of 5 dB in the low frequency 100 Hz noise associated with ships.[41] While data on underwater noise during 2020's pandemic are still coming in, it seems likely that similar positive effects will be seen.[42]


**Public Domain Free Stock Photo** | *North Atlantic right whale and calf.*

# Spotlight 4

## In the St. Lawrence Estuary: 'Mom, can you hear me?' Impacts of underwater noise on mother-calf contact in belugas.

The endangered St. Lawrence Estuary beluga population has been losing its calves at an unprecedented rate in the past decade,[43] exacerbating a worrying decline in their population. Why are calves dying? The answer is not simple, because many factors may be playing a role, including toxic algal blooms (the most likely culprit for multiple deaths in 2008), a shortage of prey availability due to climate change, high levels of contaminants, and noise and disturbance from vessel traffic.[44] Because no signs of disease were found in any of the newborn carcasses examined, researchers questioned if separation from their mothers could be contributing.

A recent study led by Ocean Wise investigated whether underwater vessel noise could interfere with the ability of beluga mothers and their newborn calves to regain contact after separation.[45] In their dark underwater world, belugas rely on sound to keep track of one another. To do this, they use a particular call type to maintain group cohesion and mother-calf contact.[46] Calves must slowly learn to produce the maternal contact-call.[47] If this system of contact-calls is compromised, the energy demands on the pair can increase, or worst case, the pair may fail to reunite, resulting in the death of the calf.

Strong masking effects were found for the underdeveloped calls of newborns. Calves produce much weaker contact calls than adults – their calls are especially weak during their first week of life – meaning their calls are much quieter and can only be heard by other belugas at one-tenth the distance of adult contact calls, to maximum distances less than 500 m. These small communication ranges make calves particularly sensitive to increases in underwater noise, which can reduce the distance that a newborn calf call can be heard to only a few tens of metres.

Thus, if mother-calf separation occurs, noise may interfere with a successful reunion. A newborn beluga may hear the mother but be too young to orient to and find her. The mother may simply not hear her calf because of noise disturbance reducing the communication range of newborn calls.

**Underwater noise appears to be playing a large role in preventing beluga mother and calves from reuniting when they have been separated, contributing to a declining population.**

**Ocean Wise, Valeria Vergara** | *Mother beluga and calf, St. Lawrence Estuary.*

# Conclusion

Noise pollution is a global conservation threat because it negatively impacts marine species, from whales and dolphins, to fish and invertebrates. Large vessels, such as commercial ships, produce low frequency noise that can travel hundreds if not thousands of kilometers underwater and mask the communication sounds of many marine mammals, especially of large baleen whales. At close ranges, the noise from ships can also be significant at higher sound frequencies, which is a problem for many smaller whale and dolphin species using these frequencies to communicate and find food, as is the high frequency noise of smaller pleasure craft.

Marine mammals are hard hit by human activities on the water. From masking of important sounds, behavioral disturbance, and stress, to mass strandings and even death, the impacts of human activities on these species are profound. Researchers across many different organisations and institutions and various levels of government have been working together to better understand underwater noise and mitigate its impacts on marine species. There are many steps that can be taken to reduce underwater noise pollution and improve the underwater soundscape for the species that live there.


**Ocean Wise, Valeria Vergara** | *Belugas in the Gulf of St. Lawrence being observed by a whale watching boat.*

# What can you do?

## Individual and Organization Actions

- ❑ Slow down to reduce the noise produced by your boat.
- ❑ Clean your hull and maintain your propeller.
- ❑ Modify your route to avoid known whale areas, such as SRKW critical habitat.
- ❑ When viewing cetaceans from a boat, follow the Be Whale Wise Guidelines to avoid disturbing or displacing them.
- ❑ Buy local products, such as fruits and vegetables grown in your own country. Avoid contributing to marine traffic by reducing unnecessary consumption (the majority of shipping is for the transport of goods).

Ocean Wise, Valeria Vergara | *A beluga mother and her calf in the Arctic.*

## Government Actions and Policy

- ❑ Enforce vessel slow downs and ship engine/hull maintenance to reduce underwater noise.
- ❑ Support the Port of Vancouver's ECHO program which has introduced vessel slowdowns and other measures to reduce ship noise. http://bit.ly/3muv3SN
- ❑ Roll-out the ECHO program model across ALL Canadian ports.
- ❑ Support research to improve ship technology (hull and propeller design, construction and operation) to reduce underwater noise.
- ❑ Require new ships to be built with optimized noise reduction designs, including propellers with reduced cavitation.
- ❑ Implement and enforce "acceptable" underwater noise emission specifications for different vessel classes that new vessels must adhere to.
- ❑ Require manufacturers to make data on the underwater noise output of their boat propulsion systems (i.e., outboard engines and stern drives) publicly available as a condition of sale in Canada.
- ❑ Make underwater noise measurements a mandatory part of sea trials for vessels constructed in Canada.
- ❑ Create legally enforceable "quiet sanctuaries" that restrict motorized vessels and other noise-creating human activities, especially in the Arctic.
- ❑ Data exists that allows the development of a vessel ranking system. Once ranking is complete, implement a gradual phase out of vessels that ranked poorly.
- ❑ Incentivize use of quieter vessels through a tiered port fee system, as done at the Vancouver Fraser Port Authority (quieter vessels pay lower port fees).
- ❑ Make requirements to limit noise (e.g., slower speed, use of improved technology and design) mandatory for vessels entering or traversing Canada's waters.

## Ocean Wise Initiatives – Addressing Knowledge Gaps

Researcher's at Ocean Wise Conservation Association have been working for many years on ways to mitigate underwater noise pollution, but many knowledge gaps still exist. Two new initiatives that Ocean Wise anticipates rolling out in the next 12 months are the Arctic Observatory and Noise Tracker.

In the Arctic, climate change is driving sea ice melt, with less sea ice forming each season and longer ice-free periods. These changes are allowing ships to enter waters they previously could not traverse and increasing the volume of vessel traffic. The result – greater levels of underwater noise pollution. However, not enough is known about the impacts of increased vessel traffic on cetacean movement, behaviour, or distribution. Ocean Wise researchers will work closely with Arctic communities to fill these knowledge gaps so new policies and management practices can be put into place to protect cetaceans, such as narwhals, that inhabit the Arctic, under a new initiative called the Arctic Underwater Noise Observatory.

As we have learned, underwater noise pollution is not just confined to the Arctic. NoiseTracker is a collaborative project to enable the quick and reliable identification of underwater noise levels in locations throughout the critical habitat of at-risk cetacean species. Through NoiseTracker, Ocean Wise will raise public awareness of underwater noise levels in the coastal environment; encourage noise mitigation efforts and track the effectiveness of those efforts over time; and reduce underwater noise impacts on at-risk marine species to contribute to their recovery and ongoing conservation.

# Resources

This list is not intended to be exhaustive. *Omission of a resource does not preclude it from having value.*

**For more information on sound channels**
https://dosits.org/science/movement/sofar-channel/sound-channel-variability/
https://dosits.org/science/movement/sofar-channel/sound-speed-minimum/

**For information on underwater sound speed**
https://dosits.org/tutorials/science/tutorial-speed/

**For more information on how sound in the air differs to sound underwater**
https://dosits.org/science/sounds-in-the-sea/how-does-sound-in-air-differ-from-sound-in-water/

**An infographic on the impacts of underwater noise from vessels on whales**
https://bit.ly/3nxCUAd

**If you are interested in "Boing" calls**
http://bit.ly/2WuavPS

**To learn more about how narwhals are threatened by increasing marine traffic in the Arctic**
https://thenarwhal.ca/narwhals-risk-shipping-arctic/

**To learn about other threats facing endangered SRKWs**
https://bit.ly/3r7O6pv

**To read more about how COVID-19 has impacted marine mammals**
https://bit.ly/3p6e1fG

**Ocean Wise, Lance Barrett-Lennard** | *Southern resident killer whales swimming together.*

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**Ocean Wise, Lance Barrett-Lennard** | *A Pacific white-side dolphin pod along the coast of B.C.*

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