

SHIPPING AND UNDERWATER NOISE

A GROWING RISK TO MARINE LIFE WORLDWIDE
2021

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Suggested citation

Shipping and underwater noise – a growing risk to marine life worldwide. (2021). WWF Report compiled by the WWF Arctic Programme and WWF Protecting Whales & Dolphins Initiative.

Cover photography: © Teo Lucas / Gigante Azul / WWF



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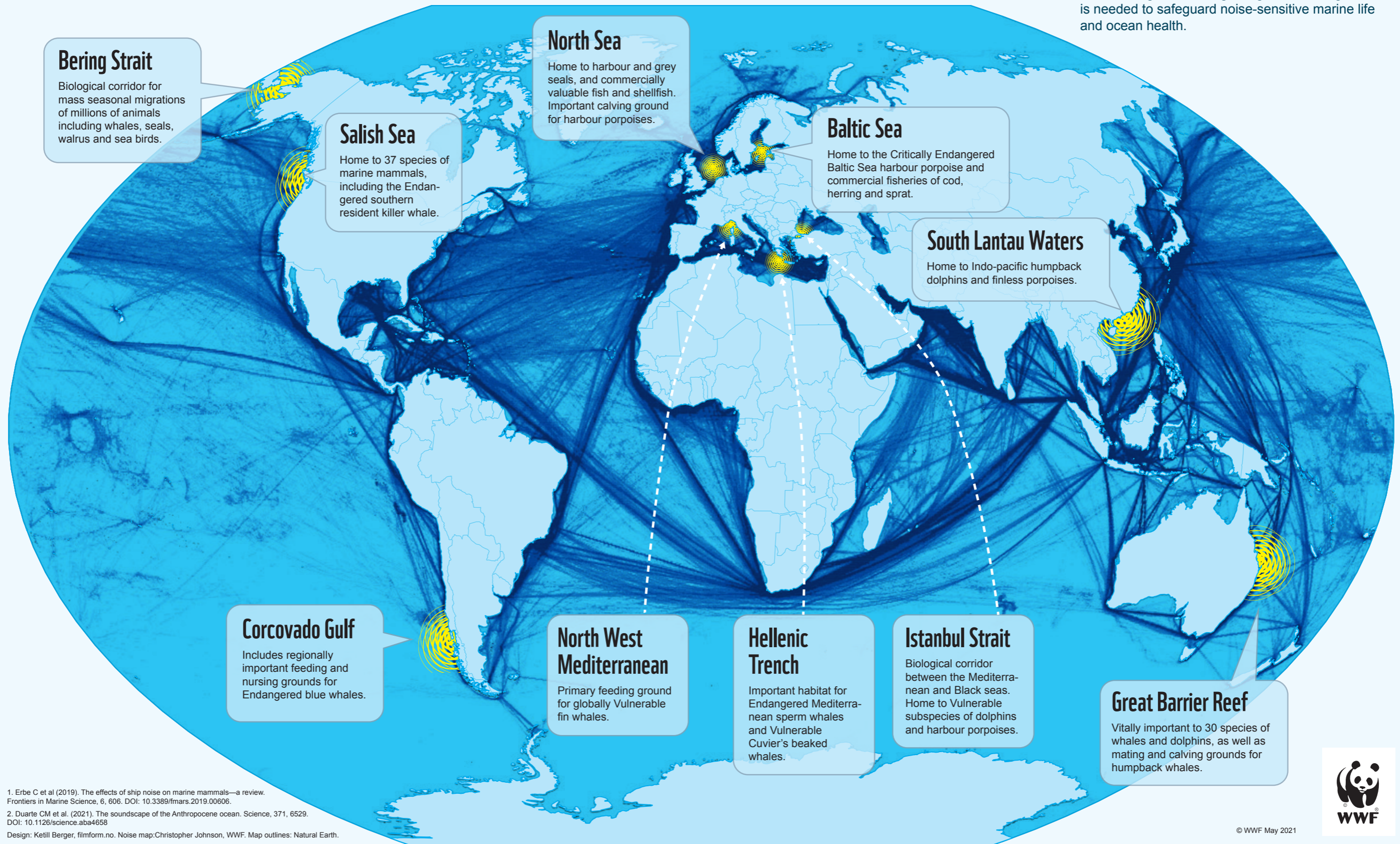
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OUR NOISY OCEANS: ship traffic risks to marine life

Shipping is the leading contributor to ocean noise pollution worldwide¹. Some of the busiest ports and channels in the world's oceans overlap with important habitats for marine species that rely on underwater sound to survive.

- Many of these locations have experienced recent growth in ship traffic, with further increases expected in the coming decades.
- Underwater noise from shipping can have harmful impacts on marine life from shellfish to whales².
- Management of ship-generated underwater noise through monitoring, mitigation and regulation is needed to safeguard noise-sensitive marine life and ocean health.



1. Erbe C et al (2019). The effects of ship noise on marine mammals—a review. *Frontiers in Marine Science*, 6, 606. DOI: 10.3389/fmars.2019.00606.
 2. Duarte CM et al. (2021). The soundscape of the Anthropocene ocean. *Science*, 371, 6529. DOI: 10.1126/science.aba4658
 Design: Ketill Berger, filmform.no. Noise map: Christopher Johnson, WWF. Map outlines: Natural Earth.

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EXECUTIVE SUMMARY

In the darkness of the underwater world, marine animals have evolved to use sound to sense the environment. For many species, sound is an essential part of daily life – the primary means by which they navigate, find food and mates, communicate with one another and avoid danger – and is crucial to their survival. But underwater noise from shipping and other industries is interfering with many species' ability to carry out these activities.



The world's oceans have always been full of natural sound: waves breaking, ice cracking, fish feeding and whales singing. But as the world has industrialized, these sounds have been joined by underwater noise from anthropogenic sources – unwanted sound introduced by human activities. It is produced by a variety of industrial and commercial activities, including shipping, construction, mineral exploration and extraction, seismic surveys and military events. Noise produced by shipping is the leading contributor to ocean noise pollution worldwide.¹ Globally, there is growing evidence that anthropogenic noise is negatively impacting marine life.²

Shipping in the world's oceans – 10 case studies

Today, more than 90 per cent of goods traded globally are transported by ship. Some of the busiest ports and channels in the oceans overlap with important marine life habitats, including those featured in the 10 case studies presented in this report:

1. The **Salish Sea** is home to the Endangered population of southern resident killer whales. On average, every hour of every day of every year, one to three large ships transits through their habitat.
2. The **Bering Strait** is the only link between the Pacific and Arctic oceans. Millions of animals migrate through the strait twice a year.³ Meanwhile, sea ice loss is making four of the trans-Arctic shipping routes more accessible, three of which converge at and pass through the Bering Strait.
3. The **Corcovado Gulf** is a key Southern Hemisphere feeding and nursing area for Endangered blue whales and a feeding ground for humpback whales. In recent years, ship traffic has increased considerably here, and noise pollution is a major concern.
4. The **Mediterranean Sea** hosts 20 per cent of global seaborne trade and 10 per cent of world container throughput. It is also home to fin whales – declared Vulnerable at both global and Mediterranean levels – and sperm whales, listed as Endangered at the Mediterranean level.
5. The **Hellenic Trench** is the only known breeding area for Endangered Mediterranean sperm whales and the largest of five high-density areas in the Mediterranean populated by Vulnerable Cuvier's beaked whales. These populations are already exposed to a range of threats, with shipping activity set to significantly increase in the region.
6. The **Istanbul Strait** is an important biological corridor between the Black and Mediterranean seas, but also supports more than 2,500 vessel crossings daily. In the past 80 years, marine traffic has increased by more than tenfold in the strait.
7. The number of ships plying the **Baltic Sea** is predicted to double between 2020 and 2030^{4,5} putting even greater pressure on the resident harbour porpoise population; this unique Baltic Sea subpopulation is listed as Critically Endangered by the International Union for Conservation of Nature.
8. The **North Sea** – home to harbour porpoises, harbour seals and grey seals – is among the most intensely used

marine regions in the world. A 15 per cent increase in shipping noise is expected to occur in the coming years.

9. Marine traffic is one of the key threats to humpback dolphins in the **South Lantau Waters** found along Hong Kong's southwest border.
10. In Australian waters, commercial shipping has grown by approximately 4 per cent each year since the early 2000s. Much of this growth has been in areas that are significant for marine mammals, including the **Great Barrier Reef World Heritage Area**.

Impacts from underwater noise

Underwater noise is known to have serious impacts on a wide range of marine species, including whales, sea turtles and fish.^{6,7}

High-intensity sources of noise – such as explosions, sonar and underwater construction – pose the greatest risks, and can cause acute injury or death.^{8,9,10} In contrast, ship noise is characterized as continuous and generally low in frequency, although it can extend to high frequencies.¹¹ Most of the noise is caused by propeller cavitation, the formation and implosion of small bubbles against propellers as they rotate. Hull vibration and engine noise also contribute to a ship's acoustic footprint.

Chronic exposure to ship noise, while less likely to result in permanent physical injury or death, can have a range of impacts on the behaviour of marine animals – particularly marine mammals – and their communication spaces (the spaces over which they can receive and transmit sound).^{12,13,14} This phenomenon is known as masking.¹⁵ Underwater ship noise can also cause masking in fish and stress in molluscs. These molluscs are important for ocean health because they play a role in cleaning the water and building reefs.¹⁶

Solutions for pollution

Underwater noise is pollution¹⁷, but there is a relatively straightforward solution to it: if we stop putting it in the ocean, it will disappear. Unlike other forms of pollution, it doesn't take years to break down or dissipate.

Managing underwater noise from shipping requires an understanding of its impact along with monitoring, mitigation and management to ensure marine animals around the world are exposed to safe levels of noise. The case studies featured in this report outline a range of measures currently being deployed or considered including rerouting vessels; reducing maritime traffic speeds; limiting the main engine power of ships (slow steaming); offering financial incentives for quiet vessels; producing educational tools for mariners; and providing support for research and monitoring.



CASE STUDIES

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SALISH SEA



Located between the province of British Columbia (Canada) and the state of Washington (United States), the Salish Sea is under the jurisdiction of both countries, and is one of the world's largest and biologically rich inland seas. It covers nearly 16,925km² of water and 7,470km of coastline, with a maximum depth of 650m.

KEY FACTS

- ✓ The Salish Sea is frequented by 37 marine mammal species and is home to the Endangered population of southern resident killer whales.
- ✓ This sea is an important shipping route between South Asia and North America. The Port of Vancouver is already Canada's largest, and will reach a capacity of more than 4,000 vessels a year by 2026.
- ✓ Underwater noise from shipping has been shown to mask communication between southern resident killer whales, interfering with echolocation and causing behavioural disturbances. Multiple initiatives are in place to reduce underwater noise.



© Natalie Bowes / WWF-Canada

Southern resident killer whale (*Orcinus orca*)

Marine life in the Salish Sea

- Increasingly, this sea and its surrounding watersheds are challenged by threats such as ocean acidification, marine shipping traffic and wastewater and sewage runoff.
- Thirty-seven marine mammal species spend time in the Salish Sea, including baleen whales, dolphins, porpoises, sea lions and seals. It also contains 172 species of seabirds, 253 species of fish and more than 3,000 species of invertebrates.¹
- The Salish Sea is also home to a small, declining population of southern resident killer whales, which both Canada and the United States list as Endangered.
- The Salish Sea is vitally important to these whales because it offers prime habitat for foraging during salmon migrations.²
- The whales are threatened by the decreasing availability of their principal prey (Chinook salmon) and by increasing physical and acoustic disturbances, oil spills and contaminants.²
- The Canadian government recognizes underwater noise from ships as a key threat to the population.²

Shipping and underwater noise in the region

- The Salish Sea is an important entry point for international shipping between South Asia and North America. It is also a busy area for domestic traffic.
- The Port of Vancouver is Canada's largest. It handles the most diversified cargo in North America and is vitally important to Canada for access to international markets.
- The port is expanding to include a new terminal. This will increase its capacity by 40 per cent by 2026.³
- Much of the identified critical habitat of southern resident killer whales is in active shipping lanes. On average, every hour of every day of every year, one to three large ships transits through this habitat.⁴
- Ship traffic through the Salish Sea is not continuous. Noise exposure varies considerably depending on bathymetry and proximity to shipping lanes.⁵
- Acoustic monitoring has identified the commercial vessel sector (including commercial deep-sea vessels, ferries and tugs) as the main contributor to underwater noise in the region.⁵
- Smaller crafts may also be important sources of underwater noise in the summer, where their presence overlaps with high-use areas for southern resident killer whales.⁵

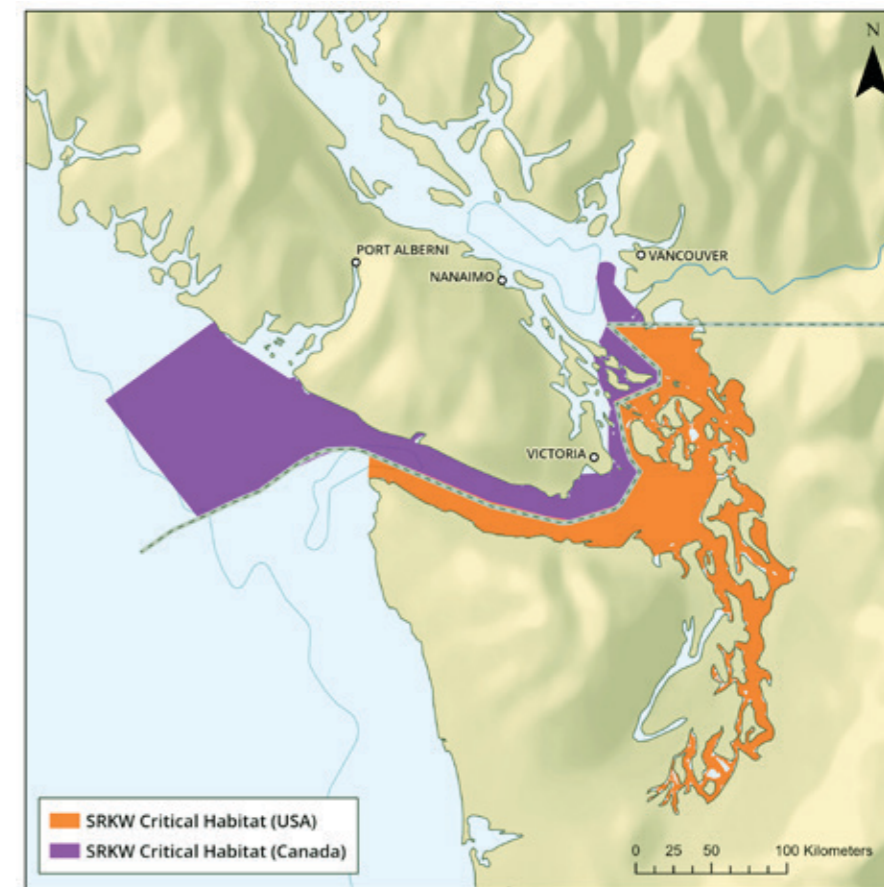


Figure 1: The critical habitat areas for southern resident killer whales (SRKW) in Canadian and northern Washington State (US) waters (Government of Canada, 2019).

Impacts of underwater noise

- Southern resident killer whales are one of the world's most-studied whale populations. Many studies have quantified the effects of vessel and underwater noise on their ability to communicate and detect prey.^{6,7,8,9,10,11,12}
- Underwater noise from shipping has several impacts on these whales. These include:
 - » behavioural disturbances, with heightened physiological stress, more avoidance behaviours, disruption of important activities (e.g., resting and foraging) and shifts in hearing sensitivity threshold;
 - » communication masking, which affects group cohesion, coordination and important social behaviours; and
 - » echolocation masking, which reduces the whales' foraging efficiency and ability to navigate, orientate and avoid hazards.

Monitoring and management

- The Vancouver Fraser Port Authority founded the Enhancing Cetacean Habitat and Observation (ECHO) Program in 2014 in response to Canadian obligations to the recovery of southern resident killer whales. The program aims to develop mitigation measures that will quantifiably reduce the threats to whales from shipping.¹³
- The ECHO Program has implemented numerous initiatives, including vessel slowdowns, lateral displacements, financial incentives for quiet vessels, educational tools for mariners, and support for research and monitoring. So far, its work has reduced underwater noise from ships and helped whales regain some "potential lost foraging time".¹³

BERING STRAIT



The Bering Strait is the only link between the Pacific and Arctic oceans, and is 82km to 88km wide at its narrowest point. Although designated as an international body of water, the Bering Strait is bordered by the Russian Federation to the west and the United States to the east. The Bering Strait region is home to more than 10,000 people. Alaska Natives comprise more than three quarters of the population of those coastal communities, many of whom depend on marine resources, including mammals, fish, birds, macro algae, shellfish and other invertebrates for their livelihoods.¹

KEY FACTS

- ✓ The Bering Strait belongs to one of the world's most productive marine ecosystems. It is both a permanent home and seasonal destination for millions of wild animals, many of which migrate through the strait each spring and fall.
- ✓ Until recently, commercial shipping in Arctic waters was limited by ice-cover. However, sea ice loss is making four of the trans-Arctic shipping routes more accessible, three of which converge at and pass through the Bering Strait.
- ✓ In 2018, the International Maritime Organization (IMO) took the first important step toward protecting this new maritime frontier when it approved the Bering Strait and Bering Sea ship routing measures proposed by the United States and the Russian Federation.



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Bowhead whale(s) (*Balaena mysticetus*)

Marine life in the Bering Strait

- Globally significant seabird populations and marine mammals – such as bowhead and beluga whales, ribbon, ringed, spotted and bearded seals, Pacific walrus and polar bears – frequent the Bering Strait. Humpback, grey, killer and minke whales visit the region seasonally.²
- Millions of individual animals migrate through the Bering Strait twice a year, every year, mostly in spring and fall. Virtually the entire western Arctic population of bowhead whales and Pacific walrus moves through the strait.

Shipping and underwater noise in the region

- Arctic communities rely on marine transportation to bring in food, fuel and other goods.³
- Until recently, commercial shipping in Arctic waters was limited by ice cover. In 2004, fewer than 2 per cent of the world's registered ocean-going vessels over 100 gross tonnage were engaged in Arctic shipping (excluding the Great Circle Route and not including fishing vessels).¹
- Sea ice loss due to climate change is providing new economic opportunities in the Arctic and more accessibility to four trans-Arctic shipping routes: the Northwest Passage (NWP), the Northeast Passage (NEP) (which includes the Northern Sea Route), the Transpolar Sea Route and the Arctic Bridge (Figure 2). All offer shorter distances compared to traditional routes via the Suez or Panama Canals.³ Except for the Arctic Bridge, all routes converge in, and transit through, the Bering Strait.
- Traffic along the Northern Sea Route has fluctuated in the past decade, increasing exponentially from 2009 (two vessels) to 2013 (71 vessels), dropping back down to 27 in both 2017 and 2018.^{4,5}

Impacts of underwater noise

- Sound plays a crucial role throughout the Arctic. Whales and seals rely on sound to sense their underwater environments. Bowhead and beluga whales, walrus, and ribbon, ringed, spotted and bearded seals all use underwater sound for different aspects of their survival. They use it to communicate, navigate, find food and avoid danger.
- Knowledge of how Arctic marine mammals in the Bering Strait respond to underwater noise from ships is limited, but behavioural impacts have been observed in other Arctic regions. Beluga whales studied in the Canadian Arctic became aware of an approaching icebreaker at a distance of 80km; at a distance of 35km to 50km, they showed a strong "flee" response. This included rapid movement, herd formation, shallow dives, "alarm" calls and subsequent avoidance of the area for days.⁶
- Bowhead whales in the Alaska Beaufort Sea have been found to respond to other sources of anthropogenic noise in their environment, including air guns. Walrus in the Chukchi Sea dived and changed their course and speed when vessels came within 500m.^{7,8}



Figure 2: Various shipping routes that are opening as warming global temperatures reduce Arctic summer sea ice. Source: The Arctic Institute.

Monitoring and management

- Until recently, there were no formally established vessel routing measures in the Bering Strait region and very few visual navigation aids. Recognizing the potential risks of increasing shipping in the region, in 2018 the IMO took the first important step toward protecting this new maritime frontier: it approved the Bering Strait and Bering Sea ship routing measures proposed by the United States and Russian Federation.
- The measures took effect in December of that year. They included six two-way routes, three areas to avoid and six precautionary areas. The IMO also approved proposed Areas to Be Avoided around St. Lawrence, King and Nunivak islands.
- Since 2017, The Protection of the Arctic Marine Environment (PAME) working group of the Arctic Council has actively worked on the issue of underwater noise. In 2019, PAME completed a State of Knowledge review on underwater noise in the Arctic and in 2019 they began a project to model and map underwater noise from shipping in the Arctic, including in the Bering Sea and Bering Strait. The project will conclude in 2021.⁹

CORCOVADO GULF



The Corcovado Gulf is a large body of water found between the coast of mainland Chile and Chiloé Island, on the southeastern border of the Pacific Ocean. The gulf was carved out by a glacier and is an entrance point to Chilean Patagonia – one of the most extensive fjord regions in the world. Strong currents and fresh water from rain, rivers, coastal runoff and glacial melting make this region one of the largest estuarine systems on the planet. The resulting salinity gradient favours high ocean productivity.¹

KEY FACTS

- ✓ As well as being home to hundreds of species, the Corcovado Gulf is a key Southern Hemisphere feeding and nursing area for Endangered blue whales and a feeding ground for humpback whales.
- ✓ The gulf is also an important area for marine traffic. In recent years, ship traffic has increased considerably, and noise pollution is a major concern.
- ✓ Acoustic monitoring in the gulf has highlighted overlap between vessel noise and blue whale vocalisations and the propensity for acoustic masking. The government of Chile is willing to address the issue of underwater noise from ships by restricting speed in the Corcovado Gulf.



Blue whale (*Balaenoptera musculus*)

Marine life in the Corcovado Gulf

- Hundreds of species are present in the Corcovado Gulf region, including fish, crustaceans, molluscs, local and migratory birds, cetaceans, marine mammals, corals and sponges.²
- Hundreds of Endangered blue whales come to the Corcovado Gulf to feed between December and April each year.
- This region is one of the most important feeding and nursing habitats in the Southern Hemisphere for Endangered blue whales.³
- The Corcovado Gulf is also an important feeding habitat for humpback whales.

Shipping and underwater noise in the region

- The Corcovado Gulf is an important area for marine traffic because it is the junction between Chiloé Island's inner waters and the Pacific Ocean and is at the entrance to southern Chile's fjords.
- In recent years, ship traffic has increased considerably in the area and underwater noise pollution is a major concern.³
- Some 250 to 1,300 vessels navigate this area each year. Vessel sizes vary from 10m to 200m long; average vessel speed is between 8.3 and 22.5 knots. Vessel types include cargo carriers, tankers, yachts, ferries and tugboats.
- Several different activities have been identified as major causes of increased maritime traffic in this region, including fishing, public transport, research and rescue, dredging and military activity.

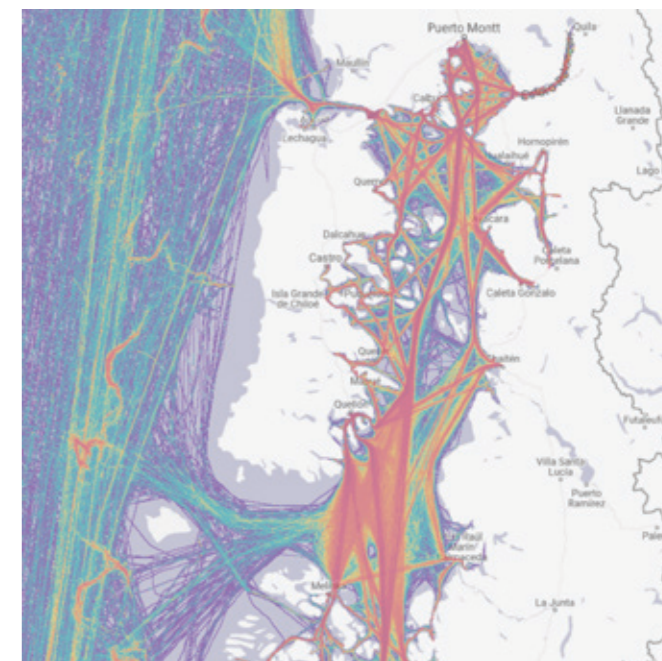


Figure 3: Marine traffic intensity map for Chiloé Island's inner waters and Corcovado Gulf.⁴

Impacts of underwater noise

- Noise generated by marine traffic in the Corcovado Gulf can result in masking, reducing the ability of blue and humpback whales to communicate and find one another.
- Passive acoustic monitoring of the Corcovado Gulf in 2016 and 2017 showed the overlap of vessel noise and Endangered blue whale vocalisations, and the risk of acoustic masking (Figure 4).⁵
- An additional study found that 26 per cent to 30 per cent of all Endangered blue whale calls made in the region over a two-week period were at least partially masked by ship noise.⁶

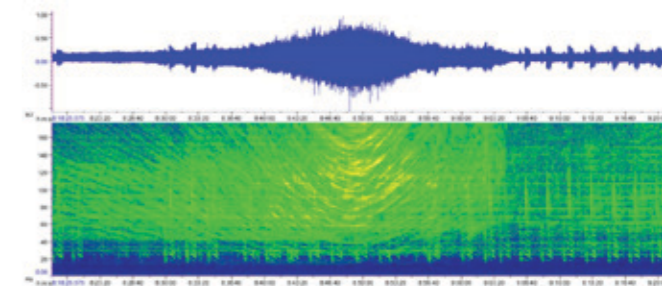


Figure 4: Vessel acoustic signature and amplitude (top) and blue whale vocalisation (bottom, sound spectrogram) as collected by a hydrophone in the Corcovado Gulf.⁵

Monitoring and management

- Passive acoustic monitoring was supplemented with active monitoring in the Corcovado Gulf in 2019 using a marine glider (an autonomous underwater vehicle). The data collected by the glider enables researchers to develop a real-time acoustic warning system to help reduce marine traffic speed and its corresponding impact on whales in Corcovado Gulf.
- The government of Chile has expressed willingness to address the issue of underwater noise from vessel traffic. Chiloé's Navy office has put in place a regulation aimed at reducing maritime traffic speeds in the gulf.

NORTH WEST MEDITERRANEAN



The North West Mediterranean, which includes the Pelagos Sanctuary between Italy, Monaco and France, is managed through an agreement on the protection of marine mammals. The area is surrounded by densely populated coastlines that receive high numbers of tourists. The Pelagos Sanctuary contains several islands, including Corsica and North Sardinia, and is 87,500km² in size, with 2,022km of coastline.

KEY FACTS

- ✓ The North West Mediterranean contains an abundance of species, including fin whales and sperm whales. The fin whale has been declared Vulnerable at both the global and Mediterranean levels. The sperm whale population is listed as Endangered at the Mediterranean level.
- ✓ Although underwater noise is a concern, it has not been measured in this area.
- ✓ WWF-Italy and the University of Turin are conducting a research project focusing on anthropogenic noise and its effects on the distribution of fin whales in the Pelagos Sanctuary.

Marine life in the North West Mediterranean

- The North West Mediterranean hosts fin whales, sperm whales, Cuvier's beaked whales, long-finned pilot whales, Risso's dolphins, bottlenose dolphins, common dolphins and striped dolphins.
- Fin whales in the North West Mediterranean are most common in deep waters, but can also be found in shelf waters, depending on the distribution of their prey. This area is recognized as a primary foraging ground for the species.
- The fin whale has been declared Vulnerable both globally and at the Mediterranean level. The sperm whale is Endangered at the Mediterranean level.¹
- Complete population estimates for the fin whale are not available for the Mediterranean region, but ongoing threats could diminish their numbers.

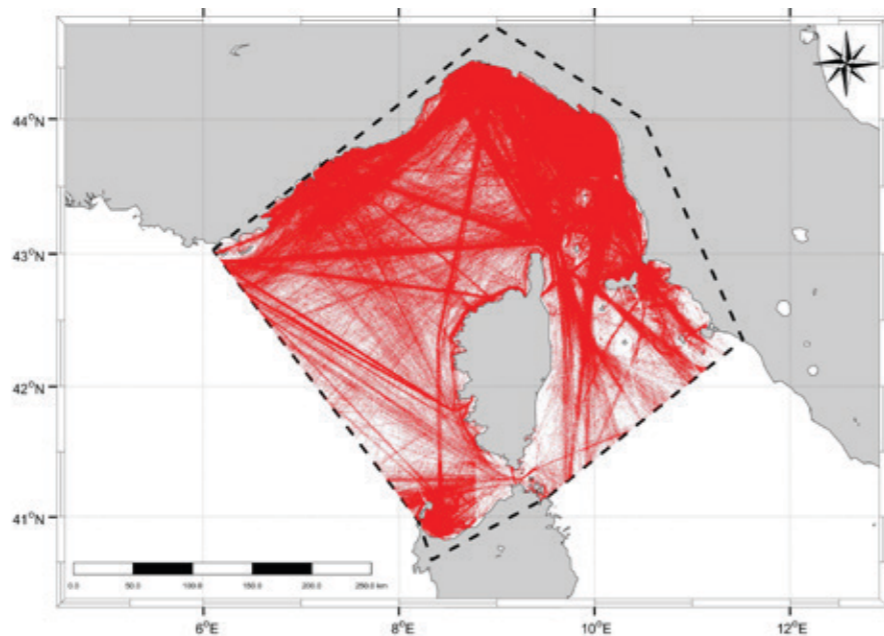


Figure 5: Automatic Identification System data for all vessels in summer 2018.⁴



Fin whale (*Balaenoptera physalus*)

Shipping and underwater noise in the region

- Relative to its small surface, the Mediterranean Sea is one of the busiest in the world, hosting 20 per cent of global seaborne trade, 10 per cent of world container throughput and more than 200 million passengers a year.²
- It is expected that shipping in the Mediterranean basin will increase in the coming years, both in terms of the number of routes and traffic intensity. Marine traffic is expected to double in 15 to 20 years.²
- The Pelagos Sanctuary is subject to strong anthropogenic pressures in the form of dense vessel traffic, particularly along well-defined routes. The area is frequented by tankers, cargo ships and ferries year-round and by pleasure boats during the summer.³
- In 2014, vessels travelled a total of 18 million km in the Sanctuary area alone (Figure 5).³

Impacts of underwater noise

- It is difficult to assess the impacts of underwater noise from maritime traffic on whales in the North West Mediterranean because of how large the area is and how challenging it is to monitor the whales when they are far from the coast for long stretches of time. Currently, there is no systematic acoustic monitoring in place.

Monitoring and management

- The European Union's Marine Strategy Framework Directive (MSFD) identifies underwater noise as a form of pollution that needs to be managed in the Mediterranean.
- WWF-Italy and the University of Turin are conducting a research project focused on anthropogenic noise and its effects on the distribution of fin whales in the Pelagos Sanctuary.
- This project and other ongoing initiatives are evaluating the impact of noise pollution on whales in the North West Mediterranean and identifying potential mitigation measures.
- These projects will provide baseline information about the acoustic environment that can be used to identify detrimental effects of underwater noise on fin whales. Noise frequency, intensity and distribution will be mapped and compared with whale vocalisations to evaluate the potential for masking. From this, potential mitigation measures will be developed and proposed.

HELLENIC TRENCH



The Hellenic Trench is found within the Ionian and Mediterranean seas. Located partially in international waters, it is bordered by EU countries and non-EU countries. It is made up of a continuous continental slope with trenches, troughs and basins.¹ The Hellenic Trench is of paramount ecological significance. This significance has been recognized by international agreements, including the Agreement for the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS).

KEY FACTS

- ✓ The Hellenic Trench is an ecologically significant area for marine mammals. It constitutes the only known breeding area for Endangered Mediterranean sperm whales and is the largest out of five high-density areas in the Mediterranean populated by Vulnerable Cuvier's beaked whales.
- ✓ Shipping activity is expected to significantly increase in the Hellenic Trench region. The expansion of nearby ports together with planned offshore development, exploration and mineral extraction will expose marine life in the area to further threats, including underwater noise pollution.
- ✓ Despite the existence of multiple governance frameworks for the conservation of Hellenic Trench species and habitats, there are currently no targeted efforts to reduce the impact of underwater noise on the marine environment.



Sperm whale (*Physeter macrocephalus*)

Marine life in the Hellenic Trench

- All cetaceans in the Hellenic Trench are sound-sensitive. They use underwater sound to echolocate, feed and socialise.
- The Hellenic Trench is a core habitat for the Endangered Mediterranean sperm whale subpopulation. It is estimated that only 200 to 250 individuals live in the eastern Mediterranean basin. The Hellenic Trench constitutes their only known breeding area.^{2,3}
- Fin whales, bottlenose, common, Risso's, striped and rough-toothed dolphins, Mediterranean monk seals and sea turtles also frequent the Hellenic Trench.
- The Hellenic Trench is the largest among the five high-density areas for the Vulnerable Cuvier's beaked whale in the Mediterranean Sea.

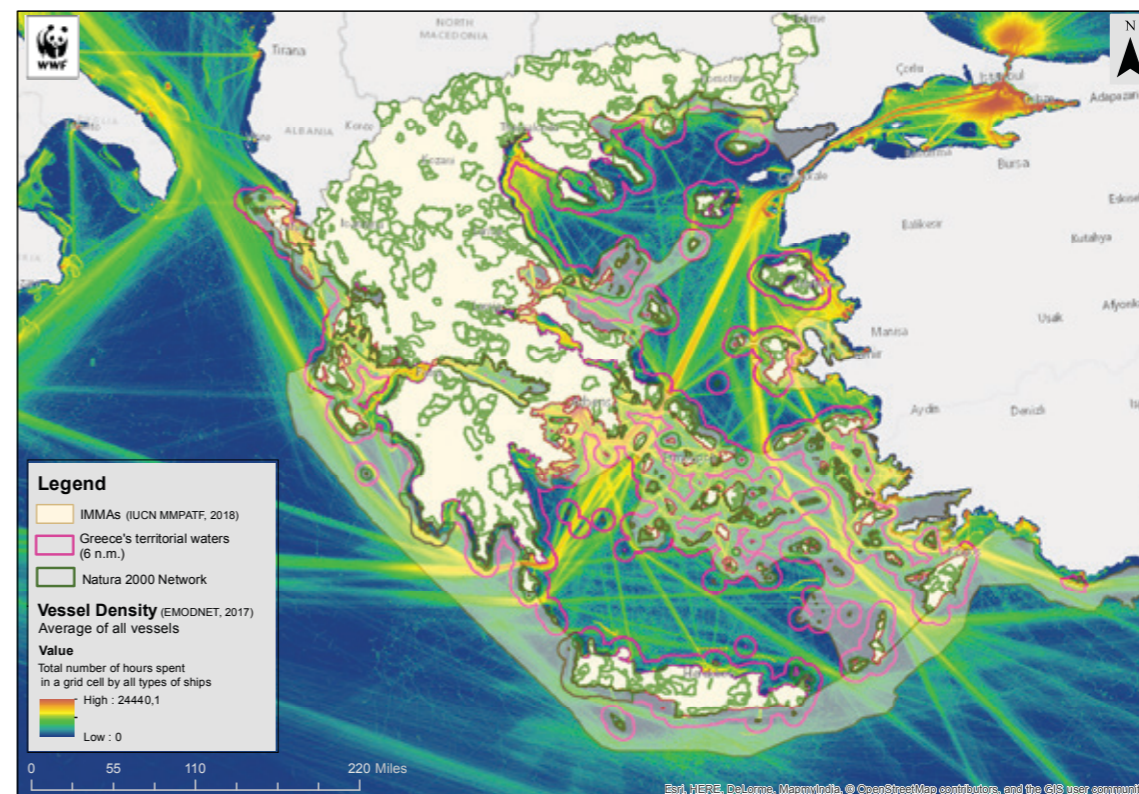


Figure 6: Shipping density in the Hellenic Trench Important Marine Mammal Area (IMMA).⁴

Shipping and underwater noise in the region

- Cetaceans in the Hellenic Trench face multiple direct and indirect threats, such as anthropogenic noise, ship strikes, fisheries interactions and plastic pollution. The impacts of these threats are poorly addressed by national authorities and international agreements.
- Sources of underwater noise in the Hellenic Trench include maritime and military activities, fisheries, seismic surveys and (planned) hydrocarbon exploration (Figure 6).
- Shipping is the main source of continuous anthropogenic low-frequency noise in Greek waters.⁵
- Ship traffic is predicted to increase significantly in this region due to the implementation of the Trans-European Networks, increased Europe–Asia exchanges, the expansion of nearby ports (e.g., the Piraeus port), coastal and offshore development and offshore resource extraction.

Impacts of underwater noise

- The impacts of underwater noise from ships on marine life in the Hellenic Trench are poorly understood. However, naval exercises involving the use of mid-frequency active sonars have caused several mass strandings of Cuvier's beaked whales along the coasts of the Hellenic Trench during the last 20 years.^{6,7,8}
- Underwater noise from ships may exacerbate the likelihood of vessels striking sperm whales in the Hellenic Trench, since the noise can disrupt the whales' ability to detect approaching ships.⁹

Monitoring and management

- The Hellenic Centre for Marine Research runs a passive acoustic monitoring program called the Poseidon Monitoring Network. The program uses buoyancy measuring stations in various locations in Greek waters, including Pylos in the Ionian Sea.¹⁰
- Additional underwater acoustic research has been completed under the framework of the European quietMED program and through ACCOBAMS.¹¹
- Governance frameworks for guaranteeing the effective conservation of Hellenic Trench species and habitats exist through Annex II of the Protocol to the Barcelona Convention concerning Specially Protected Areas and Biological Diversity in the Mediterranean and in Annexes II and/or IV of the Habitats Directive 92/43/EEC.
- Nonetheless, there are currently no targeted efforts to reduce the impacts of underwater noise on the marine environment in the Hellenic Trench.
- Greek authorities are currently supportive of International Maritime Organization discussions to limit the main engine power of ships (slow steaming) as an immediate measure to reduce greenhouse gas emissions in the shipping industry. If undertaken, slow steaming may have the co-benefit of reducing underwater noise.

ISTANBUL STRAIT



The Istanbul Strait is an important biological corridor between the Black and Mediterranean seas. Its shorelines are heavily urbanized and populated by over 12 million people. The Strait itself is among the most crowded and potentially dangerous waterways in the world. It has a narrow and winding shape and strong surface and deep-water sea currents, which hinder navigation by ships.

KEY FACTS

- ✓ The Istanbul Strait is a critical habitat for three Threatened cetacean subspecies: harbour porpoises, bottlenose dolphins and common dolphins.
- ✓ The strait is one of the busiest and narrowest in the world, crossed by some 2,500 vessels on a typical day.
- ✓ Acoustic surveys of Istanbul Strait since 2009 have confirmed the impacts of ship traffic in the strait on the behaviour of harbour porpoises and bottlenose dolphins.
- ✓ Current mitigation efforts focus on reducing ship strikes through a traffic separation scheme and the replacement of international pilots with experienced, local pilots when ships traverse the Strait.



Bottlenose dolphin (*Tursiops truncatus ponticus*)

Marine life in the Istanbul Strait

- Three species of cetacean are present in the Istanbul Strait year-round: the harbour porpoise (*Phocoena phocoena relicta*), the bottlenose dolphin (*Tursiops truncatus ponticus*) and the common dolphin (*Delphinus delphis ponticus*).
- All three are unique subspecies found only in the Black Sea and all are classified as Threatened by the International Union for Conservation of Nature (IUCN).
- The Istanbul Strait itself is a critical habitat for cetaceans due to the year-round presence of all three species and the important foraging and nursing habitats that it offers.

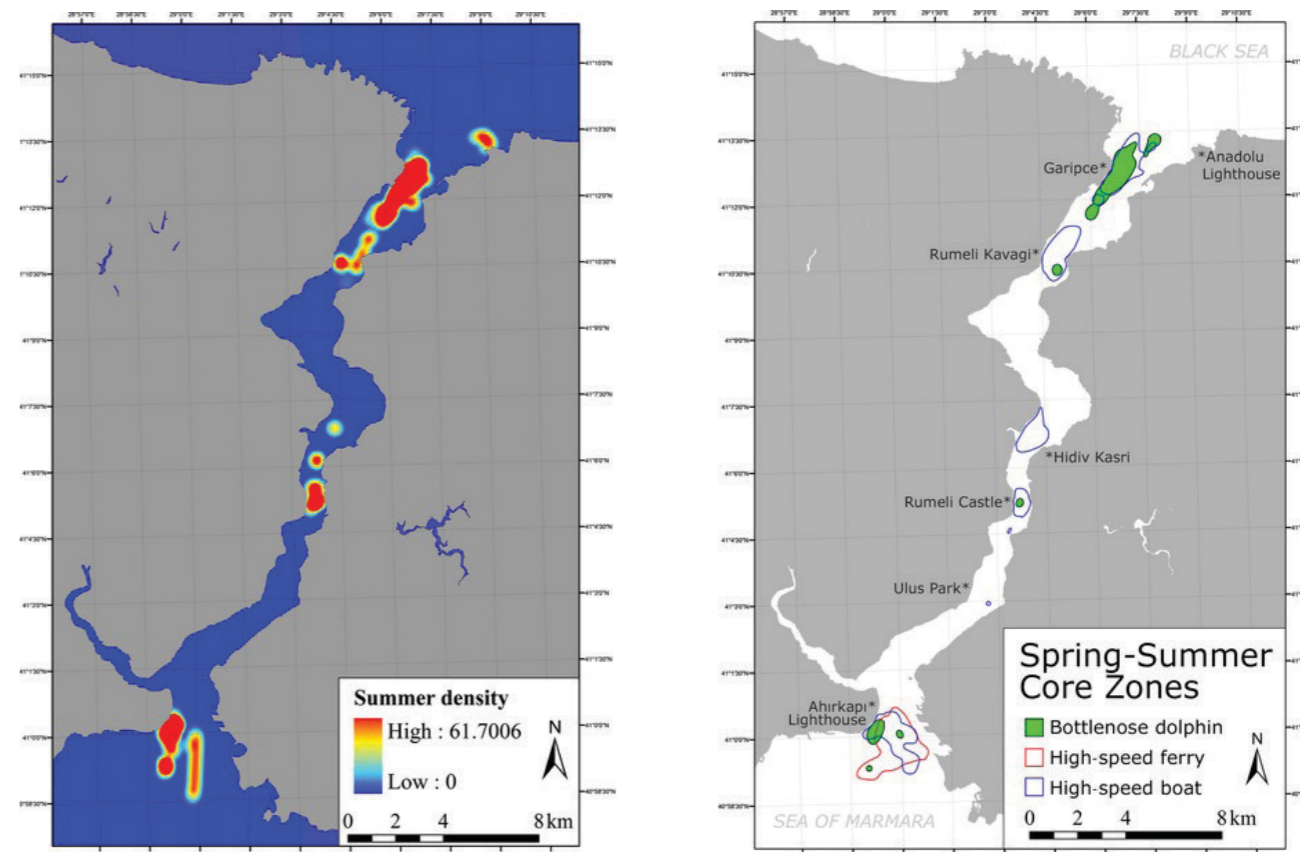


Figure 7: Bottlenose dolphin density per km2 (left) during summer 2012 and high speed ferry (right) in the Istanbul Strait.⁶

Shipping and underwater noise in the region

- The Istanbul Strait is one of the busiest and narrowest straits in the world.
- On a typical day, more than 2,500 vessels cross the Strait. Around 150 of these are cargo ships. On average, 25 of these cargo ships are carrying hazardous cargo.¹
- In the past 80 years, marine traffic has increased tenfold, from around 4,500 vessels per year in 1936 to 43,000 at present.²

Impacts of underwater noise

- The current understanding of the impacts of underwater noise pollution from shipping in Istanbul Strait is concerningly low.
- Studies have focused on the effects of marine traffic and commercial fishing vessels on the behaviour of bottlenose dolphins and harbour porpoises in the Istanbul Strait.
- In the presence of ships, harbour porpoises alter their behaviour and spend less time feeding at the water's surface. Scientists also suggest that porpoises may actively avoid areas with heavy ship traffic in the Istanbul Strait.³

- While in the Istanbul Strait, bottlenose dolphins spend over 50 per cent of their time in proximity to ships. They are visibly disturbed by the ships and spend little time resting or socialising.⁴
- Acoustic monitoring has identified the Istanbul Strait as a foraging ground and migration route for common and bottlenose dolphins and harbour porpoises. This monitoring also indicates that dolphin and porpoise activity is highest at night, when there is less ship traffic.⁵

Monitoring and management

- Acoustic surveys of Istanbul Strait by the Turkish Marine Research Foundation (TUDAV) have been carried out continuously since 2009 using a moored hydrophone.
- Management of the shipping impacts on cetaceans has focused on ship strikes through a traffic separation scheme and a pilotage system whereby experienced, local pilots replace international pilots for the duration of the Strait. However, there are no species-related monitoring systems or regulations in place to mitigate the impacts of underwater noise.

BALTIC SEA



The Baltic Sea is bordered by Denmark, Estonia, Finland, Latvia, Lithuania, Sweden, northeast Germany, Poland and Russia. The Baltic Sea has a unique salinity gradient and high variability in habitat types. These factors make it more biodiverse than would normally be expected of a low-salinity environment.¹ Its special geographical, oceanographic and climatological characteristics render the Baltic Sea's ecosystem highly sensitive to human activities.

KEY FACTS

- ✓ Bordered by nine countries, the Baltic Sea is a semi-enclosed sea in northern Europe. It is one of the planet's largest bodies of brackish water.
- ✓ Grey seals, harbour seals, ringed seals and the Critically Endangered Baltic Sea harbour porpoise are found in this sea, along with cod, herring and sprat, which are commercially valuable fish species. All are sensitive to underwater noise.
- ✓ The Baltic is one of the world's busiest seas, with maritime activities from every sector occurring there. The number of ships plying the Baltic is predicted to double between 2020 and 2030.
- ✓ Monitoring and management of underwater noise in the Baltic is done through regional programs (the Helsinki Commission, or HELCOM) and in line with the European Union's Marine Strategy Framework Directive.



Harbour porpoise (*Phocoena phocoena*)

Marine life in the Baltic Sea

- Marine mammals that spend time in the Baltic Sea include grey seals, harbour seals, ringed seals and harbour porpoises. All have acute underwater hearing abilities and use sound to sense their environments.²
- The harbour porpoise (*Phocoena phocoena*) is the only cetacean that lives in the region permanently. The International Union for Conservation of Nature (IUCN) lists the unique Baltic Sea subpopulation as Critically Endangered.³
- Fish species with high commercial value in the Baltic Sea include cod, herring and sprat. All three have been identified as noise sensitive.² Several Baltic fish species hear, produce and respond to sound at low frequencies.

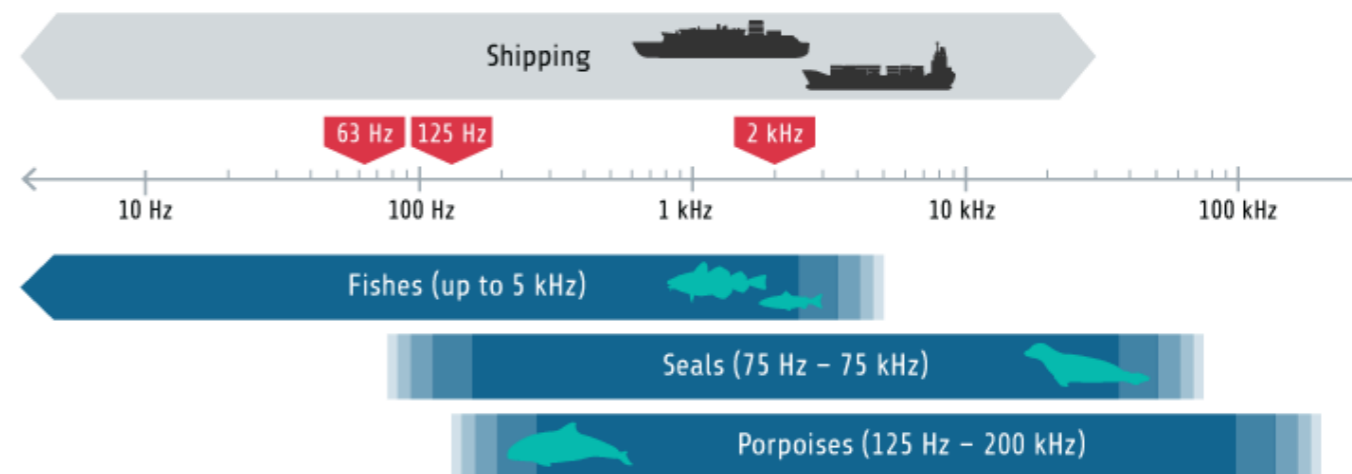


Figure 8: Sound frequencies generated by shipping overlap with the auditory range of some marine species present in the Baltic Sea. Fish typically hear sound at lower frequency ranges and harbour porpoises at higher frequency ranges. For comparison, the human ear can hear frequencies only at a range in from around 20 Hz to 20 kHz in air. Source: HELCOM.¹²

Shipping and underwater noise in the region

- The Baltic Sea is getting more and more crowded. It is used for a variety of maritime activities, almost all of which are projected to increase.
- More than 2,000 ships are afloat at any given moment in the Baltic Sea, with the number of ships predicted to double by 2030.^{4,5,6}
- A regional assessment of the Baltic Sea soundscape showed that underwater noise generated by commercial vessels is the main source of anthropogenic underwater noise in the area.⁷
- Construction of offshore wind farms in the Baltic Sea is another source of underwater noise, producing high-intensity, impulsive noise.

Impacts of underwater noise

- Although few studies have investigated the impacts of underwater noise from shipping on seals and fish in the Baltic Sea, scientists believe elevated noise levels may mask important sounds and disrupt behaviours.²
- Among harbour porpoises, underwater noise from ships interrupts foraging, causes behaviour changes and reduces their ability to use echolocation.^{8,9}
- Ship noise has been found to interrupt at-sea resting of grey seals.¹⁰

Monitoring and management

- The Convention on the Protection of the Marine Environment of the Baltic Sea Area is the main governance instrument for the Baltic Sea and its resources. The convention is governed by the nine bordering nations and the European Commission through the Helsinki Commission (HELCOM).
- HELCOM has committed to achieving good environmental status with respect to underwater noise. This is in line with the European Union's Marine Strategy Framework Directive. It requires that the level and distribution of both continuous and impulsive sounds not cause negative impacts on marine life. However, such levels have not yet been defined for sound-sensitive species in the Baltic Sea.¹¹
- A roadmap to address underwater noise in the Baltic Sea was developed by the HELCOM Expert Network on Underwater Noise (EN-Noise) and adopted in 2016. The road map includes the development of indicators aimed at setting impulsive and continuous noise thresholds at levels considered safe for marine life.¹¹
- In 2016, the Swedish government protected an important breeding and calving habitat for the Baltic Sea harbour porpoise by designating it as a Natura 2000 site. However, no conservation measures have been put in place yet to mitigate underwater noise from shipping. Ship lanes still traverse the habitat.

NORTH SEA



The North Sea is located between Great Britain, Denmark, Norway, Germany, the Netherlands, Belgium and France. Its southern shallow depths sea (down to 50m) are a dynamic and productive area due to strong tides, mixing and inputs from rivers and oceans.¹ The area is under pressure from range of human activities including commercial fishing, shipping, oil and gas, as well as climate change.

KEY FACTS

- ✓ The North Sea is one of the most intensely used marine regions in the world. The Strait of Dover is considered the world's busiest maritime route, with about 400 ship passages per day.
- ✓ Marine mammals of the southern North Sea – including harbour porpoises, harbour seals and grey seals – are sensitive to and disturbed by underwater noise, including from ships. Commercially valuable fish and shellfish are also sensitive to noise.
- ✓ The European Union considers underwater noise a pollutant under its Marine Strategy Framework Directive. The Joint Monitoring Programme for Ambient Noise North Sea (JOMOPANS) was initiated in 2018 as a framework for joint monitoring of ambient underwater noise in the region. It aims to provide maps and tools for managers, planners and other stakeholders to achieve good environmental status with respect to underwater noise in line with the directive.



Harbour seal (*Phoca vitulina*)

Marine life in the North Sea

- The North Sea, with its soft substrates and patches of solid reefs, hosts a large diversity of species, from soft corals to minke whales.
- This area is a prominent fishing ground for species such as mackerel, Atlantic cod, whiting, herring, European plaice and sole.
- The three most common marine mammals of the southern North Sea are harbour porpoises, harbour seals and grey seals. All three have excellent hearing and rely on sound for social communication. Harbour porpoises use echolocation to find food and navigate.
- Waters around two German islands in the North Sea (Sylt and Amrum) have been identified as important calving grounds for harbour porpoise.²

Shipping and underwater noise in the region

- The North Sea is among the most intensely used marine regions in the world. The Strait of Dover is considered the world's busiest maritime route.³⁻⁴
- A 15 per cent increase in shipping noise is expected to occur in the coming years.¹²
- Along with shipping, other noise-producing activities in the North Sea include bottom-trawling fisheries, oil and gas exploitation, seismic blasting, detonation of unexploded ordnance, wind farms, installation and maintenance of cables and pipelines, sand extraction and coastal development.¹
- Underwater noise from shipping adds another threat to an ecosystem already under pressure. Recent studies indicate that shipping noise accounts for the greatest amount of acoustic energy added to the North Sea system (Figures 9 & 10).^{5, 12}

Impacts of underwater noise

- Marine mammals of the North Sea are disturbed by human noise, including from shipping, sometimes over tens of kilometres from the source of the sound. Anthropogenic noise also has the potential to mask acoustic signals.^{6, 7, 8, 9} This could have serious consequences for harbour porpoise mothers and their calves.
- Mussels and oysters, both of which use sound in their life cycles, are critical for biodiversity restoration and ecosystem health. Before the dramatic decline of some species due to overfishing and disease, they covered about 20 per cent of the North Sea floor. There are now active efforts to recover these shellfish beds.
- Although there have been no known field studies of the impact of noise on mussels and oysters in the North Sea, it is known that they are sensitive to noise. Ship noise causes multiple stress responses in mussels and may affect their ability to grow and reproduce.¹⁰ This may partially explain the decline of mussel banks in some areas of the North Sea.

Monitoring and management

- The European Union considers underwater noise a pollutant under its Marine Strategy Framework Directive.
- The Joint Monitoring Programme for Ambient Noise North Sea (JOMOPANS) was set up in 2018 to monitor various sources of underwater noise, including noise caused by shipping.¹¹ This programme has produced validated maps of shipping noise in the area and provides a good example of regional noise monitoring efforts (Figures 9 and 10).
- The United Kingdom is supporting nationally coordinated efforts to quantify underwater noise levels from shipping in its national waters.

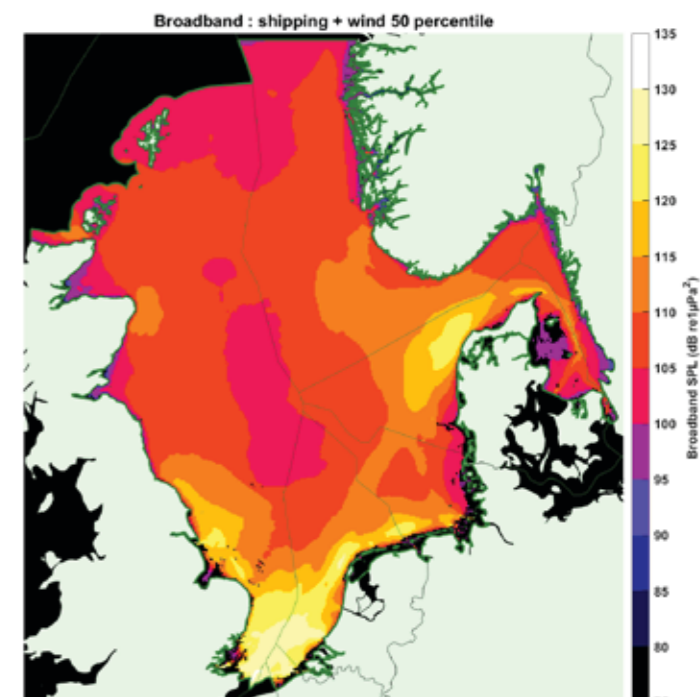


Figure 9: Total sound levels at the North Sea of both ship and natural sound. These levels range from 105 dB to 130 dB and are significantly higher than natural noise levels.¹⁴

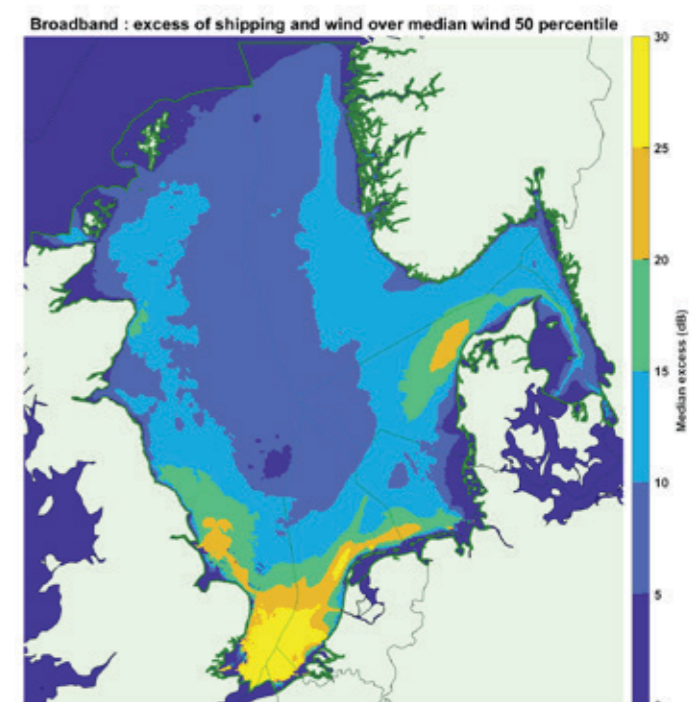


Figure 10: Excess level, the difference between the total shipping noise level and the undisturbed levels with differences up to 30 dB.¹⁴ These maps demonstrate that continuous underwater sound in the North Sea is dominated by shipping noise, especially the southern part experiences very high levels.

SOUTH LANTAU WATERS



The South Lantau Waters are found along the southwest border of the Hong Kong Special Administrative Region. The marine region of this highly urbanized city is susceptible to increasing pressures from coastal development, heavy marine traffic and water pollution. Forming part of the Pearl River Estuary in the South China Sea, the brackish waters off South Lantau Island support unique estuarine wildlife and ecosystems.

KEY FACTS

- ✓ Vulnerable Indo-pacific humpback dolphins and Indo-pacific finless porpoises inhabit the South Lantau Waters.
- ✓ Two major shipping lanes are situated off South Lantau. Maritime activities in the vessel channels off South Lantau are intensive and expected to increase due to development projects underway or commencing in the next 10 years.
- ✓ WWF-Hong Kong has been conducting an underwater sound study off South Lantau since late 2016. Acoustic monitoring indicates that dolphins and porpoises spend little time close to shipping channels and cross the channels more frequently at night, when there is less ship traffic.



Humpback dolphin, Pink dolphin (*Sousa chinensis*)

Marine life in the South Lantau Waters

- Indo-pacific humpback dolphins (*Sousa chinensis*) and Indo-pacific finless porpoises (*Neophocaena phocaenoides*) reside in the South Lantau Waters.
- Humpback dolphins in Hong Kong belong to the broader Pearl River Delta dolphin population, believed to be the largest humpback dolphin population globally. The species has been listed as Vulnerable since 2017.^{1,2}
- With a continuous natural coastline and abundant fish resources, South and West Lantau are by far the most critical foraging habitats for humpback dolphins in the Pearl River Estuary. These waters have become more important since 2015, when the dolphins shifted their range and distribution, possibly to avoid near-shore construction and reclamation works off North and Northeast Lantau.³

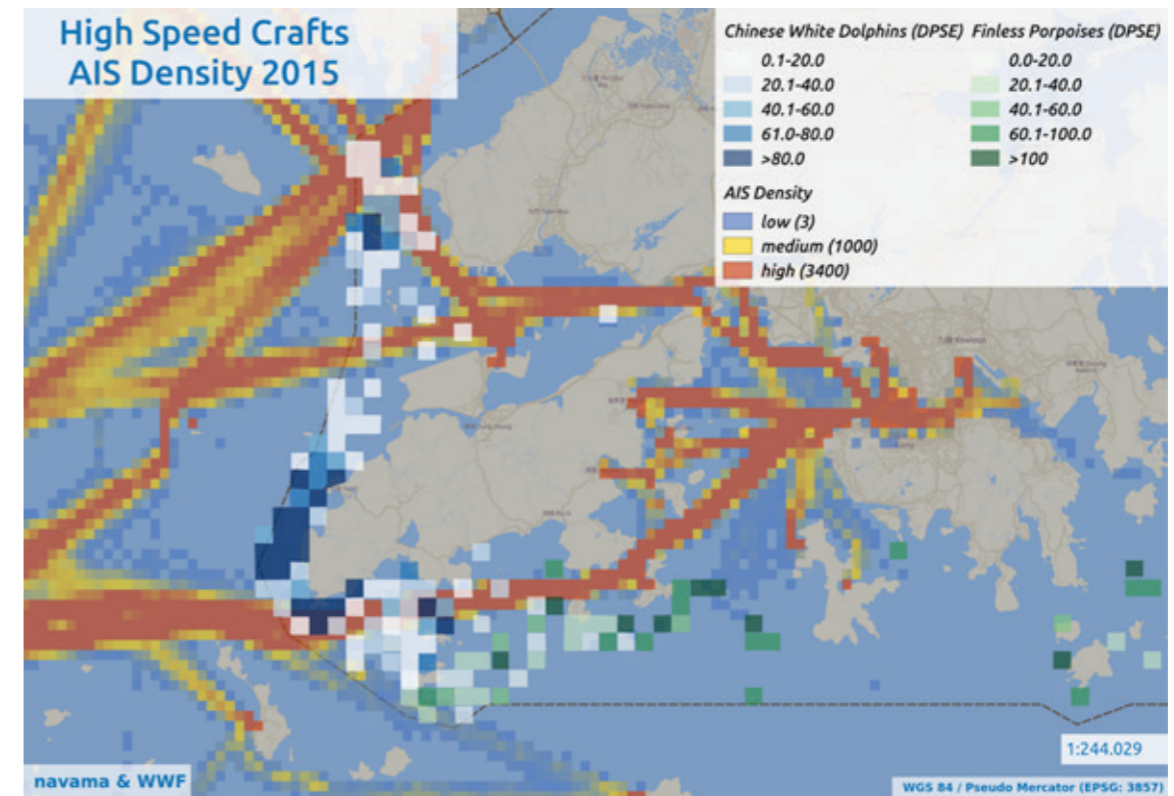


Figure 11: Shipping and local cetacean densities modelled off South Lantau and the broader Pearl River Estuary in 2015.

Shipping and underwater noise in the region

- Two major shipping lanes (the Adamasta and West Lamma channels) dissect the South Lantau Waters and are used by cross-border high-speed ferries, cargo ships and fishing vessels.
- Cross-border high-speed ferries travel at an average speed of approximately 40 knots and operate day and night every 20 minutes and 45 minutes, respectively.
- The number of passengers on ferries has been dropping gradually since the Hong Kong–Zhuhai–Macau Bridge was built in October 2018. However, maritime activities along the vessel channels are expected to increase due to marine development projects underway or commencing in the next 10 years.
- Based on Automatic Identification System (AIS) and dolphin modelling, areas with high shipping density overlap spatially with waters in high use by cetaceans off South Lantau.
- The shipping lanes are also close to several marine parks proposed for cetacean conservation, as well as foraging and socialising hotspots identified through acoustic monitoring.³

Impacts of underwater noise

- Marine traffic has been identified as one of the key threats to humpback dolphins in Hong Kong. Extensive, concurrent marine developments in both Hong Kong and Guangdong waters create additional sources of underwater noise.
- High-speed ferry noise could mask the sounds produced by humpback dolphins, interfering with their foraging behaviour and ability to navigate and communicate with each other.
- Acoustic monitoring has revealed that dolphins and porpoises only spend short periods of time close to shipping channels. They cross the channels more frequently at night, when ship traffic is less intensive.

Monitoring and management

- WWF-Hong Kong has been conducting an underwater sound study off South Lantau since late 2016 to monitor the activity and behavioural patterns of local cetaceans, characterize shipping noise by vessel type, and map fish chorus. The findings have been presented to policy makers, academics and companies.
- WWF-Hong Kong has also proposed three possible solutions to mitigate underwater vessel noise in the South Lantau area: rerouting vessels, restricting their speeds and reducing ferry shifts. Public opinion on these solutions has been collected through ferry passenger questionnaires since mid-2019.

THE GREAT BARRIER REEF



The Great Barrier Reef (GBR) covers 350,000km². It is a UNESCO World Heritage Site, recognized as one of the richest and most complex natural ecosystems on Earth.¹ The GBR is made up of some 3,000 individual coral reefs that contain an extraordinary abundance of biodiversity, with more than 1,500 fish species, 400 coral species, 4,000 mollusc species, 240 bird species and 30 marine mammal species.¹

KEY FACTS

- ✓ The Great Barrier Reef (GBR) off the coast of eastern Australia in the Coral Sea is the largest coral reef ecosystem in the world and a global biodiversity hotspot.
- ✓ As well as corals, birds, fishes and invertebrates, the GBR is home to six of the world's seven turtle species. It is also important for about 30 species of whales and dolphins. It is a major feeding ground for dugongs and contains mating and calving grounds for humpback whales.
- ✓ Within Australian waters, shipping activity has grown by about 4 per cent a year since the early 2000s. Much of this growth has been in the Coral Sea and is linked to increasing exports of natural resources.
- ✓ The Australian government plans to quantify underwater noise from ships on a national scale and develop guidelines on underwater noise for GBR species.



Humpback whale (*Megaptera novaeangliae*)

Marine life in the Great Barrier Reef

- Humpback whales are the most commonly sighted whale in the GBR Marine Park. The reef is a biologically important area for these whales, where they mate and give birth.²
- During the breeding season, male humpbacks produce songs to attract females.
- A broad range of coral reef fish species use reef sounds during the larval settlement stage of their life cycles.³
- Turtles sense and react to low-frequency underwater sound, although it's unclear how they use it.⁴

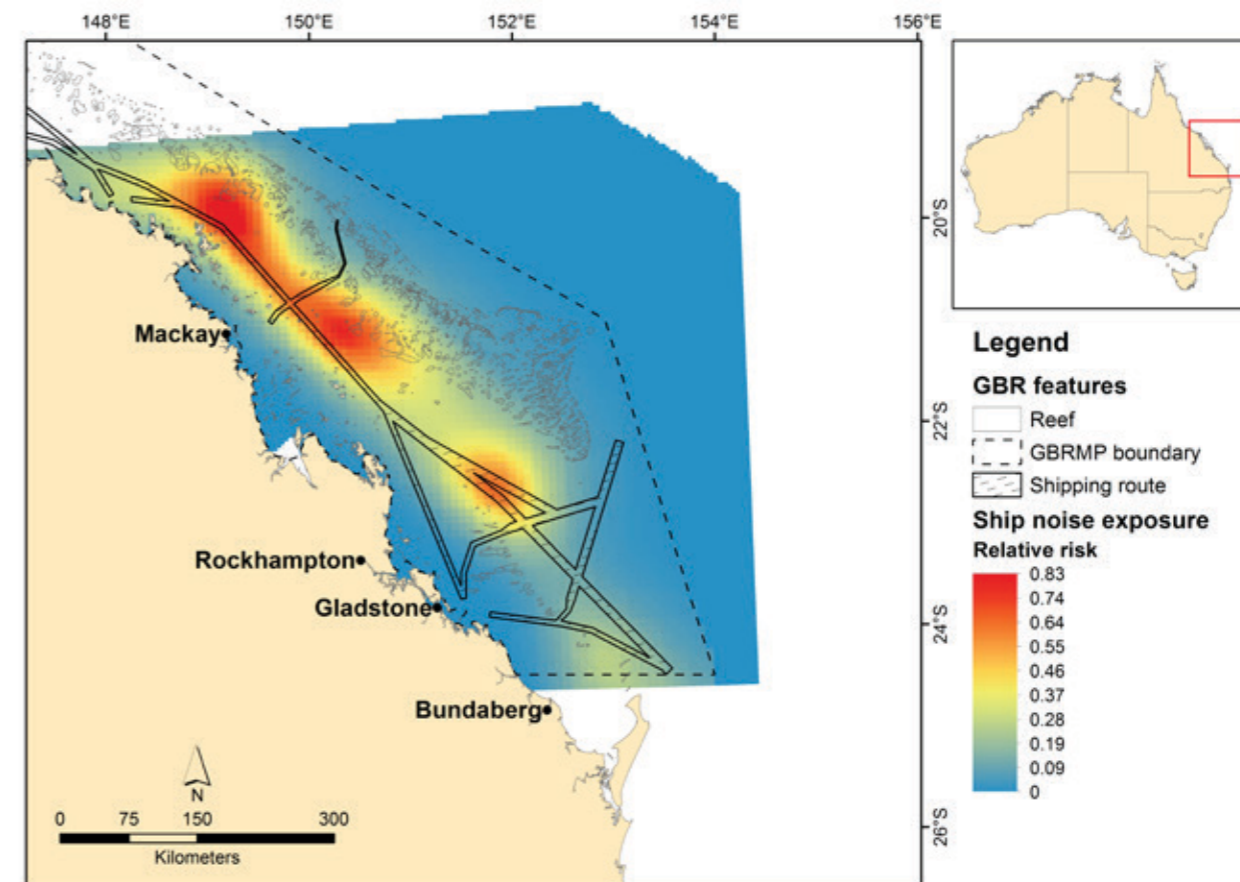


Figure 13: Map of the modelled relative risk of ship noise exposure for humpback whales in the Great Barrier Reef.¹

Shipping and underwater noise in the region

- As an island nation, Australia relies heavily on shipping for trade.
- Australia is one of the world's largest exporters of natural resources. International exports, mainly of coal and liquefied natural gas, make up about 87 per cent of its total cargo.⁵
- In Australian waters, commercial shipping has grown by approximately 4 per cent each year since the early 2000s. Much of this growth has been in areas that are significant for marine mammals, including the GBR World Heritage Area (Figure 13).
- Shipping traffic related to natural resource export and general trade continues to increase near the GBR. Port expansions (e.g., the Adani Carmichael mine project, Abbott Point) are expected to cause further increases.

Impacts of underwater noise

- It's not yet known exactly how much underwater noise breeding whales in the GBR are exposed to. However, models indicate that it could be enough to mask the sounds they make to attract mates and limit their ability to communicate across distances.
- In other parts of the world, underwater noise from ships has forced humpback whales to change their foraging

activities and singing behaviours significantly. In the GBR, their breeding grounds overlap with a shipping route that services all ports on the Queensland coast – a situation that has the potential to cause masking of their song.⁶

- Given the great diversity and volume of fishes, turtles and marine mammals in the GBR that rely on sound for aspects of their life cycles, it is likely that ship noise is causing harm. Although evidence of impacts is sparse for the GBR, it exists in other parts of the world.^{7,8}

Monitoring and management

- The Australian government recently funded a National Environmental Science Program (NESP) project to quantify shipping noise in the country's marine environment. This is the first comprehensive, nation-wide assessment of shipping noise in Australia (and within World Heritage Areas and Marine Parks).¹¹
- The government is also planning to develop federal guidelines on underwater noise through its Reef 2050 Long-Term Sustainability Plan. The plan mentions developing a new guideline on assessing and managing underwater noise impacts on GBR species. The NESP project aims to contribute to this objective.^{11,12}
- Because of coastal development and port expansions related to the mining industry, UNESCO is monitoring Australia's commitment to the sustainability of the GBR as a World Heritage Area.



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