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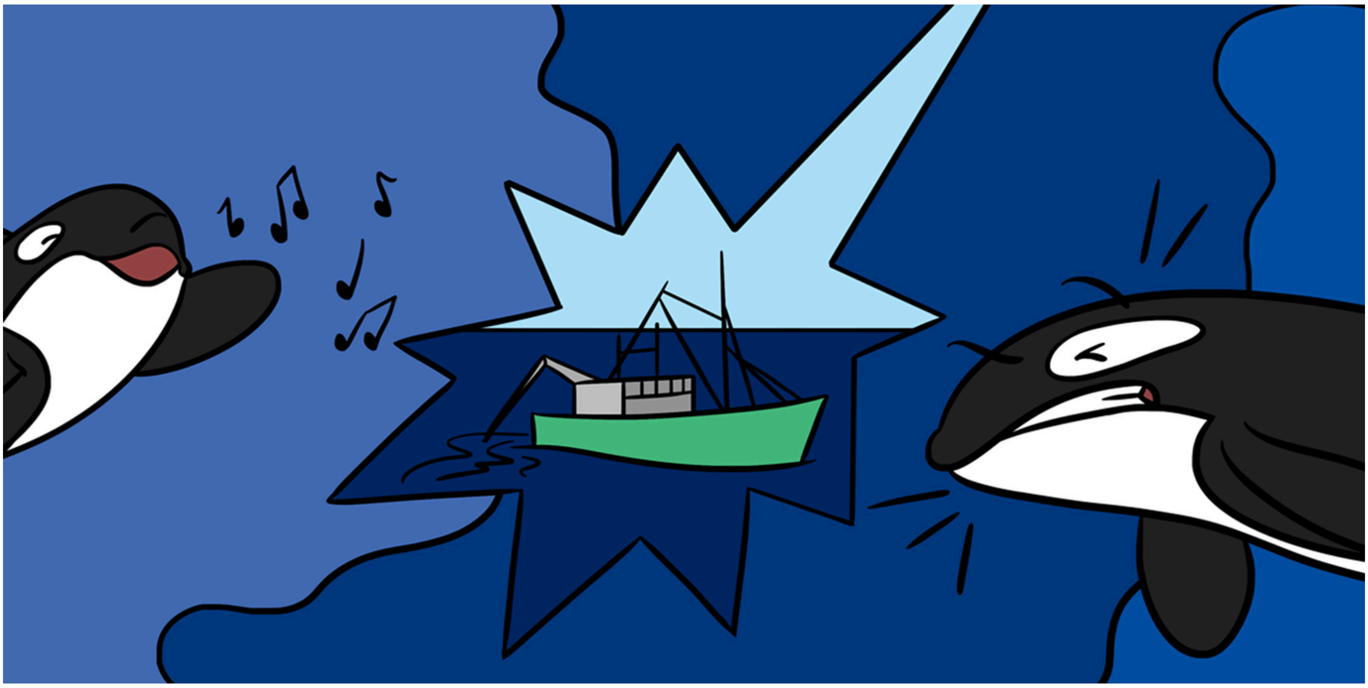

OCEAN NOISE: THE HUMAN FOOTPRINT ON UNDERWATER SOUNDSCAPES

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YOUNG REVIEWERS:

CLASS 2A—SECONDARY SCHOOL LICEO SCIENTIFICO "DUCA DEGLI ABRUZZI"
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You may have heard that our oceans are under threat due to the impacts of climate change, plastic pollution, and ocean acidification. But there is another threat that must be highlighted—noise pollution. Humans are becoming more and more reliant on the ocean for transportation and renewable energy, but these activities introduce noise. Every fishing vessel, cruise ship, ferry, cargo ship, and jet ski leaves a sound "footprint," meaning our oceans are becoming increasingly noisy places. Many animals, including whales, dolphins, and fish, produce unique sounds—and scientists are looking at how man-made noises are affecting their communication, behavior, and habitats. We hope to discover ways to create harmony between humans and marine wildlife, to reduce the impact of noise pollution on marine ecosystems. In this article, we will introduce how marine species use sound, how noise pollution affects them, and how they are adapting to sharing their environments with humans.

FREQUENCY

The number of sound waves that are recorded by a hydrophone at a fixed point in time. High-frequency sounds have a high pitch; low-frequency sounds have a low pitch.

AMPLITUDE

How loud a sound is. Scientists can measure amplitude by describing how high the sound pressure waves are, detected by a hydrophone.

Figure 1

(A) High- and low-frequency sound waves, and high- and low-amplitude waves. Large whales make calls that are low frequency and high amplitude, whereas dolphins make high-frequency calls that are loud, but not as loud as larger whales. **(B)** A spectrogram of a dolphin whistling, with echolocation clicks in the background. Spectrograms are images of sound, with time on the x-axis and pitch on the y-axis, allowing scientists to visualize the ocean soundscape.

HYDROPHONES

Underwater microphones used to listen to the ocean.

SOUNDSCAPE

The combination of sounds created by plants and animals, sounds like wind, rain, storms, earthquakes, and ice-breaking, and sounds created by humans. A region's soundscape can vary over time.

HOW DO WE RESEARCH SOUND?

When people think about the ocean, they often imagine a quiet world, but beneath the surface, oceans are very noisy places!

Sound travels through water at a speed of about 1,500 meters per second. That is three times faster than sounds move through the air, and equivalent to around 30 lengths of an Olympic swimming pool every second! Sound is created by vibrating objects. Objects in the ocean which vibrate create sound pressure waves that compress and decompress the surrounding water molecule, allowing a sound wave to travel through the water. Sounds waves traveling through the water are described by their **frequency** (pitch) and **amplitude** (loudness). High-frequency sounds have a short wavelength and do not travel very far. Low-frequency sounds have a long wavelength and can travel further, especially in water (Figure 1).

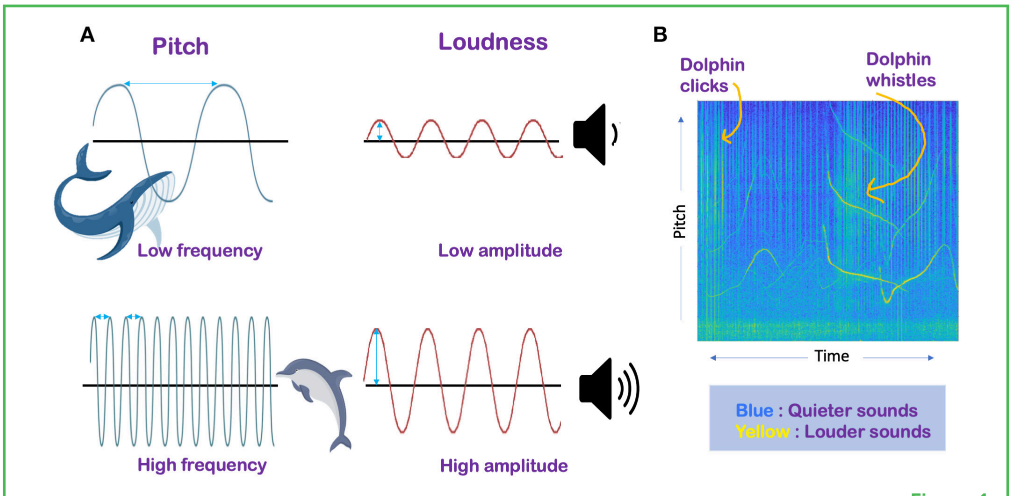

Figure 1

Scientists use underwater microphones called **hydrophones** to record sounds within the ocean. These recordings create a **soundscape**, which is a "picture" of all the sounds in one place at one point in time. Using hydrophones, we can detect weather events like hurricanes and earthquakes, and human activities such as fishing and shipping. By comparing soundscapes from various places, and from 1 year to another, scientists can track animals that travel long distances and look at changes in habitats and ecosystems over time. By understanding how each type of sound spreads underwater, we can predict how far sounds will travel in our oceans and what effects they might have on the wildlife that lives there [1].

WHY IS SOUND IMPORTANT UNDERWATER?

On land, most humans use sight to explore the world around them. Our eyes detect light patterns, and our brains work out what those light patterns mean. But light does not reach many parts of the ocean, so many animals rely on sound to "see" each other, to find their way around, and to hunt for food. Seals, fish, crabs, and even plankton all use sound to communicate with each other, but the underwater animal sounds we know the most about are those made by whales and dolphins.

Large whales, such as humpback, fin and blue whales, use low-frequency sounds that can be heard over long distances. Some are stand-alone calls and others form songs! Each whale species has a unique call, which makes it easier for scientists to detect who is who (Figure 2). Toothed whales, such as dolphins, communicate using high-frequency sounds, which we call clicks and whistles (Figure 1). Whistles are used to chat or pass on social information, although we do not yet know what the animals are chatting about! Perhaps they are warning others of danger or telling them where the best fishing spots are! The clicking sounds dolphins make are used for **echolocation**. The dolphin produces clicks that bounce off objects in the ocean, and the sound waves are reflected back to the dolphin (Figure 2). That "echo" tells the dolphin where the objects are and provides information on the size and shape of objects, allowing dolphins to "see" with sound.

ECHOLOCATION

The ability to locate objects using reflected sounds. An animal sends out a series of sounds and listens for the signal that bounces off the object and returns to the animal.

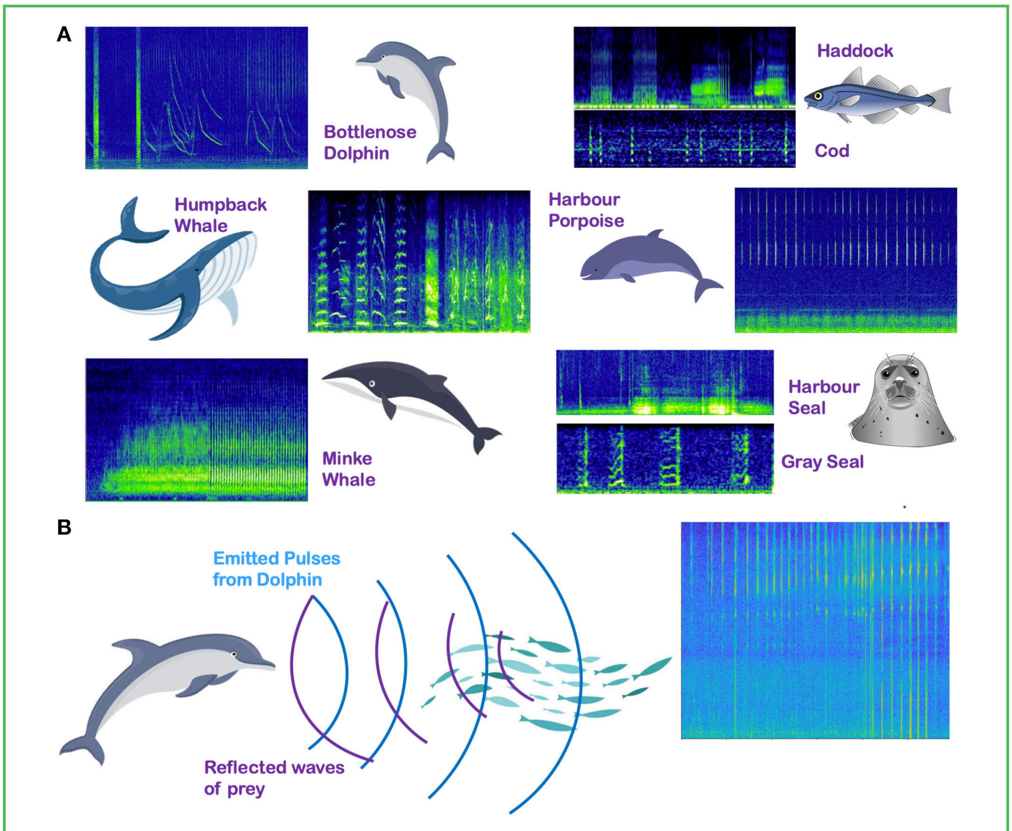

Figure 2

Figure 2

(A) Example of spectrograms of unique calls made by marine mammals, which allow scientists to identify them in the soundscape. Notice how each call type has unique pitch and loudness characteristics. Spectrograms are obtained through the US National Oceanic and Atmospheric Administration[1]. **(B)** Dolphins use echolocation to find food, by emitting clicks.

[1] If you would like to listen to what the animals sound like, head to `https://www.fisheries.noaa.gov/national/science-data/sounds-ocean` where you can listen to the spectrograms.

Using sound to listen to environments is a great way to eavesdrop on other species without affecting their day-to-day lives, which helps us to work out how humans are affecting soundscapes around the world.

THE HUMAN IMPACT ON SOUNDSCAPES

Humans depend on the oceans for transportation, fuel, and creating renewable energy (such as wind farms). The noise these activities make leaves a large "footprint" on the ocean's soundscape (Figure 3). Much of the foods we eat and the things we buy have been transported across the oceans in ships. Every day, around 60,000 ships are moving across our oceans and seas, with 500 ships in the English Channel alone. These ships carry 226 million containers packed with things humans consume, and the ships' engines produce very loud, low-frequency sounds—when a sound produced has a negative effect

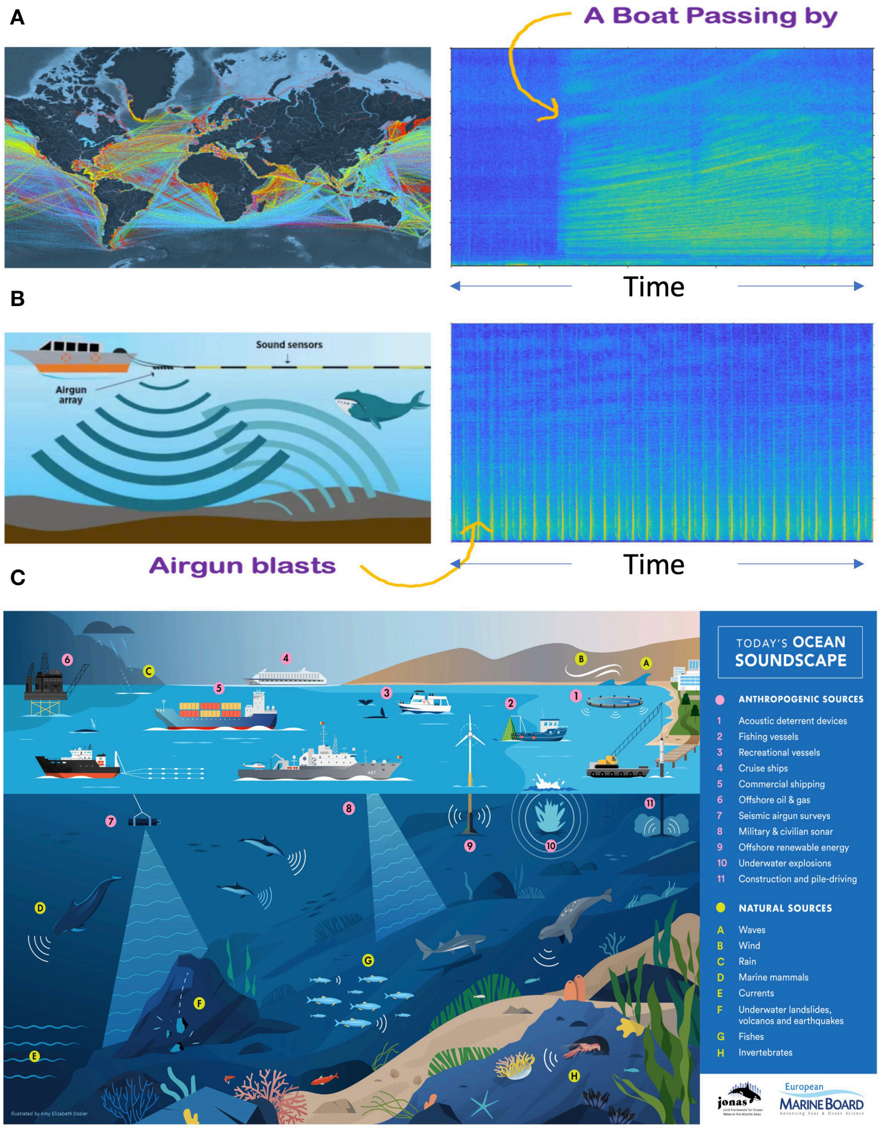

Figure 3

Figure 3

(A) Map of global ship activity per day. Each color represents a different ship type and you can see clear paths across the oceans, where there is a lot of ship noise. The spectrogram illustrates a boat passing by a hydrophone. Notice how bright the color is—this shows how loud the ship is relative to the background sound in that area. **(B)** Airguns are used to explore the seafloor, and their blasts are deafening to nearby wildlife. **(C)** Today's ocean soundscape contains many sources of noise that marine life must face. "Anthropogenic" means human generated (Image credit: the Jonas Project [2]).

on the environment it becomes "noise." Ship noise spreads great distances through the water and interferes with marine animals' ability to communicate and find food. The increasing level of ship traffic is raising the natural sound level of our oceans!

Much of the oil and gas we use comes from reserves below the seabed, and searching for new reserves is a very noisy business. Survey ships fire loud, low-frequency sounds from acoustic "guns" into the seabed. The echoes produced from each blast enable people to map the seabed and find where oil and gas may be hidden. These surveys can fire up to 40 guns every few seconds, for days or weeks at a time, and at any one time there can be 20–40 surveys going on around the world. Underwater, these blasts sound louder than standing next to a jet engine as it takes off! A seismic airgun blast is estimated to reach up to 260 underwater **decibels**. If you were standing close to a space shuttle as it launched, you would experience about 160 decibels (dB). Humans damage their hearing if they are exposed to 90 dB continuously, but we do not yet know the decibel level that causes long-term damage to marine life. The noise these guns produce is deafening to animals nearby, and as the sound waves can travel further than 4,000 km they affect the soundscape of large oceanic areas. Ocean exploration happens every day, raising noise pollution to dangerous levels and exposing marine life to levels of noise that would cause long-term damage to humans.

DECIBEL (DB)

A unit for sound, with a logarithmic scale. Every increase in 10 dB means the sound is 10 times louder. Human hearing is harmed by continuous sounds of 90 dB or above.

HOW DOES ALL THIS NOISE AFFECT MARINE ANIMALS?

Research has shown that animals may stop hunting for food or may leave protected areas because of noise pollution. Scientists often observe behavioral changes, such as species diving into deep water to escape noise or changing the amount of time they spend at the surface, alterations in the frequency of diving for food, and even changes in how vocal they are—all as a result of increasing noise in the soundscape.

Busy coral reefs are naturally noisy places, and new research shows that young fish use sounds to find the best reefs to live in [3]. But noise pollution can mask natural sounds, making it difficult for marine animals like fish (who make relatively quiet sounds) to hear each other, which interferes with their navigation. This can cause animals to become disorientated and vulnerable to predators, or even to become stranded on beaches as they try to escape underwater noise.

Studying the polluting effects of noise is difficult. We cannot give a whale a hearing test or ask a dolphin what it thinks about noisy gas and oil survey ships. Instead, we must study changes in noise levels, along with animal behavior, to find out how noise affects marine species. We can then use this information to build an idea of the impact of noise on our oceans.

Armed with this information, we might then work to make ships quieter, perhaps by redesigning their propellers and engines. We might also look at restricting how fast ships can travel and stop them from entering sensitive areas. In Boston, USA, scientists use hydrophones day and night in busy shipping lanes to listen for endangered right whales [4]. Their work is helping to reduce the number whales hit by boats.

Similar technologies are being developed for other species, and scientists are exploring how we can put hydrophones on swimming robots that roam the oceans all year, listening to the ocean soundscape and letting us know when it changes. Artificial intelligence systems are being used to teach these robots to detect calls belonging to certain whale species, enabling robots to survey our oceans much more quickly and accurately and to reach places that have never been surveyed before—including under the ice shelves of Antarctica![2]

[2] You can help! If you would like to help these swimming robots learn to recognize ocean sounds, visit Zooniverse (www.zooniverse.org). Here, you can learn to identify calls from various marine animals, then find them in recordings collected from all over the world.

Humans depend on the ocean for our way of life, but this way of life is causing harm to marine life. Understanding the effect anthropogenic noise has on marine life is increasingly important, and requires a deep understanding of the soundscapes. Reducing the amount of noise humans emit into the natural world is critical in our fight to protect wildlife all around us, and within our oceans.

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Experiment
Try out your own soundscape analysis:
Take 5 min to stand in your garden, local park or beach and listen to the sounds around you. Take a note of the time of day and maybe record what you can hear on a mobile phone. Then revisit the same place at different times of the day and re-record the soundscape. Make a list of what you can hear each time, and see if you can find any patterns. What time of day do the birds sing most? Can you hear any insects? Does traffic on the road mask specific sounds? How do sounds change throughout the day and from one day to the next?

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YOUNG REVIEWERS

CLASS 2A—SECONDARY SCHOOL LICEO SCIENTIFICO "DUCA DEGLI ABRUZZI", AGES: 15–16

We like English, problem solving, statistics, maths-science competitions and we eagerly joined in this project. We are quite sportive, quite creative, we love group activities, we all love music and the walls in our classroom are covered with posters of our favorite singers. We are tight-knit and we often go for a pizza. We are keen on sharing homemade desserts. We have a lot of fun dancing together! Our teachers say we are a very nice bunch of people.

ST OSCAR ROMERO CATHOLIC SCHOOL, AGES: 12–13

We are a group of Y8 and Y9 students at St Oscar Romero Catholic School in Worthing, UK. We love opportunities to extend our learning beyond the classroom, so it has been great to review scientific papers prior to publication!

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Ellen L. White is a Ph.D. student at the School of Ocean and Earth Science, University of Southampton. Her main research theme are bioacoustics and marine soundscapes. Through the use of machine learning algorithms, she identifies interactions between marine mammal species and human activities to understand the affect anthropogenic activities are having on regional soundscapes and the animals that live there. Starting as a marine biologist she has a passion for ocean conservation and enjoys the challenge of the tech sector, learning new skills and creating new tools for analyzing big data sets, to extract ecological information which can help inform how best to protect our oceans.
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