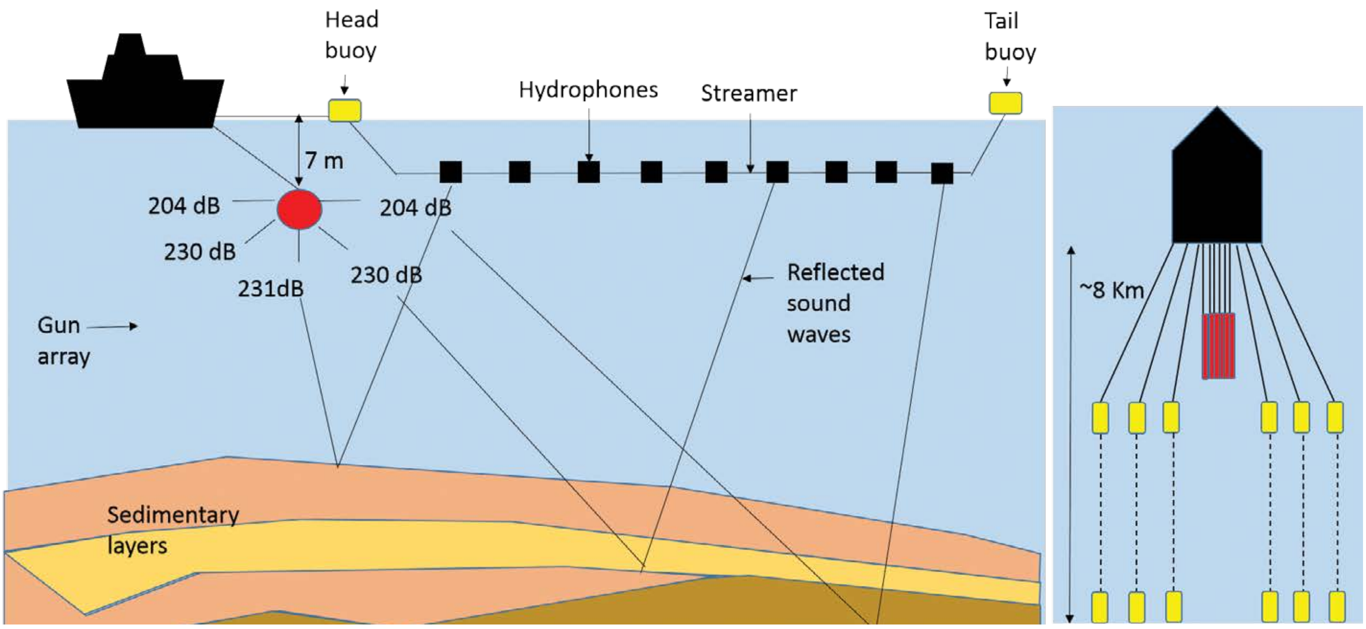
Jean Purdon explains how seismic surveys could impact marine life

For a long time I worked on ships that survey the ocean floor, looking for oil and gas. My job was to ensure that marine animals, especially whales, dolphins, seals, turtles and diving seabirds, were not hurt by the loud, sudden sounds produced during the process.

These so-called 'seismic surveys' use large compressors to power airguns, which release blasts of air, creating bubbles that produce impulsive high-intensity, low-frequency sound waves as the bubbles expand and contract. The airguns generally consist of anywhere between three and six sub-arrays with 12 to 48 single airguns, all varying in volume size. They are towed behind the seismic survey vessel, at a depth of about 10 m. The vessel also tows as many as 20 cables that can be up to 10 km long. These cables, known as streamers, contain hydrophones that receive the sound signals reflected off layers in the seabed. The sound signals are processed and analysed to determine where reserves of oil and gas may be located.

Sound is a type of energy produced by vibrations in gases, liquids or solids. The vibrations create a sound wave as particles in the medium oscillate back and forth, transmitting the energy through a 'knock on'



A typical seismic survey layout of the vessel and equipment used, in side profile (left) and aerial view (right). Sound intensity levels in decibels are measured as dB re 1 μPa @ 1 m.

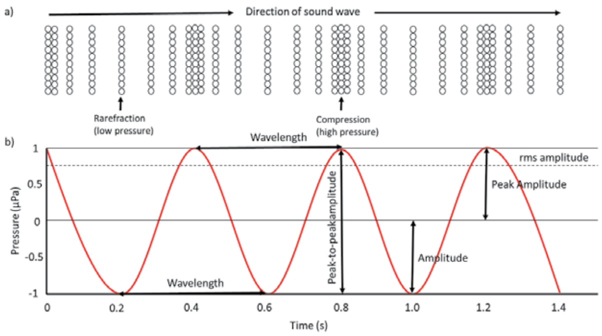


Diagram of a sound wave showing a) compression and rarefaction of particles and b) the amplitude and frequency.

effect. The particles move parallel to the direction of the wave, making sound waves longitudinal – as opposed to transverse – waves. Longitudinal waves are also known as compressional waves because they alternately compress and decompress particles, creating areas of high and low pressure. These pressure fluctuations are detected by the receiver, such as a hydrophone or a human ear.

The height of a sound pressure wave, known as the amplitude, corresponds with the highest pressure, and therefore its energy and loudness. The energy passing through a unit area per unit time is the sound intensity, measured in watts per square metre (W/m^2). Humans can hear over a very large sound range, but the way we perceive sound intensity does not follow a linear relationship. The relative loudness of sounds is therefore measured instead as a sound intensity level in decibels (dB). The decibel is a logarithmic unit that indicates the ratio of the physical intensity of a sound, relative to a reference value. In the case of sound pressure, the reference level for air is 20 µPa @ 1m (20 micropascals at a distance of one metre), but the reference level for water is 1 µPa @ 1m. The decibels measured a metre from the sound source is known as the source level, but the different reference levels mean that a source level of 150 dB measured in water is not the same as 150 dB measured in air.

Seismic surveys have been shown to produce source levels of up to 260 dB re 1 µPa @ 1 m. Because this is measured in water, a direct comparison with the level in air is difficult, but would be equivalent to about 200 dB – human eardrums typically burst at 160 dB. More typically, though, the air-equivalent sound is in the 140–180 dB range, which is still very loud, considering a rock concert produces sound measured at about 120 dB.

Seismic surveys also produce sound that is very low frequency, in the 10–100 Hz range. This low frequency enables seismic survey pulses to travel up to 4 000 km away from the source! A pulse can travel through the seabed sediment, re-emerging later in the water. As seismic survey sounds can travel so far and are so very loud, they have been shown to have significant implications for marine fauna that rely heavily on sound in the dark ocean environment.

Marine fauna use sound for many functions. For example, dolphins and toothed whales can acoustically 'visualise' their surroundings and locate food through echolocation, baleen whales communicate with each other through calls that travel long distances, while some fish and invertebrates use sound to attract mates and ward off predators. Given the importance of sound to these animals, we can begin to get a picture of how seismic surveys could affect them.

Seismic surveys can result in animals either losing their hearing completely (permanent threshold shift) or temporarily (temporary threshold shift). They have also been shown to cause the death of zooplankton, krill and some fish species. This in turn has an effect on ocean productivity, decreasing food supplies for many marine animals. Seismic surveys can also result in disorientation of deep-diving toothed whales, causing them to swim up to the surface very fast. Because of the pressure that these animals are subjected to deep in the ocean, nitrogen gas bubbles develop in their bloodstream if they rise to the surface too quickly – in the same way that human divers get

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Seismic survey vessels tow airguns as well as the hydrophone-containing 'streamers' that may be up to 10 km long.

'the bends' – and this may result in whale deaths or mass strandings.

Seismic surveys produce loud shots every 10 seconds and can continue for months at a time, resulting in prolonged effects on marine life. Low-frequency seismic pulses cause large baleen whales to start avoiding the area and their communication may decrease or increase, signifying elevated stress levels. Stress could similarly affect foraging success and the ability to produce offspring in other animals. For example, African penguins are critically endangered, their population having declined by 70% in the last decade. In the Eastern Cape, they breed on Bird Island and St Croix Island in Algoa Bay, but a study showed that seismic surveys less than 100 km away caused the penguins to divert from their primary foraging areas. Some seismic surveys have occurred 25 km away from Bird Island, which is worrisome as this could severely affect their foraging ability and reproduction in the future, especially during the breeding season when the adults stay closer to the islands to care for their chicks.

Seismic surveys typically operate 24 hours per day in South African waters, and it is likely that the continual loud banging has a negative effect on the entire ecosystem, although this is very hard to measure and monitor. Companies conducting these surveys are legally obliged to obtain an environmental management plan (EMP) from an independent company that is registered to conduct EMPs, which provide guidelines on how best to reduce the environmental impact.

The EMP usually states that the survey vessel must have marine mammal observers (MMOs) on duty during the day and passive acoustic monitoring (PAM) operators on duty during the day and night. The MMOs keep a visual lookout for marine fauna using binoculars, while the PAM operators use a hydrophone connected to a computer to monitor whale and dolphin calls. The EMP also stipulates rules and regulations on how the airguns should be started to help protect marine fauna. The MMO and PAM operators check that the airguns start 'firing' slowly so that the noise causes any animals in the area to move away. In addition, the MMOs and PAM operators are required to monitor a mitigation zone, usually 500 m in diameter. If they see or hear any animals within this zone, they are required to advise the seismic survey company to stop the airguns until the animals have left the zone.

For many years I was an MMO and PAM operator, which led me to continue to research noise pollution in South Africa's oceans. However, I realise that oil and gas are essential in our everyday lives – to travel, to heat, to cool, to manufacture, even to brush our teeth with plastic toothbrushes. The oil and gas industry itself is huge, and many people's livelihoods depend on it. The renewable energy industry is developing rapidly, but wind and solar power is still not produced at a rate that is required for our planet of over seven billion people.

I found that the crews on seismic survey vessels are also concerned about and care for the welfare of marine life, and they do try to adhere to the suggestions and recommendations made by the MMOs and PAM operators. Personally, I felt that it is important for me to work closely with this industry to try and mesh the need for oil and gas with the need to conserve our ocean environment.

It is clear that more research needs to be conducted to fully understand the impacts of sound on marine organisms, so we can protect and safeguard South Africa's ocean life for future generations.

Jean Purdon is currently completing her PhD at the University of Pretoria, focusing on acoustic pollution in the marine environment.

Being a marine mammal observer on a seismic survey vessel provides opportunities to see ocean life such as the Atlantic spotted dolphin (top) and melon-headed whale (bottom).

2021

Quest Volume 17 Number 1 2021

Academy of Science of South Africa (ASSAf)

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