Australian Government
Department of the Environment, Water, Heritage and the Arts

BACKGROUND PAPER TO

EPBC Act Policy Statement 2.1 –

Interaction between offshore seismic exploration and whales

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The purpose of this paper is to provide background information to support the **EPBC Act Policy Statement 2.1 –** ***Interaction between offshore seismic exploration and whales.***

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Sound is very important to whales and dolphins for effective hunting, navigation and communication. Toothed whales and dolphins (e.g. killer whales and bottle-nose dolphins) use natural sonar systems (echolocation) for hunting and navigating. Baleen whales (e.g. humpback and blue whales) use sound for communicating over long distances by producing a series of sounds which are frequently termed 'songs'.

There are many naturally occurring and human made sounds in the marine environment. Wind, rain, waves, marine mammal vocalizations, and other marine life all contribute sound energy to the ocean. Natural events like volcanic eruptions, earthquakes, and lightning strikes can also produce transient high intensity sounds. Human-made sound in the ocean results from a wide range of activities including shipping, sonar, industrial activities, and seismic surveys, among many other sources. All sounds produced in the ocean contribute to the level of ambient, or background, sound that is present. Since the industrial revolution, the ambient level of sound in the ocean has increased measurably due to the influence of human-made sound in some parts of the world.

The effects of human-made sound in the marine environment are a concern for marine life. This is particularly true for cetaceans (whales and dolphins), which may be sensitive to certain sound levels. The impact of human-made sounds may potentially result in physical and/or behavioral changes for these animals. The impacts of seismic surveying on whales are not fully understood. Accordingly, precautionary mitigation measures aimed at preventing physical damage and minimising detrimental behavioral changes and significant impacts should be applied to ensure protection for whales.

The Australian Government Department of the Environment and Water Resources has produced a draft revised policy statement aimed at avoiding or minimising impacts from seismic survey activity on whales. This paper has been produced to assist in explaining the policy and to provide background on the issues of concern.

Extensive research efforts over many years have been undertaken by the oil and gas industry, governments and other institutions to understand the possible impacts from seismic exploration activities on whales; this information has helped in preparing the revised policy. Gaps in this knowledge still exist, highlighting the need for further work in this area. The Australian Government will be working with industry and the international scientific community to assist in filling these knowledge gaps, which will help to inform future iterations of the policy.

WHAT IS SOUND?

Sound is produced by a vibrating object like the diaphragm in a loudspeaker. As the diaphragm vibrates back and forth, it successively and repeatedly compresses and then decompresses the molecules of the medium surrounding it (e.g. air or water). These alternating waves of higher and lower pressure travel outward from the source. Once this sound energy reaches our ears, the tiny push and pull pressures exerted on the eardrums are perceived as sound.

Characteristics of sound

Sound is often categorized in terms of its frequency, duration, and sound pressure level (SPL). The number of alternating pressure waves that occur in 1 second is defined as the *frequency* of the sound and determines its pitch. Higher frequency sounds have more pressure alternations per second, and are perceived as having a higher pitch. *Duration* of the sound is simply a measure of the length of individual sounds and helps characterize them in terms of whether they are continuous or impulsive in nature. An impulsive sound is one that is very short in duration. The pulse from a seismic air-gun is an example of an impulsive sound, as is the sound of a hand clap or thunder. The *sound pressure level* (*SPL*) can be measured at any given location. It represents the intensity of the sound at that location and is measured in decibels (dB). The *source level* is the sound pressure level that would be measured very close (1m) to a sound source. By knowing the source level of the sound you can determine the approximate SPL that will be encountered at different ranges from the source.

Box 1: Decibels and Source Levels

Complexity of Decibels (dBs): Decibels are a confusing measurement unit and as a consequence, there are many misconceptions about the magnitude and potential effects of noise levels. Firstly, dBs actually represent a ratio and are measured on a logarithmic scale. The ear is capable of hearing a very large range of sounds: the ratio of the sound pressure that causes permanent damage from short exposure to the limit that (undamaged) ears can hear is more than a million. To deal with such a range, logarithmic units are useful. Secondly, dBs are used to quantify sounds relative to some 0 dB reference. In water, measurements are expressed as dB re 1 µPa (i.e. relative to 1 microPascal). A different scale is used in air, so dB values in air cannot be compared directly with dB values in water. Finally, dBs can be calculated based on different sound characteristics. Depending on the method used, dB values calculated for the exact same impulsive signal can vary by 40dB. Therefore, different methods cannot be directly compared as they are measuring entirely different signal characteristics. Therefore it is very important to ensure dB values have been measured in the same manner before a valid comparison can be made.

Understanding seismic survey Source Levels (SLs): The source level of a sound is calculated assuming it arises from an "ideal point source." An ideal point source assumes all the sound energy is emanating from one focal point. It is important to understand that seismic air-gun arrays are not point sources. The sound producing air-guns are spread over large areas, so even an animal directly beneath the air-gun array would not experience SPLs as high as its theoretical source level. For these types of sound sources, the source level is a useful theoretical calculation to help determine likely received SPLs at greater distances from the array but it will not accurately describe the level of sound near the array.

Sound propagation

As the pressure waves of sound travel (*propagate*) outward from their source, they undergo two general processes which decrease the SPLs. The first of these processes is called *spreading loss*. Close to the source, all the sound energy is contained within a small volume, and will be accordingly high. As sound energy travels outward from the source, the same amount of energy is spread over an increasingly larger volume of space. In general, therefore, the amount of sound energy that will be measured in one location decreases as distance from the sound source increases. The second process is called *absorption*, and occurs when sound energy is absorbed by molecules of the medium it is travelling through (i.e. water or air). In water, high frequencies are absorbed to a much greater degree than low frequencies. The limited absorption of low frequency sounds enables them to travel great distances underwater relative to high frequency sounds. In the marine environment, propagation of sound is complicated by the fact that there is interaction with the sea-floor, sea-surface and characteristics of the water column. Sound can be scattered, helping reduce the SPLs at greater distances, or reflected, which can help prevent loss of sound energy as it travels away from the source. Thus, the received level and characteristics of sound at any point surrounding the sound source is a result of a complex interaction of many factors.

Sound associated with seismic exploration

Seismic reflection profiling uses high-intensity sound to image the earth's crust. Impulsive signals are directed downward, through the water column, and are reflected back by density discontinuities within sub-sea rock strata. The characteristics of the echoes received allow geological profiles to be determined.

The most commonly used noise sources are arrays of air-guns. Seismic surveys are usually conducted by towing an array of 12-48 individual air-guns. Each air-gun injects high-pressure air into the water. This air expands violently, then contracts, and re-expands. Sound is produced with each oscillation to produce a short, sharp, low frequency sound (termed "shots"). While the ship steams at approximately 5 knots, the guns are typically fired once every 10-15 seconds with streamers, arrays of hydrophones (underwater microphones), receiving the reflected signals from the seafloor. A typical seismic survey may involve many hundred thousand signals spread over several weeks during a series of parallel passes through an area of several hundreds to thousands of square kilometres.

The air-gun pulses are composed predominantly of low frequencies (< 300 Hz). Theoretical source levels from these individual air-gun signals are as high as ~250dB re 1µPa$_{(rms)}$ @ 1m. However, this value can only be used to predict the far-field SPLs of the array. An animal immediately in front of the array in the near-field would be exposed to sound pressures limited to 235-240dB re µPa$_{(rms)}$ because the air-guns are not a point source but are spread over a large area (see Box 1). The source levels of sounds produced at mid frequencies may be 20-40dB less. The far field pressure from an air-gun array is focused vertically, leading to more intense sounds propagating in the vertical direction than in the horizontal direction for typical arrays. While the direction of greatest sound intensity is down, a considerable amount of energy is also radiated in all directions away from the vertical.

Peak levels of sound pulses from air-gun arrays are much higher than the continuous sound levels from any ship or industrial source. However, the short duration of each pulse limits the total energy an animal would be exposed to. Both of these factors will play an important role in any potential effect that seismic surveying may have on marine mammals.

POTENTIAL EFFECTS OF INTENSE UNDERWATER SOUNDS ON WHALES

Potential effects of intense underwater sounds on whales can be characterised as physical, perceptual or behavioural effects. In general, the nature and degree of any acoustic disturbance will vary with the animal's distance from the source. At very close ranges to an extremely intense sound source, physical damage to body tissue is possible. As the noise attenuates with distance from the sound source, the character of its potential impact changes, grading downward through permanent hearing loss very close to the sound source, to temporary hearing loss, avoidance of the sound, masking of biologically relevant sounds and behavioural changes until the sound is no longer audible. Animals at similar ranges to the sound source may react differently, or not at all. Much depends on the specific characteristics of the sound, how it propagates through the water, and on the sensitivity of the animal.

Non-auditory **physical effects** could possibly include damage to body tissue. Potential physical effects on the auditory system are permanent hearing loss (known as permanent threshold shift, or PTS), and temporary hearing loss (known as temporary threshold shift, or TTS). To date, there is no direct evidence of either of these effects occurring in marine mammals as a consequence of normally operating seismic surveys or other sound sources (apart from explosives and laboratory experiments). However, this type of research during operational use of these sound sources has been almost non-existent.

Box 2: Minimizing the risk of TTS

Sound levels sufficient to cause TTS in whales are currently the subject of much scientific debate. Determining an energy level from seismic surveys which may cause TTS is an extremely difficult task because research has been extraordinarily limited. To date, there has been only one experiment on an individual beluga whale that has demonstrated a small, but distinct TTS after exposure to a single seismic shot at an energy level of 186dB re 1μPa^2·s (Finneran et al, 2002).

The extraordinarily limited data (1 toothed whale, and no baleen whales) and inherent uncertainties require the results of the above study to be interpreted cautiously. In particular the issues that increase uncertainty surrounding the determination of energy levels likely to cause TTS include: the individual beluga whale that was tested in the above experiment may be a particularly sensitive or insensitive individual compared to the population as a whole; baleen whales are likely to be more sensitive to TTS from low frequency sounds due to their suspected acute low frequency hearing sensitivity, though how much more sensitive is completely unknown; the cumulative or additive effect of multiple air-gun shots can allow TTS to occur after exposure to multiple shots at considerably lower levels than the sound exposure level required to cause TTS from exposure to a single shot (as in the study mentioned above).

As a means of accounting for these uncertainties and the cumulative effect of multiple exposures, the policy adopts an energy measure threshold of 160dB re 1 μPa^2·s (energy flux density) for a single seismic 'shot' at 1km. This threshold value is used in the policy to determine whale exclusion zones where seismic surveys must lower their acoustic power output, or shut down completely, in order to prevent significant exposure to sound levels that could induce TTS. If SPLs from air-gun shots will fall below this threshold, they can operate with a reduced 1km exclusion zone while if they are above this threshold, the surveys will operate with the default 2km exclusion zone. Using this threshold SPL, if we assume a baleen whale is susceptible to TTS at levels of 183dB re 1μPa^2·s (Southall et al, 2007), 3dB more sensitive than experimentally shown in a beluga, it could be exposed to 33minutes of 160dB re 1 μPa^2·s shots every 10s before levels sufficient to cause TTS would be reached. However, illustrating the considerable effect of uncertainty, if a baleen whale was actually more susceptible to TTS, at a level of 178 dB re 1 μPa^2·s, then energy levels sufficient to cause TTS would be reached after only 10 minutes.

The Policy is based on our best interpretation of the currently available science. In addition, scientists are currently investigating how the uncertainties outlined above can be most effectively accounted for in assessing TTS threshold levels. Moreover, research into the effects of sounds on marine mammals is growing, and the criteria used in the policy will be reassessed as the most current science dictates.

Direct physical effects of sound on marine mammals are of highest concern. Accordingly, the Policy has been written with the goal of minimising the risk of the lowest level of direct physical impact, i.e. TTS or temporary hearing loss. Humans often suffer TTS and low levels experienced infrequently are safe and completely reversible. The sound levels that cause TTS are well below those that can cause direct permanent hearing damage or other direct physical effects. By minimising the risk of exposure of animals to SPLs sufficient to cause more than a small amount of TTS, it can be safely assumed that the more detrimental direct physical impacts, resulting from much higher SPLs, will not occur.

Potentially, there are a wide range of **perceptual** and **behavioural effects** that may result from the interaction of marine mammals with human-made underwater sounds. These include the masking of biologically relevant sounds, interruption of feeding, breeding and nursing, changes in diving or respiratory behaviour, and both long and short-term displacement from an area. Virtually all of the studies and observations that are available have analysed short-term behavioural reactions to seismic surveys. Reactions have ranged from no notable response, through changes in vocal behaviour and breathing and/or surfacing rates, to active avoidance and short term displacement from areas where seismic surveys are occurring. The potential for these short-term behavioural responses to cause longer-term detrimental effects is unknown. There is currently no evidence to suggest seismic surveys have caused long-term displacement of whales from areas where surveys have been carried out. Considering the relatively short-term time-scale of seismic surveys, it is unlikely that there would be significant long-term negative effects on the species, unless short-term displacement occurs from locations vital to migration, feeding, breeding, resting, and parental care.

It should be noted that grey whales continue to migrate annually along the west coast of North America despite intermittent seismic exploration in that area for decades. Similarly, bowhead whales continue to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years. Bowheads are often seen in summering areas where seismic exploration occurred in preceding summers. Finally, the Australian west coast humpback whale population appears to be growing at a comparable rate to the east coast population despite migrating along a region of much greater seismic activity compared to the east coast. These factors are at least suggestive that exposure to seismic sounds is unlikely to be having any large-scale detrimental population level impact on these animals.

MANAGEMENT OF SEISMIC AIR-GUN SURVEYS

The draft policy has been written with the goal of minimising the likelihood of injury or hearing impairment to whales and to protect whales during critical life cycle stages. Calculations of sound levels and safety distances are primarily based on received sound energy levels that are estimated to lead to a temporary threshold shift (TTS) in baleen whale hearing. The policy is not intended to prevent all behavioral changes, which might occur in response to detectable, but non-traumatic sound levels. In fact, it is likely that whales in the vicinity of seismic surveying will be displaced from the immediate area due to an aversive response to the introduced sound. This response has been noted to varying degrees in all baleen whales studied to date. This aversion is relied upon as a form of mitigation to prevent whales from approaching or being approached closely enough to cause acoustic injury from intense or prolonged sound exposure. At the scale of a seismic survey, such temporary displacements are unlikely to result in any real biological cost to the animals unless the interaction occurs during critical behaviours (e.g. breeding, feeding and resting), or in important areas such as narrow migratory corridors. In these biologically important habitats, where the displacement of whales may have a more significant or biologically relevant effect, operators are encouraged to operate at times of year that will avoid overlap with the presence of whales. A report commissioned by the Department found that the most simple and cost-effective mitigating actions for noisy sound sources are:

- choosing a season when whales are absent or in their lowest expected numbers.
- undertaking pre-start visual observations and soft-start procedures (for stationary or slow-moving sources of intense noise; see below).
- reducing vessel speed (<8 knots) and minimising erratic manoeuvring (for noisy power boats, launches, whale-watching vessels or fishing vessels).
- Soft-starts (ramp-ups) have undoubted value for mitigating the potential effects of any intense source, pulsed or otherwise, that is mounted on a stationary platform or slow moving vessel. Soft-starts should not be initiated if the safety range has not been visually monitored to a distance of 1 or 3 km, depending on the location and expected number and behaviour of nearby whales and/or cow-calf pairs.

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