



AUSTRALIAN PETROLEUM PRODUCTION & EXPLORATION
ASSOCIATION LIMITED

SEISMIC AND THE MARINE ENVIRONMENT



SEISMIC EXPLORATION AND THE MARINE ENVIRONMENT

The Australian Petroleum Production & Exploration Association (APPEA) shares the beliefs of the community that the marine environment should be used in a sustainable and environmentally considerate manner. In particular, marine mammals such as whales should be protected from biologically significant impacts of ocean users.

The oil and gas industry uses seismic surveys to explore for natural resources. Seismic surveys are an exploration technique that uses the controlled release of compressed air to make sound waves that travel into the seabed and reflect back from rock layers under the sea floor. With the experience of over three decades of seismic surveying, no evidence has been found to suggest that seismic operations have resulted in physical injury or damage to hearing in any marine mammal — a group of animals that includes whales, seals and dugongs.

The oil and gas industry has carefully studied the use of sound waves as an exploration tool (known as seismic acquisition) and their effect on marine species to the point where we believe that seismic activities can be managed with minimal impact on the environment. APPEA and its members have been supporters of research in this area for many years and new research projects in Australia and overseas will continue to improve our understanding of the subject.

A number of legislative controls exist in Australia to ensure that seismic acquisition is conducted only when it has been satisfactorily demonstrated to government agencies that associated potential impacts will not be significant.



WHAT IS A SEISMIC SURVEY?

A marine seismic survey is a method of determining geological features below the sea floor, by sending acoustic sound waves into the various buried rock layers beneath the sea floor and then recording the time it takes for each wave to bounce back as well as measuring the strength of each returning wave. It is the most reliable form of initial exploration for oil and gas and is essential in identifying geological features which may contain oil or gas deposits.

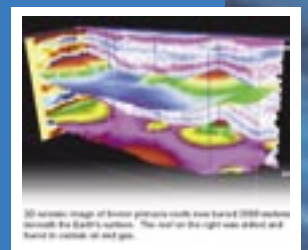
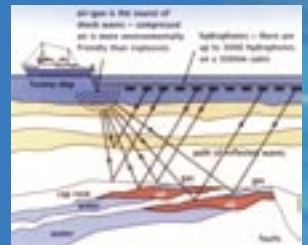
Seismic surveys generally take place over a few weeks in a given area. Once geophysicists have studied the subsurface “picture”, they may ask for some parts of the area to be surveyed again to provide greater detail. This extra data helps them to map potential prospects more accurately and to decide the best place to drill exploration wells. Shallow seabed surveys can also be used to detect changes in the sub-surface rock layers that may present a safety hazard during drilling operations.



HOW ARE SURVEYS CONDUCTED?

A survey is conducted using purpose-built ships, towing a number of percussion devices at depths of 6-10m below the sea surface. The sound (or seismic) waves are generated by the rapid release of an underwater piston in each device driven by compressed air. These seismic waves are directed down into the seabed. They are reflected back to the surface by the layers of different rock types under the sea floor. The returning sound waves are detected and recorded by waterproof microphones (called hydrophones) that are spaced out along a series of cables (called streamers) which can be up to 8km in length, towed behind the survey vessel. For regional surveys (often referred to as 2-D surveys) the seismic vessel sails up and down grid lines which can be 5km-100km apart. For detailed surveys of a smaller area (referred to as 3-D surveys) the grid lines are much more closely spaced – perhaps 100m apart.

The information gained from these surveys is then analysed by experts. Seismic waves travel through different rock types at different speeds, so it is possible to calculate the depth and the shape of the rock layers by measurements such as the time taken for the reflected seismic waves to reach the hydrophones and the strength of each returning wave. The pattern of recorded signals is then translated into geological cross sections along the lines being worked. In 2-D surveys the resultant picture is a general view because the cross sections are far apart and interpreters have to make estimations of the geology in between. In the case of a 3D survey, however, the cross sections are so close that a three-dimensional picture can be built of the strata under the sea bed. This information is used to determine with greater certainty where oil and gas might be located and then used to direct further exploration efforts, including the drilling of exploration wells.



SOUND IN THE MARINE ENVIRONMENT

There are many natural sources of sound within the marine environment. Wind, waves, fish, and whales all contribute to high levels of surrounding sound. Natural events such as sub-sea volcanic eruptions, earthquakes and lightning strikes can also produce short, sharp and loud sounds. Man-made sounds in the ocean include vessel movements (shipping, fishing, recreational), seismic exploration, sonar (navigation, fishing, defence), construction and demolition works.

Sound behaviour in marine environments

Sound travels much further in water than it does in air because pressure and particle velocity differs greatly for the same sound intensity. However, in both air and water sound intensity diminishes as a sound wave radiates from its source. High levels of sound are only experienced very close to the source and the intensity of the sound drops rapidly with increasing distance. At long range, the sound levels will be much lower and will only change slowly with increasing distance.

When considering long-range transmission of sound under water it is the near horizontal energy output from the sound source that is most crucial. The devices towed by a seismic survey vessel are arranged into precise groups, called arrays. During seismic surveys these arrays are specifically oriented so that the sound waves are directed towards the sea floor. Thus most of the energy goes downwards and does not travel very far horizontally. Therefore the sound intensity levels measured directly below the seismic source and quoted within the industry are not appropriate for measuring potential horizontal sound transmission. Acoustic energy from seismic surveys in waters less than 50m deep has been found to diminish very quickly over the horizontal distance from the source. The signal transmitted through the water may only travel, at most, a few tens of kilometres. The long-range transmission of seismic signals does increase slightly for surveys conducted in deeper water.

The table below is a comparison of some sounds heard underwater, and shows that the sounds produced during a seismic survey are not at an unusual level relative to other sounds found in the ocean.

Sound intensity and pressure (dB re 1 micro Pascal) one metre from the source

SOURCE	SOUND INTENSITY (DB)	FREQUENCY
Undersea earthquake	272	50Hz
Seafloor volcanic eruption	255+	Varied
Lightning strike on sea surface	250	Varied
Seismic acoustic source	230 – 255	< 200 Hz
Sperm Whale clicks	Up to 235dB	100 – 30,000 Hz
Bottlenose dolphin click	Up to 229	Up to 120,000 Hz
Ship sound (close to hull)	200	10 –100 Hz
Breaching whale	200	20 Hz
Blue whale vocalisations	190	12 – 400 Hz
Ambient sea sound	80 – 120	Varied

Adapted from: Swan, J.M. et al, 1994 - Environmental Implications of Offshore Oil and Gas Development in Australia, APPEA, Australia Ocean Acoustic Observatories Alternate Source Test (AST) - Acoustic Thermometry of Ocean Climate - <http://atocdb.ucsd.edu/ASTpg.html> Ketten, D. (1998). Marine Mammal Auditory Systems: A Summary of Audiometric and Anatomical Data and its Implications for Underwater Acoustic Impacts. NOAA, National Marine Fisheries Science Centre, California.

EFFECTS ON THE MARINE ENVIRONMENT

Australia's oceans host some of the most diverse environments and unique animals in the world. These animals include a large number of marine mammals, such as whales, dolphins, porpoises, seals, and dugongs. Together, whales, dolphins and porpoises are grouped as cetaceans.

Baleen whales are filter feeders, feeding on krill floating in the water, such as humpback and blue whales. Toothed whales are carnivorous, and hunt down their prey, for example killer whales and sperm whales. Whales and dolphins are known to communicate and navigate using sonar, which detects and locates objects underwater using reflected sound waves. These sound waves can travel considerable distances under the sea. Sea-going turtles (marine turtles) and fish living in the water column (called pelagic fish) have also been researched by the industry.

The oil and gas industry has commissioned a number of research projects over the years to investigate the potential effect seismic surveys have on marine mammals. In 1994 an independent scientific review commissioned by APPEA found that –

“Given the relatively small scale of seismic activity, the often large scales over which biological events occur, and the low probability of encounter between seismic surveys and ‘at risk’ populations at an appropriate time and place, then the wider implications of disruption by seismic surveys appear to be small for most species”. (Swan et al, 1994)

To date, direct scientific data on marine mammal hearing is limited to 10 toothed whale species. However, it may be that hearing sensitivity information can be inferred from ear anatomy models and known vocalisation ranges. Seismic surveys produce low frequency sound, generally below 200Hz. The majority of toothed whales have their highest sensitivities to sound in the ultra sonic ranges (> 20,000Hz), although most may have moderate sensitivity from 1000 to 20,000Hz. No toothed whale has been shown to have hearing sensitivity or exceptionally responsive hearing below 500Hz. No baleen whale has been directly tested for any hearing ability, but vocalisations are significantly lower in frequency than toothed whales (rarely above 10,000Hz) and models predict that the upper functional hearing range for most baleen whales may extend to 20,000 – 30,000Hz. Several species, including blue, fin and bowhead whales are predicted to hear at infrasonic frequencies as low as 10-15Hz.

The potential consequences of seismic operations on marine mammals could range from no effect to short term behavioural changes, such as shorter surfacings, shorter dives, changes in blow rate, or avoidance. With the experience of over three decades of seismic surveying using compressed air as the acoustic source there is no evidence to date to suggest that seismic activity has resulted in any physical injury or damage to hearing in any marine mammals.



In fact, studies on beluga whales showed that masked temporary threshold shifts (similar to the aftermath of a loud concert) from exposure to sound pulses did not occur until levels of 226 dB (1 μ Pa) were reached. This equates to the maximum levels expected within metres directly below the centre of a typical seismic sound source. Mitigation measures (discussed more fully later in this paper) employed by the oil and gas industry are designed to minimise such potential adverse effects as described and research is continuing to further understand the effect of seismic operations on cetaceans (whales and dolphins).

Studies have been undertaken to investigate the effect of seismic operations on turtles. Results showed the turtles did experience a temporary reduction in hearing that returned to normal within a short period of time, but the reptiles displayed no long-term damage to the brain. Studies have also been undertaken to investigate potential effects on fish. No lethal effects were observed for adult fish, crustaceans (such as lobsters) or shell fish exposed directly to seismic sound waves. A number of experimental studies on fish subjected to individual seismic sound waves have indicated that no damage or significant physiological stress occurs (McCauley et al, 2000; McCauley, 1999; APPEA, 1998).

The nature and extent of behavioural changes of fish may vary depending on a range of factors including the species involved and how close they are to the seismic sound source. Available evidence also suggests that changes in behaviour for some fish species may indicate the seismic survey activity is no more than a nuisance (McCauley, 1994). Generally, it is considered that such consequences will be localised and temporary, with any displacement of open sea-dwelling or migratory fish thought to be insignificant in terms of the total population level.

DISTRIBUTION AND BEHAVIOUR OF LARGE WHALES DURING PETROLEUM EXPLORATION

During November and December 2002 and 2003 Santos Ltd acquired a total of 6100km of 2D seismic data and 760sq km of 3D seismic data in a number of licences throughout the Otway, Sorrell and Duntroon Basins along the Southern Margins of South Eastern Australia.

This area consists of a remarkable marine ecosystem that is exemplified by the Bonney Upwelling. The petroleum exploration activities presented an excellent opportunity to acquire scientific information on this ecosystem. Santos worked closely with Deakin University/Australocetus Research Blue Whale Study and Curtin University Centre for Marine Science and Technology to maximise the scientific data recorded.

The use of cetacean monitors, passive acoustic monitoring (towed cable and ocean bottom recorders) and aerial surveys significantly improved understanding of the distribution and behaviour of cetaceans (particularly sperm whales and blue whales) in the area and during petroleum exploration activities.

MINIMISING OUR FOOTPRINT

With the high conservation status of whales, the importance of other marine animals, and regulatory requirements, the oil and gas industry undertakes a range of mitigation measures to minimise any potential impacts on the marine environment. Through our consultation processes with other industries and governments, the industry tries to avoid known whale feeding and breeding areas and migratory route overlaps. However, factors including unexpected whale movements, changeable weather patterns and commercial fishing interests do mean that overlaps cannot always be avoided.

Seismic survey operations are subject to a range of government legislation and approvals focused on reducing our impacts. In Commonwealth waters, the following Acts apply -

Petroleum (Submerged Lands) Act 1967 – Management of Environment Regulations

requires that a company has an approved Environment Plan prior to commencing operations. This plan details the proposed activity and the environment in which it will occur, as well as any mitigating measures that will be undertaken to minimise any disturbance to the natural environment to a level that is as low as reasonably practicable. This Act can be found at <http://scaletext.law.gov.au/html/pasteact/0/80/top.htm>

Environment Protection and Biodiversity Conservation Act 1999 states that petroleum explorers or producers must gain government approval for any activity that may have implications for a matter of national environmental significance. This includes any operation that might have a significant impact on any threatened and migratory species such as cetaceans. This Act can be found at http://www.austlii.edu.au/au/legis/cth/num_act/epabca1999n911999615/

The surprising arrival of blue whales in the Otway in November 2003 and their unexpected presence to the west of Kangaroo Island demonstrated that they appear tolerant to seismic sound waves at significantly shorter distances than previously thought i.e. down to approximately 3km, before it became necessary to shut down operations.

As this tolerance could be due to seasonal factors such as scarcity of food, further cooperative research will be needed to understand the significance of the observations.

Nevertheless considering the more than 150 sightings made before, during and after the seismic survey to the west of Kangaroo Island it can be stated that, in this instance, the behaviour and distribution of neither the blue whale population nor individuals was seen to change as a result of the presence of the seismic survey vessel.



Seismic Interaction Guidelines

In considering impacts which may arise from using seismic sound devices, operators of a seismic survey consider the Commonwealth Department of Environment and Heritage's Guidelines on the Application of the Environment Protection and Biodiversity Conservation Act to Interactions Between Offshore Seismic Operations and Larger Cetaceans.


These guidelines describe a range of measures available to avoid interference and impacts a seismic survey might have on cetaceans, and are designed to assist operators in planning surveys and seeking government approvals.

The most obvious and commonly used mitigation measure is to time surveys so that they avoid coinciding with significant cetacean activity. Various whale distribution and migration maps are available to assist in this. In cases where this is not possible, various mitigation measures are employed to ensure that any potential impacts are minimised, and peak activity seasons are avoided.

Before the commencement of operations, visual observations are undertaken both during the day and at night, to check for the presence of cetaceans in the precautionary zone for 90 minutes prior to starting operations. Government regulations establish this zone as a 3km radius around the front of the vessel. Occasionally an aerial survey is undertaken. If a cetacean is seen within 3km, the vessel must wait until the cetacean moves out of the precautionary zone. Or, if it can no longer be seen, the vessel must wait for 30 minutes after the last sighting within this zone before commencing operations.

Soft-start or ramping-up procedures are undertaken by seismic vessels as a matter of course. This involves activating a small section of the sound-producing and recording equipment and slowly adding other streamers and more devices over time, allowing mobile marine animals to move out of the area. The minimum time taken to ramp-up is usually 20 minutes, but may be extended if it is considered appropriate.

During the survey, vessels are required to shut down operations if a cetacean is seen within the precautionary zone. Dedicated cetacean observers are sometimes employed to observe the area and notify the vessel crew if a cetacean is near. The information collected by these observers is also used to further increase our knowledge of marine mammals.



Cetacean Permits

Cetacean permits must be granted by the Commonwealth Government when an activity is likely to interfere with a cetacean (whales and dolphins). Interference is a wide term that includes harassing, chasing, herding, tagging, marking or branding an individual whale or dolphin – none of which apply to the oil and gas industry. However, interference also includes causing a cetacean to significantly deviate from a migratory path or causing a substantial change in the animal's behaviour, breathing or swimming pattern.

If operations are considered likely to cause interference with whales, a permit may be required. A slight deviation from the migratory path (which might be compared to a person crossing the road to decrease the sound of construction work, then returning to the original route) is not considered to adversely affect the migration of the species. However, extra precautions, such as wider exclusion zones or longer soft-start periods are taken in the vicinity of cow/calf pairs in migration, feeding and resting areas.

A seismic operation is not considered to interfere with a cetacean if it takes place outside the migration and breeding season, and outside feeding and resting areas, and if appropriate mitigation measures are undertaken.

Public consultation is required for both approvals and permits under the EPBC Act.

STUDIES OF HUMPBACK WHALE SONGS

During 2002, Roc Oil Ltd conducted several seismic surveys offshore Western Australia which provided the opportunity to gather useful environmental information regarding the interaction between seismic operations and migrating humpback whales. The data collected provided valuable insights as to how whales react to the seismic surveys. Basically, the data, which have been passed on to the environmental community, indicated that there was no reaction. The 'song' of the whales was recorded during and after the seismic was acquired and the results clearly indicate that the whales continued to 'sing' regardless of whether or not any seismic was being acquired.



INCREASING OUR UNDERSTANDING

Significant research projects are currently underway in the oil and gas industry to further increase our knowledge and understanding of seismic acquisition and the marine environment. In Australia, various APPEA Members are involved in a large number of research projects.

Representative examples include:

- investigation of potential effects on lobster larvae, which found that very little of the combined hatchlings in South Australia, Western Australia and Tasmania were affected by a seismic survey when compared to natural mortalities and other factors.
- Trials of passive acoustic monitors (PAM) on recent surveys, found that the system has the potential to refine procedures for mitigating against disturbance to larger cetaceans. However, technical issues raised during the trials including limitations on locational accuracy limit the utility of PAM at this time.
- Numerous studies concerning underwater sound measurements during drilling and in shipping channels; a desk top study into the effect of drilling and seismic sound on blue whales; aerial surveys to investigate correlations between the presence of blue whales and krill swarms; habitat preferences of southern right whales; and satellite tagging of Australian fur seals.
- The funding of detailed aerial surveys for humpback whales off the South West coast, the North West Shelf and North West Cape of Western Australia which has aided in identifying migratory routes and timings. The provision of long-term financial and in-kind support to the West Australian Humpback Whale Research Centre, which made the important discovery of humpback whales calving location on the Kimberley coast. The Centre has also confirmed the use of Exmouth Gulf as a key resting area for migrating whales.
- Operators have conducted numerous whale surveys for many years, as well as providing sponsorship for studies of southern right whales, studies of amplitude decay models (sound dissipation), and contributing to Deakin University's ongoing cetacean studies.
- Sponsoring a genetic study (DNA testing) of the Western Australian humpback whale population by researchers from Edith Cowan University. One hundred skin samples were collected in 2002 and 150 whales were sampled in 2003. The aim is to identify population subgroups and their migration routes in the Carnarvon Basin (offshore Western Australia) to see if there are subgroups that are being affected by human activity.

All of these studies will further add to our levels of understanding of a complex marine environment, and will lead to continuous improvement in the way we manage interaction between the oil and gas industry and the marine environment.



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