The potential sensitivity of marine mammals to mining and exploration in the Great Australian Bight Marine Park Marine Mammal Protection Zone

An independent review and risk assessment report to Environment Australia

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Acknowledgement of Contributors

The following authors made contributions to this document:

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Chris Burton (Western Whale Research)	Summary of sensitivities of marine mammals to sound
Melissa Lunney (GHD Pty Ltd.)	Summary of petroleum activities within the marine environment
Dr Rob McCauley (Curtain University)	Contributed at the workshop to develop the risk ratings for the Risk Assessment process.

Acknowledgement of Reviewers

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Executive Summary

This document contains an independent review of available information related to the sensitivities of marine mammals known to occur in the Great Australian Bight Marine Park (whales, dolphins and sea lions) to activities conducted by the gas and petroleum industry during the course of their operations (including exploration, production and decommissioning). A risk assessment was undertaken to determine the potential risks associated with possible future petroleum activities occurring within the Marine Mammal Protection Zone of the Great Australian Bight Marine Park (Commonwealth waters) for incorporation into a review of the current management plan for the Marine Park, due to commence in 2003.

The study was commissioned as part of a commitment in the current management plan to assess available information on the potential impacts of petroleum industry activities on southern right whales and Australian sea lions within the Marine Mammal Protection Zone of the Park. The report was overseen and reviewed by a specially appointed reference group, as well as the Consultative Committee that provides management input to both the Commonwealth and State marine parks in the Great Australian Bight.

The risk assessment was based on available literature, and expert opinion provided by Dr Rob McCauley, who has a significant publications record in this area of scientific investigation.

Despite a significant number of publications on this topic, it was the general conclusion of the authors that there is still insufficient definitive data to determine, with any degree of certainty, what is likely to occur should petroleum operations be allowed in the Marine Mammal Protection Zone under the next management plan. In the context of the importance of the area for the recovery and conservation of the Australian sea lion and the southern right whale, application of the precautionary principle, as defined in the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), would support the continuation of the current ban on such activities until significantly more information is available demonstrating that these activities would not significantly impact upon southern right whales in this critical aggregation habitat and Australian sea lions in the coastal area..

The Great Australian Bight Marine Park (Commonwealth Waters)

The Great Australian Bight Marine Park (Commonwealth Waters) was declared in April 1998 for the purposes of:

- Protecting coastal populations of the endemic Australian sea lion;
- Protecting key breeding and calving habitat for the endangered southern right whale; and
- Preserving a representative sample of benthic flora and fauna of the Great Australian Bight, as well as a sample of the sediment layers to 1000m below the sea bed.

The Great Australian Bight supports some of the highest levels of marine diversity and endemism found anywhere in Australia, particularly among red algae, sea squirts, bryozoans, shellfish and sea urchins and sea stars. The sediments of the wide continental shelf in the Bight preserve a record of global climate and oceanographic changes along the southern temperate Australian coastline. This is because there have been no major aboveground water courses to deposit land based sediments.

The Great Australian Bight Marine Park is made up of two overlapping zones; the Benthic Protection Zone which stretches from state waters south in a 20 nautical mile strip to the edge of the Exclusive Economic Zone; and the Marine Mammal Protection Zone, which stretches from the edge of State waters to a maximum of 12 nautical miles at the Head of Bight. The Marine Park has been zoned according to the World Conservation Union (IUCN) protected area category of VI - managed resource protected area. That is, a protected area managed to ensure long-term protection and maintenance of biological diversity with a sustainable flow of natural products and services to meet community needs.

Marine Mammals within the Great Australian Bight

The only pinniped (seals and sea lions) known to occur within the Great Australian Bight (GAB) is the Australian sea lion, Australia's only endemic pinniped. According to Environment Australia's cetacean database, 27 species of cetacean (whales and dolphins) have either been recorded in the GAB, or have modelled distributions in the area.

The Australian sea lion is a listed marine species under Commonwealth legislation, and has a national conservation status as 'lower risk, near threatened' in the Action Plan for Australian Seals (Shaughnessy, 1999). It is listed as 'rare' under the South Australian *National Parks and Wildlife Act 1972*, and 'specially protected' under the Western Australian *Wildlife Conservation Act 1950*.

Under the EPBC Act, all whale and dolphin species are fully protected within Australia's Commonwealth waters through the establishment of the Australian Whale Sanctuary (s225). The EPBC Act also provides for the inclusion of State or Territory waters in the Sanctuary. Killing, injuring, taking or interfering with a cetacean can attract fines and imprisonment. Several species are also protected under State legislation. Under s178 of the EPBC Act, the blue whale and the southern right whale are listed as endangered and the sei whale, fin whale and humpback whale are listed as vulnerable. Several species have designated status under the World Conservation Union (IUCN) and the Convention on the International Trade of Endangered Species of Wild Flora and Fauna (CITES).

Mining and Exploration activities in the Marine Environment

Mining operations, as defined under the EPBC Act, can be divided into three major phases: exploration, production (including the construction of associated infrastructure such as pipelines) and decommissioning.

Petroleum and gas industry activities include:

Preliminary Exploration surveys:
- Airborne laser fluorosensor (ALF);
- Airborne aeromagnetic surveys;
- Preliminary geotechnical works and geophysical works; and
- Boat based sniffer survey.

Exploration surveys:
- 2D seismic survey;
- 3D/4D seismic survey;
- exploration and appraisal drilling; and
- well testing and well abandonment.

Construction / operation activities:
- platform construction (for fixed platforms);
- use of anchored / floating platforms;
- pipeline construction (for facilities close to the coast); and
- production well drilling and maintenance.

Decommissioning:
- removal of all infrastructure; and
- plugging of well(s)

There are no other mineral exploration or mineral extraction activities being undertaken in the Great Australian Bight, or known to be proposed for future development (M Bissell, Minerals Council of Australia, *pers comm.*).

Potential sources of direct and indirect impacts

Impacts on marine mammals from the gas and petroleum industry can come from a number of sources. These include direct impacts: noise from seismic survey, drilling activities, boat or rig operations; collisions with ships involved with petroleum industry activities; chemical impacts associated with oil spills or other sources of industry-based pollution; and indirect impacts through effects on prey species populations from industry activities such as seismic surveys or events such as oil spills.

It is generally agreed by those that study effects of the petroleum industry on marine mammals in Australian waters, that the primary potential source of impact or disturbance from the industry is through sound. Data on the extent of impacts through boat strike are sparse due to the difficulty in collecting injury and mortality information. Observations of marine mammals following oil spills have produced often conflicting and incomplete information on which to base a quantitative assessment of impacts.

While some controlled studies have been undertaken on prey items such as fish larvae, information on the impacts of seismic activities or oil spills is extremely limited and field data do not exist.

Potential direct and indirect impacts and sensitivities

The greatest potential for direct and indirect impacts on Australian sea lions come from oil spills, and possibly impacts of seismic activities on populations of their main prey species, namely shellfish and squid. Impacts from oil spill include inhibition of maternal recognition of young covered with oil, endocrine or stress impacts leading to premature delivery or spontaneous abortion of pups, and disturbance of sea lions through clean-up activities associated with coastal oil spills.

The noise created during seismic surveys is generally considered to be outside of the hearing range of Australian sea lions, and is therefore not considered to be a great source of disturbance. While no studies have been undertaken, Australian sea lions are assumed to be highly adaptable and able to habituate to other more constant noises such as an operating facility.

Ship strike is not considered to be a risk for Australian sea lions.

For cetaceans (whales and dolphins), noise from seismic surveys and operating facilities is considered to pose the greatest potential for direct and indirect impacts, and there is a large volume of literature that examines the sensitivities of cetaceans to such noises.

From the literature, the following summary points emerge:

- Whales are more susceptible to noise while resting or breeding compared to during migration or feeding;
- For continuous noise (for example, rig operation), whales begin to avoid sounds at exposure levels of 110 dB and more than 80% of species observed show avoidance to sounds of 130 dB;
- For seismic noise, most whales show avoidance behaviour at 180 dB.

Mother-calf pairs of humpback and southern right whales have been observed to be displaced from major nursery grounds by noise disturbance from vessel activities associated with the whale-watching industry.

Ship strike is considered a serious risk for some species of whale, particularly right whales (both southern and northern). Right whales, and particularly young whales of the species, are particularly susceptible to ship strike, probably because they tend to rest on or near the water’s surface.

Oil spills are not considered a significant risk to whales and dolphins.

Risk Assessment

A risk assessment was carried out on potential for impacts on marine mammals from mining and exploration activities within the Great Australian Bight Marine Park Marine Mammal Protection Zone. The risk assessment methodology was based on the Australian Standard AS/NZS 4360: 1999 *Risk Management* (the Standard) and HB 203: 2000 *Environmental risk management – Principles and process* (the Guidelines).

Risk assessment was carried out separately for exploration and production activities.

From the risk assessment outcomes, it is clear that the greatest risks to marine mammals are posed by exploration activities, while production activities carry with them moderate to low risks. While the authors’ general conclusions regarding the current ban on exploration and mining activities within the Marine Mammal Protection Zone is highlighted above, it is up to the Commonwealth Government to determine acceptable levels of risk for the Marine Park and how to interpret and use the risk assessment.

Implications for future management and possible mitigation considerations

While this review and risk assessment provides a relative guide to the potential sensitivities of marine mammals to petroleum industry activities, there is still a significant lack of information.

Information needs range from acoustic modelling of sound characteristics and propagation within the Great Australian Bight region, to more complete information on the possible sensitivities of Australian sea lions, southern right whales and other cetaceans, rather than relying on the extrapolation of data from other species that may or may not have similar sensitivities to these species.

In the event of any future petroleum activities within the Marine Mammal Protection Zone, information is provided for management consideration in order to minimise any impacts. This advice is centred on managing the timing of activities to occur outside of sensitive times for the identified marine mammal species.

1. Introduction

1.1 The Great Australian Bight Marine Park (Commonwealth Waters)

The Great Australian Bight region is an area of great conservation significance. It contains important habitat for the endangered southern right whale and the Australian sea lion, Australia's only endemic pinniped. It supports some of the highest levels of marine diversity and endemism found anywhere in Australia, particularly among red algae, sea squirts, bryozoans, shellfish and sea urchins and sea stars (Shepherd, 1991 and Poore, 1995, *cited in* Environment Australia 2000).

The sediments of the wide continental shelf in the Bight preserve a record of global climate and oceanographic changes along the southern temperate Australian coastline. This is because there have been no major aboveground water courses to deposit land based sediments (James *et al in press, cited in* Environment Australia 2000).

Due to these significant conservation values, the Great Australian Bight Marine Park – Commonwealth Waters was declared in April 1998. The marine park is made up of two overlapping zones. Directly adjacent to the State Marine National Park is the Marine Mammal Protection Zone from three nautical miles to a maximum of approximately 12 nautical miles offshore. This area is primarily to complement the State Marine Park in providing for undisturbed calving for the southern right whale and protection of Australian sea lion colonies (Environment Australia, 2000).

To the west of the Head of Bight, a 20 nautical mile-wide representative strip of the ocean floor stretches from the edge of the State Park (at three nautical miles) directly south to the edge of the Exclusive Economic Zone of Australia at 200 nautical miles. This strip is called the Benthic Protection Zone and is for the protection of the unique and diverse plants and animals that live on, and are associated with, the ocean floor. The unique sediments of the Bight region are also represented and protected in this area of the Great Australian Bight Marine Park to a depth of 1000 metres underneath the sea bed (Figure 1).

The Great Australian Bight Marine Park is classified as IUCN reserve management category VI – managed resource protected area. That is, a protected area managed to ensure long-term protection and maintenance of biological diversity with a sustainable flow of natural products and services to meet community needs. The Great Australian Bight Marine Park is the first, and currently the only, Commonwealth marine protected area (MPA) that allows for ‘operations for the recovery of minerals’. Therefore, this MPA is considered to set a precedent for dealing with the mining and petroleum industries within Commonwealth MPAs (Environment Australia, 2000).

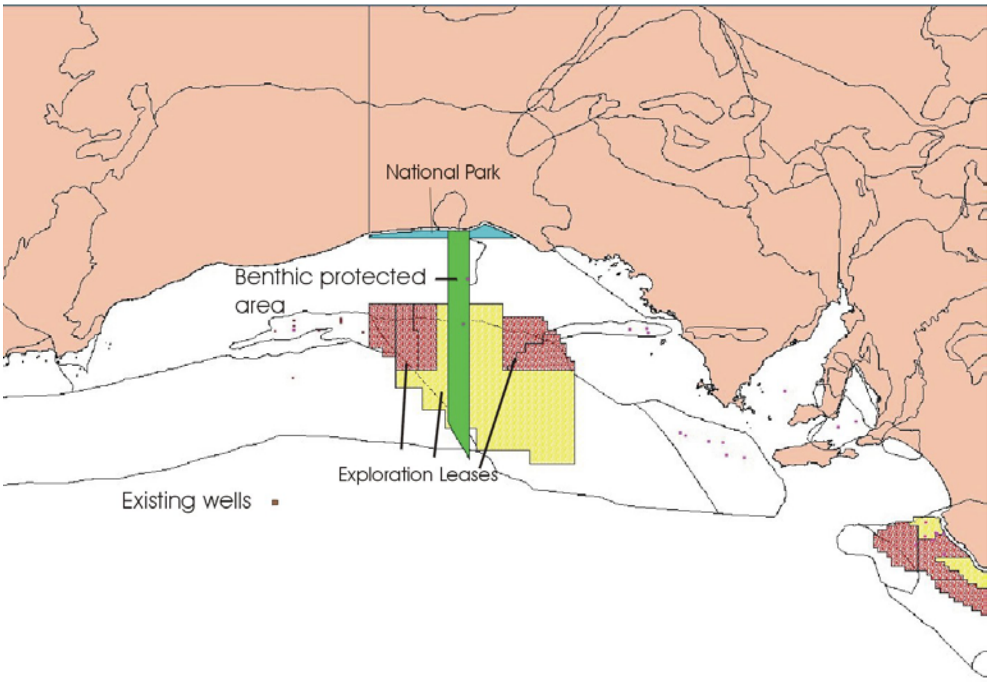


Figure 1: **Diagram of the Great Australian Bight Marine Park (Commonwealth Waters) with the Benthic Protection Zone (green), the Marine Mammal Protection Zone (blue) and current petroleum exploration leases (yellow and red).**

1.2 Purpose of this review

While preparing the management plan for the marine park, extensive consultation was undertaken with all stakeholders, including conservation groups, indigenous communities, fishers and the mining and petroleum industries. During discussions, the issue of ‘in principle’ exclusion of mining and /or petroleum exploration and production activities arose as one of great concern to the relevant industries. The argument of the mining/petroleum industry representatives was that, as long as potential and actual impacts could be adequately managed and shown not to be significant, there was no basis upon which to exclude their activities (APPEA, *pers. comm.*).

While this approach was adopted within the Benthic Protection Zone of the marine park, the level of information at hand was not sufficient to allay concerns about the impacts of any such activities on southern right whales and Australian sea lions during a time when they would be particularly vulnerable, namely females when they are heavily pregnant or have just given birth, new-borns and juveniles, and on other cetaceans and marine mammals near the coast. This meant that no such provisions for mining or petroleum industry access were made within the Marine Mammal Protection Zone in the current management plan. For the purposes of ensuring any future management provisions addressed both the issues of inter-industry equity and determining the adequacy of information regarding all possible impacts on marine mammals, the following management prescriptions concerning operations for the recovery of minerals were included:

“During the life of this Plan the Government will not release acreage within the Marine Mammal Protection Zone. Also during this Plan, an **independent review of available information on the potential sensitivity of marine mammals to mining and exploration within the Marine Mammal Protection Zone will be undertaken with particular references to vulnerability during calving**. This will form part of a review of the entire Plan of Management (see Section 7). The assessment will be undertaken on a precautionary basis, recognising the particular objectives for the Marine Mammal Protection Zone” (Environment Australia, 2000).

Therefore, the outcomes and recommendations of report do not apply to impacts from mining or petroleum activities that might be conducted outside of the Marine Mammal Protection Zone. Furthermore, the jurisdiction of the next management plan for the park is constrained by the park boundaries. Regulation of any such activities outside of the marine park boundary would come under the EPBC Act Referrals process.

This document meets the undertaking given in the current management plan.

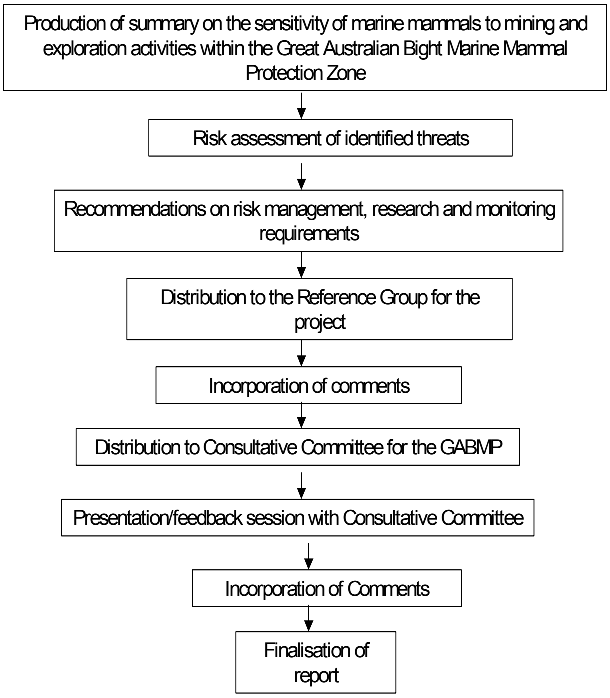
1.3 Method of review

For the purposes of this project, a Reference Group (membership listed at Appendix A) was established. The Reference Group was made up of interested individuals considered to have expertise in the subject of this review, and was established to ensure technical comprehensiveness, and the independence of this project from Environment Australia and established stakeholders.

Therefore, incorporated in to the methodology for this project were two main consultation points. The first consultation point was at the first drafting of the review document, where the members of the Reference Group were asked to give their assessment of the comprehensiveness of the information and appropriateness of any risk assessment.

After incorporation of any Reference Group comments, the document was then distributed to the Great Australian Bight Marine Park Consultative Committee for the second main consultation phase. The Consultative Committee is an established committee that has regular input into the management decisions for both the Commonwealth and State marine parks.

The following steps were undertaken to conduct this review:


Production of summary on the sensitivity of marine mammals to mining and exploration activities within the Great Australian Bight Marine Mammal Protection Zone
Risk assessment of identified threats
Recommendations on risk management, research and monitoring requirements
Distribution to the Reference Group for the project
Incorporation of comments
Distribution to Consultative Committee for the GABMP
Presentation/feedback session with Consultative Committee
Incorporation of Comments
Finalisation of report

2. Marine Mammals in the Great Australian Bight

2.1 The Marine Mammal Protection Zone of the Great Australian Bight Marine Park – Commonwealth Waters

The Marine Mammal Protection Zone (3,875 square kilometres) is a small part (20%) of the Marine Park (approximately 240,000 square kilometres) and a very small proportion of the total Great Australian Bight area (approximately 1.5%). As such, the impacts on particular species that may be transient or seasonal in their occurrence within the Marine Mammal Protection Zone must be considered in terms of the broader distribution outside the Marine Mammal Protection Zone. Thus an activity that is not permitted within the Marine Mammal Protection Zone but can occur outside of the area requires consideration in terms of any effects on species or its prey that use that area, for example, southern right whales that migrate to or from a calving area.

The most important and also the most 'visible' marine mammals that are specifically protected by the implementation of the Marine Mammal Protection Zone are the southern right whale (*Eubalaena australis*), and the Australian sea lion (*Neophoca cinera*). The entire Great Australian Bight region also supports a diverse range of marine mammals (See Section 2.2 of this report), including at least 27 species of cetaceans, 17 of which have been recorded in offshore waters (Kemper and Ling 1991; Bannister *et al.* 1996), although the relative abundance of some species is considered low (Bannister *pers comm*.). Many of these species' distributions have been derived from reports on the stranding of individuals or occasional sightings. In terms of understanding of the life histories of these species, very little is known.

The southern right whale has been studied over a protracted period of time at the Head of Bight (Burnell and Bryden 1997; Burnell 1999; Burnell 2001) and along the southern coastal margins of South and Western Australia (Bannister *et al.* 1996; Bannister *et al.* 1997; Bannister *et al.* 1999; Bannister 2001). The Australian sea lion has been studied by a number of scientists providing information on reproduction and distribution along South and Western Australia (Gales 1990; Gales 1991; Gales *et al.* 1992; Gales *et al.* 1994; Dennis and Shaughnessy 1996; Dennis and Shaughnessy 1999). Other whale and pinniped species have been studied at several locations around Australia and overseas. Only a few dedicated marine mammal ship-board surveys have been conducted in the GAB (Kato *et al.* 1996; Burton *et al.* 2001). Details of odontocetes (toothed whales) are even more sparse with some work on the influence of oceanographic conditions on cetaceans in the Great Australian Bight (Kemper and Ling 1991) and from a species synopsis of Australian cetaceans (Bannister *et al.* 1996).

2.2 Species of marine mammals that occur in the region

The only species of pinniped (seals and sea lions) that occurs, or is likely to occur within the Great Australian Bight Marine Park in either State or Commonwealth waters is the Australian sea lion (Peter Shaughnessy, *pers*. *comm*., the Australian Museum, 1983). The Australian sea lion is a listed marine species under Commonwealth legislation, and has a national conservation status as ‘lower risk, near threatened’ in the Action Plan for Australian Seals (Shaughnessy, 1999). It is listed as ‘rare’ under the South Australian *National Parks and Wildlife Act 1972*, and ‘specially protected’ under the Western Australian *Wildlife Conservation Act 1950*.

According to the Environment Australia database, which outlines the most up-to-date modelled information on distribution of cetaceans in Australian waters, there are 27 whales and dolphins with distributions that overlap the Great Australian Bight Marine Park (nine of which overlap the Marine Mammal Protection Zone). A further 10 species have distributions in the region (the area from the middle of the southern coast of Western Australia east to the Victorian border, southwards to the boundary of the Exclusive Economic Zone), though not within the boundaries of the marine park. These species are listed in Table 1 and Table 2 below.

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), all whale and dolphin species are fully protected within Australia’s Commonwealth waters through the establishment of the Australian Whale Sanctuary (s225). The EPBC Act also provides for the inclusion of State or Territory waters in the Sanctuary. Killing, injuring, taking or interfering with a cetacean can attract fines and imprisonment. Several species are also protected under State legislation (Table 1 contains listings under South Australian and Western Australian legislation, which are relevant to the area under consideration).

Under s178 of the EPBC Act, the blue whale and the southern right whale are listed as endangered and the sei whale, fin whale and humpback whale are listed as vulnerable.

Several species have designated status under the World Conservation Union (IUCN) and the Convention on the International Trade of Endangered Species of Wild Flora and Fauna (CITES). These are included in the tables below.

Table 1: Cetaceans with distributions overlapping the Great Australian Bight Marine Park

(**Sources of information:** Environment Australia cetaceans database, State and Commonwealth Legislation, IUCN Red List and CITES Appendices)

Common name	**Scientific name**	**South Australian / Western Australian protection**	**IUCN / CITES Status**
Whales			
Minke whale ✭	*Balaenoptera acutorostrata*	Rare – SA National Parks and Wildlife Act	Insufficiently known / Appendix I
Antarctic minke whale	*Balaenoptera bonaerensis*		
Sei whale ✭	*Balaenoptera borealis*	Rare – WA Wildlife Conservation Act	Endangered / Appendix I
Bryde’s whale ✭	*Balaenoptera*		Insufficiently known /

Common name	Scientific name	South Australian / Western Australian protection	IUCN / CITES Status
	edeni		Appendix I
Blue whale ✩	*Balaenoptera musculus*	Endangered - SA National Parks and Wildlife Act Rare - WA Wildlife Conservation Act	Endangered / Appendix I
Fin whale ✩	*Balaenoptera physalus*	Endangered - SA National Parks and Wildlife Act Rare - WA Wildlife Conservation Act	Vulnerable / Appendix I
Arnoux's beaked whale	*Berardius arnuxii*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix I
Pygmy right whale ✩	*Caparea marginata*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix I
Southern right whale ✩	*Eubalaena australis*	Vulnerable - SA National Parks and Wildlife Act Rare - WA Wildlife Conservation Act	Vulnerable / Appendix I
Pygmy killer whale	*Feresa attenuata*		Insufficiently known / Appendix II
Short-finned pilot whale	*Glopbicephala macrorhynchus*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix II
Long-finned pilot whale	*Glopbicephala marcochynchus*		Insufficiently known / Appendix II
Dwarf sperm whale	*Kogia sinus*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Not on appendices I or II
Humpback whale ✩	*Megaptera novaeangliae*	Vulnerable - SA National Parks and Wildlife Act Rare - WA Wildlife Conservation Act	Vulnerable / Appendix I
Blainville's beaked whale	*Mesoplodon densirostris*		Insufficiently known / Appendix II
Gray's beaked	*Mesoplodon*	Rare - SA National	Insufficiently known /

Common name	Scientific name	South Australian / Western Australian protection	IUCN / CITES Status
whale	*grayi*	Parks and Wildlife Act	Appendix II
Killer whale ✯	*Orcinus orca*		Insufficiently known / Appendix II
Sperm whale	*Physeter catadon*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix I
False killer whale	*Pseudorca crassidens*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix II
Dolphins			
Common dolphin ✯	*Delphinus delphis*		Insufficiently known / Appendix II
Risso's dolphin ✯	*Grampus griseus*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix II
Dusky dolphin ✯	*Lagenorhynchus obscurus*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix II
Southern right whale dolphin	*Lissodelphis peronii*		Insufficiently known / Appendix II
Spotted dolphin ✯	*Stenalla attenuata*		
Long-snouted spinner dolphin	*Stenalla longirostris*		Insufficiently known / Appendix II
Rough-toothed dolphin	*Steno bredanensis*		Insufficiently known / Appendix II
Bottlenose dolphin ✯	*Tursiops aduncus & truncates)*		Insufficiently known / Appendix II

NOTE: ★ identifies those species whose distribution overlaps the Marine Mammal Protection Zone.

Table 2: Cetaceans with distributions in the vicinity of the GABMP, but not within the park boundary

(**Sources of information:** Environment Australia cetaceans database, State and Commonwealth Legislation, IUCN Red List and CITES Appendices)

Common name	Scientific name	South Australian / Western Australian protection	IUCN / CITES Status
Southern bottlenose whale	*Hyperoodon planifrons*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix I
Pygmy sperm whale	*Kogia breviceps*	Rare - SA National Parks and Wildlife Act	Insufficiently known / not on either Appendix I or II
Andrew's beaked whale	*Mesoplodon bowdoini*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix II
Gingko-toothed beaked whale	*Mesoplodon gingkodens*		Insufficiently known / Appendix II
Hector's beaked whale	*Mesoplodon hectori*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix II
Strap-toothed beaked whale	*Mesoplodon layandii*		Insufficiently known / Appendix II
True's beaked whale	*Mesoplodon mirus*		Insufficiently known / Appendix II
Melon-headed whale	*Peponocephala electra*		Insufficiently known / Appendix II
Tasman beaked whale	*Tasmacetus shepherdi*		
Cuvier's beaked whale	*Ziphius cavirostris*	Rare - SA National Parks and Wildlife Act	Insufficiently known / Appendix II

2.3 Species for which the Marine Mammal Protection Zone was proclaimed

2.3.1 Australian sea lion (*Neophoca cinera*)

The Australian sea lion is endemic to Australia and is considered as one of the rarest and most endangered pinnipeds in the world (Gales, 1990). Its status, distribution, habitat requirements and threats were assessed as part of an assessment of the conservation values of the Great Australian Bight (Environment Australia, 1996). Although the number of Australian sea lions in the Great Australian Bight are relatively low, these populations form an important genetic link between the larger eastern and western populations (Dennis and Shaughnessy, 1996; Dennis and Shaughnessy, 1999).

The low numbers and isolation of colonies combined with their asynchronous breeding seasons, restricted movement patterns and relatively strong site fidelity make this species particularly vulnerable to external threats that may impact on individuals. This has already previously occurred on a large scale during the heavy exploitation by the nineteenth century sealing industry, which completely removed the species from Victorian waters. (Campbell, R. *pers comm*).

2.3.2 Southern Right Whale (*Eubalaena australis*)

Southern right whales have a current southern hemisphere population estimated to be around 3,500 animals (Burnell, 1999) and are recovering from severe over-exploitation during the 18th and 19th centuries whaling on an original population thought to number between 40,000 and 100,000 animals. Continued illegal whaling in the southern hemisphere by fleets of the USSR up to 1980 may also have impacted on the recovery of southern right whales (Zemsky *et al.,* 1996). The population that frequents the southern Australian coastline from May to November each year has an estimated minimum number of approximately 700 whales (Bannister *et al.,* 1996; Burnell, 1999; Bannister, 2001), distributed from southern NSW to the west coast of Western Australia as far as Exmouth Gulf. The Head of Bight represents the main breeding area for southern right whales in Australia (Burnell and Bryden, 1997; Burnell, 1999). Historical whaling records for the area are very scant, with early descriptions of 'bay whaling' occurring from around the 1820s and increased activities in the period from 1838 to 1845 (Kostoglou and McCarthy, 1991). The Great Australian Bight was not a particularly favoured place west of Fowlers Bay due to the extensive cliffs and lack of secure anchorages.

Their movements are seasonally broad, with recent first direct evidence of movement between Antarctic feeding grounds over summer, south of 60° S, and warm-water breeding grounds of southern Australia in winter (Bannister *et al.,* 1999). Two individuals were photo-identified while feeding on copepods in waters at 43° S during a vessel-based survey for blue whales (Kato *et al.,* 1996; Bannister *et al.,* 1997). These animals were subsequently identified from photographs taken off the southern Australian coastline, the first direct evidence of movement between winter breeding areas to sub-Antarctic waters for feeding. Their winter movements are thought to be generally westward along the southern Australian coastline, an in an anti-clockwise direction south to the feeding grounds in the southern ocean (Burnell, 1999; Bannister 2001; Burnell, 2001).

Movements on a much wider scale (providing the intermingling of populations) can be anticipated as the population increases. For example, Best *et al.,* (1993) cite six instances of southern right whales that had undertaken long-range movements (in the order of thousands of km) in the South Atlantic.

Over 350 individual southern right whales have been photographically identified at the Head of Bight, between 1991 and 1997 (Burnell 2001). Calving occurs on average every 3 years with over 90% of females returning to the Head of Bight. Similar rates for calving and females returning to a major nursery ground were found in Argentina (Rowntree *et al.,* 2001).

3. Mining and Exploration activities in the Marine Environment

Mining operations, as defined under the (EPBC Act), can be divided into three major phases: exploration, production (including the construction of associated infrastructure such as pipelines) and decommissioning. This chapter contains brief descriptions of activities that are generally conducted during these three phases. These descriptions concentrate on the petroleum industry, as prospectivity for other minerals does not currently exist.

3.1 Petroleum (Oil and Gas) Industry

3.1.1 Prospectivity of the Great Australian Bight

Petroleum exploration and production activities are most likely in the more prospective areas. Table 3 and Figure 2 show the distribution of geological provinces and a preliminary estimate of their prospectivity as a guide to the likely distribution of activities (Phil O'Brien, Geoscience Australia, *pers comm*.).

The classification uses preliminary categories being worked out by Geoscience Australia and the Department of Industry Tourism and Resources in consultation with State Governments. Estimates of prospectivity will undoubtedly change with additional data from current and future exploration.

Table 3: Categories of Hydrocarbon Prospectivity

	Category	Criteria
Prospective (Certainty of Information)	Proven	Oil and/or gas production; advanced development plans
	High-certainty	Likely extension of proven areas; hydrocarbon shows in wells
	Indicated	Thick sediment fill; indirect evidence of hydrocarbons – e.g. seepage, seismic evidence
	Inferred	Reasonable sediment thickness (>2km)
	Unknown	Insufficient data to evaluate
Non-Prospective	Likely	Insufficient sediment thickness for generation and/or competent seal facies; little chance of migration from a hydrocarbon kitchen and/or preservation
	Certain	Continental basement/volcanics/oceanic crust

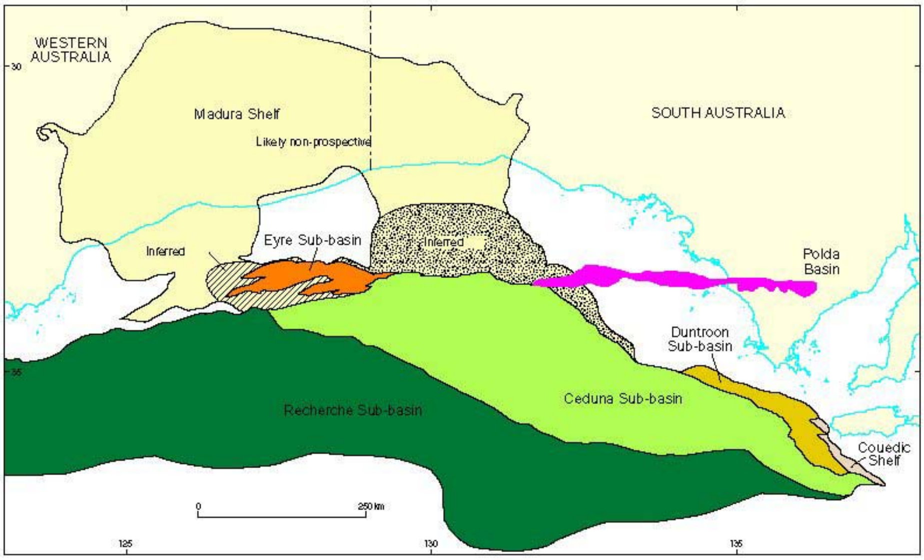


Figure 2: **Distribution of basins and sub-basins indicating prospectivity across the Bight.**
The current classification of different provinces is as follows (East to West):

Couedic Shelf – Inferred
Duntroon Sub-basin – High certainty
Ceduna Sub-basin – indicated
Polda Basin – Inferred
Southern Madura Shelf (stippled) – Inferred because of possible hydrocarbon migration pathways from the Ceduna Sub-basin
Recherche Sub-basin – Inferred because of great water depth and lack of data
Eyre Sub-basin and surrounding Madura Shelf (cross hatched) – Indicated
Madura Shelf (other than above) – Likely non-prospective
White areas on shelf and deep ocean – Certainly non-prospective

3.1.2 Preliminary Exploration Activities

Airborne survey – Laser Fluorescence Survey

Airborne laser fluorescence (ALF) utilises a remote sensing technique to detect the presence of oil on the ocean surface from natural sea floor oil seepages. Detection of natural oil seepages provides useful information about the likely presence of petroleum hydrocarbon reserves, which may then be further explored (URS, 2001).

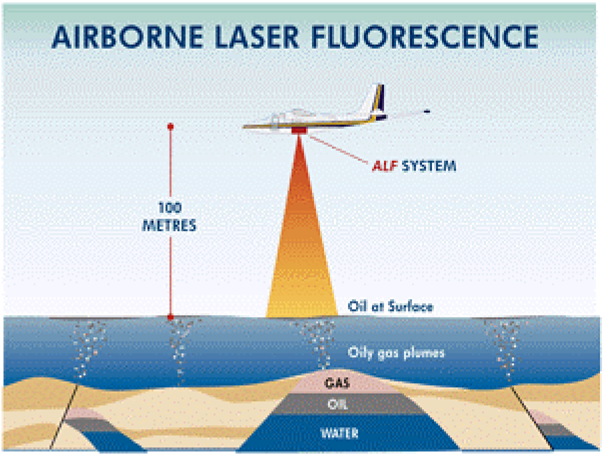


Figure 3: Diagram of Airborne Laser Fluorosensor (Source: Fugro Airborne Surveys)

ALF uses laser technology to generate an ultra violet (UV) light, which is pulsed to induce fluorescence in any fresh petroleum hydrocarbons (Fugro). ALF can distinguish between different types of oils because oils fluoresce with different intensities and exhibit different spectral signatures (URS, 2001).

The aircraft utilised for the ALF process normally flies at between 80m and 100m above sea level, with surveys generally lasting a few days (Fugro; URS, 2001).

Airborne survey – Airborne Hyperspectral Surveys

Airborne hyperspectral surveys utilise a high resolution swath technique which measures the spectral response of the earths surface and is undertaken in a spectral range of visible to near-infrared.

The technique allows for differentiation of oil seeps and algae, provides a full 2D image of slicks and can operate in rougher seas than is possible for airborne laser fluorescence surveys. The aircraft flies at approximately 300m above sea level whilst undertaking the hyperspectral survey.

Airborne survey – Aeromagnetic survey

Aeromagnetic surveys are undertaken to detect features such as subtle faulting and folding (Fugro), and map sedimentary anomalies in areas of prospective petroleum reserves (URS, 2001).

The aircraft utilised for aeromagnetic surveys normally fly at between 80m and 150m above sea level, with line spacing ranging from 35m to 1200m. Surveys are generally undertaken during summer in southern waters, to minimise data anomalies due to ocean swell (URS, 2001).

Vessel based survey - Preliminary geotechnical and geophysical surveys

Preliminary geotechnical works and geophysical works are undertaken prior to exploration drilling to determine information about the seafloor and substrate including investigations for the following:

- Bathymetric and sidescan sonar surveys to define the depth, slope and relief of the seafloor.
- Shallow seismic surveys to detect shallow gas reserves.
- Sub-bottom profiling and geotechnical core drilling to determine site suitability for jack-up platforms or securing anchors for floating drill platforms.
- Drop core and grab sampling to identify seafloor sediment types (URS, 2001).

Boat based survey – Sniffer survey

As for airborne laser fluorescence surveys, sniffer surveys are undertaken to detect the presence of petroleum hydrocarbons within the water column from natural sea floor oil seepages.

URS provided the following information in relation to sniffer surveys:

> "A sniffer system is designed to be a modular one that tows a device called a 'fish'. The 'fish' contains a submersible pump, echo sounder and data logger suspended on a cable. The cable consists of a nylon-tubing core, for pumping seawater. Water and data from the fish are delivered to an onboard portable laboratory. A typical tow speed for the fish is 5 to 9 knots. The echo sounder is used to control the height at which the fish is 'flown' above the sea floor. The working depth is from the surface to 240m. The data logger is fitted with various probes to record parameters such as temperature, dissolved oxygen, salinity, depth and turbidity. Seawater pumped from the 'fish' is sprayed into a glass container. A vacuum pump applies pressure to the headspace thereby extracting volatile hydrocarbons. These are piped to a gas chromatograph for onboard analysis at predetermined intervals." (URS, 2001)

3.1.3 Exploration Activities

Seismic survey

In marine seismic surveying, energy waves are directed at the sea floor and underlying geological strata to various depths - from several hundred metres underground to several thousand metres (APPEA (1)). The energy waves are reflected and refracted off the different substrata and recorded for processing and interpretation. The data collected from seismic surveys is interpreted to identify structures likely to contain petroleum hydrocarbons.

The energy waves are in the form of low frequency and high intensity sound waves generated by one of the following:

- Air gun arrays produce a pulse by rapidly releasing a volume of compressed air (URS, 2001). Marine seismic surveys in Australia are generally undertaken using air gun arrays.
- Sleeve exploders or gas guns explode a mixture of oxygen and propane in a sleeve and produce a pulse with similar characteristics to an air gun (McCauley, 1994).

- Water guns produce a pulse by suddenly releasing a volume of water into the sea (McCauley, 1994).
- Sparkers produce a sound pulse by the sudden discharge of electrical energy stored in a bank of capacitors (McCauley, 1994).

Airguns are discharged every 6 to 20 seconds with a duration of 10 to 30 milliseconds (URS, 2001). Airguns are placed in arrays and towed behind the survey vessel. The reflected signals are recorded by sound detection recorders (hydrophones) embedded in a hydrophone streamer or cable, 4 to 7 km in length (URS, 2001). The streamer/s are towed behind the survey vessel at predetermined depths of 5m to 12m below the surface (URS, 2001). The streamers maintain buoyancy through either solid buoyancy devices or kerosene (URS, 2001).

Different arrays of instruments yield different types of survey result:

- 2D seismic surveys capture and process data of a single slice of substrate at any one time. Airguns are arranged as a single array source and single hydrophone streamer towed behind the vessel (McCauley, 1994). 2D seismic lines are typically undertaken 500m to 10 km apart (URS, 2001).
- 3D seismic surveys capture and process data of multiple slices of substrate at any one time (URS, 2001). Airguns are arranged into either single or multiple array sources with multiple hydrophone streamers towed behind the vessel (McCauley, 1994). In Australia, 3D seismic ships typically tow 6 to 10 streamers, at about 50m to 100m spacing, with each traverse typically being 300m to 500m apart.
- Ocean Bottom Cable (OBC) seismic survey.

For further detailed information regarding seismic survey, the following references are recommended:

- Gulland, J.A. and C.D.T. Walker (1998). Marine Seismic Overview. Proceedings of a UK workshop on impacts of seismic activities on marine mammals.
- McCauley, R.D. (1994). Environmental implications of offshore oil and gas development in Australia – Seismic Surveys, pp 19 – 122 *in* J.M. Swan, J.M. Neff and P.C. Young (1994). Environmental implications of offshore oil and gas development in Australia.
- McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, MN. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe (2000). Marine Seismic Surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on Humpback Whales, Sea Turtles, Fishes and Squid.

Exploration and appraisal drilling

Exploration and appraisal drilling is generally undertaken to determine if a particular geological structure contains petroleum hydrocarbon reserves. Drilling may take weeks or months before the targeted location is reached.

Drilling programs can be categorised into three types:

- Exploration drilling – drilling programs in mature or semi-mature basins where previous drilling experience or seismic surveys have been undertaken.
- Wildcats – drilling programs in areas with no previous exploration history within the area.
- Appraisal Drilling – drilling programs undertaken to assess the spatial extent and hydrocarbon reserves of known fields (URS, 2001).

The first stage of the drilling process is locating and preparing the drill rig. Offshore rigs used to drill wells may include:

- Jackups - Usually towed to the drill location, the legs are then lowered to the seabed and the hull is jacked-up clear of the sea surface. Used in waters to about 160 metres deep (APPEA (1)).
- Drill ship - These look like ordinary ships but have a derrick on top, which drills through a hole in the hull. Drill ships are either anchored or positioned with computer-controlled propellers along the hull, which continually correct the ships drift. Often used to drill "wildcat" wells in deep waters (APPEA (1)).
- Semi submersible - Mobile structures, some with their own locomotion. Their superstructures are supported by columns sitting on hulls or pontoons which are ballasted below the water surface, providing stability in rough, deep seas (APPEA (1)).
- Submersibles - They can be floated to shallow water locations then ballasted to sit on the seabed. Submersibles are rarely used. (APPEA (1)).

The second stage drilling then commences. The drill bit is attached to a drill pipe (or a drill string) and rotated by motors, which are usually located on the drill rig. As the drill hole deepens, extra lengths of drill pipe are attached. Pipe casing is inserted into the drill hole and cemented into place (APPEA (1)). Exploration wells are typically drilled vertically (Hinwood *et al.,* 1994), however wells may be directionally drilled at a variety of angles to intercept the reservoir of interest (APPEA (1)).

Drilling fluid is pumped down the drill pipe and into the hole at high velocity through nozzles in the drill bit. The drilling fluid serves several purposes, including raising the drill cuttings to the surface for disposal, providing the "weight" to keep the underground pressures controlled, keeping the hole stable by caking the wall with a thin layer of clay; and cleaning and cooling the drill bit. The fluid is recycled through a circulation system where equipment mounted on the drilling rig separates out the drill cuttings and allows the clean fluid to be pumped back down the hole (APPEA (1)). Water-based fluids may be discharged to sea (URS, 2001). The fluid is usually water based (URS, 2001), being a mixture of water, clay, a weighting material (usually barite), and various chemicals. With a few exceptions, Australian wells since 1985 have been drilled using water-based drilling fluids, not oil-based (APPEA (1)). Where synthetic and oil based drilling fluids (low toxicity) are used, they are generally recovered during the drilling process and re-used (URS, 2001).

If during drilling an influx of pressurised oil or gas occurs which is greater than the pressure provided by the drilling fluid, well control is maintained through the drilling rig blowout prevention system. The blowout prevention system is a set of hydraulically operated valves and other closure devices (rams), which seal off the well and direct the well fluids to specialised pressure controlling equipment (APPEA (1)).

During the drilling process the drill bit forms drill cuttings from particles of rock ranging in size from 0.1 to 10mm (URS, 2001). At the commencement of drilling and prior to the installation of a riser to take the cuttings to the surface, the cuttings are released directly to the sea floor (URS, 2001). If the well is drilled using a closed drilling fluid circulation system, the cuttings are brought to the surface by the drilling fluid, separated and discharged overboard. The drill cuttings are removed from the drilling fluid via a drilling fluid solids control system, which depending on the operation may be able to remove solids as fine as 2 microns through a series of shakers, hydrocyclones and centrifuges (Hinwood *et al.*, 1994). The separated cuttings and fines are discharged to the sea via a pipe flushed with seawater. The discharge may occur at or below the surface depending on the sensitivity of the environment and the likely dispersion and deposition (Hinwood *et al.*, 1994). As the plume of drilling fluid and cuttings falls to the seabed, it disperses, with 90 percent of it settling within 100 metres of the platform (APPEA (1)). In sensitive environments, cuttings may be removed for disposal elsewhere or re-injected where practical (URS, 2001).

In an open drilling fluid system, seawater is often used as the circulating fluid along with regular slugs of high viscosity drilling fluid to clean the drill cuttings from the wellbore, with both the drill cuttings and drilling fluid discharged directly from the well to the seafloor (Hinwood *et al.,* 1994).

For further detailed information regarding exploration drilling, the following references are recommended:

- Hinwood, J.B., A.E. Potts, L.R. Dennis, J.M. Carey, H. Houridis, R.J. Bell, J.R. Thomson, P. Boudreau and A.M. Ayling (1994). Environmental implications of offshore oil and gas development in Australia – Drilling Activities, pp 123 - 208 in J.M. Swan, J.M. Neff and P.C. Young (1994). Environmental implications of offshore oil and gas development in Australia.

Well testing

Well testing is undertaken to determine if a petroleum hydrocarbon reservoir is viable for production. Flows from the well are controlled via a choke manifold (a controlled chamber with a number of outlets) and directed to a separator to separate the oil, water and gas phases. The gas and oil are metered, sampled as required, and directed to a flare boom for combustion (URS, 2001). Well testing, including the flaring or burning of gas and oil, may be undertaken 24 hours per day as required for the testing.

In some circumstances, extended periods of well testing may be undertaken, with stabilisation of crude oil occurring, and potential for transfer of the oil to tankers for shipment (URS, 2001).

Well abandonment

Where petroleum hydrocarbons are not found or not worth developing, the well is plugged and abandoned. Plugging of the well involves setting several cement plugs within the well as required by the *Petroleum (Submerged Lands) Act Schedule 1995* (URS, 2001).

The concrete is pumped down the drill string into the well at various levels to form plugs (K.Gardner, Peak Group, *pers. comm*.).

Wells may be also be suspended through the use of concrete plugs, which are drilled out in the event the well is recommissioned (K.Gardner, Peak Group, *pers. comm*.).

3.1.4 Construction, Commissioning and Operation Activities

In the event that production is to be undertaken in a reservoir area, a production facility is developed. No operational activities or construction of operation facilities are presently being undertaken within the Great Australian Bight.

Production platforms

The production platform and associated components are generally constructed on land, tested and transported to the site and assembled or installed (R.Johnson, Intec Engineering, *pers. comm*.). During construction, domestic wastes such as sewerage and putrescible wastes (food scraps etc) are disposed to the sea. All other solid wastes are stored and transported to land for disposal (R.Johnson, Intec Engineering, *pers. comm*.). Diesel pumps and engines, along with other construction equipment and lighting are commonly used as required during the construction process.

Platforms vary in size, shape and type depending on the size of the field, the water depth and the distance from shore. Production facilities in less than 100m are generally platforms constructed on piers or resting on the seabed. Production facilities in greater than 100m are generally anchored structures (I.Black, GHD, *pers. comm*.). Anchoring is generally undertaken using marine anchors, with piles installed for anchoring where sediments or substrate do not allow direct anchoring (R.Johnson, Intec Engineering, *pers. comm*.).

In Australia's medium to large fields, fixed production platforms are commonly used which are made of steel and fixed to the seabed with steel piles. Alternatives include concrete structures, small remotely controlled monopod platforms (in shallow water fields, near land or another platform), floating structures (which are either anchored or tethered, called a Floating Production Storage Offloading Vessel) or Tension Leg platforms (suitable for deep water production and built of steel or concrete and anchored to the sea floor with vertical tethers) (APPEA (1)).

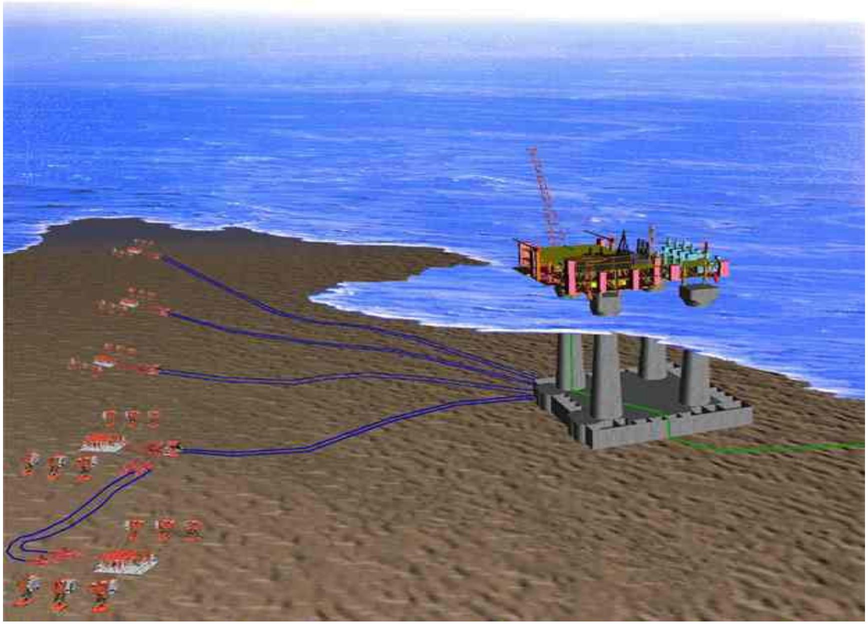


Figure 4: Diagram of platform structure mounted on the seabed showing several production wells

(Source: University of Western Australia Subsea Technology Course)

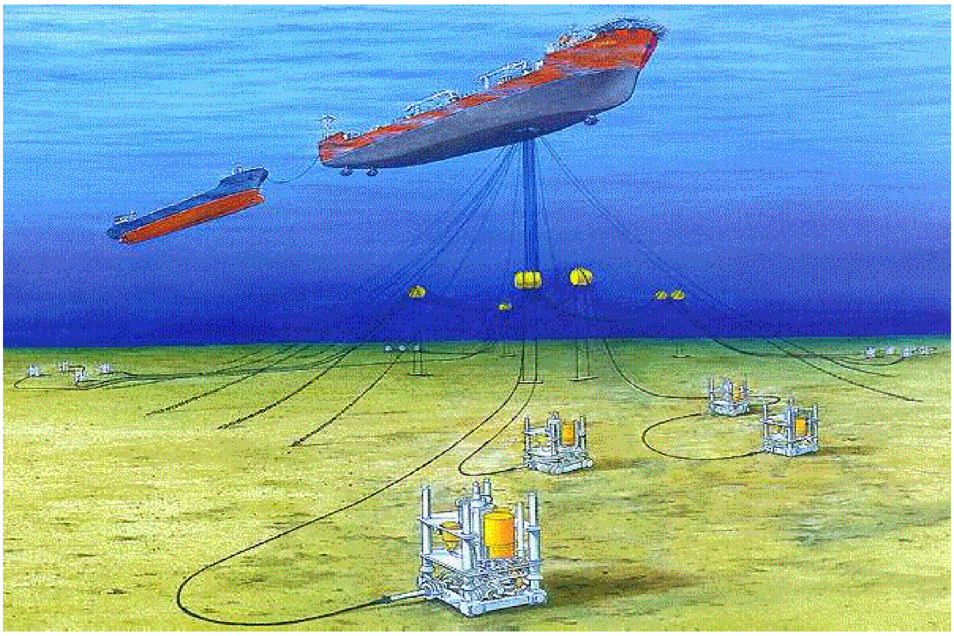


Figure 5: Diagram of anchored floating platform structure showing several production wells

(Source: University of Western Australia Subsea Technology Course)

Disposal to the sea of domestic waste water, putresible wastes, and cooling water is often undertaken during operation (Black *et al.,* 1994). Other aqueous waste streams disposed to sea may include produced formation water, corrosion inhibitors, scale inhibitors, emulsion breakers, reverse emulsion breakers and biocides (Black *et al.,* 1994).

For further detailed information regarding production platforms and associated activities, the following references are recommended:

- Black, K.P., G.W. Brand, H. Grynberg, D. Gwyther, L.S. Hammond, S. Mourtikas, B.J. Richardson and J.A. Wardrop (1994). Environmental implications of offshore oil and gas development in Australia – Production Activities, pp 209 - 408 in J.M. Swan, J.M. Neff and P.C. Young (1994). Environmental implications of offshore oil and gas development in Australia.

Pipelines

The installation and construction of pipelines along the seafloor may be laid on the seafloor surface or buried via trenching as appropriate to the site conditions. Pipelines are generally constructed at a rate of about 5km per day and protected from corrosion by sacrificial anodes (R.Johnson, Intec Engineering, *pers. comm.*). Piping to the production platform may be constructed of either fixed or flexible piping. Following construction the pipelines and associated facilities are hydrostatically tested. The test water is normally a combination of seawater with the addition of dyes, biocides and corrosion inhibitors, which is usually discharged to the sea following the completion of testing (R.Johnson, Intec Engineering, *pers. comm.*).

Water based control fluids, similar to those used for drilling are used within lines from the platforms to the valves and either returned for reuse or discharged to sea (R.Johnson, Intec Engineering, *pers. comm.*).

Development/production wells

Development or production wells are normally drilled from the production platform, in a similar manner to exploration wells, however they are normally drilled into areas of known geology and pressure (Hinwood *et al*., 1994). When the well has been drilled to its target depth, production casing is set and cemented. Tubing is lowered into the hole together with packers, which seal the space between the tubing and the casing. In order to allow the oil or gas under its natural pressure to flow to the surface, small holes are perforated in the casing at predetermined depths by small remotely detonated explosive charges (APPEA (1)).

Production wells may be drilled either vertically or at various angles to horizontal in order to allow optimum drainage of the producing reservoir (Hinwood *et al*., 1994).

Where required, deep sea divers may be used to manually connect seafloor pipework associated with well development. Divers are generally not used where other options exist to complete the task (K.Gardner, Peak Group, *pers. comm.*).

For further detailed information regarding production wells, the following references are recommended:

- Hinwood, J.B., A.E. Potts, L.R. Dennis, J.M. Carey, H. Houridis, R.J. Bell, J.R. Thomson, P. Boudreau and A.M. Ayling (1994). Environmental implications of offshore oil and gas development in Australia – Drilling Activities, pp 123 - 208 in J.M. Swan, J.M. Neff and P.C. Young (1994). Environmental implications of offshore oil and gas development in Australia.

Produced formation water

Oil drawn from a reservoir usually carries with it water, and it is therefore necessary to separate the water and oil. This separated water is what is known as "produced formation water" (PFW) and is generally returned to the ocean. The PFW is treated to ensure water returned to the ocean is as free as possible from oil and chemicals. Mechanical separation devices and chemical treatments are used to separate oil and water efficiently (APPEA (1)).

The volume of PFW produced from a production platform is dependent upon the reservoir and the period of development. PFW is usually the largest single aqueous discharge from offshore production platforms. PFW is derived from two sources:

- Fossil water – water naturally trapped within the oil-bearing sedimentary rocks. The composition of this water may vary greatly between sources.
- Injection water – usually seawater injected into the well to increase reservoir pressure and thereby increase production of oil and gas (Black *et al.,* 1994).

PFW discharge to the sea in Australian waters must meet regulatory requirements of 30mg/L 24 hour average and 50mg/L maximum total oil. The most abundant petroleum hydrocarbons in Australian PFW are monoaromatic hydrocarbons/BTEX. PFW at the time of discharge may have elevated temperature, low dissolved oxygen concentration and a pH below that of seawater (Black *et al*., 1994).

For further detailed information regarding produced formation water, the following references are recommended:

- Black, K.P., G.W. Brand, H. Grynberg, D. Gwyther, L.S. Hammond, S. Mourtikas, B.J. Richardson and J.A. Wardrop (1994). Environmental implications of offshore oil and gas development in Australia – Production Activities, pp 209 - 408 in J.M. Swan, J.M. Neff and P.C. Young (1994). Environmental implications of offshore oil and gas development in Australia.

3.1.5 Decommissioning

Presently there are no production/operation facilities within the Great Australian Bight and therefore decommissioning in this area has not been undertaken.

The International Maritime Organisation, of which Australia is a participating nation has provided guidelines for removal of abandoned offshore installations, including "…on or after 1 January 1998, no installation or structure should be placed on any continental shelf or in any exclusive economic zone unless the design and construction of the installation or structure is such that entire removal upon abandonment or permanent disuse would be feasible." (APPEA (2), 1997)

In general terms, all structures are removed and the wells plugged. The plugging of wells is either done through pouring concrete down the well, or through use of explosives.

For further detailed information regarding decommissioning, the following references are recommended:

- Australian Petroleum Production and Exploration Association Limitied (2) (1997). Decommissioning in Australia.

3.2 Other minerals

There are no mineral exploration or mineral extraction activities being undertaken in the Great Australian Bight, or known to be proposed for future development (M Bissell, Minerals Council of Australia, *pers comm.*).

4. Potential sources of direct and indirect impacts

Impacts on marine mammals from the gas and petroleum industry can come from a number of sources. These include direct impacts: noise from seismic survey, drilling activities, boat or rig operations; collisions with ships involved with petroleum industry activities; chemical impacts associated with oil spills or other sources of industry-based pollution; and indirect impacts through effects on prey species populations from industry activities such as seismic surveys or events such as oil spills.

Following is a brief summary of available information regarding the nature of the sources of potential direct and indirect impacts to marine mammals from oil and petroleum industry activities.

It is generally agreed by those that study effects of the petroleum industry on marine mammals in Australian waters, that the primary source of impact or disturbance from the industry is through sound. Data on the extent of impacts through boat strike are sparse due to the difficulty in collecting injury and mortality information. Observations of marine mammals following oil spills have produced often conflicting and incomplete information on which to base a quantitative assessment of impacts.

While some controlled studies have been undertaken on prey items such as fish larvae, information on the impacts of seismic activities or oil spills is extremely limited and field data do not exist.

4.1 Characteristics and sources of noise

A propagating **sound wave** either in air or water consists of alternating compressions and rarefactions that are detected by a receiver as changes in pressure, called sound pressure. Structures in our ears and those of most marine mammals are sensitive to these changes in sound pressure (Richardson *et al*., 1995; Gausland, 1998).

The basic properties of a sound wave are **amplitude**, **wavelength**, and **frequency** (Figure 6).

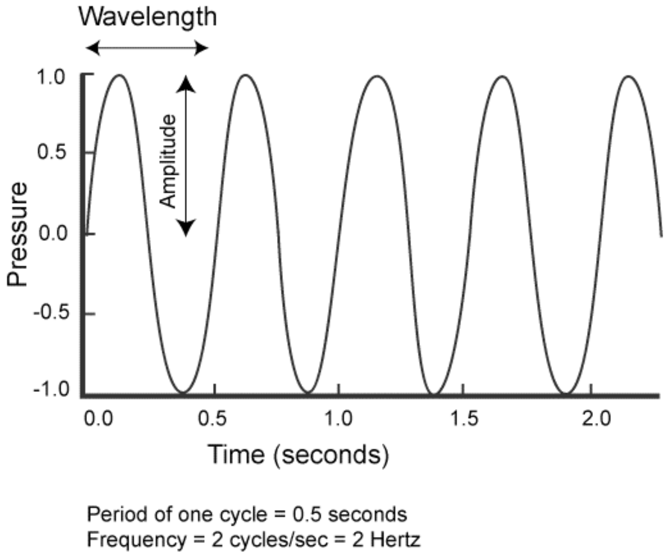


Figure 6: Graphic representation of a sound wave showing its frequency, amplitude and wavelength (from a NOAA web site: http://www.pmel.noaa.gov/vents/acoustics/tutorial/tutorial.html)

The **amplitude** of a sound wave is proportional to the maximum distance a vibrating particle is displaced from rest. Small amplitudes produce weak or quiet sounds, while large amplitudes produce strong or loud sounds.

The **wavelength** of a sound wave is the distance between two successive compressions or the distance the wave travels in one cycle of vibration.

The **frequency** of a sound wave is the rate of oscillation or vibration of the wave particles (i.e. the rate amplitude cycles from high to low to high, etc.). Frequency is measured in **cycles/sec** or **Hertz (Hz)**. To the human ear, an increase in frequency is perceived as a higher pitched sound, while an increase in amplitude is perceived as a louder sound. Humans are unable to hear frequencies between 20 Hz (Infrasonic) and 20,000 Hz (Ultrasonic). Different cetaceans may be able to hear frequencies either side of this range.

Two other factors that influence the nature of sound and its propagation are **sound pressure** and **acoustic intensity**:

Sound pressure is the parameter measured by most instruments and it is expressed in pressure units called micro pascals (μPa).

Acoustic intensity is the power of the sound per unit area in the direction of propagation. The intensity, or loudness of a sound is proportional to the squared value of the average of the sound pressure over a given time (mean square pressure). In presenting sound measurements, acousticians use ratios of pressures, or pressures squared, relative to a standard reference pressure. The universally adopted reference pressures are 1 μPa for underwater sound and 20 μPa for airborne sound.

4.1.1 Sources of noise in the marine environment

The ocean has a base level of background or ambient noise that can be categorised into natural and human induced sound sources. Natural noise sources are divided into physical (wind, sea state, swell and earthquakes) and biological (whales, fish and invertebrates) in origin, producing a range of frequencies and power levels (McCauley, 1994; McCauley and Duncan, 2001). At any one time several of these sources are likely to contribute to ambient noise. Ambient noise varies with season, location, time of day and frequency, and has the same attributes as other sounds including transient and continuous components, tones, hisses and rumbles. Additional to these natural sources are human induced sources (shipping, small vessel traffic, seismic and drilling).

Natural physical sources of noise

Weather, particularly wind, is the dominant natural underwater noise source in the ocean. As the wind blows across the ocean surface, small bubbles that are pushed into the water by wave action produce noise. These air bubbles then collapse under the pressure of the surrounding water, producing noise (Banner and Cato, 1988). As wind speed increases, so too does the resulting underwater noise. The sound of raindrops falling onto the sea surface is another natural source of underwater noise (Cato, 1978).

High underwater noise levels at frequencies < 50 Hz may be produced by earthquakes. Small earthquakes of magnitude 4 or less are comparatively frequently recorded around Australia. These moderate earthquakes average around 17 per year on the Australian continental shelf, and Penrose *et al.*, (1998) recorded 7 events over 21 days over June - July 1998 from the deep sound channel off Cape Leeuwin, WA. Based on the observations of Penrose *et al.,* (1998) and of data on the occurrence and magnitude of earthquakes on the Australian continental shelf (McCue and Paull, 1991), it could be expected that the Great Australian Bight continental shelf area would receive signals from tens of small earthquakes (< magnitude 4) per year. There is a low probability of a larger event (Geosciences Australia, earthquakes database).

These moderate earthquakes produce sound levels ranging from 35 to 199 dB re 1 µPa at 10 – 50 Hz within several kilometres of their epicentre.

Natural biological sources of noise

Very little work has been done to measure or evaluate noise produced by Australian sea lions. Sea lions produce a range of sounds that are considered to be important for breeding and socialising, or in territorial behaviour.

Cetaceans (whales and dolphins) create sounds to communicate the presence of danger, food, an individual of the same species or other animal; and about their own position, identity and territorial or reproductive status (Richardson *et al.*, 1995). In addition, toothed cetaceans use echolocation to detect, locate, and characterise underwater objects, including obstacles, prey and one another. Another identified source of natural biological noise is from fish that may use noise during breeding, or territorial or other behavioural displays.

Very little work has been done on the measurement of sounds produced by the Australian sea lion, or on the effects of noise on their behaviour (Nick Gales, *pers comm*.). The literature that is available refers to the California sea lion in the northern hemisphere, a species that is considered to show some similar characteristics to the Australian sea lion.

California sea lions make both airborne and underwater sounds. Underwater, sounds include barks, whinnies and buzzing associated with social interactions. The frequency of these sounds is below 4 kHz. Both males and females make a range of sounds during their breeding seasons within the colonies. Most energy for these sounds is projected between 0.25 and 2 kHz (Richardson *et al.*, 1995).

The Australian sea lion has a similar series of 'life-style' patterns to California sea lions, including strong site fidelity at the breeding colonies and restricted movements to undertake benthic foraging for food (Costa and Gales, 2002). It is likely that the Australian sea lion has a similar repertoire of sounds to other sea lions, to maintain communication with other individuals of the same species, both during haul out and while foraging offshore.

Baleen whales produce a rich and complex range of underwater sounds ranging from about 12 Hz to 8 kHz, with the most common frequencies below 1 kHz (McCauley, 1994). Some characteristics of underwater sounds produced by a number of species of baleen whales are shown in Table 4.

Table 4: Some sounds used by baleen whales (see Richardson *et al.,* 1995 for source references).

Species	Signal type	Call frequency (Hz)	Dominant frequency (Hz)	Source level (dB re 1uPa m)
Southern right	Tonal	30-1250	160-500	-
	Pulsive	30-2200	50-500	172-187
Humpback	Song	30-8000	120-4000	144-174
Blue	Moans	12-390	16-25	188
	Clicks	6000-8000	6000-8000	130,159
Fin	Moans, sweeps	14-118	20	160-186
Brydes	Moans	70-245	124-132	152-174
Sei	Frequency modulated sweeps	1500-3500	-	-
Minke	Moans, grunts	60-140	60-140	151-175

Southern right whales produce a variety of sounds including tones, high-frequency tonal sweeps, complex amplitude – modulated pulsatile sounds, mixtures of amplitude and frequency modulation, noisy broadband blows and impulsive slaps, all with major energy at 50-1000 Hz (Richardson *et al.*, 1995). Source levels of southern right whales have been estimated as 172 – 187 dB re 1 µPa. More recent work by McCauley *et al.*, (1998) reports the song components of southern right and humpback whales reaching 192 dB re µPa.

Blue whales are known to frequent Australian waters from the Otway basin in western Bass Straight (McCauley and Duncan, 2001) across the Great Australian Bight (Bannister, 1993) to the south and west coasts of Western Australia (Kato *et al.*, 1996). It is well known that blue whales make high-energy low frequency calls (McDonald *et al.*, 1995; Rivers, 1997; Stafford *et al.*, 1998; Stafford *et al.*, 1999; Ljungblad *et al.*, 1998; McCauley *et al.*, 2001).

The presumed 'pygmy' blue whales in the Rottnest trench produce a repertoire of sounds, the dominant types being a series of three long tonal signals spread over nearly two minutes and repeated every 78 seconds (between end/start of consecutive sequences) (McCauley *et al.*, 2001). McCauley *et al.,* (2001) estimated the source level of these calls at 183 dB re 1 µPa. They also found this type of calling to be twice as frequent during the night compared to the day and estimated the maximum daily numbers of callers at 14-28% of the total population in an area. These authors found that the prolific blue whale calling produced increases in ambient noise to high levels for sustained periods (weeks).

Toothed whales (Odontocetes) produce a wide range of sounds including tonal whistles, clicks, pulsed sounds and echolocation clicks. The frequency range of their sounds is 100 Hz to 20 kHz, excluding the echolocation clicks, with the majority being around 10 kHz (Table 5). Source levels range from 100 - 180 db re 1 µPa, (Richardson *et al.*, 1995). A summary table of sounds used by toothed whales found in the Southern Ocean gives an indication of the frequency range.

Table 5: Sounds used by toothed whales in the Southern Ocean (from Richardson *et al.,* 1995).

Species	Call frequency (kHz)	Dominant frequency (kHz)	Source level (dB re 1uPa m)	Echo location frequency (kHz)	Echo location source level (dB re 1uPa m)
Sperm	0.1-30	2-4, 10-16	160-180		
Pygmy sperm	60-200	120			
Killer whale	0.5-25	1-12	160	12-25	180
False killer		4-9.5		25-30,95-130	220-228
Long-finned pilot	1-18	1.6-6.7		6-11?	
Short – finned pilot	0.5-20	2-14	180	30-60	180
Common dolphin		2-18		23-67	
Bottlenose dolphin	0.8-24	3.5-14.5	125-173	110-130	218-228

Fish make sound. Choruses have been recorded on a regular basis in a water depth of 450m west of Rottnest Island and off North West Cape, in Western Australia (McCauley and Duncan, 2001).

Human induced sources of noise

The main sources of human induced noise in the marine environment are vessel traffic (from both small vessels and larger ships) and industrial noise from the mining and petroleum industries associated with operations (drilling rig and tender vessel noise) and exploration (2D and 3D/4D seismic surveys). Human induced sounds such as shipping or seismic noise have most energy between a frequency range of 5-1000 Hz, which encompasses the believed best ‘hearing range’ of baleen whales (10-1000 Hz).

Sonar surveys from swath mapping or preliminary seabed mapping for petroleum exploration is another potential source of noise. However, there is no detailed information on these sources in the literature. While there is significant information on the powerful Mid Frequency (MF) and Low Frequency (LF) Sonar systems used by the US Navy, and its impacts on cetaceans, no such information, or stranding events, associated with use of other types of sonar exist.

Noise produced from small vessels is expected to be variable, depending on the vessel class, its speed and maintenance state. A study of the noise measurement of a fleet of whale-watching vessels in Hervey Bay in Queensland, found that the primary predictor of radiated underwater noise for a small vessel was its speed (McCauley *et al.*, 1996). Small vessels steaming had strong noise directionality patterns, radiating more noise fore and aft, than abeam. This was attributed to a lack of hull noise shielding in the forward direction and limited attenuation by bubble clouds of propeller noise in the aft direction.

In another study of noise produced from two different sized vessels, a 20 metre fishing vessel and a 64 metre oil-rig tender both underway at 11-12 knots in the Timor Sea, different source levels summed across the frequency bands of 168 and 177 dB re 1uPa respectively were recorded (McCauley, 1998). Therefore, the larger the boat, the more noise it produces at a given speed.

McCauley and Duncan (2001) describe merchant shipping (larger ships) noise in two general categories; distant shipping noise (traffic noise) and nearby shipping noise. Distant shipping causes elevated sea noise levels across a defined frequency band (5-100 Hz), and in regions of Australia with high numbers of shipping movements and good sound propagation the noise levels will be high. Nearby shipping is readily discernable as a ship, with each ship having a different noise spectrum, depending on such attributes as vessel speed and tonnage, the number, depth and type of propellers and number of blades. For a merchant vessel underway, propeller noise dominates the contribution to the total radiated noise field.

A sophisticated model developed by the Centre for Marine Science and Technology (CMST) at Curtin University has produced an example of a predicted noise spectrum for a 173 m bulk carrier steaming at 10 knots (McCauley and Duncan, 2001). The frequency encompassing all the effective energy of the noise output of this vessel lies between 3.5 – 100 Hz.

There are 3 main shipping routes that traverse the Great Australian Bight, from Cape Leeuwin in the west to a number of ports in South Australia and Victoria (Woodside, 2000; McCauley *et al.*, 2001). All three routes are at least 400 km to the south (south of 35° S) of the Head of Bight. There is a limited number of ship movements into Ceduna, situated approximately 250 km to the east of the Head of Bight, primarily for the loading of grain. Most of the merchant shipping can be expected to stay in deep water off the continental shelf.

There is considerable variation in noise production from drilling rigs and tender vessels between rig platforms depending on the operation being carried out, and the equipment being used at any given time, and on the surrounding sea bed composition and bathymetry (McCauley, 1998). In a study of the noise from drilling operations in the Timor Sea, McCauley (1998) found the noise to be comparatively low (with rig tenders shut down) and dominated by a mix of tones believed related to the drill string rotation rate. The average noise was measured as 169 dB re 1uPa when drilling, and around 146 dB re 1uPa when not drilling. The noise dropped steadily and was not audible beyond 11 km from the rig, under quiet ambient conditions. In contrast, the noise produced by the rig tender during the extraction process was audible to 30 km, and had an average noise level of approximately 182 dB re 1uPa. This noise was produced mainly by the bow thrusters that operate to maintain the vessel perpendicular to the rig, and would be expected to vary depending on the vessel and its propeller usage (which in turn would be influenced by currents and sea conditions).

The discharge of the airgun arrays during seismic survey represents the key potential disturbance on marine fauna, specifically marine mammals, through the input of high energy, low frequency sound. The airgun is a device that produces an impulsive signal by violently releasing compressed air into the surrounding water column. A number of articles describe airgun arrays, how they work and provide results of modelling of the signals (Caldwell and Dragoset, 2000; Dragoset, 2000). The signals produced travel down through the water column, into the seabed where some energy may be reflected off density discontinuities in the sub-sea layering. These 'echoes' are received by strings of hydrophones (array) towed by the seismic vessel, and their travel times and character allows geophysicists to map the sub-sea strata and so locate potential petroleum traps.

Air-gun signals are more intense in the signal level reached and shorter in duration (< 200 milliseconds near to the source) than continual noise from shipping or drilling associated noise. Air-gun signals are generally repeated at short intervals of 8-15 seconds within a track line, which will vary according to the spatial and temporal scale of the whole survey. Thus seismic surveys may present as a locally intense and persistent noise source active over a large region for a protracted period (McCauley and Duncan, 2001).

In general, air guns may produce broadband source levels approximately between 215 – 230 dB re 1µPa, although the exact source level will be a function of air gun design, capacity (litres), operational air pressure and detonation depth. Most of the sound energy produced by an air gun can be considered to be in the range of 10 – 300 Hz, with the highest levels at frequencies less than 100 Hz (McCauley, 1994).

Although the low frequency energy is transmitted relatively evenly about the array, higher frequencies are focused downwards off the array beam. The level of sound attenuates with the increase in distance from the source. The rate of attenuation depends on a number of factors that influence sound propagation within the ocean area of operation (McCauley and Duncan, 2001).

4.1.2 Propagation of noise in the marine environment

Determining the way in which sound may travel through the marine environment, and the factors acting upon the sound waves as they travel is extremely complex, and the subject of many predictive models (McCauley and Duncan, 2001; Erbe and Farmer, 2000; Erbe, 2002). While this report summarises some of the factors that influence sound propagation, it is beyond the scope of this study to attempt to determine or characterise this area of investigation in any detail. Please refer to cited works for more detail.

The propagation of sound underwater is influenced by a complex mix of factors, including:

- The frequency of the sound of interest;
- The energy of the sound source;
- Absorption losses to the environment, which are negligible at low frequencies (5-20 Hz) but increase with increasing frequency to become critical for frequencies above 2-3 kHz;
- The sound speed profile throughout the water column, which is influenced by salinity, pressure and temperature. For a specified frequency the vertical sound speed structure determines how a travelling sound wave refracts or bends as it travels horizontally, which defines interactions with the seafloor and sea surface;
- The bathymetry path along the sound wave direction of travel;
- Interactions with the sea surface; and
- The nature of the seabed (sound energy may directly reflect off the sea bed or penetrate the sea floor, travel through the sea bed and be reflected or refracted back into the water column).

The source level, the propagation efficiency, the ambient noise and the hearing sensitivity of the subject species combine to determine the apparent loudness of a noise source. The local sound transmission conditions are also very important. In practice, the decay rate of a sound wave will be dependant on the frequency, the local conditions such as water temperature, depth and bottom conditions as well as the depth at which the signal is generated (Gausland, 1998). In deep water, depth variations in water properties strongly affect sound propagation, while in shallow water, interactions with the surface and bottom have strong effects (Richardson *et al.*, 1995).

In general sound level decreases with increasing distance from the source. To compare different sound sources, it is necessary to refer to a standard distance at which source levels will be determined (Richardson *et al.*, 1995). The loudness of each source is then estimated by adjusting the measured level to allow for transmission loss between the standard reference range and the range where the sound was measured. Transmission loss can depend upon a number of things, including medium (air, water, soil), temperature and topography (ground or seabed).

4.2 Collision

Another source of potential harm is through collisions between marine mammals and ships. As part of offshore petroleum operations, ship travel by a range of vessels of different sizes is central to activities. Vessel travel can include seismic vessels, tankers transporting oil from the drilling platform to shore or other smaller vessels for transport or supplies to or between rigs.

4.3 Oil or chemical spill

Although spills may result in spatially and temporally restricted areas of high concentrations of potentially toxic compounds, such releases generally account for a very small percentage of the total load delivered to the environment. Conversely, if the background concentration of toxic compounds attributable to chronic loads is high in a given area, small spills that would normally dilute rapidly to below levels of concern may raise the ambient background concentration above a concentration of concern for a significant length of time (National Academy of Sciences, 2002).

Oil spills can result from pipeline leaks and/or pipeline failure, accidents on a platform, accidents related to the onshore production facility and vessel collisions (Redoubt Shoal Unit Development Project, 2002). Treated oily water from drilling fluids, deck drainage and bilge water could also potentially affect marine mammals (White Rose Comprehensive Study Report, 2001; Heyward, *et al.,* 2000).

4.4 Indirect impacts

Although a particular species may not suffer directly from an activity, such as noise induced behavioural effects, they may suffer indirectly because the activity alters the actions of another species they are dependant upon such as prey species (McCauley 1994).

5. Potential for direct and indirect impacts

The greatest potential for direct and indirect impacts on Australian sea lions come from oil spills, and possibly impacts of seismic activities on populations of their main prey species, namely shellfish and squid. Impacts from oil spill include inhibition of maternal recognition of young covered with oil, endocrine or stress impacts leading to premature delivery or spontaneous abortion of pups, and disturbance of sea lions through clean-up activities associated with coastal oil spills.

The noise created during seismic surveys is generally considered to be outside of the hearing range of Australian sea lions, and is therefore not considered to be a significant source of disturbance. While no studies have been undertaken, Australian sea lions are assumed to be highly adaptable and able to habituate to other more constant noises such as an operating facility.

Ship strike is not considered to be a risk for Australian sea lions.

For cetaceans (whales and dolphins), noise from seismic surveys and operating facilities is considered to pose the greatest potential for direct and indirect impacts, and there is a large volume of literature that examines the sensitivities of cetaceans to such noises.

From the literature, the following summary points emerge:

- Whales are more susceptible to noise while resting or breeding compared to during migration or feeding;
- For continuous noise (for example, rig operation), whales begin to avoid sounds at exposure levels of 110 dB and more than 80% of species observed show avoidance to sounds of 130 dB;
- For seismic noise, most whales show avoidance behaviour at 180 dB.

Mother-calf pairs of humpback and southern right whales have been observed to be displaced from major nursery grounds by noise disturbance from vessel activities associated with the whale-watching industry.

Ship strike is considered a serious risk for some species of whale, particularly right whales (both southern and northern). Right whales, and particularly young whales of the species, are highly susceptible to ship strike, probably because they tend to rest on or near the water's surface.

Oil spills are not considered a significant risk to whales and dolphins.

This chapter summarises the available literature on the impacts and sensitivities of marine mammals to activities undertaken by the petroleum industry.

5.1 General information on noise impacts

There is considerable national and international concern that the sounds introduced into the sea by humans could be having detrimental effects on marine mammals, by interfering with their ability to detect calls from individuals of the same species, echolocation pulses or other important natural sounds (Richardson *et al.*, 1995). Potential effects of the elevated background noise levels caused by this introduced man-made noise include:

- Limiting the detection by the mammals of natural sounds;
- Disturbing their normal behaviour resulting in possible displacement from areas, and
- Causing temporary or permanent reductions in hearing sensitivity.

These potential effects depend to a degree on the type of marine mammal involved. The potential area or zone of influence of a man-made sound is also influenced strongly by the levels and types of ambient noise (Richardson *et al.*, 1995).

Cetaceans (whales, dolphins and porpoises) are mammals that spend all their time in the marine environment, while most of the pinnipeds (seals, sea lions, fur seals and walrus) divide their time between water and land. Airborne noise is therefore also of concern, mainly to pinnipeds during their haul-outs onto land areas, but also to some species of whales.

There is a large volume of literature concerned with the description of various impacts upon marine mammals (Richardson *et al.*, 1995; McCauley, 1994; Tasker and Weir, 1998; Gisiner, 1998; Davis *et al.*, 1998; McCauley and Duncan, 2001; and O'Brien, 2002). Generally, these impacts are measured through observations of behavioural responses to noises. As such, these responses are used as a surrogate measure for sensitivity or susceptibility. The number of extensive reviews available has drawn on the same limited experimental and observational data, indicating that much more of this work is required. Consequently, when considering the possible impacts of underwater noise on marine mammals, in general McCauley and Duncan (2001) suggest that it is necessary to recognise that:

- Each species in question has receptor systems for detecting the signal and that the noise frequency content must be such that it overlaps the hearing range of any species impacted;
- Different types of noises may have different effects;
- Different effects may be elicited from an approaching noise source as compared to a stationary or departing noise source; and
- The scale of the noise disturbance needs to be considered (i.e. is it frequent, infrequent or continual over short and long time scales?).

Based on a review of anatomical and audiometric data Ketten (1998) supports the notion that marine mammals are acoustically diverse, with wide variations in ear anatomy, frequency range and amplitude sensitivity. The general trend is that larger species tend to have lower frequency ranges than smaller species.

All marine mammals have sensitive ears that are simultaneously adapted to sustain moderately rapid and extreme pressure changes, and which appear capable of accommodating acoustic power relationships several magnitudes greater than in air.

This is likely due to the fact that the aquatic environment propagates sound significantly more efficiently than air, and so aquatic auditory systems are adapted to these conditions. In addition, virtually all marine mammals are potentially impacted by sound sources with a frequency of 500 Hz or higher, but relatively few species are likely to be impacted by lower frequencies.

An animal's sensitivity to sounds varies with frequency, and its response to a sound is expected to depend strongly on the presence and levels of sound in the frequency band or range of frequencies to which it is sensitive (Richardson *et al.*, 1995).

Below is a summary table (Table 6) outlining the acoustic intensity and frequency of those sources of marine noise for which there is data, relative to the call and vocalisation ranges of marine mammals. While this information provides an indication of their known range of acoustic interactions, it does not necessarily relate to their acoustic or other physical tolerances to low frequency, high energy sound waves.

Table 6: Summary table of acoustic intensity and frequency for a range of noise sources relative to those for marine mammals (approximated from the literature)

Source	Acoustic intensity (dB re 1µPa)	Frequency range (Hz)
Great whales	130 - 188	16 – 8,000
Toothed whales (vocal)	125 - 180	1,600 – 120,000
Toothed whales (echolocation)	180 - 228	6,000 – 130,000
Seals / sea lions	unknown	2,000 – 32,000
Earthquakes (≤4)	35 - 199	10 - 50
Ships	177	5 - 100
Seismic	215 – 230	10 - 300
Drilling rig (operating)	169	?
Drilling rig (not operating)	146	?
Extraction operations	182	?

5.2 General information on oil or chemical spills

Information on the impacts of oil or chemical spills on marine mammals is sparse and often conflicting. Generally speaking, impacts are heavily influenced by factors such as habitat (oceanic, rocky shores, mangroves or sandy beaches) oceanic conditions (bays, high energy marine environments) and currents (strength and direction). These factors determine the length of exposure to certain types of oil, and also the nature and persistence of different oils in the environment (Irwin, 1997). Studies of oil spill impacts on marine mammals are generally anecdotal.

Surface winds are an important factor in the initial dispersal of an oil spill. Surface leaks generally move in the same direction as the prevailing winds at about 3.5% of the wind speed (Volkman *et al.*, 1994). Large oceanic currents usually have little effect on coastal zone spills. Exceptions to this general rule are the Alaska Coastal Current, which carried oil from the *Exxon Valdez* spill several hundred kilometres along the coast, and the Leeuwin Current, which flows southward along the Western Australian coast, and then east along the South Australian Coast from February to October. The effect of the Leeuwin Current was demonstrated by the trajectory taken by oil spilled from the *Kirki* oil tanker where the oil was taken offshore by the Leeuwin Current (Volkman *et al.*, 1994).

This section deals with both general information on oil, oil spills and the physiological effects of the chemical constituents of oil, as well as some observational information on the impacts and recovery times of marine mammal populations after oil spills.

5.2.1 Petroleum – General information

Petroleum is a complex mixture of thousands of different hydrocarbons and related substances, all with different physical and chemical properties. As such, determination of the fate and toxicity of oil and its constituents is a difficult task. Impacts can also be influenced by the synergistic, antagonistic and additive effects of components of petroleum hydrocarbons (Overton, *et al.* 1994). This means that the effect of different components of oil could either be worse or not as bad as the sum of the parts due to interactions between the components. The constituents of oil include naphthalene and its variants, various tricyclic- and polycyclic aromatic hydrocarbons (PAHs) (that is, those aromatic hydrocarbons that are heavier than naphthalene with low water-solubility), and BTEX compounds (benzene, toluene, ethyl benzene, and xylenes) (Irwin, 1997). Some of these organic chemicals are more persistent than others. While oil is a mixture of hydrocarbons, and is at least theoretically biodegradable, large-scale spills can overwhelm the ability of ecosystems to break the oil down.

The toxicological implications from petroleum occur primarily from exposure to, or biological metabolism of, aromatic structures. These implications change as an oil spill ages. Some studies have indicated that the soluble aromatics of an oil (such as benzene, toluene, ethylbenzene, xylenes, and napthalenes) produce the majority of its toxic effects in the environment (Irwin, 1997; Overton *et al.*, 1994). However, one study of oil product toxicity tests found that LC_{50} (the concentration at which 50% of the exposed organisms die) values that are from the same product class (classes include: bunker, crude, lube, diesel, gasoline, and jet fuel) can vary over three orders of magnitude depending on the methods used in conducting the test (Irwin, 1997).

Several compounds in petroleum products are carcinogenic, for example benzene and possibly napthalenes, but carcinogenic effects are associated more with chronic exposure (Overton *et al.*, 1994) than the short-term exposure likely in a high-energy open marine environment.

Commonly reported effects of petroleum and individual PAHs on living organisms are impaired immune systems for mammals and altered endocrine functions for fish and birds.

Some components of oil can be bioaccumulated by marine organisms, particularly the group of longer-lasting PAHs. While bioaccumulation occurs to some degree in detritus-feeding bivalves and suspension feeders, it is unlikely that biomagnification (that is, the magnification of concentrations of contaminants over two or more trophic levels) occurs, due to the ability in fish and possibly other organisms to process aromatic hydrocarbons relatively efficiently (NOAA, 1992; Irwin, 1997). For example, in a field study conducted in Prince William Sound after the *Exxon Valdez* oil spill, bioaccumulation of PAH in intertidal mussels, snails and drills was measured. However, no evidence of biomagnification was found (ERCE, 1991, *cited in* NOAA, 1992).

The three main exposure routes of marine mammals to petroleum products are:

- direct surface fouling;
- direct and indirect ingestion with the affects of bioaccumulation; and
- inhalation of the toxic vapours released from the petroleum hydrocarbons as they evaporate.

5.3 Impacts and sensitivities of pinnipeds (seals and sea lions)

5.3.1 Direct impacts

Noise

There is a shortage of information on the effects of seismic operations on pinnipeds, especially in Australia. Richardson *et al.*, (1995) acknowledged the paucity of detailed data on reactions of seals to noise from seismic exploration in open water. These authors did however expect seals to be rather tolerant of, or able to habituate to, repeated underwater sounds from distant seismic sources, at least when animals are strongly attracted to an area. Reactions of pinnipeds to seismic operations at close ranges are virtually unknown. Monitoring studies in 1996 – 97 indicated that seals (mainly ringed seals) usually tolerate strong sound pulses from nearby seismic vessels. Only a minority of the seals within a few hundred metres show evidence of localised avoidance, and any effects on seal behaviour are not very consistent or conspicuous (Richardson, 1999). Evidence suggests that hearing in all pinnipeds is poor at low frequencies. Comparisons of the hearing characteristics of Otariid and Phocid seals suggest that there are at least two types of pinniped ears, with phocids being better adapted for underwater hearing (Ketten, 1998). Australian sea lions are Otariids.

One recent study in the Alaskan Beaufort Sea categorised behaviours and distance from the vessel of arctic seals during a seismic operation (Harris *et al.*, 2001). During the full-array seismic survey there was partial avoidance of a zone < 150 metres from the vessel, with the seals not moving farther than 250 metres.

Oil spill

All walrus, seal and sea lion species are considered to have the ability to detect and avoid oil and other petroleum hydrocarbons. While no targeted studies have been conducted regarding their detection abilities, anecdotal data indicates that they will avoid a spill. However, in the wild there are also many contradictory incidents where seals, sea lions and fur seals have swum directly into an affected area, not seeming to notice the oil slicks (NOAA, 1992; O'Sullivan & Jaques, 2001). Numerous deaths and population effects have been related to direct and indirect exposure of seals and sea lions to petroleum hydrocarbons. A summary is provided in Table 7 below.

Table 7: Historical Interactions and Impact of Seals, Sea lions, and Walruses with Oil

Date	Location and Source	Oil Type and Quantity	Species	Impacts
late 1940s	Antarctic; Ship discharge	Fuel oil; quantity unknown	Unspecified seals	Bloodshot eyes. Surface fouling with tarry oil.
1949	Ramsay Island, Wales; Source unknown	Fuel oil; quantity unknown	Gray seals	Pups largely unaffected by thick coating of oil. Two fouled pups drowned.
Mar. 1967	English Channel: *Torrey Canyon*	Crude oil; 30 x 10^6 gal	Gray seals	Three oiled seals were recovered, confirmed deaths.
Jan. 1969	Gulf of St. Lawrence; Storage tank	Bunker C; 4,000 gal	Harp seals	10-15,000 seals coasted. Unspecified number of dead recovered.
Feb. 1969	Santa Barbara, CA; Union Oil Well	Crude oil; >30 x 10^6 gal	Harbor seals Elephant seals Cal. Seal lions	Oiled seals observed. Mortalities not linked conclusively to incident.
Nov. 1969	N. Dyfed, Wales; Source unknown	Unknown; quantity unknown	Gray seals	14 oiled. Dead pups found. No causal relationship established.
Feb. 1970	Chedabucto Bay and Sable Island, N.S; *Arrow*	Bunker C; 4 x 10^6 gal	Gray seals Harbour seals	150-160 seals oiled on Sable Island; 500 seals oiled in Chedabucto Bay. 24 found dead, some with oil in mouth or stomach.
Feb-Mar 1970	Kodiak Island, AK; Ship discharge	Slop oil or oily ballast; quantity unknown	Hari seals Sea lions	Estimated 500 mammals contacted. No mortalities recorded.
Apr. 1970	Alaska Peninsula; Source unknown	Diesel fuel; quantity unknown	Hair seals	400 seals exhibited unusual behavior. No mortalities recorded.

Date	Location and Source	Oil Type and Quantity	Species	Impacts
Nov. 1970	Fame Islands; Source unknown	Unknown; quantity unknown	Gray seal	Yearling seal found with oil-stained pelt and crusting around mouth. Animal was otherwise healthy.
Mar. 1972	British Columbia *Vanlene*	Bunker B; 10,000 gal	Seals	Seal herds in area were unaffected.
Sept. 1973	Repulse Bay, NWT; Ship discharge	Refuse oil; quantity unknown	Ringed seals	Hunters killed 5 oil-covered seals.
1973	Dutch coast; Source unknown	Unknown; quantity unknown	Harbour seal	Patch of oil inconclusively associated with skin lesions.
1974-1979	Cape Town, S.A; Ships and Industry	Chronic discharge	Cape fur seals	Fur seals lingering in polluted harbour without obvious effect.
Aug. 1974	Straits of Magellan; *Metula*	Crude oil; 14×10^6 gal	S. seal lions S. Am. Fur seals	Seal lions and fur seals in the area apparently unaffected.
Aug. 1974	Coast of France; Source unknown	Fuel oil; quantity unknown	Harbor seals Gray seals	Oil in intestine of one harbour seal. Three oiled gray seals, one with ingested oil.
Sep. 1974	Pembrokeshire, Wales; Source unknown	Unknown; quantity unknown	Gray seals	Two heavily oil pups drowned when washed off beach. 25 pups and 23 adults were fouled.
Jan. 1975	Ireland; *African Zodiac*	Bunker C; 1.1×10^6 gal	Seals	Seals in the area were apparently unaffected.
Aug. 1977	Greenland; *USNS Polomac*	Bunker C; 1×10^6 gal	Ringed seals other seals	16 oiled seals were observed one month after the spill.
Mar. 1978	France; *Amoco Cadiz*	Crude oil; 60×10^6 gal	Gray seals	Two of four dead seals were coated with oil. No causal relations was established.

Date	Location and Source	Oil Type and Quantity	Species	Impacts
May 1978	Great Yarmouth; *UK Eleni V*	Heavy fuel; 1×10^6 gal	Seals	20 oiled seals were observed.
Oct. 1978	South Wales; *Christos Bitas*	Crude oil; 840,000 gal	Seals	Mortality of 16 of 23 oiled individuals.
Dec. 1978	Shetland Is., Scotland; *Esso Bernicia*	Bunker C; 370,000 gal	Seals	One seal killed by oil.
Mar. 1979	Cabot Str., N.S; *Kurdistan*	Bunker C; 2.1×10^6 gal	Gray seals Harbour seals	At least 4 gray and 6 harbor seals were found dead and coated with oil. No causal relationship was established. Oiled seals were found on Sable Island.
Nov. 1979	Pribilof Is., AK; *F/V Ryuyo Maru*	Fuel oil; 290,000 gal	Northern fur seals	Some oiled dead pups were found. Causal relationship was never demonstrated.
Feb. 1984	Sable Is., N.S.; Well blow out	Gas condensate; quantity unknown	Gray seals	Four oiled seals were observed on Sable Island. No mortalities were reported.
Jan. 1989	Anvers Is., Antarctica; *Bahia Paraiso*	Diesel fuel; 233,000 gal	Crabeater seals Elephant seals Southern fur seals	Two crabeater seals were affected. Elephant seals and fur seals were oiled, but unharmed.
Mar. 1989	Prince Williams Sound, AK; *Exxon Valdez*	Crude oil; 11×10^6 gal	Harbor seals Fur seals Stellar seal lions	Seals were observed swimming in the oil. Thirty-one harbor seals, two fur seals, and 14 seal lion carcasses were recovered with some oil fouling.

Date	Location and Source	Oil Type and Quantity	Species	Impacts
July 1995	Bass Strait Coast, Australia; *Iron Baron*	Unspecified volume	Fur seals	Reduced number of pups born at Tenth Island in 1995. There was a strong relationship between the productivity of the seal colonies and the proximity of the islands to the oil spill.

[a] Table was developed from J.R. Geraci and D.J. St. Aubin (1990), incorporating information from DPIWE (Tas)

Direct surface fouling

Furred species, such as fur seals are most likely at risk during an oil spill. However, lesser furred seals and sea lions are less threatened by surface oiling. Thick layers of blubber retain the animals' core temperature (NOAA, 1992; O'Sullivan & Jaques, 2001). Contact with oil can cause surface lesions in the skin, especially around the eyes which may become damaged. The effect of such damage on the long-term survival of the animals is unknown (O'Sullivan & Jaques, 2001).

Inhalation

No studies have been conducted on the effects of inhalation on pinnipeds, however it is assumed that the effects would be similar to those exhibited in other mammals (NOAA, 1992).

Ingestion

Ingestion can occur either through direct ingestion while foraging, or through grooming. The ingestion of petroleum hydrocarbons has been implicated in numerous seal and sea lion deaths. Experimental results indicate that seals and sea lions would be able to tolerate the ingestion of small quantities of oil, however, symptoms related to oil ingestion can range from organ disease to permanent damage and / or death (NOAA, 1992). Following the Santa Barbara oil spill, there was anecdotal information concerning premature births in sea lions.

The principle diet of most seals and sea lions consist of cephalopod molluscs and fish; unlike bivalves and suspension feeders these prey are not likely to accumulate petroleum hydrocarbons. All seals and sea lion species are assumed to have the necessary enzymes available within their systems to metabolise some petroleum fractions, while others may be deposited into fat stores. To date, no evidence of deleterious effects related to bioaccumulation of petroleum hydrocarbons have been documented (NOAA, 1992).

Areas of special concern for Australian sea lions in the Great Australian Bight Marine Park Marine Mammal Protection Zone

According to NOAA (1992), certain behaviours and habitats may increase the risk of exposure to petroleum hydrocarbons by pinnipeds. Australian sea lions express very high sight fidelity, and have had a protracted recovery from commercial exploitation. The significance of the population at the Head of Bight, as mentioned in earlier in this report, is that they form an important genetic link between larger eastern and western populations. The elements of risk relevant to the Australian sea lion, and particularly the populations at the Head of Bight are identified below:

Maternal recognition: Maternal recognition may be hampered if a pup becomes oiled. This loss of olfactory recognition may result in the pup being abandoned. Oiling of nursery haulouts may result in major losses to a breeding subpopulation. Additionally, pups which are cleaned at rehabilitation centres may no longer be accepted by the mother, again resulting in abandonment.

Reproduction: Contact with oil during the breeding season is thought to reduce the reproductive success of the colony. Additionally, theories suggest that exposure to oil during the breeding season may result in mass, premature delivery of pups (or spontaneous abortions) due to stresses during early delivery season as observed in California sea lions.

Interactions with humans: Cleanup activity during a spill may result in abandonment of haulout areas. In certain species, pups may be permanently abandoned, while others will eventually return to their young.

Other

Other effects from the petroleum industry include colonisation by pinnipeds of rig infrastructure and buoys. There is no robust data that quantifies or characterises the impacts of this aspect of petroleum industry operations, but anecdotal information suggests that some species of seal / sea lion readily colonise structures such as oceanic buoys. It is unknown whether Australian sea lions would readily colonise rig infrastructure in an area such as the Great Australian Bight Marine Mammal Protection Zone, as this species displays high site fidelity.

Australian sea lions, and pinnipeds in general are not considered to be at risk of large vessel collision.

5.3.2 Indirect impacts

While there is little dietary information for the Australian sea lion, the main prey source for Australian sea lions is thought to consist of squid. Please refer to the section on 'Possible indirect effects on cetaceans' for information on potential impacts on prey species populations (section 5.4.2).

5.4 Impacts and sensitivities of cetaceans (whales and dolphins)

5.4.1 Direct impacts

Noise

The types of effects underwater noise may produce on marine mammals range from severe to no effect (McCauley, 1994). There has been no documented evidence of any lethal effects for most whale species resulting from exposure to noise. Possible exceptions include a stranding of 12 Cuvier's beaked whales in Greece during 1996 where it was speculated that they had died as a result of the exposure to high powered low frequency tones (Frantzis, 1998), and more recently in 2000, up to 17 whales, including 2 minke, one dolphin and 14 beaked whales live-stranded in the Bahamas, coincidentally with the use of low frequency US Navy sonar in the area (Balcomb and Claridge, 2001).

Several studies (Malme *et al.*, 1983; 1984; 1986; 1988, *cited in* McCauley, 1994) have shown that some whales begin to avoid sounds at exposure levels of 110 dB received acoustic intensity, and more than 80% of the whales investigated (humpbacks, grey and bowhead whales) showed avoidance to sounds of 130 dB received acoustic intensity. These sound events were continuous source (for example, ships) events.

The US *Marine Mammal Protection Act 1972* will approve any seismic operation if received noise is kept below 180 dB (US Fish and Wildlife Service). While there are no such legislative provisions under the EPBC Act, under the Guidelines on the application of the Environment Protection and Biodiversity Conservation Act to interactions between offshore seismic operations and larger cetaceans (Environment Australia, October 2001), sounds heard by whales of over approximately 140 dB in feeding, breeding or resting areas may be considered likely to significantly disturb whales that are present. Sounds heard by whales of over 150 dB in other areas, such as migratory paths, may significantly disturb whales that are in the area. These sound level thresholds are applied through enforcing a nominated distance of 20 kilometres from any sighted whale during seismic operations, and are supported by an observer program on seismic vessels.

Recent experiments have been undertaken on bottlenose dolphins and white whales to test if any permanent changes in hearing thresholds occurred from exposure to intense signals (Schlundt *et al.*, 2000). The tones in the range 40-7,500 Hz with levels up to 202 dB re 1 uPa (within the frequency and acoustic intensity ranges for seismic surveys and vocalisations of cetaceans, see Table 6) caused temporary threshold shifts in hearing, but returned to normal within a few days. This suggested that these whales had not suffered any sub-lethal effects from exposure. There have been no similar studies on large baleen whales.

There may be other impacts from noise that are not yet fully understood. The following sections summarise the literature on known impacts from noise on cetaceans.

Seismic noise

In most vertebrates tested, impulsive signals produce different hearing responses to continual signals. Marine mammals may tolerate high levels of impulsive noise but this may not necessarily mean the long-term function of their hearing systems are not being impaired. For example in humans, impulsive signals such as gunfire can be tolerated since they are often not excessively “loud”, but they may overdrive the inner ear and cause hearing damage (McCauley and Duncan, 2001).

Physical damage is caused by the peak pressure and the time it takes to achieve that pressure (rise time) (Davis *et al.*, 1998). Seismic sounds occur in the order of milliseconds compared to explosives that happen in microseconds. A seismic air gun array is towed behind a ship at a depth around six to eight metres, with shots fired typically every 10 seconds. Because the array is configured to focus sound toward the bottom, the sound from air guns would seem louder to whales positioned directly below the arrays, compared with whales either at the same depth as the air guns, or at distance.

Indexes of surface behaviour, blow rates and movement patterns have been used for most behavioural response studies on marine mammals. The clearest responses have been shown for whales, mainly bowhead and gray whales, responding to an approaching air gun array (Richardson *et al.*, 1995). These species have been observed to avoid seismic operations 7.5 km away at received signal levels in the range 150-180 dB re 1uPa, and also show evidence of discernable behavioural changes at greater distances, and at lower signal levels. More recent work of Thomson *et al.* (2000) that is summarised in Richardson (1999) and McCauley and Duncan (2001) suggest that bowheads avoid the sound field of a seismic vessel at approximately 20-30 km away, at a received signal level of approximately 130 dB re 1uPa, but return to normal migration routes within 12-24 hours following seismic shutdown.

McCauley and Duncan (2001) have provided a summary of the response of great (large) whales to petroleum seismic activity, which suggests that:

- Early work showed avoidance of seismic from approximately 7 km by bowhead and gray whales;
- Later work suggested that migrating bowheads kept approximately 20 km from seismic operations;
- Migrating humpbacks appeared to avoid operational seismic from 3-4 km and did not appear to change their migratory route (McCauley *et al.*, 1998);
- Resting humpbacks were far more sensitive than migrating animals and showed avoidance at an estimated 12 km from seismic operations.
- In California blue whales have been observed to apparently not respond to seismic operations at ranges equivalent to 10-15km in the Otway Basin;
- Many great whale species have shown short term behavioural and startle responses to seismic operations starting at comparatively long (10-30km) ranges (for example, 11 km for migrating humpbacks in McCauley *et al.* (2000) and 30 km for startle response in Ljungblad *et al.* (1985)).

For humpback pods containing females resting with or without calves in a key habitat, it was found that their responses occurred from an estimated 7-12 km from a seismic vessel, as compared to 3-4 km while migrating (McCauley *et al.*, 2000).

An important aspect identified by Gordon *et al*. (1998) is the expansion of seismic surveys to be conducted in ever deeper water with advancing deep-water mining technology, and the concomitant impacts likely on deep diving marine mammals (Gordon *et al.*, 1998). Species that dive to depth, including both whales and pinnipeds, may incur impacts from seismic pulses at depth that other more surface orientated species may avoid.

There have been no direct measurements for southern right whales in Australian waters. If observations of work done on bowhead and northern right whales, similar species in the northern hemisphere, can be used as a guide, southern right whales could be expected to respond to approaching seismic at anything from 10-30 km and may avoid seismic operations from 3-20 km, depending on the acoustic characteristics of the Great Australian Bight environment.

Caution is required due to the fact that the Marine Mammal Protection Zone is an important breeding ground and not a recognised feeding ground. Responses of whales to seismic and other noises may be influenced by their current behaviour i.e. feeding or breeding. Females with new calves, calves, and pregnant females within this area may have different responses. The impact of high noise levels on unborn calves is not known.

Most authors recognise the continuing debate about the effects of seismic operations on marine mammals and why no definitive answers have been found even though much research has been published. The answer may lie in the great complexity of the issue including the interaction of airgun design, underwater acoustics, marine mammal physiological and behavioural differences and geographical and temporal variation (Dragoset 2000).

Continuous and industrial noise

In a long term study over 25 years of whale responses to vessel approaches (Watkins, 1986), the most vigorous response by whales came from the noise sources that changed suddenly, rapidly increased or were unexpected. Watkins also noted that whales that were preoccupied were less responsive than whales that were inactive. Other authors have found similar results where rapidly changing vessel noise often evokes a strong avoidance response, while a slow non-aggressive vessel approach results in little response from the whales (Richardson *et al.*, 1995; McCauley *et al.*, 1996). These authors also assert that feeding whales may be less responsive to vessel traffic than inactive whales, as they are involved in a directed activity, feeding.

Vessel activity has been implicated in long-term (Norris and Reeves, 1978) and short-term (Jurasz and Palmer, 1981; Baker and Herman, 1989) changes in distribution of humpback whales in Hawaiian waters. Other studies have suggested that human activities can affect the distribution of humpback whale mother-calf pairs (Glockner-Ferrari and Ferrari, 1985; Salden, 1988; Glockner-Ferrari and Ferrari, 1990).

A long-term study over 27 years of southern right whales in Argentina has provided evidence of flexibility in several aspects of their habitat use (Rowntree *et al.,* 2001), including the abandonment of a major nursery ground and the establishment of a new nursery area adjacent to the centre of a growing whale-watching industry, and some small-scale shifts in distribution possibly in response to natural and human disturbance.

Work undertaken to assess the effects of small vessel approaches on the behaviour of bottlenose dolphins found significant differences in responses compared to control periods (Nowacek *et al.*, 2001). Dolphins decreased inter-animal distance, changed heading, and increased swimming speed significantly more often in response to an approaching vessel, with a higher probability of this occurring while in shallow water.

A more recent study of the potential effects of underwater noise from whale-watching vessels on killer whales off southern Canada (Erbe, 2002), was based on an acoustic impact model. It predicted that faster boats made more noise, being audible to killer whales over 16 km away, to mask killer whale calls over 14 km, to elicit behavioural response over 200 m and to cause changes in hearing of 5 db after 30 minutes within 450 m. For slower vessel speeds the predicted ranges were 1 km for audibility and masking, 50 m for behavioural responses, and 20 m for hearing changes. The effects of combined vessel noise around a pod were close to the predicted level assumed to cause permanent hearing loss over prolonged exposure.

To estimate the predicted ranges at which blue whales in the Otway Basin may respond to three noise scenarios, McCauley and Duncan (2001) use the values from Richardson *et al*. (1995) for broadband levels at which avoidance occurred in various observations and experimental trials for gray and bowhead whales. Their results indicate that it is probable that during times when a drill rig is drilling and the rig tenders are idle, blue whales may be found to within less than 1 km of the drill rig. When the rig tenders are active and at their noisiest state (i.e. with full use of main engines and bow thrusters) then it is unlikely blue whales will be found within a few kilometres of a drilling rig.

Collision

A recent study has compiled information on the frequency of occurrence of motorised ship strikes on large whales and their contributing factors (Laist *et al.*, 2001). From historical records and stranding databases, the authors found the species most frequently hit by ships were fin whales (*Balaeanoptera physalus*) with right whales, including southern right whales, humpback whales, sperm whales and gray whales hit commonly. The most lethal or severe injuries to whales are caused by ships over 80 m in length and by those travelling at more than 14 knots. A higher proportion of right and humpback whale calves and juveniles were struck by ships, indicating a higher vulnerability by young whales.

Documentation of the mortalities of southern right whales in waters of South Africa from 1963 to 1998 show that of the 55 animals that had died, 31 were calves of the year, 8 were juveniles and 14 were adults (Best *et al.*, 2001). Ship strikes caused at least 11 deaths and 5 non-fatal wounds. The data, however, indicated that the current level of (human induced) mortality appears not to be affecting the population recovery.

The right whale is particularly susceptible to the dangers posed by ships and equipment because of its habits of resting near and on the surface (Terhune and Verboom, 1999) as well as surface courtship and feeding. Off the east coast of the US, vessel encounters accounted for 7 percent of injuries and 28 percent of all known northern right whale deaths between 1970 and 1994 (Corn, 1995). Often, the whales are not killed outright but are fatally injured by propeller blades, and eventually die because of impairment or loss of appendage function.

Oil or chemical spill

In general, whales, dolphins and porpoises are considered to have the ability to detect and avoid oil and other petroleum hydrocarbons. Numerous studies have been conducted on dolphins regarding their detection abilities, and in all instances, the representative test animals were able to identify the presence of the pollutant and actively avoided contact with surface slicks (NOAA, 1992). Other whales and dolphins would also probably be able to detect and avoid contamination (Overton *et al.*, 1994). However, in their natural environment, there are many instances where whales and dolphins have swum directly in to affected areas and even fed, not seeming to notice the oil slicks (NOAA, 1992; Anne Hill, 1999; O'Sullivan & Jaques, 2001; Volkman *et al.*, 1994).

The ability or inclination of pregnant or lactating females to move away from preferred calving and nursery sites has not been identified in the literature, although breeding females and calves are considered more at risk from oil spill than other individuals. Neither has the potential short term nor long term impacts on reproductive success from an oil spill in such an area been discussed.

The question of lethal and sublethal effects of oil on whale, dolphin and porpoise species has not been successfully answered. Historical information on observations of impacts on cetaceans during actual oil spills is summarised in Table 8 (NOAA 1992).

Table 8: Historic interactions and impacts of whales and dolphins with oil[a]

Date	Location and Source	Oil Type and Quantity	Species	Impacts
Feb. 1969	Santa Barbara, CA; Union Oil Well	Crude oil; >30 x 10^6 gal	Gray whales Pilot whales Sperm whales Common dolphins White-sided dolphins	Sixteen stranded whales and dolphins were recovered. No causal relationship was established.
Apr. 1970	Alaska Peninsula; Source unknown	Diesel Fuel; quantity unknown	Killer whales	One sick and one dead killer whales were observed. No examination was conducted to determine causal relationship.
1974	Japan; Source unknown	Bunker C; 11.3 x 10^6 gal	Porpoise	One dead porpoise found.
Oct. 1976	Aransas Pass, TX; Pipeline leak	Crude oil; 15,500 gal	Bottlenose dolphins	Dolphins swan through the oil without any apparent effects.
Dec. 1976	Nantucket Shoals; *Argo Merchant*	Bunker C; 7.9 x 10^6 gal	Fin whales Pilot whales and others	Forty-three sightings were recorded for animals in and around patches of oil. No obvious reaction was observed.
Mar. 1978	France; *Amoco Cadiz*	Crude oil; 60 x 10^6 gal	White sided dolphins Common dolphins Pilot whales	Six stranded animals were recovered. No causal relationship was established.
Sept. 1978	Matagorda Bay, TX; Boat grounding	Fuel oil; 3,000 gal	Bottlenose dolphins	Twenty dolphins were observed to be swimming through the oil without any effect.
June 1979	Gulf of Mexico; *Intoc-1*	Crude oil; 70 x 10^6 gal	Bottlenose dolphins Spotted dolphins	Animals were sighted in areas with oil-coated debris. The animals were apparently unaffected.

Date	Location and Source	Oil Type and Quantity	Species	Impacts
June 1979	Cape Cod, M.A; *Regal Sword*	Bunker C/Fuel oil; 80,000 gal/6,300 gal	Humpback whales Fin whales Minke whales Right whales White-sided dolphins	Animals were observed feeding, surfacing, and swimming through heavy concentrations of oil.
May 1981	Outer Banks, NC; *Hellemic Carrier*	Unknown; 3,000 gal	Porpoise	Unconfirmed report of a dead porpoise.
Mar. 1982	Rodanthe, NC; Source unknown	Tar; quantity unknown	Pilot whale	One stranded whale was recovered with a small patch of dry tar on its skin.
July 1984	Gulf of Mexico; *Alvenas*	Crude oil; 11×10^6 gal	Bottlenose dolphins	One dolphin was swimming in the midst of oil patches. Others were observed at the edge of the slick.
Mar. 1989	Prince William Sound, AK; *Exxon Valdez*	Crude oil; 11×10^6 gal	Gray whales Fin whale Minke whales Unidentified whales Harbour porpoises	The following quantities of carcasses were recovered: 25 gray, 1 fin, 2 minke, and 3 unidentified whales, 7 harbour porpoises. It is possible that these mortalities were of natural causes.
June 1990	Gulf of Mexico; *Mega Borg*	Crude oil; 4.3×10^6 gal	Bottlenose dolphins	Dolphins were observed to swim in the midst of oil patches while others were observed at the edge of the slicks. NO observable effect was identified.

[a] Table was developed from J.R. Geraci and D.J. St. Aubin (1990)

Geraci (1990, *cited in* USEPA, 2000) reviewed a number of studies pertaining to the physiological and toxic impacts of oil on whales and concluded no evidence exists that oil contamination had been responsible for the death of a cetacean. During daily surveys, cetaceans observed during the *Exxon Valdez* oil spill in Prince William Sound made no effort to alter their behaviour in the presence of oil (Harvey & Dalheim, 1994 and Laughlin, 1994, *cited in* USEPA, 2000). However, 37 cetacean deaths and the absence of 14 killer whale pod members from a resident Prince William Sound pod were noted, the latter representing an unprecedented loss to the population. While the deaths and loss of the killer whales were correlated with the oil spill, no cause-and-effect relationship could be identified.

Effects of direct surface fouling:

Direct oiling of whales, dolphins and porpoises is not considered a serious risk to the thermoregulatory capabilities of these animals. After extensive studies, Geraci (1990, *cited in* NOAA, 1992 and USEPA, 2000) determined that direct surface fouling poses little if any problem to these animals due to their extraordinarily thick epidermal layer which is highly effective as a barrier to the toxic, penetrating substances found in petroleum. He also concluded that exposure to petroleum did not make a cetacean vulnerable to disease by altering skin microflora or by removing inhibitory substances from the epidermis (USEPA, 2000).

Up to 1992, only one baleen whale had ever been reported as having its baleen plates fouled by oil (Brownell, 1971, *cited in* NOAA, 1992). In an effort to determine the degree of impact, a series of tests was conducted to detect the effects of various petroleum hydrocarbons on isolated baleen plates. The tests showed that even the heaviest of petroleum compounds may only temporarily reduce a baleen whale’s feeding efficiency (NOAA, 1992).

Effects of inhalation:

Inhalation of the toxic volatile fractions from fresh oil spills may produce a variety of problems for these air-breathing mammals, which could cause effects ranging from mild irritation to permanent damage to respiratory surfaces and mucosal membranes (NOAA, 1992; Overton *et al*, 1994).

Effects from ingestion:

Direct consumption of petroleum hydrocarbons is considered highly unlikely in whales, dolphins and porpoises, and any quantity consumed is not likely to have any direct effect upon the individual. A more likely form of petroleum hydrocarbon ingestion is through the incidental consumption of contaminated food. As most toothed cetaceans are predators it is thought they would not (with the exception of bottlenose dolphins) scavenge oil-killed fish. They would also probably avoid oil-tainted fish (NOAA, 1992).

Baleen whales may have greater risk of ingesting contaminated foods. However, the zooplankton that comprises the majority of their diet is able to rapidly process oil particles. Therefore, the greatest risk is likely to come from baleen whales feeding directly in and around a fresh oil spill (NOAA, 1992).

Because marine carnivores generally do not assimilate petroleum compounds from food efficiently, biomagnification does not usually occur. To date, no sublethal effects on cetaceans have been attributed to bioaccumulation of petroleum hydrocarbons (NOAA, 1992).

Areas of special concern for southern right whales and other cetaceans in the Great Australian Bight Marine Park Marine Mammal Protection Zone

According to NOAA (1992), certain behaviours and habitats may increase the risk of exposure to petroleum hydrocarbons by cetaceans. Those that are relevant to the southern right whale are identified below:

Migration routes: migration routes that pass through areas of petroleum exploration or production activities have a higher risk of exposure to petroleum products. This risk would apply to all species migrating through the Marine Mammal Protection Zone.

Dietary preferences: Many species exhibit dietary preferences. If a species food source were affected, it may be forced to consume contaminated food or be forced to adjust its diet. However, site fidelity is not considered to be strong in cetaceans generally, and it is assumed that the animals would move to another, unaffected area to feed. In the case of southern right whales, they are not known to feed within the Great Australian Bight area or the marine park. Therefore, an oil spill within the park would not affect feeding for the southern right whale populations. However, there may be other species of cetacean that feed within the Marine Park, or Marine Mammal Protection Zone that could be affected in this context. Stresses associated with migration preparation may adversely affect a cetacean if further stressed by a spill.

Reproduction: The reproductive success may be reduced by exposure to a spill. Pregnant females are considered most at risk to effects. Southern right whales are considered to exhibit levels of site fidelity for the breeding site at the Head of Bight (Burnell and McCulloch 2002), and therefore may be at risk. The level of site fidelity displayed by other cetacean spieces within the marine park is unknown.

5.4.2 Indirect impacts

An example of potential indirect impacts on cetaceans has been identified in the Otway Basin of southern Australia. McCauley and Duncan (2001) identify potential impacts on krill swarms as a real issue in the Otway Basin, with the assertion that if the krill swarms were affected by a man-made noise then the blue whales would also be indirectly affected. However it is uncertain how, as they also point out that there is no literature at all where the possibility of effects of noise on krill, or a demonstration that krill can indeed detect sound, has been investigated.

However, man-made noise may influence other prey species (eg. squid and fish) that are important to other cetaceans (eg. beaked whales, dolphins). McCauley and Duncan (2001) also present a brief summary of the findings regarding sound sensing organs in crustaceans and cephalopods, and indicate that squid show behavioural responses to air guns. Based on their air gun modelling in the Otway Basin, avoidance by squid from air gun noise would be expected at several kilometres, and behavioural effects may be seen at longer range, estimated to be 5 km.

For fish eggs, laboratory experiments have found that exposure to an air gun pulse within five metres result in injured larvae within the eggs (Kostyuchenko, 1971 in Swan *et al*., 1994). Further, experiments on the cod, *Gadus morhua*, exposing them to 'shots' from both air guns and water guns (Dalen and Knutsen, 1986 in Swan *et al*., 1994) showed that while the fish initially suffered balance difficulties for both types of 'shots', there was no mortality caused from exposure to the air gun. Exposure to the water gun, however, resulted in 90% mortality of fry aged 110 days for those within 2-3m of the source. The cause of death was ruptured swim bladders. In all experiments, the impact area was within 6m of the source.

For fish subjected to air gun 'shots', experimental results indicate that such exposure is not lethal, though may result in either temporary or long-term deafness (McCauley, 1994). No field testing of the outcomes from the laboratory testing to establish how the findings relate to prey populations has been undertaken.

6. Risk assessment

This risk assessment has been developed in order to estimate the risk posed to marine mammals by various activities. The purpose of the risk assessment is to allow the identified environmental aspects to be classified according to the risk posed into four categories (Extreme, High, Moderate and Low). The classification then allows priorities to be set to address and/or mitigate these risks. The estimates used in this analysis were derived through judgements by the consultancy team based on available published literature and research experience

6.1 Risk Management Standards

The risk assessment methodology has been based on the Australian Standard AS/NZS 4360: 1999 *Risk Management* (the Standard) and HB 203: 2000 *Environmental risk management – Principles and process* (the Guidelines). The Standard and Guidelines set out a generic framework for establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risks.

6.2 Risk Assessment Methodology

The objective of a risk assessment is to filter minor risks from major risks. It involves consideration of the sources of risks, their consequences and the likelihood that those consequences may occur.

Risk analysis may be undertaken to various degrees of refinement depending on the risk information and data available. Analysis techniques include:

- Qualitative assessment
- Semi-Quantitative assessment
- Quantitative assessment

In practice, a qualitative analysis is often used to first obtain a general indication of the level of risk and then a more quantitative analysis is applied to refine the risk.

A quantitative risk assessment can be undertaken based on statistical analysis for various consequences and probabilities. In the absence of statistical data, an estimate may be made of the degree of the consequence and frequency (refer to section 4.3 of the Standard).

The risk assessment methodology for this assessment uses a semi-quantitative process for determining risk. The semi-quantitative process estimates the degree of the consequence and probability and assigns a score to each. The score allocated "does not have to bear an accurate relationship to the actual magnitude of consequences or likelihood" (refer to section 4.3.4 of the Standard).

The risk assessment methodology used to analyse and evaluate the risks is described in detail below. The ratings of consequence, probability and resultant risk have been developed using the following risk analysis tables.

6.2.1 Identifying Impacts and Consequences

In order to conduct an initial risk assessment, impacts (actual and potential) have been identified for each environmental aspect.

In this semi-quantitative level of analysis, a point score has been used which rates the consequences of the impact for each different aspect. For this risk assessment, five levels of severity of consequences have been used – insignificant, minor, moderate, major and catastrophic. The definitions used to assess relative consequences have been adopted from HB 203:2000, as shown in Table 9 below. The table provides a consistent method of assessment that can be applied by different people and at different times.

Comparing the severity of impacts from different sources

It is not possible to compare, in absolute terms, the impacts from a diverse range of environmental aspects (for example, comparing the noise impacts of construction to the impacts of leaking chemicals to marine ecosystem degradation caused by an oil spill). Therefore, relative consequences must be judged according to different criteria and using all available information.

For example, in the case of the discharge of a pollutant, the relative consequences were assessed by evaluating such factors as:

- Persistence;
- Toxicity;
- Strength of chemical;
- Volume discharged per event;
- Duration of the discharge;
- Proximity to discrete waterbodies;
- Potential dilution;
- The area of land/ marine waters affected; and
- Taking into account secondary consequences and existing mitigation measures.

The standard methodology for applying values and relative rankings to risk from various sources is outlined below:

Step 1: Identifying the environmental aspects

From the information available through literature and expert opinion, all of the aspects of an activity that are likely to have an impact on subject (marine mammals in this case) are identified. These are the items identified in the 'Area impacted' column in Table 9 below.

Step 2: Describing the range of possible consequences

Again from available information, the range of possible consequences is determined and given a score ranging from 1 – insignificant to 5 – catastrophic. A full and preferably quantitative description is provided for each of the scores to provide transparency in the methodology and the ultimate risk scores.

For a number of the ‘areas impacted’ that were identified (for example light pollution, water quality, marine mammal overall health) there is no information in the literature. Judgements were made about these issues based on the knowledge of general marine mammal biology and behavioural characteristics.

Table 9: Potential Environmental Impact Consequences Rating

Area impacted (a)	**Insignificant consequences** **(Score = 1)**	**Minor consequences** **(Score = 2)**	**Moderate consequences** **(Score = 3)**	**Major consequences** **(Score = 4)**	**Catastrophic consequences** **(Score = 5)**
Acoustic environment – direct effects	Insignificant environmental impact. Occasional minor reaction to noise. Minor disruption to migratory / breeding / feeding / resting behaviour over a short time. For migratory species, impact could be removed by limiting activity to outside period of residence or transit of the area.	Minor impacts on marine mammals and habitat (<5% of local population affected), but no negative impacts on ecosystem function. Limited impact to a relatively minimal area of sea of no significant value (ie. not within key identified migratory / breeding / feeding / resting areas). Temporary disruption (several days) to marine mammal habitats.	Significant changes in marine mammal populations and habitat. Non-permanent displacement of marine mammals away from acoustic source. Temporary disruption to communications or some temporary disorientation. Moderate inhibition of breeding behaviour (5-10% of local population) and / or success leading to small reduction of recovery rates of listed species	Continuous and serious disruption to behaviour of marine mammals. Significant and long-term (10-50% of residence time) displacement of marine mammals from their key habitats. Long-term disruption to breeding / feeding / resting behaviour and reproductive success (involving 10-50% of reproductive/feeding population).	Long-term and significant change in population (eg. removal of endangered species from the area) or habitat. Widespread death of marine mammals (eg through mass strandings from disorientation). Inhibition of >50% of local population of all breeding / feeding / resting behaviour and avoidance by >50% of population of area for migration leading to significant and detrimental changes to migration routes.

Area impacted (a)	Insignificant consequences (Score = 1)	Minor consequences (Score = 2)	Moderate consequences (Score = 3)	Major consequences (Score = 4)	Catastrophic consequences (Score = 5)
Light environment	Occasional short-term attraction and/or disruption to marine mammals.	Minor impact on aquatic ecosystem, including flora, fauna and habitat. Minor disruption to normal marine mammal behaviour over short durations.	Significant changes in marine mammal behaviour, populations and habitat. Disruption to marine mammals through changed behaviours or other changes (eg occurrence or attraction of predators). Non-permanent displacement of marine mammals away from light source. Some temporary disorientation. Moderate (<10% of local population) inhibition of breeding behaviour and / or success leading to small reduction of recovery rates of listed species.	Continuous and serious disruption to behaviour of marine mammals. Significant and long-term displacement of marine mammals from their key habitats. Long-term disruption to breeding / feeding / resting behaviour and reproductive success (involving 10-50% of reproductive/feeding population).	Long-term and significant change in population (eg. removal of endangered species from the area) or habitat. Widespread death of marine mammals (eg through mass strandings from disorientation). Inhibition of >50% of local population of all breeding / feeding / resting behaviour and total avoidance by >50% of population of area for migration leading to significant and detrimental changes to migration routes.

Area impacted (a)	Insignificant consequences (Score = 1)	Minor consequences (Score = 2)	Moderate consequences (Score = 3)	Major consequences (Score = 4)	Catastrophic consequences (Score = 5)
Chemical/water quality	Temporary and small-scale release of pollutant that disperses to negligible or undetectable levels within a short time.	Minor environmental impact due to contained release of pollutant (including oil, drilling fluid, fuel or fuel-suppression materials) with no persistence or lasting detrimental effects. No outside assistance required.	Environmental impact due to controlled / uncontrolled release of pollutant that persists in the environment for weeks and is available for ingestion by, or coating of, marine mammals. Results in the generation of significant quantities of hazardous wastes over a large area and/or with the potential to contaminate the coastline. Some marine mammal deaths and some reduction in reproductive success for one to three years. Outside assistance may or may not be required.	Major environmental impact due to uncontained release, fire or explosion with detrimental effects. Volume or nature of chemicals released means that the pollutant persists in the environment for months, particularly while listed migratory cetaceans in the area. Wide-spread ingestion by, and/or coating of chemicals of, marine mammals, with significant resultant mortalities in marine mammal populations and significant reduction in calving/pupping success for three or more years. Outside assistance required.	Catastrophic environmental impact due to uncontained release, fire or explosion with detrimental effects. Significant quantities of pollutant released that it covers a large area and persists in the environment at detectable levels for several months to years. Outside assistance with significant clean-up activities required. Extensive chronic discharge of persistent hazardous pollutant. Results in >50% reduction in reproductive success in local marine mammals for a decade or more, or the eradication of endangered species.

Area impacted (a)	Insignificant consequences (Score = 1)	Minor consequences (Score = 2)	Moderate consequences (Score = 3)	Major consequences (Score = 4)	Catastrophic consequences (Score = 5)
Prey / food source (This does not impact on migratory species that do not feed in the area, eg, southern right whales)	Temporary and small-scale reduction in food abundance (greater than expected from natural variation levels) arising from exploration and/or production activities within a relatively small area. Food able to be found nearby.	Minor environmental impact from reduction in food abundance through disruption to recruitment of prey species. Duration of prey reduction not long-lasting (days). Some nutritional impacts on marine mammals, but not leading to starvation.	Environmental impact due to wide-spread kill of prey species and their spawn of moderate duration (months). Nutrition impacts on marine mammals resulting in a reduction of breeding success and some deaths (<10% of breeding population) due to starvation (nutrition impacts).	Major kills of prey species and damage to their key habitats such that recovery of prey populations is slow (a year or more). Nutritional impacts resulting in numerous deaths and significant reduction in calving/pupping success for one or more years.	Large scale fish and other kills and significant damage to their breeding habitats resulting in long-term reductions in prey species for several years. Effects leading to widespread mortality in marine mammal species, particularly local and non-migratory species (eg, Australian sea lions).
Collision	Low rate of collisions and minor collisions with marine mammals that result only in superficial injury and no loss of breeding success.	Some collisions during particular times of the year that result in minor injury to marine mammals, generally not leading to death of marine mammals.	Several collisions resulting in injury of marine mammals and a significant reduction in breeding success (<10% of breeding population) and recruitment to the population of young.	Many collisions resulting in significantly reducing recruitment to the population to or near zero population growth.	Significant numbers of collisions resulting in death of many cetaceans causing significant population declines when combined with other mortality factors, which will ultimately lead to extinction.

Area impacted (a)	Insignificant consequences (Score = 1)	Minor consequences (Score = 2)	Moderate consequences (Score = 3)	Major consequences (Score = 4)	Catastrophic consequences (Score = 5)
Breeding	Temporary impact that does not disrupt breeding in the area.	Minor impact that disrupts <5% of population's breeding activity for one or more years. Results in a temporary decrease in the rate of recovery of endangered or vulnerable species.	Disruption to breeding of 5-10% of local breeding population for one or more years. Reduction in the survival of calves/pups. Results in the long-term reduction in the rate of recovery for endangered or vulnerable species.	Significant long-term disruption to breeding of 10-50% of local population or significant reduction in survival of calves/pups.	Catastrophic impact due to complete and permanent disruption of breeding for >50% of local population. Environmental characteristics required for breeding removed or significantly damaged. Results in permanent or long-term cessation of breeding of marine mammals in the area.
Marine mammal health	Trivial injuries or ailments that do not jeopardise the survival or reproduction of individuals.	Minor short-term symptoms of illness or discomfort. Individuals may need to spend longer than usual resting in a sheltered area.	Serious injury resulting in unsuccessful breeding and/or death of calf/pup. Renders 5-10% of females unable to breed for one to three years.	Serious injuries requiring human assistance. Renders 10-50% of females of the species in the local population unable to breed for three or more years.	Long term or permanently disabling effects on >50% of population. Death of individuals. Lead to early death.

Area impacted (a)	Insignificant consequences (Score = 1)	Minor consequences (Score = 2)	Moderate consequences (Score = 3)	Major consequences (Score = 4)	Catastrophic consequences (Score = 5)
Legislation	Insignificant technical/ legal issues. (No legal action taken)	No serious breach of legislation or regulations. Covered by environmental licence conditions or permits. Minor legislative/ licence non-compliances. Minor on-the-spot fines.	Breach of regulation identified with significant prosecution or fine. Reportable on-site incident.	Major breach of regulation identified and/or serious incident notification and/or major investigation by authority. Involved in significant litigation.	Extreme deliberate breach of regulation identified and/or serious incident notification and/or major investigation by authority with prosecution and very significant fines. Very serious litigation, including imprisonment.
Public/ media reaction & reputation	Possibility of detrimental local media reports. Trivial substantiated complaints from the community. Public concern restricted to local complaints.	Detrimental local media reports. Random substantiated complaints from the community. Minor negative impacts on reputation.	Detrimental national or state media reports. Subject of parliamentary questions or ministerials. Systematic substantiated community concerns and complaints.	Numerous detrimental national or state media reports. Subject of a number of parliamentary questions or ministerials. Organised community concern. Mobilisation of significant green NGO campaign.	Sustained detrimental international, national or state media reports. Subject of parliamentary committee hearing. Sustained community outrage.
Total cost	Financial loss (compensation, fines, cost to repair) of less than $5,000.	Financial loss (compensation, fines, cost to repair) of $5,000 - $50,000.	Financial loss (compensation, fines, cost to repair) of $50,000 - $500,000	Financial loss (compensation, fines, cost to repair) of $500,000 - $10M. Inability to operate committed infrastructure.	Severe financial penalties or legal liabilities. Financial loss (compensation, fines, cost to repair) of greater than $10M. Impacts on permit requirements.

Model: Standards Australia/ Standards New Zealand "HB 203:2000, Environmental risk management – Principles and process" 2001.

6.2.2 Estimate Probability of Occurrence

The probability of occurrence then needs to be estimated. The table below provides probability ratings with descriptions for estimating the likelihood of each occurrence.

Table 10: Probability of Occurrence

Descriptor	Likelihood	Probability
Almost Certain	Is expected to occur in most circumstances	5
Likely	Will probably occur in most circumstances	4
Possible	Could Occur	3
Unlikely	Could Occur but not expected	2
Rare	Occurs only in exceptional circumstances	1

The probability of occurrence from any event, mode of occurrence or failure mechanism should be considered.

In addition to evaluating the frequency for normal operating conditions, the following conditions could be considered:

- abnormal, startup and shutdown operation conditions;
- incidents, accidents and potential emergency situations; and
- current activities and planned future activities.

6.2.3 Risk Estimation

The level of risk is calculated by multiplying the Consequence Score and Probability of Occurrence together.

Risk = Consequence Score x Probability of Occurrence

The final outcome is in relative point scores, rather than actual risks.

Note that risk estimations were carried out for a well-managed installation operating under normal conditions. Risk scores do not reflect the highest risks under adverse conditions/ worst case scenarios.

6.2.4 Risk Evaluation

The relative risk score estimated above enables definition between those risks that are significant and those that are of a lesser nature. This allows a better understanding of the least probable with high consequence against the highly probable low consequence events.

Having established the comparative risk level applicable to individual impacts, it is possible to rank those risks. Four risk categories have been used: Extreme, High, Moderate, and Low.

Table 11: Risk Categories

	CONSEQUENCE				
LIKELIHOOD	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Rare (1)	1	2	3	4	5
Unlikely (2)	2	4	6	8	10
Possible (3)	3	6	9	12	15
Likely (4)	4	8	12	16	20
Almost certain (5)	5	10	15	20	25

Extreme risk	Requires extreme vigilance and heightened reporting requirements or can only be undertaken during certain lower risk times of the year. Where risk cannot be mitigated, banning of activity from area
High risk	Requires demonstration of high level risk management
Moderate risk	Requires special mention within Environmental Management Plan
Low risk	Routinely managed through Environmental Management Plan

Once the impact has been ranked according to the relative risk level it poses, then it is possible to target the treatment of the risk exposure, beginning with the highest risks.

6.3 Limitations

As with any model, the relevance and applicability of the risk model revolves around a number of basic assumptions and enhancements. The application of the risk model has been based on subjectively estimated ranges of consequences and probabilities.

Limitations of the application of the risk methodology for this study include:

- Data used for the assessment of individual threat sources was not complete (as mentioned under 6.2.1);
- Data was not available or adequate for all of the threat sources identified;
- The assessment has been limited to a selected number of primary consequences;
- The assessment of cumulative risk to the environment from multiple threat sources or sources of environmental degradation has not been addressed.

Although a semi-quantitative methodology was used to conduct the risk assessment, the resultant risk estimation is purely relative. The risk estimations do not imply an absolute scale of risk that can be applied to any other situation or assessment.

6.4 Risk Assessment Outcomes

Below are two tables (Table 12 and Table 13) summarising the risk estimations for exploration and production activities. Detailed consequence and likelihood ratings are described at **Appendix D**. As highlighted throughout this chapter, these risk rankings are based on best available information. Where information is sparse or absent, judgements were made by those members of the assessment team based on their experience and general knowledge about the nature of petroleum activities and the biology of marine mammals.

From the tables below, it is clear that the greatest risks to marine mammals are posed by exploration activities, while production activities carry with them moderate to low risks.

This means:

- The risk ratings provide a potentially useful guide in comparing various types of proposed mining operations.
- The risk estimates also do not cover cumulative risks.

In applying these risk rankings for future use in management decisions, it is important for the park managers to determine what, if any, level of risk they are prepared to accept, particularly, in this case, with regards to their responsibilities for the conservation of both populations and individuals of the two key species the Australian sea lion and the southern right whale. For the southern right whale consideration must also be given to the Head of Bight being a recognised significant Aggregation Area under the Draft Recovery Plan. This decision must also account for the provision of the application of the 'precautionary principle' under the EPBC Act.

Table 12: Summary of Risks in exploration activities in the Great Australian Bight Marine Park and Region

	Extreme Risk	High Risk	Moderate Risk	Low Risk
Southern Right Whale and other cetaceans	***Noise impacts*** 3D/4D seismic ***Media/reputation impacts*** High media coverage in the case of an incident	***Prey/food impact*** Prey mortality Changes in prey behaviour ***Collision*** Collision with seismic ships and gear ***Impacts on breeding success*** Displacement by noise from seismic Collision with seismic ships and gear Calf death through separation from mother ***Health effects*** Stress? – unknown Injury from collision	***Noise impacts*** 2D seismic Drilling (Tender noise) Shipping noise ***Water contamination*** Oil/chemical spill from ship ***Collision*** Collision with service ships ***Impacts on breeding success*** Displacement by noise from drilling Calf injury (prenatal deafness?) ***Health effects*** Stress? – unknown Hearing impairment ***Legislative impacts*** Breach of legislative requirements	***Noise impacts*** Geophysical site surveys ***Light pollution*** Night work Flaring ***Water contamination*** Waste disposal ***Health effects*** Stress? - unknown

	Extreme Risk	High Risk	Moderate Risk	Low Risk
Australian Sea Lion	***Noise impacts*** 3D/4D seismic	***Prey/food impact*** Prey mortality Changes in prey behaviour ***Impacts on breeding success*** Displacement by noise from seismic Prey mortality Changes in prey behaviour ***Media/reputation impacts*** High media interest in the case of an incident	***Noise impacts*** 2D seismic Drilling (Tender noise) Shipping noise ***Water contamination*** Oil/chemical spill from ship ***Impacts on breeding success*** Displacement by noise from drilling	***Noise impacts*** Geophysical site surveys ***Light pollution*** Night work Flaring *Water contamination* Waste disposal ***Collision*** Collision with seismic ships and gear Collision with service ships ***Impacts on breeding success*** Collision with seismic ships and gear pup injury (prenatal deafness?) pup death through separation from mother ***Health effects*** Stress? – unknown Hearing impairment Injury from collision ***Legislative impacts*** Breach of legislative requirements

Table 13: Summary of Risks in production activities in the Great Australian Bight Marine Park and Region

	Extreme Risk	High Risk	Moderate Risk	Low Risk
Southern Right Whale and other cetaceans	***Media/reputation impacts*** High media coverage in the case of an incident		***Noise impacts*** Rig/infrastructure construction Rig/infrastructure operation Drilling Shipping ***Water contamination*** Waste disposal Oil/chemical spill from rig Oil/chemical spill from ship Oil spill during transfer of oil from rig to ship ***Impacts on breeding success*** Displacement by rig operation ***Health effects*** Increase in background noise levels Chronic pollution ***Legislative impacts*** Breach of legislative requirements	***Light pollution*** Light from rig Light from ships ***Prey/food impact*** Prey mortality Changes in prey behaviour ***Collision*** Collision with service boats ***Impacts on breeding success*** Ship strikes Disturbance from helicopter visitation ***Health effects*** Injury from collision with service ships

	Extreme Risk	High Risk	Moderate Risk	Low Risk
Australian Sea Lion		***Media/reputation impacts*** High media interest in the case of an incident	***Noise impacts*** Rig/infrastructure construction Rig/infrastructure operation Drilling Shipping ***Water contamination*** Waste disposal Oil/chemical spill from rig Oil/chemical spill from ship Oil spill during transfer of oil from rig to ship ***Health effects*** Increase in background noise levels Chronic pollution ***Legislative impacts*** Breach of legislative requirements	***Light pollution*** Light from rig Light from ships ***Prey/food impact*** Prey mortality Changes in prey behaviour ***Collision*** Collision with service boats ***Impacts on breeding success*** Displacement by rig operation Ship strikes Disturbance from helicopter visitation ***Health effects*** Injury from collision with service ships

7. Implications for future management and possible mitigation considerations

7.1 Overall conclusions

While this review and risk assessment provides a relative guide to the potential sensitivities of marine mammals to petroleum industry activities, there is still a significant lack of information to determine, with any degree of certainty, what is likely to occur should petroleum operations be allowed within the Marine Mammal Protection Zone under the next management plan.

In the context of the importance of this area for the recovery and conservation of the Australian sea lion, the southern right whale (the Head of Bight is identified as a Significant Current Aggregation Area under the Southern Right Whale Draft Recovery Plan 2002) and other cetaceans in the area, application of the precautionary principle as defined under the EPBC Act would support the continuation of the current ban on such activities until more definitive information is available.

7.2 Further information needs

For most of the elements identified and ranked under this risk assessment, the level of information is very poor for most species, and outside of current areas of focus for the petroleum industry (that is, seismic survey observations of impacts on cetaceans). While it is known that mothers with calves are more sensitive to disturbance by noise while migrating, and that resting whales are more sensitive than those undertaking an activity such as feeding, there is no clear information about their sensitivity to disturbance from an operating production facility in the vicinity of their calving area.

Also, no sound propagation modelling has been done for the Head of Bight.

Similarly, while some information exists for a range of species from which opinions can be extrapolated, there is no information to support any real assessment of the specific sensitivities of southern right whales to petroleum industry activities, or even their foraging range in order to determine areas in which they may be sensitive.

Based on available information, the highest risks to marine mammals and their prey result from 3D/4D seismic activities. However, the impacts of a production facility in the vicinity of an important calving and pupping area for southern right whales and Australian sea lions remain unclear.

Accordingly, the authors have identified several priority areas for further data gathering, which are outlined below.

GAB inshore

- Characterisation of the acoustic environment (local sound transmission conditions or acoustic characteristics) for the area for modelling purposes, similar to those of the Otway.

Southern right whales

- determine the extent, if any, of the offshore distribution of southern right whales during the breeding season with aerial surveys and satellite tagging of individuals;
- Measurements of the vocalisation repertoire of southern right whales.

Australian sea lion

- an acoustics study to determine their vocalisation repertoire and sensitivity levels to noise sources (in response to comment by the Whale and Dolphin Conservation Society, it is not suggested to subject sea lions to high disturbance noise);

Other marine mammals

- obtain a more precise list of cetaceans for the inshore Great Australian Bight area, and their distribution, abundance, seasonal and reproductive patterns.
- movement and foraging study to determine the range of movement and diet of animals from the central Great Australian Bight colonies.

7.3 Contingency mitigation measures

In the event of any future petroleum activities within the Marine Mammal Protection Zone, the following information is provided for management consideration. The most obvious and simple solution for an effective mitigation measure for many activities is to time them so that they fall outside of the time window that is crucial to particular species. However this strategy needs to be considered in light of other species (McCauley and Duncan, 2001).

The assessment of mitigation measures needs to consider a wider range of issues than simply the focal species, and requires a complete strategy for minimising the impacts of human activities on ecosystems, particularly petroleum exploration, taken on a case-by-case basis. The real risks for a range of species that are inter-dependent should be established and the timing or techniques of the activity adapted to reduce the total impact to those species most at risk (McCauley and Duncan, 2001). This approach may result in some activities being allowed to proceed in a way that presents low risks to some marine mammal populations, and which also reduce risk for other marine mammals and non-marine mammal species. A recent paper dealing with environmental and stakeholder issues of offshore exploration in the Otway Basin outlined the practical details regarding the temporal patterns of various species in the area (Table 14) in relation to their general activity and available weather windows (Colman *et al.*, 2002). A similar approach can be used for the Marine Mammal Protection Zone, substituting key species and fisheries where appropriate.

For the Marine Mammal Protection Zone the southern right whale and Australian sea lion are the two most important species for which the Protection Zone was established. The details in Table 14 for right whales would apply to the Great Australian Bight. The Australian sea lion is less straightforward, as it has asynchronous breeding over a 17-month period. It does however remain in the area foraging from specific colonies over the 12 months. Blue whales do not feed in the area but are probably seasonally transient, as are humpbacks and other large baleen whales. Unfortunately there is a paucity of data on the life history characteristics of many of the other marine mammal species that are known within the Great Australian Bight Marine Park and the Marine Mammal Protection Zone.

Table 14: Temporal patterns and activities of key species and fisheries in the Otway Basin (Colman *et al.*, 2002)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Southern right whale					Migration, Calving and Breeding							
Blue whale	Feeding											
Australian fur seal											Pupping	
Little penguins							Breeding					
WZRLF	Fishery								Larval Production			Fishery
SSF	Fishery									Migration		
Weather window	Best period			(T)								(T)

(T) Transitional period

(SSF) – Southern Shark Fishery
(WZRLF) – Western Zone Rock Lobster Fishery

A comprehensive review of mitigation procedures employed internationally is given by Pierson *et al.* (1998) in the seismic and marine mammals workshop. These authors cite a suite of standard mitigation and monitoring measures that have evolved including seasonal and geographical restrictions, ramp-up, ship-based visual monitoring of safety zones and associated shutdown procedures, and aerial surveys and passive acoustic monitoring. In addition recent developments in automation and software design has improved the acoustic detection rates between five and eight times higher than corresponding visual surveys (Gillespie and Chappell, 1998). The duel use of visual and acoustic systems will greatly improve the detection and identification of marine mammals in the vicinity of the noise source.

International efforts are continuing to refine the guidelines and procedures to mitigate effects of seismic on marine mammals (HESS, 1999; APPEA, 2000; IAGC, 2001; JNCC, 2002). Environment Australia developed a guideline regarding seismic activities entitled "Guidelines on the Application of the Environment Protection and Biodiversity Conservation Act to Interactions Between Offshore Seismic Operations and Larger Cetaceans" (Environment Australia 2001). From these guidelines, it is clear that the operation of seismic surveys within 20 kilometres of the Great Australian Bight Marine Park Marine Mammal Protection Zone as an identified breeding area, during the calving season for southern right whales, would generally be considered as interfering with southern right whales and therefore require approval.

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The southeast Indian Ocean and Great Australian Bight: A brief oceanographic survey

http://www.es.flinders.edu.au/~pbarker/bye.html

8.2.2 USA and Canada

Acoustical Society of America

http://asa.aip.org/

Acoustic Research Laboratory

http://www.arl.nus.edu.sg/

American Cetacean Society links to related web sites

http://www.acsonline.org/links.htm

ATOC's Marine Mammal Page – low frequency sound

http://atoc.ucsd.edu/MMRP_page.html

Bioacoustics program at Cornell University: Whale communication research

http://birds.cornell.edu/BRP/HumanMadeSound.html

Cetacean Research Technology links

http://www.cetaceanresearch.com/links.html

Floating Production Storage and Offloading (FPSO) – international workshop in September 2002

http://www.fpso-global-workshop.com/

International Association of Geophysical Contractors – marine seismic affects on marine mammals

http://www.iagc.org/content/docs/searchresults.asp

Marine mammals and noise - Institute of Ocean Sciences in Sidney, British Columbia, Canada

http://pulson.seos.uvic.ca/people/erbe/

Minerals Management Service USA – Scientific and Technical publications (Offshore)

http://www.mms.gov/itd/index.htm#Pacific%20New%20Releases

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http://www.gomr.mms.gov/homepg/offshore/fpso/fpso.html

National Council for Science and Environment

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NOAA Fisheries. National Marine Fisheries Service – 'sound in the ocean'

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http://www.pmel.noaa.gov/vents/acoustics/whales/bioacoustics.html

NOAA Office of response and restoration

http://response.restoration.noaa.gov/index.html

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8.2.3 UK

Energy Research Clearing House (ERCH)

http://www.erch.org/

Joint Nature Conservation Committee (JNCC) – Minimising acoustic disturbance

http://www.jncc.gov.uk/marine/seismic_survey/default.htm

Sea Mammal Research Unit: Proceedings of the Seismic and Marine Mammals Workshop

http://smub.st-and.ac.uk/seismic/seismicintro.htm

United Kingdom Offshore Operators Association

http://www.ukooa.co.uk/

Whale and Dolphin Conservation Society – Seismic Exploration

http://www.wdcs.org/dan/publishing.nsf/allweb/6B7D8FD1BAB453F4802568FF004B9189

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8.2.5 International

UNEP Offshore oil and gas ENVIRONMENT forum

http://www.oilandgasforum.net/

Appendix A

Reference Group membership list

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Appendix B

Summary of pertinent papers on the impacts of human induced noise on cetaceans

Summary of several pertinent studies of whale response to various manmade noises (in McCauley and Duncan, 2001; Table 3). (* Some recent references have been added).

Reference	Study type, species and location	Noise source	Results
Frankel and Clark 2002 *	Comparison of humpback distribution and abundance with (1998) and without (1994, 1998) ATOC low frequency signals; land-based sightings made. Hawaii	Actual transmission of low frequency signals from ATOC; also natural noise effects	Sighting rates did not differ between control and ATOC conditions in 1998; No effect of ATOC on the distance from shore station to whales, or depth of water where pods were located; overall variable response rather than simple avoidance; No vessel effect on sighting rates.
Croll et al, 2001 *	observations on foraging blue and fin whales off California: shipboard, acoustic and aerial surveys	loud LFS (US Navy SURTASS LFA) source. estimated received levels in the study area exceeded 140 dB re 1uPa.	Encounter rates and diving behaviour seemed to be more closely linked to prey abundance than LF sound levels. However the authors caution that the cumulative effects of anthropogenic LF noise over larger temporal and spatial scales may be an important consideration.
McCauley et al, 2000 a & b	Observations of migrating humpback whales traversing an area of active seismic, Western Australia	2678 cui 3D array of air-guns	Whales avoided air-guns at levels of 157-164 dB re 1uPa msp; in one instance a single animal crossed the air-gun vessel bow at short range; no evidence of changes in whale migratory patterns
McCauley et at, 2000 a & b	Experimental approaches with a single air gun towards resting humpback whales, WA.	20 cui single air-gun	Persistent responses from resting cows (with or without calves) showing avoidance at 140 dB re 1uPa msp; attraction of believed males to air gun due to similarity of signal with whale breaching event.
Schlundt et al 2000	Experimental exposure of bottlenose dolphin and white whales to intense tones, California, USA.	Sound projector, 0.4-75 kHz tones of 1s duration, received levels of 160-202 dB re 1uPa msp	192-201 dB re 1uPa signals induced temporary threshold shifts (reduction in hearing sensitivity) of 6 dB magnitude; all animals recovered after exposure.

Reference	Study type, species and location	Noise source	Results
Frankel and Clark 1998	Playback of low frequency signals and vessel approaches to humpback whales, Hawaii	Playback of ATOC M type signals, source level of 172 dB re 1uPa msp, spectral max at 75 Hz	No detectable response to playbacks of ATOC signals up to 130 dB re 1uPa msp (upper limit of trials); some response to vessel noise.
Frantzis 1998	Observations of beaked whale strandings and use of military sonar systems, Kyparissiakos Gulf, Mediterranean	Experimental military sonar – Low Frequency Active (LFAS, no technical details given)	Correlation of stranding of Cuviers beaked whales with tests of LFAS sonar; correlation only – no causative effect given, no acoustic measurements presented.
Goold and Fish 1998	Measurement of air-guns signals over 0.2-20 kHz, observations of common dolphins and seismic	2120 cui., 2D air-gun array measured over 1-8 km but band limited.	Common dolphins ‘avoided the immediate vicinity of the air-gun array while firing was
McCauley 1998	Measured noise of exploration drilling operations in Timor Sea, NW Australia, observations of nearby fauna	Drill rig *Ocean General*, several rig tenders, operating in 110 m of water	Drill ship noise was comparatively low; supply vessels holding station at rig were dominant noise source detectable out to 30 km, dolphins commonly sighted rear rig.
Andre et al 1997	Response of sperm whales to playbacks, Canary Islands	Playbacks of killer whale sounds, 1-30 kHz sweeps, sperm whale sounds, engine noise, 10 kHz pulses, slapping	No significant responses by whales
McCauley et al 1996	Measurements of vessel noise from whale watching fleet to 60 tonnes, observations of humpback responses to nearby vessel operations, Hervey Bay, eastern Australia	Actual vessels	Vessel speed dominant influence on steaming vessel underwater noise, high speed catamarans noisiest; vessel design critical in actual whale-vessel interactions; greater whale responses to noises which changed suddenly, increased rapidly or to vessels which manoeuvred extensively
Richardson (ed.) 1999	Measurements of responses to open-water seismic operations in Alaskan Beaufort Sea by bowhead, Gray and beluga whales.	Actual observational data during seismic operations	Bowhead whales rarely seen within 20km of operating seismic vessel. Gray whales remained approx. 25 km away from seismic operations. No discernable disturbance to beluga whales was detected, though the

Reference	Study type, species and location	Noise source	Results
			individuals observed would have been exposed to 160dB or less.
Todd et al 1996	Response of humpbacks to explosions	Explosives used in harbour works, Trinity Bay, Newfoundland, Canada	No dramatic immediate responses of humpbacks to explosions, but an unexplained increase in the rate of 'entrapment' or residency in bays with explosives used
McDonald et al 1995	Used sea floor recorders to track vocalising blue and fin whales, northeast Pacific	Air-guns and Merchant shipping	No marked responses for air-gun signals to 143 dB re 1uPa p-p, or merchant shipping noise to 106 dB re 1uPa msp
Bowles et al 1995	Playback of ATOC signals, observations of nearby marine fauna; from near Heard Island Southern Ocean	Array of transducers, source level of 209-220 dB re 1uPa msp, spectral peak at 57 Hz, duty cycle 33% for total of 32hr transmission	No definitive differences in marine mammal numbers in study area before or during playback; possible change in sperm and pilot whale vocalisations during signal transmission
Gordon et al 1992	Observations of sperm whales and small vessels in whale watching, Kaikoura, New Zealand	Small vessels approaches to sperm whales	Evidence that non-resident sperm whales responded to whale watching by changing behaviour and in some cases moving off but that resident sperms whales responded less vigorously and showed a greater tolerance to whale watching vessels
Richardson et al 1990	Response of bowhead whales to drilling and dredging noise in the Canadian Beaufort Sea	Playback of drilling dredge noise	Avoidance of some whales from equivalent of several km from actual drill ship / dredges
Baker and Herman 1989	Observations of humpbacks to vessel traffic, Glacier Bay, Alaska	Actual vessel approaches	Evidence of startle responses from sudden increases or decreases in noise; evidence of predictable changes in behaviour for vessels moving within 4 km from altered blow rates and dive cycles
Richardson et al 1987	Distribution of bowhead whales with respect to industrial activities, summary of several years observations, Canadian Beaufort	Island construction, drilling and helicopter traffic	Correlation of increased industrial activity and associated noise with reduced usage of region by bowhead whales, but causative effect not shown

Reference	Study type, species and location	Noise source	Results
	Sea		
Bauer and Herman 1986	Response of humpback whales to vessel traffic, Hawaii	Vessel approaches and passes	Changes in behaviour correlated with proximity to vessels
Richardson et al 1986	Response of bowheads to seismic, Canadian Beaufort Sea	Air-gun arrays and controlled approaches of single air-gun	Bowheads showed consistent avoidance to seismic pulses > 160 dB re 1uPa rms over pulse duration
Watkins 1986	Review of 25 years of whale observations from response of minke, finback, northern right and humpback whales, Cape Cod, eastern US	Vessel traffic and whale watching noise	Different general responses through time for different species – minke changed from positive to uninterested; finback from negative to uninterested; right whales responses remained the same; humpbacks changed from often negative to strongly positive- response of all whales to some extent dictated by their activity pattern at the time, with greater response from inactive whales - negative whale responses associated with sounds that were: unexpected; too loud; suddenly changing; or perceived as being associated with a potentially threatening action, such as an approaching vessel on a collision course.
Ljungblad et al 1985	Observations of the bowhead whale in response to approaching seismic, Alaskan Beaufort Sea	Commercial seismic source directed to approach whales	Approached whales all avoided the operating seismic vessel with startle responses and avoidance occurring at many km
Malme and Miles 1985	Experimental approach to migrating gray whales, California	100 cui. Single air-gun, 4000 cui air-gun array	Consistent response of most animals avoiding seismic pulse levels of 164 dB re 1uPa msp, all avoiding seismic pulses of > 180 dB re 1uPa msp
Richardson et al 1985	Observations of bowhead whales to petroleum exploration drilling, vessels and aircraft, Beaufort Sea	Various actual sources and playback experiments	Response to aircraft only significant if aircraft < 457 m; avoidance of approaching vessels from 1-4 km; evidence of some avoidance of drilling operations and seismic < 6 km

Reference	Study type, species and location	Noise source	Results
Baker et al 1983	Controlled and opportunistic vessel approaches towards humpback whales, Glacier Bay, Alaska	Range of vessels	Avoidance of approaching vessels from 8 km, @ 2-4 km avoid by swimming off track, @ 0-2 km by diving
Gales 1982	Measurement of noise of oil and gas production facilities, observations of marine mammals about such facilities, Southern California	Various petroleum drilling and production activities	1) Oil and gas platforms produce significant noise with highest levels < 100 Hz; 2) Supply vessel cavitation noise was the highest noise source; 3) Probable that mysticete whales can detect platform from long range; 4) Anecdotal information suggested whales ignore or easily avoided petroleum platforms.
Clark and Clark 1980	Playback to southern right whales	Southern right whale sounds, humpback sounds, 200 Hz tones	Attraction to southern right whale sounds but not other sounds

Appendix C

Environmental risks to blue whales in the Otway Basin

Synthesis of features important in assessing environmental risks for three man made noise sources on blue whales, that are used in Australian waters (in McCauley and Duncan, 2001: Table 5).

Event	Seismic	Drilling	Shipping
Behavioural effects direct	Subtle changes to tens km, local avoidance to 3-20 km depending on animals sensitivity and behavioural state at time	Drilling only – no displacement; Victualling – whales displaced from 2-8km	Likely to displace whales out to 6 km but probable considerable habituation as shipping traffic ubiquitous
Pathological effects	Possible but unlikely, very low risk and animals need to be << 1 km to be at any risk	Not possible	Not possible
Geographical effects	Relatively small at scale of individual signal but larger when considered through time (eg > 100,000 shots);	Very small – confined to near drill site	Moderate -??? How many ships per day at what distance ? Small vessel noise - fishing
Timing/duration of action	Depends on scale of survey; weeks to months during favourable weather	Exploration drilling may be of order of several months	Intermittent – low number of vessels / day
Cumulative effect of action	Unknown	Very localised effect only, except with multiple rigs.	Unknown

Appendix D

Detailed risk assessment tables for exploration and production activities in the Great Australian Bight Marine Park Marine Mammal Protection Zone

Risk Assessment Exploration

	Aspect	Consequences	Impact Consequences rating	Likelihood	Risk Rating
Noise Pollution – direct effects	Site surveys (geophysical) – low power seismic	Disturbance to marine mammals Alteration of migration route during migration times	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2
	Seismic testing (2D)	Disturbance to marine mammals Alteration of migration route during migration times	SRW = 3 ASL = 3 Other = 3	SRW = 3 ASL = 3 Other = 3	SRW = 6 ASL = 6 Other = 6
	Seismic testing (3D/4D)	Disturbance to marine mammals Alteration of migration route during migration times	SRW = 4 ASL = 4 Other = 4	SRW = 4 ASL = 4 Other = 4	SRW = 16 ASL = 16 Other = 16
	Drilling (tender vessel noise)	Raises background noise level Potential small scale (within 10km) disruption	SRW = 2 ASL = 2 Other = 2	SRW = 3 ASL = 3 Other = 3	SRW = 6 ASL = 6 Other = 6
	Shipping noise	Raise background noise levels Temporary disruption during passing of vessel	SRW = 2 ASL = 2 Other = 2	SRW = 3 ASL = 3 Other = 3	SRW = 6 ASL = 6 Other = 6
Light Pollution	Night work	Disorientation of marine mammals Attraction of predators of marine mammals Attraction of marine mammals.	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2
	Flaring	Disorientation of marine mammals Attraction of predators of marine mammals Attraction of marine mammals.	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2
Water contamination	Waste disposal	Sewage flow doesn't receive full treatment prior to discharge into ocean. Putrescible wastes discharged overboard	SRW = 2 ASL = 2 Other = 2	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2
	Oil / Chemical spill from ship	Ingestion by marine mammals Coating of marine mammals with oil	SRW = 4 ASL = 4 Other = 4	SRW = 1 ASL = 1 Other = 1	SRW = 4 ASL = 4 Other = 4

	Aspect	Consequences	Impact Consequences rating	Likelihood	Risk Rating
Prey / food impact	Prey mortality	Absence of prey species	SRW = 4 ASL = 4 Other = 4	SRW = 3 ASL = 3 Other = 3	SRW = 12 ASL = 12 Other = 12
	Changes in prey behaviour to make them more difficult to catch	Dispersal of prey increasing foraging effort	SRW = 4 ASL = 4 Other = 4	SRW = 3 ASL = 3 Other = 3	SRW = 12 ASL = 12 Other = 12
Collision	Seismic ships	Collision with vessel Collision with towed gear	SRW = 3 ASL = 3 Other = 3	SRW = 3 ASL = 1 Other = 3	SRW = 9 ASL = 3 Other = 9
	Service Ships	Injury from collision with vessel	SRW = 3 ASL = 3 Other = 3	SRW = 2 ASL = 1 Other = 2	SRW = 6 ASL = 3 Other = 6
Impact on Breeding success	Displacement through noise (seismic)	Move away from preferred calving or feeding area	SRW = 3 ASL = 3 Other = 3	SRW = 3 ASL = 3 Other = 3	SRW = 9 ASL = 9 Other = 9
	Displacement through noise (drilling test wells)	Move away from preferred calving area	SRW = 3 ASL = 3 Other = 3	SRW = 2 ASL = 2 Other = 2	SRW = 6 ASL = 6 Other = 6
	Boat strike (see collision)	Collision with boats or gear	SRW = 3 ASL = 3 Other = 3	SRW = 3 ASL = 1 Other = 3	SRW = 9 ASL = 3 Other = 9
	Calf injury - prenatal deafness ?	Hearing impairment leading to reduction in fitness - difficulty in finding prey? - difficulty in navigation? - communication difficulties with co-specifics?	SRW = 4 ASL = 1 Other = 4	SRW = 3 ASL = 1 Other = 3	SRW = 6 ASL = 1 Other = 6
	Calf injury - separation from mother	Death of calf	SRW = 4 ASL = 1 Other = 4	SRW = 3 ASL = 1 Other = 3	SRW = 12 ASL = 1 Other = 12

	Aspect	Consequences	Impact Consequences rating	Likelihood	Risk Rating
Health impacts	Stress	Reduction of immune system function leading to general decline in reproductive success of population	Unknown	Unknown	Unknown
	Hearing impairment	Hearing impairment leading to reduction in fitness - difficulty in finding prey? - difficulty in navigation? - communication difficulties with co-specifics?	SRW = 4 ASL = 1 Other = 4	SRW = 3 ASL = 1 Other = 3	SRW = 6 ASL = 1 Other = 6
	Injury from collision	(see collision)	SRW = 3 ASL = 3 Other = 3	SRW = 3 ASL = 1 Other = 3	SRW = 9 ASL = 3 Other = 9
Legislative impacts	Breach of legislative requirements	Lack of reporting of any incident Lack of reporting of observed impact on marine mammal	SRW = 4 ASL = 3 Other =4	SRW = 1 ASL = 1 Other = 1	SRW = 4 ASL = 3 Other = 4
Media / reputation impacts	Death or observable injury to marine mammal(s)	Reports from community or fishers in the area Sightings of dead or injured whales during whale watching activities	SRW = 4 ASL = 3 Other = 4	SRW = 4 ASL = 3 Other = 4	SRW = 16 ASL = 9 Other = 16
Costs	Legislation Rehabilitation Media	Fines under the EPBC Act and possibly Petroleum and Submerged Lands Act ???? Costs of rehabilitating any surviving individuals Cost of mitigating poor media coverage Possible loss of exploration license in severe incident	Unknown	Unknown	Unknown

Risk Assessment Production

	Aspect	Consequences	Impact Consequences rating	Likelihood	Risk Rating
Noise Pollution	Rig/infrastructure construction	Detectable disturbance of marine mammals, including avoidance behaviour	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2	SRW = 4 ASL = 4 Other = 4
	Rig/infrastructure operation	Increase in ambient noise	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2	SRW = 4 ASL = 4 Other = 4
	Drilling	Raises background noise level Potential small scale (within 10km) disruption	SRW = 2 ASL = 2 Other = 2	SRW = 3 ASL = 3 Other = 3	SRW = 6 ASL = 6 Other = 6
	Shipping	Raise background noise levels Temporary disruption during passing of vessel	SRW = 2* ASL = 2* Other = 2*	SRW = 3 ASL = 3 Other = 3	SRW = 6 ASL = 6 Other = 6
Light Pollution	Light from Rig	Attraction of predators of marine mammals Attraction of marine mammals Disorientation of marine mammals	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2
	Light from Ships	Attraction of predators of marine mammals Attraction of marine mammals Disorientation of marine mammals	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2
Water contamination	Waste disposal	Ingestion of Produced Formation Water if disposed of at surface.	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2	SRW = 4 ASL = 4 Other = 4
	Oil spill from Rig	Ingestion by marine mammals Coating of marine mammals	SRW = 4 ASL = 4 Other = 4	SRW = 1 ASL = 1 Other = 1	SRW = 4 ASL = 4 Other = 4
	Oil spill from ship	Ingestion by marine mammals Coating of marine mammals	SRW = 4 ASL = 4 Other = 4	SRW = 1 ASL = 1 Other = 1	SRW = 4 ASL = 4 Other = 4

	Aspect	Consequences	Impact Consequences rating	Likelihood	Risk Rating
	Oil spill from transfer to ship	Ingestion by marine mammals Coating of marine mammals	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2	SRW = 4 ASL = 4 Other = 4
Prey / food impacts	Prey mortality	Absence of prey species	SRW = 1 ASL = 2 Other = 2	SRW = 1 ASL = 1 Other = 1	SRW = 1 ASL = 2 Other = 2
	Changes in prey behaviour making them more difficult to catch	Dispersal of prey increasing foraging effort	SRW = 1 ASL = 2 Other = 2	SRW = 1 ASL = 1 Other = 1	SRW = 1 ASL = 2 Other = 2
Collisions	Service boats on a weekly basis	Collision with service boats	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2
Impacts on breeding success	Rig operation	Dislocation / displacement	SRW = 2 ASL = 1 Other = 2	SRW = 3 ASL = 3 Other = 3	SRW = 6 ASL = 3 Other = 6
	Strikes from service vessels	Injury to cows or calves	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2
	Helicopter visitation	Disturbance	SRW = 1 ASL = 1 Other = 1	SRW = 3 ASL = 3 Other = 3	SRW = 3 ASL = 3 Other = 3
Health impacts	Noise from operation	Raise background levels of noise	SRW = 2 ASL = 2 Other = 2	SRW = 3 ASL = 3 Other = 3	SRW = 6 ASL = 6 Other = 6
	Chronic pollution	Build-up of toxins in tissues	SRW = 3 ASL = 3 Other = 3	SRW = 2 ASL = 2 Other = 2	SRW = 6 ASL = 6 Other = 6
	Strikes from service boats	Injury to cows or calves	SRW = 1 ASL = 1 Other = 1	SRW = 2 ASL = 2 Other = 2	SRW = 2 ASL = 2 Other = 2

	Aspect	Consequences	Impact Consequences rating	Likelihood	Risk Rating
Legislation impacts	Breech of legislative requirements	Lack of reporting of any incident Lack of reporting of observed impact on marine mammal	SRW = 4 ASL = 4 Other = 4	SRW = 1 ASL = 1 Other = 1	SRW = 4 ASL = 4 Other = 4
Media / reputation impacts	Death or observable injury to marine mammal(s)	Reports from community or fishers in the area Sightings of dead or injured whales during whale watching activities	SRW = 4 ASL = 3 Other = 4	SRW = 5 ASL = 3 Other = 5	SRW = 20 ASL = 9 Other = 20
Costs	Legislation Rehabilitation Media	Fines under the EPBC Act and possibly Petroleum and Submerged Lands Act ???? Costs of rehabilitating any surviving individuals Cost of mitigating poor media coverage Possible loss of operating license in severe incident	Unknown	Unknown	Unknown

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