Lord Howe Rise Marine Seismic and Sampling Survey

Section 2 - Matters of National Environmental Significance

Describe the affected area and the likely impacts of the proposal, emphasising the relevant matters protected by the EPBC Act. Refer to relevant maps as appropriate. The interactive map tool can help determine whether matters of national environmental significance or other matters protected by the EPBC Act are likely to occur in your area of interest. Consideration of likely impacts should include both direct and indirect impacts.

Your assessment of likely impacts should consider whether a bioregional plan is relevant to your proposal. The following resources can assist you in your assessment of likely impacts:

- **Profiles of relevant species/communities (where available), that will assist in the identification of whether there is likely to be a significant impact on them if the proposal proceeds;**
- **Significant Impact Guidelines 1.1 – Matters of National Environmental Significance;**
- **Significant Impact Guideline 1.2 – Actions on or impacting upon, Commonwealth land and Actions by Commonwealth Agencies.**

2.1 Is the proposed action likely to have ANY direct or indirect impact on the values of any World Heritage properties?

There are no World Heritage Properties located within the proposed survey area. The closest World Heritage Site is the Lord Howe Island Group (which comprises Lord Howe Island, Admiralty Islands, Mutton Bird Islands, Ball's Pyramid, and associated coral reefs and marine environments), located more than 350 km from the proposed survey area.

The primary impact of the survey will derive from the propagation of sound generated by seismic airguns. To understand this impact, Geoscience Australia commissioned Curtin University to undertake acoustic propagation modelling specific to the largest (7800 in^3) seismic airgun array that will be used on this survey, and to assess the expected ranges for potential impacts of acoustic exposure on cetaceans (see Attachments C and D and EPBC Referral 2015/7623). The model was designed to extend into surrounding Commonwealth Marine Reserves (CMRs) to understand the sound exposure levels that these reserves would likely receive.

Sound-modelling demonstrated that indirect behavioural responses in cetaceans are expected to occur at distances exceeding 250 km from the source, which intersects nearby CMRs (including declared Ramsar wetlands at Elizabeth and Middleton Reefs). It is also possible that sound generated from the seismic airguns will travel as far as the World Heritage listed Lord Howe Island Group. However, modelled sound levels that extend into the northern Lord Howe CMR are predicted to range between 110 – 130 dB re 1 µPa^2.s (see Figure 12 and Figure 13 in Attachment D). These levels do not exceed the levels specified for recoverable injury and mortality for fish or sea turtles (see Table 7.4 in Popper et al. 2014b). The proposed survey is therefore not likely to have direct impacts on World Heritage values of the Lord Howe Island Group. A full description of the potential direct and indirect impacts of received sound levels on matters of national environmental significance (including mobile marine fauna) is provided in Section 2.5.

2.2 Is the proposed action likely to have ANY direct or indirect impact on the values of any National Heritage places??

There are no National Heritage Places located within the proposed survey area. The nearest National Heritage Place is the Lord Howe Island Group. See response to Section 2.1 (above).

2.3 Is the proposed action likely to have ANY direct or indirect impact on the ecological character of a Ramsar wetland?

There are no Wetlands of International Importance (declared RAMSAR Wetlands) within the proposed survey area. The nearest Wetlands of International Importance are Elizabeth and Middleton Reefs, located more than 130 km from the proposed survey area. Elizabeth and Middleton Reefs were designated a RAMSAR site in 2002 due to the rare and representative examples of coral reef wetland that support diverse marine fauna, including uncommon and undescribed fishes (over 300 species) and several endemic species of mollusc. The lagoons of both reefs are strongholds for populations of black cod and the Galapagos shark.

As noted in Section 2.1, sound levels are predicted to extend into the northern Lord Howe CMR, which includes Elizabeth and Middleton Reefs, but do not exceed guidelines for recoverable injury and mortality for fish (see Table 7.4 in Popper et al. 2014b). The proposed survey is therefore not likely to have direct impacts on the ecological character of Elizabeth and Middleton Reefs Marine National Nature Reserve. Please refer to Section 2.5 for a full description of the potential direct and indirect impacts of received sound levels on matters of national environmental significance (including mobile marine fauna).

2.4 Is the proposed action likely to have ANY direct or indirect impact on the members of any listed species or any threatened ecological community, or their habitat?

A search of the Department of the Environment and Energy (DoEE) Protected Matters Search Tool database was completed to identify matters of national environmental significance within the proposed survey area (Attachment E), which is located in the Temperate East Marine Region. The search identified 29 listed threatened species or species habitat that may occur in the area (Table 2.4.1). No threatened ecological communities were identified. A database search using the Atlas of Living Australia was also completed for the proposed study region (see Figures 7 – 9).

Descriptions of listed threatened species are provided below in the context of their known distributions in Australian waters, including the Temperate East marine region.

Table 2.4.1: Listed threatened species or species habitat that may (or are likely to) occur within the proposed study area

Listed threatened Species		
Marine mammals		
Scientific name	Common name	Status
Balaenoptera borealis	Sei Whale	Vulnerable
Balaenoptera musculus	Blue Whale	Endangered
Balaenoptera physalus	Fin Whale	Vulnerable
Eubalaena australis	Southern Right Whale	Endangered
Megaptera novaeangliae	Humpback Whale	Vulnerable
Turtles		
Scientific name	Common name	Status
Caretta caretta	Loggerhead Turtle	Endangered
Chelonia mydas	Green Turtle	Vulnerable
Dermochelys coriacea	Leatherback Turtle	Endangered
Eretmochelys imbricata	Hawksbill Turtle	Vulnerable
Natator depressus	Flatback Turtle	Vulnerable
Sharks		
Scientific name	Common name	Status
Carcharodon carcharias	White Shark	Vulnerable
Rhincodon typus	Whale Shark	Vulnerable
Seabirds		
Scientific name	Common name	Status
Calidris ferruginea	Curlew Sandpiper	Critically Endangered
Diomedea antipodensis	Antipodean Albatross	Vulnerable

Listed threatened Species		
Marine mammals		
Scientific name	Common name	Status
Diomedea antipodensis gibsoni	Gibson's Albatross	Vulnerable
Diomedea epomophora	Southern Royal Albatross	Vulnerable
Diomedea exulans (sensu lato)	Wandering Albatross	Vulnerable
Fregetta grallaria grallaria	White-bellied Storm-Petrel	Vulnerable
Macronectes giganteus	Southern Giant-Petrel	Endangered
Macronectes halli	Northern Giant-Petrel	Vulnerable
Numenius madagascariensis	Eastern Curlew, Far Eastern Curlew	Critically Endangered
Pterodroma leucoptera leucoptera	Gould's Petrel	Endangered
Pterodroma neglecta neglecta	Kermadec Petrel (western)	Vulnerable
Thalassarche cauta cauta	Shy Albatross	Vulnerable
Thalassarche cauta steadi	White-capped Albatross	Vulnerable
Thalassarche eremita	Chatham Albatross	Endangered
Thalassarche impavida	Campbell Albatross	Vulnerable
Thalassarche melanophris	Black-browed Albatross	Vulnerable
Thalassarche salvini	Salvin's Albatross	Vulnerable

Marine mammals

The five listed threatened species of *baleen whale* (blue, fin, sei, humpack and southern right whale) identified in the EPBC Protected Matters search (Table 2.4.1) are wide-ranging oceanic species found in a variety of coastal, shelf and pelagic habitats, but are not (relative to some toothed whales) deep divers (Clapham et al. 1999). Although migration patterns may vary considerably within and among species, most baleen whales undertake extensive seasonal migrations between cold, productive summer feeding grounds in temperate or high latitudes, and winter mating and calving areas in tropical or warm temperate waters (Clapham et al. 1999). The proposed survey has been scheduled outside known peak migration periods for cetaceans, particularly for baleen whales (e.g. peak migration southward for humpback whales likely to be September/October at the proposed study site), so as to avoid detrimental impacts on these mammals.

<u>Blue whales</u>: Little is known about the distribution and migration of blue whales in the Southern Hemisphere (Branch et al. 2007). In the Australian region there are two recognised subspecies, the Antarctic (or true) blue whale (*B. m. intermedia*) and the pygmy blue whale (*B. m. brevicauda*). In the austral summer, Antarctic blue whales are typically found south of 55° S, while pygmy blue whales are generally believed to remain north of 54° S (Kato et al. 1995). Feeding aggregations of pygmy blue whales occur at the Perth Canyon off Western Australia (Rennie et al. 2009) and the Bonney Upwelling in western Victoria and south-east South Australia, where they forage from November to April (Gill 2002, Gill and Morrice 2003, Gill et al. 2011). Australian blue whales migrate between these feeding grounds during warmer months to lower latitude breeding grounds during colder months (Bannister et al. 1996, Attard et al. 2010). The operational area for this survey is not located close to any important biological areas for blue whales, nor to any known or likely migration routes (Figure 7). Hence, the likelihood of encountering blue whales during the proposed survey is low.

<u>Fin whales (*Balaenoptera physalus*)</u>: This species is found throughout the world's oceans, predominantly in deep offshore waters between latitudes 20° and 75° (Mackintosh 1966) but is more common in temperate waters, and the Arctic and Antarctic Oceans (DoE 2015d). In Australia, there are confirmed records of fin whales for all coastal waters except offshore New South Wales and the Northern Territory (Bannister et al. 1996). Fin whales migrate seasonally from high latitude feeding grounds in summer to relatively low latitude breeding and calving grounds in winter. Arrival time into the summer feeding areas may differ according to sexual class, with pregnant females arriving earlier in the season than other whales (Mackintosh 1966). Fin whales tend to migrate in the open ocean, hence migration routes and the location of winter breeding areas remain largely unknown (DoE 2015d). There are no known migration routes

or mating or calving areas in Australian waters (DoE 2015d). The likelihood of encountering Fin whales within the survey area is therefore low.

<u>Sei whales (*Balaenoptera borealis*)</u>: This species is not well documented in Australian waters (DoE 2015b) and there are no known mating or calving areas (Parker 1978). However, sei whales are known to spend the summer at high latitudes for feeding and the winter at lower latitudes for calving and breeding (Horwood 1987). The similarity in appearance of Sei whales and Bryde's whales (*Balaenoptera edeni*) has resulted in uncertainty about distributional limits and frequency of occurrence, especially in warmer waters (>20 °C) where Bryde's whales are more common (Bannister et al. 1996). Sei whales are thought to have the same general pattern of migration as most other baleen whales, including blue and fin whales (see Gill et al. 2008), although the timing is generally considered to be later and they do not reach such high latitudes (Gambell 1968). The Australian Antarctic waters are important feeding grounds for Sei whales (Horwood 1987) and sighting of Sei whales feeding in the Bonney Upwelling area in summer and autumn indicate that this area is potentially an important feeding ground (DoE 2015b). The proposed survey is scheduled to occur outside peak migration times for baleen whales. It is therefore unlikely that Sei whales will be encountered in the survey area.

<u>Southern right whales (*Eubalaena australis*)</u>: This species is listed as one of 'Least Concern' by the International Union for the Conservation of Nature but as 'Endangered' under the EPBC Act. The species has a southern hemisphere circumpolar distribution between latitude 30° and 60°S (Bannister et al. 1996). Between May and October, the Australian population of Southern right whales migrates between higher latitude feeding grounds (40-65°S) to calving/nursery grounds in coastal Australian waters, including the east coast (Kemper et al. 1997). The winter period is the peak for southern right whale abundance, especially along the southern coast of Australia (Kemper et al. 1997). The head of the Great Australian Bight is one of the principal aggregation areas (DoE 2015h). The operational area of the proposed survey lies outside the coastal range of this species. It also lies outside the known biologically important areas for migration (Figure 7). Therefore, the likelihood of encountering this whale species during the survey is low.

<u>Humpback whales (*Megaptera novaeangliae*)</u>: A biologically important area for migratory humpback whales occurs within the proposed study area (Figure 7). This species migrates annually along the continental shelf of Australia's eastern and western coasts between their summer feeding grounds in Antarctica and their tropical breeding grounds in winter. Generally, the species is sighted migrating north between May and August, and south between September and December (Bannister et al. 1996, Noad et al. 2011). Along parts of their migratory route there are narrow corridors and bottlenecks resulting from physical and other barriers where the majority of the population passes close to shore (i.e. within 30 km of the coastline). For example, off the southern coastline of Queensland most whales pass within 10 km of some prominent headlands (Bryden 1985, Brown 1998). The winter breeding area off the east coast of Australia is likely to be dispersed inside the Great Barrier Reef (Simmons and Marsh 1986, Paterson and Paterson 1989) and the migration to and from these waters occurs primarily along the eastern continental coastline (Figure 7).

Turtles

Five species of marine turtle and/or their habitat are likely to occur in the proposed survey area (Figure 8). They include the loggerhead turtle, green turtle, hawksbill turtle, leatherback turtle and the Australian endemic flatback turtle. All five species are listed as threatened and migratory under the EPBC Act (Table 2.4.1; Table 2.5.1; see also 'Recovery Plan for Marine Turtles in Australia, Commonwealth of Australia 2017'.). However, the proposed survey area does not intersect any known biologically important habitat for these species (Figure 8). Given the lack of nesting habitat in the study area, it is unlikely that foraging or migrating turtles will be encountered during the survey. Additional information on these turtle species is given below.

<u>Loggerhead turtle (*Caretta caretta*)</u>: This species is known to breed along the eastern Australian coast, predominantly on beaches close to and north of Bundaberg, as well as the islands of the southern Great Barrier Reef (DoE 2015f). Loggerhead turtles nest from late October, reaching a peak in late December and finish nesting in late February or early March. Hatchlings emerge from nests from late December until about April with most hatching from February to early March (DoE 2015f). During their post-hatchling phase they are carried southward by the East Australian Current to

around 30° S (Limpus et al. 1994), then eastward out to New Zealand, before re-entering the region via the Coral Sea as large immature turtles (DoE 2015f).

Green turtle (*Chelonia mydas*): There are seven widely separated breeding aggregations of green turtle recognised in Australia (FitzSimmons et al. 1997, Dethmers et al. 2006, Limpus and Fien 2009). On the east coast, the southern Great Barrier Reef (GBR) genetic stock of green turtles comprises a spatially disjunct metapopulation with numerous foraging grounds spanning ca. 12° latitude (1,800 km) from tropical waters in the northern GBR to warm temperate seasonal waters in southern coastal Queensland (Limpus and Fien 2009). It is individuals from this southern population that are most likely to be found in the Temperate East Marine Region (DSEWPaC 2012b). Like the loggerhead, green turtles are carried southward by the East Australian Current during their post-hatchling phase, leaving the region as it flows eastward to New Zealand, and then into the South Pacific Gyre, which transports them back to Australian waters via the Coral Sea (DSEWPaC 2012b).

Hawksbill turtle (*Eretmochelys imbricata*): This species has a worldwide circumtropical and subtropical distribution and Australian waters are habitat for the largest remaining stocks of breeding *E. imbricata* within the Indian Ocean–Western Pacific Ocean region (Limpus et al. 2008). There are two genetically separate subpopulations in Australia; one in the northern Great Barrier Reef, Torres Strait and Arnhem Land; and the other on the North West Shelf of Western Australia (Limpus et al. 2008, DoE 2015g). Of these subpopulations, the northern Great Barrier Reef population lives adjacent to the Temperate East Marine Region (DSEWPaC 2012b) and it is individuals from this subpopulation that are most likely to be found in the survey area. Hawksbill turtles that forage within the GBR migrate to breed in areas throughout the Indo-Pacific region, including Vanuatu, Solomon Islands, Papua New Guinea and Indonesia (Miller et al. 1998). Only small disjunct foraging assemblages are found on the shallow reefal areas beyond the continental shelf including the Coral Sea platform, Elizabeth and Middleton Reefs, and reefs associated with Norfolk and Lord Howe Islands (Tzioumis and Keable 2007).

Leatherback turtle (*Dermochelys coriacea*): This species is distributed worldwide across tropical and temperate seas and is considered to be in serious decline across the Pacific Ocean basin (Spotila et al. 1996). Although there are no major nesting sites in Australia, the species is known to forage in Australian waters, including in the Temperate East Marine Region, migrating from larger nesting populations in neighbouring countries, particularly in Indonesia, Papua New Guinea and the Solomon Islands (Hamann et al. 2007, Limpus and Fien 2009). Leatherback turtles migrate as juveniles and adults through the pelagic environment of the Coral Sea, Tasman Sea (Figure 8) including Bass Strait and therefore could be encountered throughout the oceanic areas of the east marine region (Tzioumis and Keable 2007).

Flatback turtle (*Natator depressus*): This species is reproductively endemic to the Australian continental shelf with principal feeding grounds concentrated in turbid, shallow inshore water off north-eastern Australia and in the Gulf of Carpentaria. There are no records beyond the continental shelf (Limpus et al. 1983). The species is rarely found foraging in reefal habitats or in intertidal and shallow subtidal habitats and the turtle does not breed in eastern Australia (Tzioumis and Keable 2007). The major eastern Australian breeding aggregations occur on continental islands in inshore areas of the southern Great Barrier Reef (GBR) at Peak, Wild Duck, Avoid and Curtis Islands (Limpus et al. 1983).

Sharks

White sharks (*Carcharodon carcharias*): The Temperate East Marine Region and adjacent waters are known to support aggregations of white shark. The species is listed as both vulnerable and migratory under the EPBC Act due to its life history characteristics (long lived and low levels of reproduction), limited local distribution and abundance, and pressure from Australian commercial and recreational fisheries and shark control programs (DoE 2015e). In Australian waters, white sharks extend from southern Queensland around the southern coastline to North West Cape in Western Australia (DoE 2015e). It is commonly encountered on the continental shelf, often close inshore, and has been recorded from the surface down to water depths of 1,280 m (Bruce et al. 2006). Movements of tagged white sharks, together with data from bycatch records and shark control programs, suggest a seasonal movement northward along the east coast of Australia during the autumn–winter months and south in spring–early summer (Bruce et al. 2006). However, satellite tracking of white sharks tagged in southern Australia showed broad-scale movements consistent with mixing of the population across their entire Australian range, as well as across the Tasman Sea to New Zealand (Bruce et al. 2006), adding further evidence to indicate that these sharks sometimes move into open ocean waters and cross deep ocean basins (Boustany et al. 2002, Bonfil et al. 2005, Bonfil et al. 2010). Given that the majority of movements of tagged white sharks in Australia waters are confined to shelf waters, generally in areas of less than 100 m depth (Bruce et al. 2006), it is unlikely that white sharks will be encountered in the survey area.

Whale sharks (*Rhincodon typus*): This species is listed as both vulnerable and migratory under the EPBC Act 1999. It is also classed as vulnerable in the World Conservation Union's Red List. This species is the world's largest fish and one of only three species of plankton-feeding shark. It is broadly distributed in tropical and temperate seas, usually between latitudes 30°N and 35°S and is widely distributed in Australian waters. The reproductive biology of whale sharks is almost unknown, but it is thought that whale sharks mate in waters surrounding Taiwan, the Philippines and India (DoE 2015j). Although mostly solitary, whale sharks form feeding aggregations in some regions during periods of increased food supply. Between March and May, whale sharks congregate on Ningaloo Reef (Western Australia) in response to increased nutrients available after mass coral spawning (Meekan et al. 2006). The migratory habits of whale sharks after they leave Ningaloo are poorly understood, but seasonal aggregations occur off Christmas Island (Indian Ocean) between December and January and in the Coral Sea between November and December (DoE 2015j). Tagging of several animals at Ningaloo revealed that they subsequently swam to Christmas Island and Indonesia (Meekan et al. 2006, DoE 2015j and references therein). Sightings have also been confirmed further south than Kalbarri (on the mid-west coast of Western Australia), Eden (on the New South Wales south coast) and Balls Pyramid (Tasman Sea). Given the seasonal patterns of known whale shark aggregations, it is considered unlikely that whale sharks will be encountered during the proposed survey.

Seabirds

There are several seabird species that may occur within the survey area due to proximity of islands in the Tasman Sea and Coral Sea that support nesting sites, most notably the Lord Howe and Norfolk Island groups (Figure 9), as well as a series of smaller islands along the NSW coast (DSEWPaC 2012c). These include endangered, vulnerable and migratory albatross and petrel species (order Procellariiformes) that use the region for foraging, feeding or related behaviour. Procellariiformes face a range of threats in the marine environment including direct interactions with fishing operations; ingestion of, and entanglement in, marine debris; contamination from pollutants; and over-fishing of prey species (Baker et al. 2002).

Nature and extent of likely impact

The nature and extent of potential impacts on threatened species (described above), as a result of the proposed survey, relate to underwater acoustic disturbance, the physical presence of the marine vessel, light emissions, and seabed disturbance associated with the temporary deployment of Ocean Bottom Seismometers (OBS). Each of these impacts is discussed separately below.

Acoustic disturbance

The main impact to marine life as a result of the proposed survey is acoustic disturbance caused by the discharge of underwater seismic pulses. This seismic survey will involve the use of airgun arrays that are trailed behind the vessel and produce high intensity, low frequency impulsive sounds at regular intervals. The optimum frequency range for an array is a trade-off between resolution and depth of penetration, with most sound produced between 10–300 Hz and highest levels less than 100 Hz (McCauley et al. 2000a). These sounds are directed towards the seabed and are used to generate detailed descriptions of sub-seabed geological formations (McCauley et al. 2000a, Gausland 2003). The predominant frequency range of seismic airgun emissions is within the detectable hearing range of cetaceans and most fishes and elasmobranchs (Popper et al. 2003, Popper and Fay 2011, Ladich and Fay 2013). It can also elicit a neurological response in cephalopods (Mooney et al. 2010) and decapods (Lovell et al. 2005).

Many marine animals, from small invertebrates to large cetaceans, make extensive use of underwater sounds for important biological activities such as intraspecific communication, predator avoidance, navigation, larval orientation, foraging and reproduction (Montgomery et al. 2006, Vermeij et al. 2010, Mooney et al. 2012). The ability to detect low-frequency sound may have evolved in fish, cephalopods, and other mobile marine invertebrates to avoid predators (Mooney et al. 2010). Anthropogenic noise can interfere with the ability of an animal to detect and/or use its 'acoustic' or 'auditory' scene and potentially decrease its fitness and chance of survival (Popper and Hastings 2009). Potential effects of intense anthropogenic sound sources on marine animals range from disturbance that may lead to displacement from feeding or breeding areas, to auditory damage and potential mortality (Popper and Hawkins 2012). Alternatively, some marine species may experience no effect of exposure to intense sources, particularly if the received level of sound does not exceed hearing thresholds (Popper and Hastings 2009). The area over which seismic noise may adversely impact marine species therefore depends on multiple factors, including the extent of sound propagation underwater, its frequency characteristics and duration, its distribution relative to the location and movements of organisms, and the absolute sensitivity and range of spectral hearing among species (Slabbekoorn et al. 2010, Popper and Hawkins 2012).

<u>Impact on cetaceans</u>

The potential biological effects of airgun noise on marine mammals has been extensively reviewed (e.g. Gordon et al. 2003, McCauley et al. 2003a, Nowacek et al. 2007, Southall et al. 2007, Richardson et al. 2013) and may include direct physical/physiological effects, such as auditory damage and shifts in hearing thresholds (either permanent or temporary) as well as non-auditory disruption; perceptual effects, which include masking of biologically significant sound like communication signals, echolocation, and sounds associated with orientation, finding prey or avoiding threats; behavioural effects, such as disruption of foraging, avoidance of particular areas, altered dive and respiratory patterns, and disruption of mating system; and, indirect effects such as reduced prey availability resulting in reduced feeding rates (Gordon et al. 2003). Behavioural responses and long-term biological consequences are of particular concern because they can occur at large distances, are difficult to manage, and are not fully understood (Cato et al. 2013). There is also the potential that the animal 'avoids' not only the source of noise but also the vessel operating the source (Dunlop et al. 2015), which can make quantification of the dose (i.e. received level of noise)-response (i.e. avoiding the source) relationship difficult (see Dunlop et al. 2017). Moreover, determining which natural factors significantly affect behaviour is essential for ensuring that any observed behavioural changes are correctly attributed to a particular disturbance (Kavanagh et al. 2017).

Baleen whales (e.g., blue, southern right and humpback whales) have displayed a variety of behavioural responses to seismic noise, which often vary within and between species (Richardson et al. 1995, McCauley et al. 2000b, Weir 2008). For example, a comparative study of blue whale communication found that calling was more consistent during seismic acquisition than on non-survey days, and was observed for the discrete, audible calls that are emitted during social encounters and feeding (Di Iorio and Clark 2010). This response was presumed to represent a compensatory behaviour to the elevated ambient noise from seismic survey operations (Di Iorio and Clark 2010). However, as noted above, it is unlikely that foraging or migrating blue whales will be encountered within the Lord Howe Rise survey area. Potential direct or indirect disturbance to blue whales is therefore not expected.

For humpback whales, McCauley et al (2000b) showed that avoidance of 3D seismic operations by pods (which were involved in resting behaviour in key habitat types), occurred between 7 and 12 km from a survey vessel, whereas migrating individuals were less sensitive in their avoidance behaviour, tending to adjust their course and speed to enable an avoidance range of around 3 km (received sound level in the range of 157 to 164 dB re 1 µPa rms). During experimental exposures, some male humpbacks appeared attracted to the airgun signals and were observed approaching the seismic survey vessels to within 1 to 2 km (McCauley et al. 2000b). McCauley et al (2000b) concluded that given only localised avoidance was seen in migrating whales, any 'risk factor' associated with the seismic survey was confined to a comparatively short period and small range displacement. Similarly, Weir (2008) found no evidence for prolonged or large-scale displacement of humpback whales during two consecutive geophysical 3-D seismic surveys (total airgun volume of 5,085 in^3 and 3,147 in^3). More recent studies investigating the behavioural response of migrating humpback whale groups to various airgun arrays have shown that whale groups may respond by decreasing their dive time and speed of movement (Dunlop et al. 2015, Kavanagh et al. 2017) and are more likely to avoid the air gun arrays (but not the controls) within 3 km of the source at levels over 140 re. 1 µPa2 s−1, further emphasising that both the proximity and the received level were important factors and the relationship between dose (i.e. received level) and response is not a simple one (Dunlop et al. 2017).

Sound modelling

To assess the range of impact on cetaceans from the proposed seismic surveys undertaken as part of this multi-year project, Geoscience Australia commissioned Curtin University (Centre for Marine Science and Technology) in 2015 to undertake acoustic propagation modelling specific to the 7800 in^3 seismic airgun array (see Attachment C and D). Modelling was undertaken at four representative source locations to predict received sound exposure levels (SELs) and peak-to-peak sound pressure levels (SPL $p{-}p$) from the proposed 2016 seismic survey at both short (< 5 km) and long (250 km) spatial ranges. An overview of the sampling design, methodology and key results from these studies is provided below.

The geographical distribution of sound exposure levels (SELs) due to a single airgun shot was computed with the seismic source at four representative locations – three along the east-west seismic line acquired during site survey one and one at a high-priority site being considered for stratigraphic drilling (Figure 1 in Attachment C). When plotted relative to the source location, modelled results were considered representative of levels received when the source was located at other locations with similar water depth, seabed slope, and seabed geology. Two different modelling methods were used: long-range modelling, which is computationally efficient and suitable for modelling sound exposure levels at ranges from a few kilometres to hundreds of kilometres; and short-range modelling, which is suitable for computing a variety of signal parameters out to ranges of a few kilometres. Long-range modelling was carried out for all four source locations, whereas short-range modelling was carried out for a single source location that corresponds to one of the high-priority sites being considered for stratigraphic drilling. The short range modelling results are considered to be representative of all the sites at which the source is operated at a depth of 6 m (see Section 2.1).

Potential ranges of impact due to sound produced during the proposed 2016 seismic survey were based on the susceptibility of cetaceans to permanent and temporary threshold shift (PTS and TTS, respectively) in hearing sensitivity, and behavioural responses. Cetaceans were split into three general categories – low-frequency, mid-frequency, and high-frequency cetaceans – based on similarities in their hearing range (auditory sensitivity at different frequencies) and corresponding generalized frequency-weighting (“M-weighting”) functions (Southall et al. 2007). “Low-frequency” cetaceans (7 Hz to 22 kHz) include the mysticetes (baleen whales), “mid-frequency” cetaceans (150 Hz to 160 kHz) include most odontocetes (toothed whales), and “high-frequency” cetaceans (200 Hz to 180 kHz) include those odontocetes specialised in using high frequencies (of which, relevant species likely to occur in the survey area include sperm whales and beaked whales) (Southall et al. 2007). Levels for which the onset of behavioural responses can be expected vary widely among the limited number of studies that have been undertaken. For example, for mid-frequency cetaceans exposed to multiple, consecutive pulses, expected received levels as low as 100 dB re 1 µPa rms to as high as 160–180 dB re 1 µPa rms, can result in a behavioural response (Southall et al. 2007). PTS and TTS were based on single pulses, while behavioural responses were based on multiple pulses. This is because estimating potential ranges based on multiple pulses, such as those produced during seismic surveys, requires the number and sound levels of pulses that animals are exposed to, to be known with certainty. For PTS and TTS, the required levels are higher, and so the corresponding ranges from the source are smaller.

Instantaneous physiological damage is only likely to occur to cetaceans if received peak sound levels exceed 265–275 dB re 1 µPa (Parvin et al. 2007). These levels are unlikely to be exceeded beyond approximately 50 m from a typical seismic source (Parvin et al. 2007). Results from the acoustic sound modelling show that the rate at which received SELs decrease with increasing range varied with bathymetry and source depth, but for all four source locations, the maximum levels were predicted to be between 130 dB re 1 µPa^2.s and 140 dB re 1 µPa^2.s at the largest modelled range of 250 km (see Figure 6 and Figure 7). Further reductions in sound exposure levels with increasing range are likely to be quite slow in directions where the sound remains in deep water and would be expected to approach the cylindrical spreading rate of a 10 dB reduction in level for every factor of ten increase in range.

Based on the modelling results above, PTS and TTS are expected to occur for low-frequency cetaceans at ≤66 m distance from the source, and ≤50 m for mid- and high-frequency cetaceans. Ranges for TTS are predicted to be ≤390 m for low-frequency, and ≤224 m for mid- and high frequency cetaceans. The low-frequency PTS and TTS ranges were determined by the M-weighted sound exposure level criteria, whereas the mid-frequency and high-frequency cetacean ranges were determined by the peak-to-peak sound level criteria in Southall et al. (2007). The assessment study recommended that these results be applied with caution for sections of the survey where the source is being operated at a depth of 10 m (refer Section 2.1), as levels are expected to increase with increasing source depth.

Behavioural responses in cetaceans were predicted to occur at 400 m from the source for high-frequency cetaceans and 1.4 km for low and mid-frequency cetaceans, but potentially extending to >250 km. Because seismic surveys require multiple pulses normally undertaken over extended periods, cumulative exposure can reach PTS and TTS thresholds across larger distances. Measures to reduce the impact of the seismic source on baleen whales (e.g. the use of an additional pair of passive acoustic monitoring hydrophones with a very low frequency response) are detailed in Section 4.

<u>Impact on turtles</u>

There are very few studies on the effects of seismic airgun activity on sea turtles and turtle audition is fairly poorly studied to date. However, existing data suggest that turtles hear best between about 100 Hz and 1 kHz, and should thus be able detect low-frequency, high-amplitude pulses from airgun arrays (DeRuiter and Doukara 2012). Given the current lack of comprehensive data on turtle hearing sensitivity, it is difficult to predict the sound exposure levels that would be required to cause temporary or permanent hearing loss. However, marine turtles, including the loggerhead turtle (*Caretta caretta*) have displayed avoidance behaviour to air-gun arrays (O'Hara and Wilcox 1990, McCauley et al. 2000b, DeRuiter and Doukara 2012). McCauley et al. (2000b) estimated that a typical airgun array operating in 100–120 m water depth could impact marine turtles behaviour at a distance of about 2 km (at received levels around 166 dB re 1µPa rms) and cause avoidance at around 1 km (at 175 dB re 1µPa rms). Modelled sound exposure levels generated by the proposed survey do not exceed guidelines for recoverable injury and mortality of turtles (see Table 7.4 in Popper et al. 2014b). Turtles present in the region at the time of the survey are likely to display avoidance behaviour in response to the approaching seismic noise. It is therefore unlikely that turtles will be detrimentally impacted at an individual or population level.

<u>Impact on fish</u>

The available peer-reviewed research on the potential impacts of marine seismic surveys on fish and invertebrates was critically evaluated in a recent scientific publication undertaken by Geoscience Australia in collaboration with Curtin University and CSIRO (Carroll et al. 2017). This review highlighted data gaps, identified limitations with existing research, and provided recommendations for future studies. Relevant sections from this review are provided below.

Although marine fish typically have less acute hearing than marine mammals, many are more sensitive than odontocetes in the range 100–500 Hz, where most seismic sound is produced (Gordon et al. 2003). While there is little information available on permanent hearing loss in fish resulting from exposure to high-intensity sounds, there is a growing body of literature which shows that anthropogenic sounds that exceed normal ambient noise may result in a temporary change in hearing sensitivity from which the animal will recover over time (Popper and Hastings 2009, Popper et al. 2014a). This loss of hearing (also referred to as temporary threshold shift (TTS)), is a temporary reduction in hearing sensitivity caused by exposure to intense sound. The level and duration of exposure that causes TTS varies widely and can be affected by factors such as repetition rate, frequency and duration of the sound, SPL, as well as the health condition of the exposed organisms (Popper and Hastings 2009).

The presence of gas bladders, and their anatomical location within the body, make fish particularly susceptible to pressure-mediated injury to the ears and body tissues (Popper et al. 2014a). There are few data on the effects of seismic airguns on fish mortality and damage to organ systems, and of these none have shown mortality (Popper et al. 2007, McCauley and Kent 2012, Miller and Cripps 2013). McCauley et al. (2003b) demonstrated that exposure to repeated single air-gun shots (1m of 222.6 dB re 1µPa (peak to peak) or 203.6 dB re 1µPa RMS) caused extensive damage to the sensory hair cells of the saccule of the inner ear of caged pink snapper (*Pagrus auratus*), while other studies have demonstrated no damage in several other species (Popper et al. 2005, Song et al. 2008). Fish have been shown to recover from temporary reductions in hearing sensitivity resulting from exposure to seismic sound (Popper and Hastings 2009, Popper et al. 2014a).

Behavioural effects are the most studied variable in assessments of low-frequency sound on fish, although few studies have observed the behaviour of fish exposed to a seismic survey directly (Popper et al. 2014a). Airgun discharges have been reported to elicit varying degrees of startle and alarm responses and changes in schooling patterns, position in the water column and swimming speeds in fish (e.g. Pearson et al. 1992, Santulli et al. 1999, Wardle et al. 2001, Boeger et al. 2006, Fewtrell and McCauley 2012, reviewed in Carroll et al. 2017).

Potential habituation to repeated airgun exposure has been demonstrated for some fish. During airgun activity, some captive rockfish returned to pre-exposure behavioural patterns late in the exposure period, suggesting habituation to the air-gun sounds (Pearson et al. 1992). Similarly, behavioural observations of three coral reef fish species (*Lutjanus synagris*, *Lutjanus apodus*, *Chaetodipterus faber)* in field enclosures before, during and after exposure to airguns showed that repeated exposure resulted in increasingly less obvious startle responses (Boeger et al. 2006). Temporary habituation to airgun discharges was observed in schooling whiting when they returned to pre-exposure depth range following continual exposure to airgun sound over one hour, but again ascended to greater depths when airgun discharges recommenced after a period of non-shooting (Chapman and Hawkins 1969).

A number of studies have shown that seismic airguns have an impact on fish catch and abundance, presumably due to changes in fish behaviour and distribution (reviewed by Hirst and Rodhouse 2000, McCauley et al. 2000a, Popper and Hastings 2009). Peña et al. (2013) investigated the real-time behaviour of herring schools exposed to a full-scale 3D seismic survey and observed changes in swimming speed, swimming direction, or school size that could be attributed to the transmitting seismic vessel as it approached from a distance of 27 to 2 km, over a 6 h period (Peña et al. 2013). Miller and Cripps (2013) investigated the effects of a 3D seismic survey on a shallow-water fish community at six locations at Scott Reef, before and after the survey. No significant effect was found on the overall abundance or species richness of species belonging to the family Pomacentridae (a group that exhibit a high degree of site fidelity) or non-Pomacentridae families (which comprised larger, more mobile roaming demersal species) (Miller and Cripps 2013).

Hearing sensitivities among sharks are poorly understood. This lack of knowledge makes it difficult to evaluate the potential effects that could be associated with exposure to seismic noise. Hearing abilities among sharks have demonstrated highest sensitivity to low frequency sound (40 Hz to approximately 800 Hz), which is sensed solely through the particle-motion component of an acoustical field (Myrberg Jr 2001). Sharks do not possess swim bladders and are therefore perceived to be less sensitive to underwater noise and trauma. The Temperate East Bioregional Plan species report card assesses noise pollution from seismic exploration as ‘not of concern’ for all shark species identified in the EPBC protected matters search. Impacts of the proposed seismic activity on sharks are therefore insignificant.

Although modelled sound exposure levels do not exceed guidelines for recoverable injury and mortality of fish (see Table 7.4 in Popper et al. 2014b), it is anticipated that some behavioural impacts on fish may occur within close range to the seismic source. Sharks and the vast majority of other fish likely to occur within the proposed survey area are highly-mobile pelagic species, and are therefore more likely to move away from the approaching sound source which will reduce the likelihood of any direct pathological damage. The survey vessel will be constantly moving and therefore any given location will only be affected for a relatively short period of time, thereby reducing the risk of population impacts. The use of soft starts prior to firing the airguns (see Section 5) will also act as a warning signal to fish in the nearby region.

Impact on invertebrates

Like elasmobranchs, marine invertebrates lack a gas-filled bladder and are thus unable to detect the pressure changes associated with sound waves. However, all cephalopods as well as some bivalves, echinoderms, and crustaceans have a sac-like structure called a statocyst which includes a mineralised mass (statolith) and associated sensory hairs (e.g. crustaceans in (Edmonds et al. 2016). Statocysts develop during the larval stage (Young et al. 2006) and may allow an organism to detect the particle motion associated with sound waves in water to orient itself (Sekiguchi and Terazawa 1997, Kaifu et al. 2008). In addition to statocysts, cephalopods have epidermal hair cells which help them to detect particle motion in their immediate vicinity (Kaifu et al. 2008), comparable to lateral lines in fish. Similarly, decapods have sensory setae on their body (Popper et al. 2001), including on their antennae which may be used to detect low-frequency vibrations (Montgomery et al. 2006). Whole body vibrations due to particle motion have been detected in cuttlefish and scallops, although species names and details of associated behavioural responses are not specified (André et al. 2016)

For marine invertebrates, exposure to nearfield low-frequency sound may cause anatomical damage, although research to demonstrate this is limited. Anecdotal evidence shows pronounced statocyst and organ damage in seven stranded giant squid after nearby seismic surveys (Guerra et al. 2004). After two hours of continuous sound treatment (1-second sweeps, 50-400 Hz) in 200-litre glass tanks, four species of cephalopod exhibited acoustic trauma in their statocysts, including lesions, hair cell loss and damage, and neuron swelling (André et al. 2011, Solé et al. 2013) (see Section 4 for limitations associated with artificial tanks). Day et al. (2016a) found airgun exposure caused damaged statocysts in rock lobsters up to a year later. However, no such effects were detected in snow crabs at frequencies and exposure durations more closely resembling typical seismic operations (200 shots at 10 second intervals, 17-31 Hz) (Christian et al. 2003). A theoretical study similarly found that particle displacements produced in crabs due to seismic sound would be too small to damage tissue (Lee-Dadswell 2009). The disparate results between these studies therefore seem to be due to differences in sound exposure levels and duration, possibly due to tank interference, although taxa-specific differences in physical vulnerability to acoustic stress cannot be discounted.

In the absence of more subtle anatomical studies on most marine invertebrates after exposure to acute low-frequency sound, mortality may be the most useful indicator of barotrauma in marine invertebrates. Previous field-based studies on adult populations revealed no evidence of increased mortality due to airgun exposure in scallops up to ten months after exposure (Parry et al. 2002, Harrington et al. 2010, Day et al. 2016a, Przeslawski et al. 2016), clams two days after exposure (La Bella et al. 1996), or lobsters up to eight months after exposure (Payne et al. 2007, Day et al. 2016a). Similarly, there was no evidence of mortality-associated population effects such as reduced abundance or catch rates in plankton a few hours after exposure (Parry et al. 2002), reef-associated invertebrates four days after exposure (Wardle et al. 2001), snow crabs up to 12 days after exposure (Christian et al. 2003), shrimp two days after exposure (Andriguetto-Filho et al. 2005), or lobsters weeks or years after exposure (Parry and Gason 2006).

Behavioural studies on the response of marine invertebrates to seismic sound are also dominated by those using startle responses. For example, jetting and inking in squid have been observed during air gun operations, with startle responses occurring more frequently as sound levels increase (McCauley et al. 2000b, Fewtrell and McCauley 2012), and scallops have shown a distinctive flinching response although no energetically costly responses such as swimming (Day et al. 2016a). Behaviour not necessarily associated with startle responses has been observed in invertebrates (e.g. mussel valve closure, hermit crab antennae movement in (Roberts et al. 2015, Roberts et al. 2016)), but the biological relevance of these minor responses extends only to establishing thresholds of sound detection or intraspecific differences. For example, based on valve closure, sensitivity to particle motion was higher in smaller than larger mussels (Roberts et al. 2015). On the other hand, changes in predator avoidance behaviours may have population-level implications if predation rates increase due to sound-induced behavioural changes in prey. Scallops were faster to recess into sediments after exposure to airguns, but they were slower to right themselves after overturning (Day et al. 2016a). Similarly, the rock lobster (*Jasus edwardsii*) showed delayed time to right itself after exposure to airguns (Day et al. 2016a). In contrast, no differences in righting time were detected in the American lobster (*Homarus americanus*) 9, 65, or 142 days after exposure to airgun noise, indicating no immediate or long-term effects on predator avoidance behaviour of this species (Payne et al. 2007).

As with fish, some invertebrates may become habituated to sound, with squid showing fewer alarm responses with subsequent exposure to noise from air guns (Fewtrell and McCauley 2012), cuttlefish habituating to repeated 200 Hz tone pips (Samson et al. 2014), and squid showing decreased responses over sound exposure trials (Mooney et al. 2016). There is also some indication of habituation in crabs to vibrations, with greatest sensitivity to particle motion in crabs held in captivity for the shortest period (Roberts et al. 2016). Cephalopods may also be able to adapt their behaviour to particular sounds types. In a series of caged trials in which turtles, fish, and squid were exposed to air guns, the squid were the only animals to shelter in the sound shadow at the ocean surface (McCauley et al. 2000a).

For marine invertebrates, the potential effects of seismic signals on catch rates or abundances have been tested on cephalopods, bivalves, gastropods, decapods, stomatopods, and ophiuroids with no significant differences detected in any of these studies between sites exposed to seismic operations and those not exposed (Wardle et al. 2001, Parry et al. 2002, Christian et al. 2003, Parry and Gason 2006, Courtenay et al. 2009, Przeslawski et al. 2016)

Many benthic invertebrates have a free-swimming larval stage which means that the magnitude of seismic sound exposure also depends on ontogeny. Larval stages are often considered more sensitive to stressors than adult stages (Byrne and Przeslawski 2013), although recent evidence by (Day et al. 2016b) and Day et al (in press) suggest that embryonic stages of rock lobster are more tolerant to seismic airgun exposure than adults. Exposure to seismic sound reveals no differences in larval mortality or abundance for fish (Dalen et al. 2007, Payne et al. 2009), crabs (Pearson et al. 1994), lobsters (Day et al. 2016b), or scallops (Parry et al. 2002). There were similarly no effects on the mortality, abnormality, competency, or energy content of lobster larvae (*Jasus edwardsii)* after exposure of embryonic stages to airgun shots with sound exposure levels >185 dB re µPa2·s (Day et al. 2016b). However, intense and lengthy periods of exposure to low-frequency sound such as those adopted for scallops (Aguilar de Soto et al. 2013) (3 second shot intervals for 90 hours, 1 m distance from sound source), crabs (Christian et al. 2003) (216 dB re 1µPa every 10 seconds for 33 minutes) or fish (Booman et al. 1996) (unknown number of shots, 220-242 dB re 1µPa SPL, 0.75-6 m from sound source) can increase abnormality and mortality rates, indicating that larvae exposed to nearfield airgun shots may be vulnerable.

Impact on zooplankton

A recent study by McCauley et al. (2017) was the first large-scale *in situ* field experiment on the impact of seismic airguns on zooplankton. The study used sonar and sampling to assess zooplankton following exposure to a 150 cubic inch air gun in southern Tasmania (34-36 m depth). The authors found significant reductions in zooplankton abundance and survival after air gun operations, and identified 'backscatter holes' on the sonar as further evidence of negative effects. These impacts were observed out to the maximum assessed range of 1.2 km. Applying the mortality rate from McCauley et al. (2017), Richardson et al. (2017) modelled the spatial and temporal impact of seismic activity on zooplankton on the Northwest Shelf of Australia using a large-scale seismic survey, accounting for typical growth rates, natural mortality rates, and the ocean circulation in the region. They found substantial impact within the seismic survey area and within 15 km of it. However, these impacts were not discernible at the largest scale of the Northwest Shelf Bioregion and were barely discernible within 150 km of the survey area (Richardson et al. 2017). The authors noted that zooplankton populations recovered quickly following seismic exposure due to their fast growth rates, and the dispersal and mixing of zooplankton from both inside and outside the impacted region. Both studies recommended additional research to mitigate, model and better understand the potential impacts of seismic surveys on zooplankton. However, given the predicted rapid recovery of zooplankton populations following exposure to seismic airguns the proposed survey is unlikely to have significant long-term impacts on zooplankton.

<u>Impact on seabirds</u>

Direct impacts of the proposed survey on seabirds identified in Table 2.4.1 are unlikely to occur to a significant level. While it is possible that seismic emissions may affect some diving seabirds, these affects are considered to be short in duration given the brief periods of time seabirds spend underwater. Few studies have been done on the potential impacts of seismic activities on seabirds, which makes it difficult to assess the potential effects on movements and diving behaviour (e.g. Lacroix et al. 2003). However, indirect effects may occur as a result of the potential displacement of the seabirds prey fish species (see above).

<u>Vessel presence and light emissions</u>

In addition to noise produced by the seismic airguns, vessel noise also represents a potential source of underwater acoustic disturbance. Analysis of noise from ships revealed that their propulsion systems are a dominant source of radiated underwater noise at frequencies <200 Hz (Hildebrand 2009). Acoustic masking from anthropogenic noise, including ship noise, is increasingly being considered as a potential threat to marine mammals, especially low-frequency specialists such as baleen whales (Clark et al. 2009), as it may prevent foraging and communication. Some marine mammals have been found to sing longer songs (e.g. Fristrup et al. 2003), increase their call levels (e.g. Holt et al. 2009) and/or change their call rates (e.g. Lesage et al. 1999, Miksis-Olds and Tyack 2009) when exposed to high-level boat or shipping noise (Parks et al. 2011). Baleen whales, such as the humpback, sei, and fin whales are not expected to be encountered during the survey, which is scheduled to occur outside of known peak migratory activity. Several studies have also demonstrated that noise from boat traffic may reduce the effective range of communication signals and therefore the signalling efficiency between individual fish (Amoser et al. 2004, Vasconcelos et al. 2007, Codarin et al. 2009), due to reduced detection distances through masking (Codarin et al. 2009) and/or diminished auditory sensitivity of receivers (Vasconcelos et al. 2007). Picciulin et al. (2012) found that the mean vocalization pulse rate of brown meagres (*Sciaena umbra*) was higher following repeated, though not single, boat passes compared with ambient conditions, and suggested that the observed vocal enhancement may have occurred as a result of an increased density of callers, or from an increased acoustic output by those individuals already calling. Shipping traffic routes that occur within the proposed survey area (see Section 3) have the potential to result in acoustic masking of some species. The presence of the survey vessel (RV *Kairei*) will be temporary, so if additional masking occurs it is unlikely to impact significantly on existing masking in the region.

The physical presence of the survey vessel represents a physical hazard to marine fauna similar to commercial shipping in the area (see Section 3.3). Potential impacts include short-term behavioural changes, such as avoidance, or wounding and/or mortality in the event of a collision. Cetaceans that are known to be at-risk of collision include fin whales, humpback, gray, minke, southern right and sperm whales (Laist et al. 2001, Jensen et al. 2004). Far fewer reports of strikes exist for blue, Bryde's, sei and killer whales (Laist et al. 2001, Jensen et al. 2004). Certain areas, namely continental shelf and slope, are considered hotspots for collision (Laist et al. 2001). Of the collision-risk species listed above, the sperm whales and killer whale are likely to occur in the research area at the time of proposed survey. Other odontocete species, including beaked whales, are also likely to occur in the area (see Attachment D). Large cetaceans demonstrate a variety of behaviours in response to approaching vessels (attributed to vessel noise), including moving away from the vessel's path with increased swimming speed and longer dive times (Baker and Herman 1989, Scheidat et al. 2004). These behavioural responses are likely to reduce the risk of vessel strike. Research has also shown that most lethal or severe injuries involve ships over 80 m in length and travelling 14 kn or faster (Laist et al. 2001). The RV *Kairei* will be acquiring seismic data on the proposed survey at an average speed of 4–5 kn, which will dramatically reduce the risk of collision with marine fauna. If required, and safe to do so, evasive action may be taken to avoid collisions with marine mammals while the vessel is in transit. In addition to potential physiological impacts as a result of acoustic noise, marine turtles may potentially collide with or become entangled in the towed seismic array, leading to possible injury or death from physical damage or drowning. However, the likelihood of collision or entanglement is considered low given the avoidance behaviour demonstrated for turtles in response to seismic surveys (discussed above). Furthermore, the slow speed of the survey vessel combined with mitigation measures to minimise potential effects (see Section 4 for details on soft-start procedures; early detection of turtles by MMOs) will further reduce the risk of collision and/or entanglement.

Lighting on vessels operating offshore may affect light sensitive marine fauna, such as marine turtles, fish and seabirds. Given the distance of the survey area from known biologically important areas for marine turtles (e.g. significant turtle nesting sites along the eastern coast of Australia), significant impacts to marine turtles are not expected. Studies have shown that nocturnally migrating birds may die or lose a large amount of their energy reserves during migration as a result of encountering and being attracted to artificial light sources of the many offshore platforms in the North Sea (Marquenie et al. 2008, Poot et al. 2008). Artificial light fields around offshore petroleum platforms have also been shown to provide an enhanced foraging environment for larval, juvenile and adult fishes by providing sufficient light to locate and capture prey, as well as by attracting and concentrating positively phototaxic prey taxa (Keenan et al. 2007). As these examples relate to permanent offshore structures, rather than a constantly moving vessel, the potential effects of light emissions from the survey on fish and birds are likely to be less pronounced. Furthermore, the Temperate east Bioregional Plan species report card assesses light pollution from shipping vessels as either 'of less concern' or 'not of concern' for the majority of seabird species identified in the EPBC protected matters search (DSEWPaC 2012c). Lighting is required for safety and navigational purposes on the vessel 24 hours a day during the proposed survey. In sum, the impacts of the proposed seismic activity on turtles, fish and seabirds are likely to be insignificant.

<u>Impact of other acoustic equipment</u>

Other proposed survey equipment capable of generating underwater acoustic noise is summarised in the Table 2.4.2. The table shows equipment mounted to the deep-tow system that will only be operated over targeted areas of seabed covering ~ 50 km^2 for limited periods (i.e. deployments of up to 24 hrs). Echo-sounders and sub-bottom profilers are commonly used in marine geophysical surveys around the world. These acoustic devices transmit sound waves towards the seafloor and use the returning echo to provide information about the seafloor and its shallow underlying geology. There are few published measurements of the underwater sound levels from echo-sounders and sub-bottom profilers across the different frequencies band widths. As a result, there is uncertainty about the potential impact these acoustic devices may have on marine fauna, particularly marine mammals.

Multibeam ecosounders (MBES) designed for seabed mapping have frequencies which typically range from 10 kHz to 1 MHz, corresponding to their various application domains in terms of water depths (Lurton 2016). The auditory frequency range of mysticetes (baleen whales) is thought to lie between 10–20 kHz (depending on species) and a few Hz to a few tens of Hz; while for odontocetes (toothed whales) the optimal auditory bandwidth is in the range from 10 kHz to 100 kHz, with a high-frequency cut-off at 150–180 kHz (also species-dependent)(Lurton 2016). Unlike seismic sources (high intensity, low-frequency, impulsive sounds), MBES have long been considered to cause little direct impact to marine organisms due to their high spatial selectivity and high-frequency range (Lurton 2016). However, despite the inherent characteristics of MBES (i.e. high frequencies, short signals and narrow transmitting lobes), concerns have been raised about their potential impact on marine mammals (e.g. Southall et al. 2013). In response to these concerns, Lurton (2016) modelled the sound field radiated by multibeam ecosounders in the context of their potential impacts on marine mammals. Using a worse-case configuration of a low-frequency 12kHz multisector MBES system (high source level and long pulse duration), Lurton (2016) demonstrated that the computational ranges of impact were negligible for both SPL and SEL – using commonly accepted threshold levels (Southall et al. 2008). However, it is possible that displacement of whales might occur in the form of avoidance from the survey area for the days during the systematic mapping of an area.

The sidescan sonar and MBES mounted to the deep-tow system operate at frequencies of 38–400 kHz and have wide swath angles. However, given that the system will be towed at an elevation 100 m above the seafloor (i.e. 1,400 to 1,600 m below the sea surface), the swath width of this equipment will be relatively narrow (<400 m) and the sound will be directed downwards into soft sediment. Acoustic transmission will therefore be highly localised across absorbent seabed. The sub-bottom profiler mounted to the deep-tow system operates at frequencies of 2–16 kHz and is also highly directional towards the seabed. The received sound levels from all acoustic instruments on the deep-tow (at 1 km from the source) fall below thresholds requiring additional management procedures (Table 2.4.2).

Table 2.4.2: Specifications of deep-tow acoustic equipment

Acoustic equipment					
Deep-tow system (6KSDT)					
Equipment	Operating Frequency	Source Level	Pulse length	SEL received at 500 m from source (dB re µPa^2/Hz)	SEL at 1 km from source (dB re µPa^2/Hz)
MBES (Multibeam Echo Sounder): SEABAT 7125	400kHz	220 dB at 1m	50 µsec ~ 300 µsec	160	155
SSS (Side Scan Sonar)	38kHz (PORT); 42kHz (STBD	227 dB at 1m (PORT); 227 dB at 1m (STBD)	0.2 msec ~ 1 msec	143 (PORT/STBD)	137
SSS (Side Scan Sonar): EdgeTech 2200-M modified	120kHz / 400kHz	226 dB re µPa at 1m	1 ~ 20 msec	155	149
SBP (Sub-bottom Profiler) EdgeTech DW-106	2-16 kHz	183 dB re 1µPa^2.s	66 ms	129	123
Transponder: OKI Electric Industry	13kHz (Rx) 14kHz (Tx)	190 dB at 1m (Rx) 185 dB at 1m (Tx)	9 msec ~ 11 msec	116 111	110 105
Altimeter	120kHz	211 dB at 1m	20µsec ~ 1000 µsec	141	131
DVL: Workhorse Navigator DVL	600 kHz	217 dB re µPa at 1m	6.5 msec	141	135

<u>Seabed disturbance</u>

The temporary deployment of Ocean Bottom Seismometers (OBSs) will occur on areas of flat to gently sloping seabed typically characterised by soft sediment (pelagic mud). Any impact from the presence of OBS on the benthic environment will therefore be short-term in nature and highly localised. The steel anchors that will be left on the seabed following recovery of OBS will slowly corrode but may also be colonised by epibenthic fauna and/or flora. Similarly, impacts on the benthic environment resulting from piston coring, box coring and grab sampling will be highly localised and short-term in nature. The piston corer is a long and heavy tubular tool designed to take a core sample of seafloor sediment (core diameter of ~ 10 cm) to a depth of up to 20 m below the seabed, with minimum disturbance of its sedimentary structures. The grab samplers collect a consistent volume (~40 × 40 cm) of unconsolidated sediments (i.e. mud, sand) using a set of “closable jaws”. Coring and grab sampling will remove some sediment from a localised area of the seafloor and also has the potential to suspend a small amount of sediment which may increase the turbidity of the immediate area, and be deposited on the surrounding benthos. However, this is expected to have minimal impact on the benthic environment. Coring and grab locations will first be investigated using multi-beam, sub-bottom profiles and underwater imagery to avoid sensitive or unique benthic habitats.

<u>Summary</u>

Given the location and timing of the survey, continual movement of the vessel and the control measures to be adopted during the survey activities (refer Section 4), the proposed action is unlikely to have a significant impact on listed threatened species, as identified in the EPBC protected matters search (Attachment E); or on their habitat. The proposed survey is therefore unlikely to cause any of the significant impacts as defined for threatened species in *Significant Impact Guidelines 1.1, Matters of National Environmental Significance* (DoE 2013; see Section 5)

2.5 Is the proposed action likely to impact on the members of any listed migratory species, or their habitat?

A search of the Department of Environments and Energy’s (DoEE) Protected Matters Search Tool database (Attachment E) identified 34 migratory species or species habitat that may occur in the survey area. These species and their current conservation status are shown in Table 2.5.1. Note: threatened and migratory species as highlighted in Table 2.4.1 have been described in in Section 2.4 above. Species listed as Migratory only are described in the section below.

Table 2.5.1. Listed migratory species or species habitats that may (or are likely to) occur within the proposed study area

Listed Migratory Species		
Marine Mammals		
Scientific name	Common name	Status
Balaenoptera bonaerensis	Antarctic Minke Whale, Dark-shoulder Minke Whale	
Balaenoptera borealis	Sei Whale	Vulnerable
Balaenoptera edeni	Bryde's Whale	
Balaenoptera musculus	Blue Whale	Endangered
Balaenoptera physalus	Fin Whale	Vulnerable
Eubalaena australis	Southern Right Whale	Endangered
Lagenorhynchus obscurus	Dusky Dolphin	
Megaptera novaeangliae	Humpback Whale	Vulnerable
Orcinus orca	Killer Whale, Orca	
Physeter macrocephalus	Sperm Whale	
Turtles		
Species	Common name	Status
Caretta caretta	Loggerhead Turtle	Endangered
Chelonia mydas	Green Turtle	Vulnerable
Dermochelys coriacea	Leatherback Turtle, Leathery Turtle	Endangered
Eretmochelys imbricata	Hawksbill Turtle	Vulnerable
Natator depressus	Flatback Turtle	Vulnerable
Elasmobranchs		
Species	Common name	Status
Carcharodon carcharias	White Shark	Vulnerable
Isurus oxyrinchus	Shortfin Mako, Mako Shark	
Isurus paucus	Longfin Mako	
Lamna nasus	Porbeagle, Mackerel Shark	
Manta alfredi	Reef, Coastal, Inshore, Prince Alfred's, Manta Ray	
Manta birostris	Giant, Chevron, Pacific, Pelagic, Oceanic, Manta Ray	
Rhincodon typus	Whale Shark	Vulnerable
Seabirds		
Scientific name	Common name	Status
Anous stolidus	Common Noddy	
Diomedea epomophora	Southern Royal Albatross	Vulnerable
Diomedea exulans	Wandering Albatross	Vulnerable
Fregata ariel	Lesser Frigatebird, Least Frigatebird	
Fregata minor	Great Frigatebird, Greater Frigatebird	
Macronectes giganteus	Southern Giant-Petrel	Endangered
Macronectes halli	Northern Giant-Petrel	Vulnerable
Puffinus carneipes	Flesh-footed Shearwater	
Thalassarche cauta	Tasmanian Shy Albatross	Vulnerable*
Thalassarche melanophris	Black-browed Albatross	Vulnerable
Migratory Wetland Species		
Scientific name	Common name	Status
Calidris ferruginea	Curlew Sandpiper	Critically Endangered
Numenius madagascariensis	Eastern Curlew, Far Eastern Curlew	Critically Endangered

(*Species is listed under a different scientific name on the EPBC Act - Threatened Species list).

Mammals

In addition to the five listed threatened species of baleen whale described in Section 2.4, Bryde's whales and Antarctic minke whales are listed Migratory species that may occur in the proposed survey area (Table 2.5.1; Figure 3). Three odontocete species, the sperm whale, killer whale and dusky dolphin, are also listed Migratory species that may occur in the region (Table 2.5.1; Figure 3).

Bryde's whales (*Balaenoptera edeni*) are small balaenopterids found in pelagic temperate to tropical waters, both oceanic and inshore (DoE 2015c). Due to uncertainty regarding inshore and offshore forms of Bryde's Whales, their life history and migratory movements are difficult to ascertain. However, no evidence exists for large-scale movements for the inshore form, while seasonal migrations to tropical waters during winter are possible for offshore forms of Bryde's Whales (DSEWPaC 2012a, DoE 2015c). Insufficient information exists as to how Australian Bryde's whales use their habitat, as no specific feeding or breeding grounds have been documented off Australia (DoE 2015c). While the recognised range of Bryde's whales extends into the Tasman Sea, the likelihood of the survey vessel encountering this species is low.

Antarctic Minke Whales (*Balaenoptera bonaernsis*) often occupy offshore and pelagic waters to >600 m depths within cold temperate Antarctic waters between 21° and 65° (DoE 2015a). Their distribution along the west coast of Australia is currently unknown; however, they are known to occur north to 21° S off the east coast (Bannister et al. 1996). Mating periods occur between June and December, and the gestation period lasts approximately 10 months (late May-June) within the warmer waters north of the Antarctic Convergence (ca 50°S). This species migrates between the summer Antarctic feeding grounds and winter sub-tropical to tropical breeding grounds (DoE 2015a). They have been reported up to 350 km south of the ice edge during winter, suggesting that some portions of the population may over-winter in higher latitudes (Thiele and Gill 1999, Perrin and Brownell Jr 2002). The likelihood of the survey vessel encountering or coming within close proximity to Antarctic Minke whales is low given the known migration patterns of this species.

Sperm whales (*Physeter macrocephalus*) are a cosmopolitan species commonly found in deep, pelagic, offshore waters and have been recorded offshore from all Australian states (Bannister et al. 1996). Key localities include: the area between Cape Leeuwin and Esperance, WA, close to the edge of the continental shelf (averaging 20 to 30 nautical miles offshore); south-west of Kangaroo Island, SA; off the Tasmanian west and south coasts; off New South Wales, including Wollongong; and off Stradbroke Island, Queensland (Bannister et al. 1996). The area of occupancy of sperm whales remains uncertain due to the paucity of records for pelagic waters off Australia and the Australian subantarctic and Antarctic territories (DoE 2015i). Female and young male sperm whales appear to be restricted to warmer waters north of about 45° S in the Southern Hemisphere, while adult males travel to and from colder waters of Antarctica (Bannister et al. 1996, Lyrholm et al. 1999). Sperm whales feed on a variety of large squids (Evans and Hindell 2004) and fishes and tend to inhabit the offshore continental margin where canyons are present or the seabed rises steeply resulting in high concentrations of prey due to upwelling (Bannister et al. 1996).

During the 2016 Lord Howe Rise Marine seismic survey (EPBC Referral 2015/7623) marine fauna monitoring effort was conducted over a period of 39 days and included a total of 442 hours and 33 minutes of visual observations and 456 hours and one minute of passive acoustic monitoring (PAM). A total of 29 marine fauna sightings and 50 marine fauna detections were recorded during this time. Of these, sperm whales accounted for 21 (72%) of the 29 sightings and 35 (70%) of the 50 acoustic detections. Although no biologically important habitat for sperm whales has been proposed within the vicinity of the study area, canyon features on the eastern continental slope and the Tasmantid seamount chain provide ideal feeding grounds for this species and sighting records obtained from the first site survey completed in 2016, as well as the Atlas of Living Australia, confirm their presence in the region (Figure 3; Marine Fauna Observation Report 2016). Given these findings it is highly likely that sperm whales will again be encountered in the survey area.

Killer whales (*Orcinus orca*) are found throughout the world's oceans and are widely recognised as predators of other marine mammals, including large sperm and baleen whales (Jefferson et al. 1991, Forney and Wade 2006). In Australia, killer whales have been recorded from all coastal waters, with concentrations around Tasmania (Bannister et al. 1996), frequent sightings in South Australia and Victoria (Ling 1991) and in the Antarctic south of 60° (Bannister et al. 1996, Pitman and Ensor 2003). The species is distributed from the equator to polar waters, and is generally more common at higher latitudes in highly-productive, near-shore areas (DSEWPaC 2012a). Killer whales forage in the Temperate East Marine Region and are likely to breed in and migrate through the region (DSEWPaC 2012a). It is possible that this species may be encountered during the survey, although numbers are not anticipated to be high.

Dusky dolphins (*Lagenorhynchus obscurus*) are widely distributed in southern cool temperate waters from about 55° to 26°S, but with extensions north of this latitudinal range in association with cold currents (Bannister et al. 1996). They are distributed across southern Australian waters from Western Australia to Tasmania (Gill et al. 2000) and are listed as Migratory under the EPBC Act (Table 2.5.1). This cetacean species is known to occur in the Temperate East Marine Region on an infrequent basis (DSEWPaC 2012a). It is unlikely that this species will be encountered in large numbers within the proposed study area.

<u>Sharks</u>

In addition to the aforementioned white shark and whale shark (see Section 2.4), shortfin and longfin Mako and Porbeagle sharks are also listed as Migratory under the EPBC Act (Table 2.5.1). These sharks are wide-ranging, highly migratory, pelagic species, found predominately in deeper offshore oceanic waters where they utilise productivity hotspots generated by currents and eddies as key foraging sites (DSEWPaC 2012d; Figure 4). The Temperate East Marine Region and its adjacent state waters are known to play an important role for these species, providing key breeding, feeding and aggregation rounds.

The shortfin Mako (*Isurus oxyrinchus*) is an epipelagic shark known to occur in both tropical and temperate waters >16 °C (Last and Stevens 2009). It is normally oceanic and cosmopolitan in its distribution and is widespread occurring from the surface to water depths of at least 888 m (Stevens 2010, Abascal et al. 2011). It is widely distributed in Australian waters, with the exception of the Arafura Sea, Gulf of Carpentaria and Torres Strait, and is occasionally found close inshore (Last and Stevens 2009). Shortfin Mako feed mainly on teleost fish and cephalopods, with larger individuals (>3m) known to take larger prey such as billfish and small cetaceans (Last and Stevens 2009). The targeted commercial take of shortfin Mako is prohibited in Commonwealth waters; however, individuals can be retained (as byproduct) if they are dead upon capture (DSEWPaC 2012d). The longfin Mako (*Isurus paucus*) is a widely-distributed epipelagic shark (Reardon 2006). This species is deep-dwelling (usually between 120 and 240 m) and appears to be cosmopolitan in tropical and warm temperate waters; however its distribution within Australia remains unclear and it is often confused with the more common shortfin Mako (DSEWPaC 2012d). Sighting records obtained from Atlas of Living Australia confirm their wide-ranging migratory movements (Figure 4). It is therefore highly likely that both species of Maki may transit the survey area and surrounding waters.

The porbeagle shark is a wide-ranging, oceanic species found in subtropical and temperate of the North Atlantic and Southern Hemisphere (1 to 18°C), although it is more commonly found on continental shelves. In Australia, it occurs from southern Queensland to south-west Australia (Last and Stevens 2009). Porbeagle sharks have been shown to occupy a broad depth range (0 – 552 m), diving frequently from the surface to near the seabed in shelf areas and making extended dives in shelf-edge habitats >300 m (Pade et al. 2009), while mature female porbeagles have also been shown to migrate up to 2,300 km through the winter, at depths down to 1360 m (Campana et al. 2010). Little data exists for Southern Hemisphere populations, although they are thought to give birth off New Zealand and Australia in winter (Francis and Stevens 2000).

The giant manta ray (*Manta birostris*) is usually found offshore, often around oceanic islands, sometimes coastal, and most commonly in tropical waters. They are large filter-feeding elasmobranch fishes that have a circumglobal distribution (Last and Stevens 2009) and like other large planktivorous elasmobranchs (e.g. *Rhincodon typus*), they exhibit long-distance migrations. However, little is known about its distribution and movement patterns along Australia's east coast (Couturier et al. 2011). Although this species may transit through the survey area and surrounding waters (see Figure 4), it is unlikely to be encountered in large numbers within the survey area.

<u>Turtles</u>

The five species of marine turtle likely to occur within the proposed survey area are also classified as Threatened species, and have been described in Section 2.4.

<u>Seabirds</u>

The majority of vulnerable and endangered albatross and petrel species (order Procellariiformes) listed as Threatened species (Table 2.4.1) are also listed as Migratory (Table 2.5.1) in the EPBC Act. Additional migratory species likely to occur in the study area include the Flesh-footed Shearwater (*Puffinus carneipes*). The world's largest population of Flesh-footed Shearwaters on Lord Howe Island in eastern Australia has been declining for more than two decades as a result of bycatch in long-line fisheries (Baker and Wise 2005) and loss of nesting habitat (Lavers et al. 2014). This species mainly forages offshore over continental shelves, where it feeds on fish and squid and may therefore be encountered during the survey.

The potential impacts to listed migratory marine species are the same as those described for listed threatened species in Section 2.4. As summarised above, the proposed survey will be short in duration and managed to mitigate impacts to as low as reasonably practicable (see Section 4). To this end, the proposed survey is unlikely to cause significant impacts as defined for migratory baleen whales, turtles, fish or seabirds. Additional discussion on potential acoustic-related impacts to high-frequency cetaceans is provided below.

<u>Whales</u>

Mid- and high-frequency cetaceans are all odontocetes (toothed whales) which have an auditory bandwidth range between 150 Hz and 180 kHz. Unlike the mysticetes, all odontocete cetaceans appear to have highly advanced echolocation (biosonar) systems that use intermediate to very high frequencies (Southall et al. 2007). Sperm whales are the largest odontocetes and are thought to have better low frequency hearing than smaller odontocetes and may thus be more vulnerable to potential disturbance from seismic surveys (Gordon et al. 2003). However, the reactions of sperm whales to seismic noise vary among studies. Mate et al. (1994) found a negative correlation between seismic surveys and the presence of sperm whales in the Gulf of Mexico, and Bowles et al. (1994) reported that sperm whales ceased clicking, possibly as a response to seismic survey pulses, with received levels some 15 dB above background noise levels. In contrast, Stone and Tasker (2006) reported that sighting rates of sperm whales did not differ significantly with seismic surveys and Madsen (2002) demonstrated that exposure to the seismic survey pulses did not elicit observable avoidance or changes in vocal patterns during feeding dives. Moreover, examination of the behaviour of sperm whales before, during and after five separate 1–2 h controlled sound exposures of airgun arrays in the highly-exposed Gulf of Mexico, showed that sperm whales did not exhibit avoidance reactions to airguns (Miller et al. 2009). Small odontocetes have shown strong lateral spatial avoidance and there is some evidence to suggest that killer whales may demonstrate localised spatial avoidance of seismic sounds (Stone and Tasker 2006).

Observations of beaked whale strandings coincident with mid-frequency naval sonar (e.g. Jepson et al. 2003) have focused attention on the potential impact of such sounds on beaked whales (particularly Cuvier's beaked) (reviewed in Barlow and Gisiner 2006, Cox et al. 2006, Tyack et al. 2011). The potential impacts of anthropogenic noise, including seismic airgun emissions, on beaked whales remain poorly understood, partly due to their elusive nature (Cato et al. 2009, Tyack et al. 2011). Some marine mammals show strong avoidance responses when evading predators and sounds from tactical mid-frequency sonars somewhat resemble, in frequency band and modulation, the social signals of one of the only predators of large marine mammals, the killer whale (Southall et al. 2007). However, it remains unknown as to whether beaked whales in certain conditions mistake tactical mid-frequency sonar signals for killer whales and consequently change their behaviour (Southall et al. 2007).

While the survey area does not overlap with any known biologically important areas for sperm whales or beaked whales, it is highly likely that these species may be encountered due to the presence of suitable habitat for foraging (see Section 2.4). Sound modelling results indicate that seismic pulses with received levels of 180 dB re 1 µPa or more are restricted to a radius of approximately 300 m around the seismic airgun array, therefore the potential for PTS and TTS is low as a whale would need to be less than one kilometre from the airgun array and remain within this range for a period of time to sustain this level of hearing impairment. PTS and TTS were predicted to occur in mid- and high-frequency cetaceans at ≤50 m and the ranges for TTS in mid- and high frequency cetaceans were predicted to be ≤224 m (see Attachment C and D). It is possible that these whales may exhibit avoidance behaviour in response to the seismic source, but such a response is likely to be temporary and localised and unlikely to lead to significant impacts at the population level.

Due to the likelihood of encountering sperm whales and/or beaked whales, increased precaution and buffer zones, in conjunction with adaptive management procedures will be implemented (see Section 4). The vocalisations of *Ziphius cavirostris* (Cuvier's beaked whale) and *Mesoplodon densirostris* (Blainville's beaked whale) are distinctively different in several acoustical characteristics from those of other toothed whales, providing a reliable means of detection and identification (Cato et al. 2009). The planned use of Passive Acoustic Monitoring (PAM) will therefore provide an effective means of mitigation. Given the ability of cetaceans to avoid vessels and the acoustic source and the adoption of proposed mitigation measures (see Section 4), it is highly unlikely that cetaceans will be exposed to sound levels that may cause pathological damage or permanent threshold shifts in hearing. In addition, the short duration and transient nature of the survey will mean that it is unlikely to cause long-term disturbance to or displacement of marine mammals that may be present in the survey area.

<u>Summary</u>

Given the location and timing of the survey, continual movement of the vessel and the control measures to be adopted during the seismic activities (refer Section 4), the proposed action is unlikely to have a significant effect on any listed migratory species as identified in the EPBC protected matters search (Attachment E); or on their habitat. The proposed survey is therefore unlikely to cause any of the significant impacts as defined for migratory species in Significant Impact Guidelines 1.1, Matters of National Environmental Significance (DoE 2013; see Section 5).

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