7 ENVIRONMENTAL IMPACT ASSESSMENT – PLANNED EVENTS

This section of the EP presents the results of the impact assessment of planned events for the Eureka 3D MSS using the methodology described in Section 6. As required by Section 21 of the OPGGS(E) Regulations, this assessment demonstrates that the impacts associated with the activity will be reduced to ALARP and to an acceptable level. Potential impacts associated with transit of the survey vessel and support/chase vessels to and from the OA, are considered outside the activity and therefore outside the scope of this EP and assessment. A summary of the impacts risk ranking for the Eureka 3D MSS is presented in Table 7-1.

Table 7-1: Summary of risk rankings for Identified impacts during the Eureka 3D MSS

Potential impacts and risks	Residual risk ranking
Impacts (expected to occur during routine operations)	
Underwater sound – seismic operations	Low – Moderate
Underwater sound – vessel operations	Low
Interactions with other marine users	Low - Moderate
Light emissions – vessels	Low
Routine discharges – vessels	Low
Atmospheric emissions – vessels	Low
Seabed disturbance – placement of ocean bottom nodes	Low

7.1 Impact 1: Underwater sound – seismic operations

In accordance with the Pilot Energy risk assessment methodology (Section 6) this impact is classified as higher order. Therefore, an additional assessment and detail is required to demonstrate this impact is of an acceptable level.

7.1.1 Identification of hazard and extent

Hazard	The activity is a typical 3D survey like most seismic surveys conducted in Australian marine waters in terms of technical methods and procedures. During the survey, ocean bottom nodes (OBN) may be used within a small area in shallow waters (Node Survey Area) within the ASA; therefore, this activity has been included in this assessment. The dominant source of underwater noise during the Eureka 3D MSS will be from the operation of the seismic source (airgun array). The airgun array will have a maximum volume of 2495 in^3 in the streamer area and 1420in^3 in the nodal area During the proposed activity, the seismic survey streamer vessel will traverse a series of pre-determined sail lines at approximately 300m apart, within the ASA at a speed of approximately 4.5 knots (8 km/hr), with a 50m source line spacing on the nodal component as a similar vessel speed. Seismic data will be acquired with the source active in water depths of between 10 to 52 m for up to 40 days. The seismic array is highly directional, focussing sound energy on the seabed but will also ensonify the surrounding water column to a lesser extent, as demonstrated by the acoustic modelling. The underwater sound generated by the array will be strongest at the source and rapidly decrease with distance from the source. Marine biota will be exposed to different received levels of sound energy, depending on their behaviour e.g., whether they flee or are affiliated with habitat or oceanographic features, and where they are in relation to the source. However, actual near-field and far-field received sound levels are influenced by several factors including the overall size (capacity) of the acoustic source, the array configuration, water depths in the area, position in the water column, distance from the source and acoustic properties of the seabed.
Extent	The areas of ensonification for marine fauna groups are based on the largest area of effect predicted by the underwater sound modelling for the marine fauna thresholds (Appendix G(i) & (ii)) applied to this assessment. These areas are defined by the following distances from the source: • Plankton – up to 280 m from the source (based on mortality recorded by McCauley et al. 2017) • Sponges and coral – up to 15 m from the source (based on sound levels reported in Heyward et al. 2018 as causing no effects) • Crustaceans (e.g., Lobsters and prawns) – up to 292 m from the source (based on sub-lethal effects recorded by Day et al. 2016a, 2016b) • Squid – up to 2.9 km from the source (based on startle response recorded by Fewtrell & McCauley 2012) • Fishes (demersal species, including site-attached species) – up to 4.06 km from the source (based on TTS effects for accumulated 24-hour exposure scenario) • Fishes (pelagic and demersal species) up to 4.06 km from the source • Marine turtles – up to 60 m from the source (based on PTS effects for accumulated 24-hour exposure scenario) • Marine turtles (behavioural response) – up to 4.9 km from the source • Low-frequency cetaceans (pygmy blue, southern right, humpback whales) – potentially up to 43 km from the source (based on TTS effects for accumulated 24-hour exposure) • High-frequency cetaceans (dolphins, beaked whales, sperm whales – potentially up to 9.2 km from the source (behavioural response) • Very high-frequency cetaceans – potentially up to 9.2 km from the source (behavioural response) • Pinnipeds (sea lions) – potentially up to 9.2 km from the source (behavioural response).
Duration	Duration of survey – up to 40 days in early February to the end of March. This includes 30 days of acquisition with additional time for weather and/or fauna downtime and potential infill.

7.1.2 Defined acceptable levels

Pilot Energy's risk assessment methodology for demonstrating that impacts and risks are at an acceptable level distinguishes between higher-order and lower-order impacts and risks. For lower-order impacts and risks, acceptability is demonstrated when the impact or risk has been shown to be reduced to as low as reasonably practicable (ALARP). However, for the underwater sound impact from seismic operations, an additional demonstration is required. Before the assessment, acceptable levels of impact are defined (below). Once the assessment is complete, the predicted impact levels are compared with these predefined acceptable levels. If the predicted levels are lower than the defined thresholds, the impact is at an acceptable level.

Marine receptors (general)

AL 1. Seismic operations (including soft starts / ramping up) are limited to within the OA

AL 2. Seismic discharge intensities are always limited to the minimal levels while performing operational objectives

AL 3. Soft starts of airgun array will be used every time the array is first started

AL 4. Zoning of ASA to reduce potential impacts on BIAs and to avoid intense sonification of any one area for the duration of the survey.

Plankton (incl. fish larvae, eggs)

AL 5. Minimise overlap of seismic acquisition with spawning activity in important areas for fish/ invertebrates

AL 6. No long-term impact to zooplankton communities or zooplankton biomass resulting in alteration to ecosystem functioning or population effects.

Fishes (incl. spawning)

AL 7. Survey has negligible effects on the spawning output of commercially important species likely to be present within the OA

AL 8. The activity is not inconsistent with any relevant objectives of the Recovery Plan for the White Shark (DSEWPAC 2013b) as demonstrated by the impact assessment in this EP (refer Section 9)

AL 9. No population or ecosystem level effects

AL 10. No impacts to fish populations that would impact the sustainability of fish stocks within the OA

Invertebrates (incl. spawning)

AL 11. Survey has negligible effects on the spawning output of commercially important species likely to be present within the OA

AL 12. No population or ecosystem level effects

AL 13. No injury to cephalopod populations which would affect the sustainability of commercially fished cephalopod stocks.

Marine turtles

AL 14. Predicted effects limited to behavioural disturbance of a small number of individuals

AL 15. The activity is not inconsistent with any relevant objectives of the Recovery Plan for Marine Turtles (DSEWPAC 2013b) as demonstrated by the impact assessment in this EP (refer Section 9)

AL 16. No predicted impacts on breeding, migration or foraging of marine turtles

AL 17. No population level effects.

Cetaceans

AL 18. Application of measures defined in Part A and Part B of EPBC Act PS 2.1 and additional measures if necessary to align with conservation management plans and good practice

AL 19. No displacement or exclusion of foraging, aggregating, calving/breeding, migrating cetaceans from BIAs

AL 20. This activity is not inconsistent with the relevant management actions in the Conservation Management Plan for the Blue Whale (Commonwealth of Australia 2015a):

a. PBWs will continue to use BIAs without injury and are not displaced from foraging areas

b. Apply Part A and B measures where relevant as specified in the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales

c. Behavioural impacts are to be considered when assessing the effect of anthropogenic noise on PBW

AL 21. This activity is not inconsistent with the relevant recovery actions in the Draft National Recovery Plan for the Southern Right Whale (DCCEEW 2024a):

a. The activity will not prevent any SRW from utilising a BIA, or cause injury (TTS and PTS) and/or disturbance

b. Apply the measures specified in the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales

c. Behavioural impacts are to be considered when assessing the effect of anthropogenic noise on SRW

AL 22. This activity aligns with the management actions of the humpback whale Conservation Advice by:

a. Performing site-specific underwater acoustic modelling to assess the impacts from noise on cetaceans

b. Applying standard measures specified in the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales (because the seismic survey is not within known calving, resting, foraging or a confined migration pathway, additional measures for HBW are not required)

AL 23. This activity aligns with the management actions of the sei whale and fin whale Conservation Advice for an assessment of noise impacts

AL 24. No population level effects.

Australian sea lion

AL 25. Predicted effects limited to short term behavioural disturbance of a small number of individuals

AL 26. This activity is not inconsistent with the relevant management actions in the Recovery Plan for the Australian Sea Lion (DSEWPC 2013a)

AL 27. Australian sea lions continue to forage within foraging BIAs

AL 28. Prey species (i.e. western rock lobster, octopus and cuttlefish) remain available within foraging BIA with impacts limited to temporary and localised (within 3 km of moving array) behavioural disturbance

AL 29. No population level effects.

Commercial and recreational fisheries

AL 30. ASA reduced to as small an area as possible to minimise overlap with habitats for adult rock lobster, but some habitat overlap is acceptable

AL 31. Stakeholder concerns/objections received have been merit assessed and changes to survey activity have been adopted, or control measures developed to address merited concerns/objections, where required. No outstanding merited concerns that are not being addressed

AL 32. Some short-term disruption of fishers with fixed equipment within the ASA (i.e. WRL and octopus fishers) is acceptable

AL 33. Some short-term displacement of other commercial and recreational fishing activities from the Safe Navigation Area (SNA) during seismic acquisition is acceptable

AL 34. No ongoing impact on catchability as fishes/invertebrates predicted to recover in the short-term after survey completion.

Protected areas and KEFs

AL 35. No impacts on the values of the Abrolhos Marine Park

AL 36. No impacts on the values of the Jurien Marine Park

AL 37. No impacts on the values of the Western rock lobster KEF

AL 38. No impacts on the values of the Commonwealth marine environment within and adjacent to the west coast inshore lagoons.

Tourism and recreation

AL 39. No long-term impacts on local tourism and recreational activities (e.g. Diving, snorkelling, spearfishing, sea lion tours)

AL 40. Some short-term disruption during seismic acquisition is acceptable.

7.1.3 Sound metric terminology

7.1.3.1 Sound levels and the decibel scale

The decibel (dB) scale is used to measure the amplitude or 'loudness' of a sound wave. For underwater sounds, the dB scale is denoted relative to the reference pressure of 1 micro pascal (µPa) e.g., dB re 1 µPa, whereas the reference pressure level used in air is 20 µPa, which was selected to match human hearing sensitivity. Because of these differences in reference standards, dB sound levels in air are not comparable to underwater sound levels i.e., dB sound levels underwater are much quieter than the same dB sound levels in air (Carroll et al. 2017).

7.1.3.2 Sound metrics

Marine seismic surveys emit pulses of underwater sound. These sounds are termed 'impulsive' sounds as they are brief and intermittent with rapid rise times and decay back to ambient levels (within a few seconds).

There are four main metrics used to measure and describe underwater sound pressure and energy that are applied to the assessment of these types of sound, all of which use the decibel scale (adapted from ISO/DIS 18405.2:2017):

- Zero-to-peak sound pressure (PK), the greatest magnitude of the sound pressure during a specified time interval (Figure 7-1); unit: db re 1 µpa; PK levels are relevant to the assessment of potential physical injury and impairment impacts to marine fauna and biota resulting from a single seismic pulse
- Peak-to-peak sound pressure (PK-PK), sum of the peak compressional pressure and the peak rarefactional pressure during a specified time interval (approximately double the zero-to-peak pressure) (Figure 7-1); unit: db re 1 µpa; PK-PK levels, like PK levels, are relevant to the assessment of potential physical injury and impairment impacts to marine fauna and biota resulting from a single seismic pulse
- Root-mean-square sound pressure level (SPL), the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure over the duration of an acoustic event (i.e. the duration of a single seismic pulse) (Figure 7-1); unit: db re 1 µpa; because the SPL represents the effective sound pressure over the full duration of the acoustic event rather than the maximum instantaneous peak pressure, it is regularly used to represent the effective loudness of a sound and to assess the potential for a behavioural response from marine fauna

- Sound exposure level (SEL), a measure related to the sound energy (instead of the sound pressure) in one or more pulses, or the ratio of the time-integrated squared sound pressure to the specified reference value; unit: db re 1 $\mu pa^2 \cdot s$; SEL is specified in terms of either a per-pulse SEL or an accumulated SEL (sel_{cum}) from multiple pulses over a given period. SEL recognises that the effects of sound can be a function of exposure duration as well as maximum instantaneous peak pressure. SEL can therefore be considered a dose-type measurement with sel_{cum} being used to assess dose-type impacts such as the potential for the gradual onset of temporary threshold shift (TTS) in marine fauna hearing because of prolonged exposure to high sound levels. It is standard practice for sel_{cum} to be assessed over a summation period of 24-hours (SEL_{24h}).

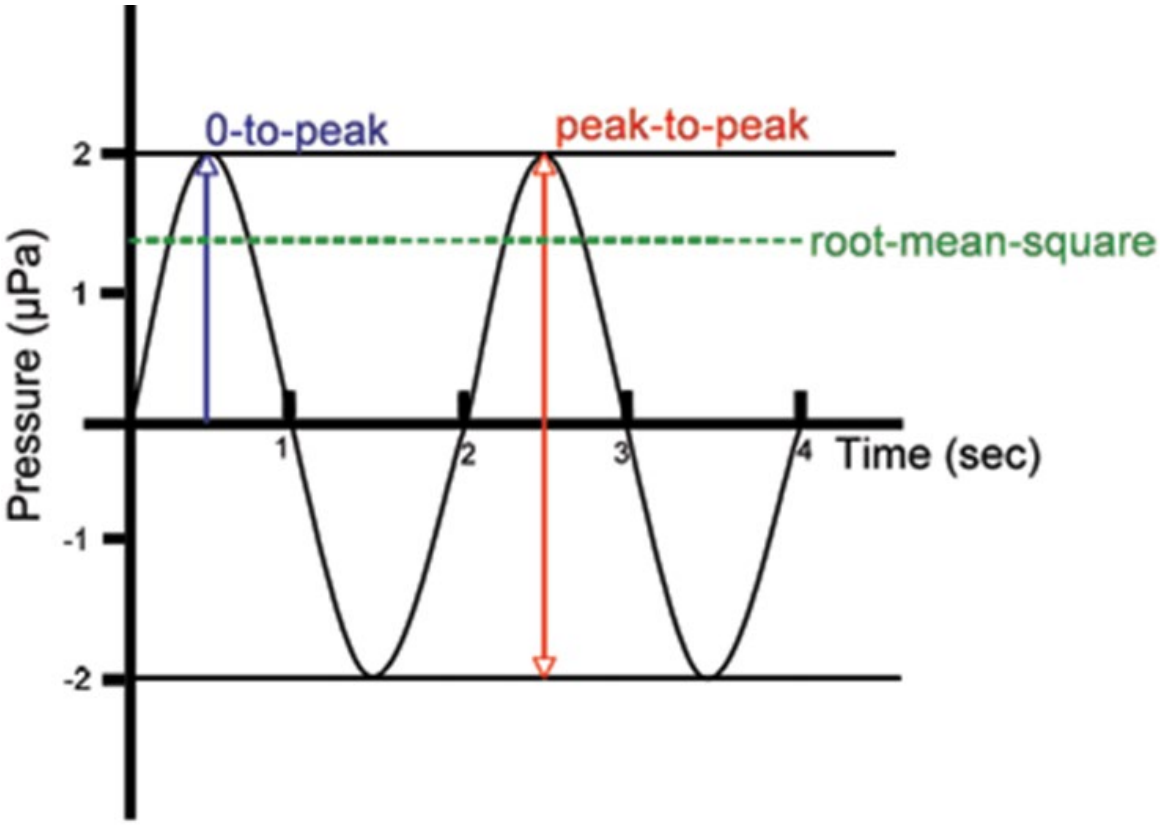


Figure 7-1: Simplified sound wave and sound pressure metrics (DOSITS1)

7.1.3.3 Particle motion

The particle motion component of sound is also relevant to the assessment of potential impacts to marine fauna. Acoustic particle motion refers to the physical motion caused by a sound wave within the water, seabed or other medium. Unlike pressure, particle motion is directional in nature, although the actual to-and-fro particle displacements that constitute sound are extremely small, in the order of nanometres (Popper & Hawkins 2018). Particle motion can be described in terms of particle displacement (m), velocity (m/s), or acceleration (m/s^2) (Popper et al. 2014; Carroll et al. 2017). Alternatively, it is sometimes expressed in dB with respect to a reference value of displacement (dB re 1 pm), velocity (dB re 1 nm/s) or acceleration (dB re 1 $\mu m/s^2$) (Nedelec et al. 2016).

Particle motion is important because marine invertebrates and most fishes are primarily sensitive to particle motion rather than sound pressure and, therefore, particle motion is the most relevant metric for perceiving underwater sound by invertebrates and most fish species (Popper & Hawkins 2019). However, there is currently limited information available to quantify the particle motion sensitivity of fishes and invertebrates. It is complex and challenging to directly measure particle motion compared to sound pressure, hence most research is presented in the context of sound pressure or exposure levels instead of particle motion (Carroll et al. 2017; Popper & Hawkins 2018). Therefore, while the assessment

of underwater noise impacts in this EP considers the role of particle motion and its effect on fishes and invertebrates, the acoustic modelling and impact threshold criteria are based upon sound pressure and sound exposure metrics.

It should be noted that particle motion is most relevant close to the source where it is the dominant component of a sound wave, while pressure will dominate a sound wave propagating over distance (Radford et al. 2012; Morley et al. 2014; Nedelec et al. 2016; Popper & Hawkins 2018). Sound pressure levels received at increasing distance from a source do not, therefore, provide a reliable representation of particle motion. Organisms that are sensitive only to particle motion have typically been found to be sensitive only at close range where these particle motions are greatest (Popper et al. 2014; Edmonds et al. 2016; Popper & Hawkins 2018).

7.1.3.4 Sound frequency and hearing sensitivity

Different animals are sensitive to different sound frequencies, which are measured in hertz (Hz) and kilohertz (kHz). Therefore, if an animal is sensitive to a particular frequency range, a sound in that frequency range will seem louder to that animal than to a different animal which is less sensitive to those frequencies. For example, some large baleen whales are sensitive to very low frequency sounds (7 Hz to 35 kHz), while other toothed whales and dolphin species are considered more sensitive to mid-high frequency sounds (150 Hz to 160 kHz) with their peak hearing frequency somewhere between these frequency ranges (NMFS 2018). Therefore, how loud a sound will be perceived will differ between species.

In some cases, a sound level is specified relative to a given frequency range or is weighted according to the auditory sensitivity of an animal (e.g., low-frequency, medium-frequency and high-frequency groups of cetaceans). This has the advantage of placing the sound into a more biologically relevant context for that animal. If a frequency range or weighting is not specified, the frequency of the sound is generally referred to as “broadband” sound i.e., the sound level accounts for sound across all frequencies, noting again that a particular animal may not be able to detect all the sound frequencies and associated energy that are emitted.

Therefore, the frequency of a sound and how sensitive different animals are to sound can make a considerable difference to how loud the sound is perceived to be and any resultant impact.

7.1.4 Acoustic modelling

To assess the potential magnitude and extent of impacts from underwater noise produced during the Eureka 3D MSS, Pilot commissioned JASCO Applied Sciences (JASCO) to model sound propagation at several locations that were representative of the different water depths, bathymetry and seabed properties within the ASA (Koessler & McPherson 2023; Appendix G(i)).

The objective of this acoustic modelling study was to evaluate the potential effects of sound on marine fauna including marine mammals, turtles, fishes, elasmobranchs, benthic invertebrates and zooplankton, and on socio-economic receptors such as commercial and recreational fisheries and divers.

Two nominal acquisition scenarios were considered using both acoustic source and propagation modelling to evaluate accumulated sound exposure. Acoustic source and propagation modelling was also conducted at six individual single pulse sites. The single pulse sites and the accumulated SEL scenarios were determined based on proposed survey line plans with lines orientated either at 0/180°. The locations of the modelled sites are provided presented in Figure 7-2. This study considered a 2495 in^3 seismic source towed in a double array configuration at an assumed speed of ~4.5 knots with an impulse interval (inter-pulse interval) of 12.5 m and a crossline array separation of 50 m. The acoustic propagation modelling utilised an August sound speed profile as resulted in worst-case propagation conditions (i.e., longer propagation ranges) and can therefore be regarded as ‘worst-case’ for the proposed acquisition period (February–March) for the survey.

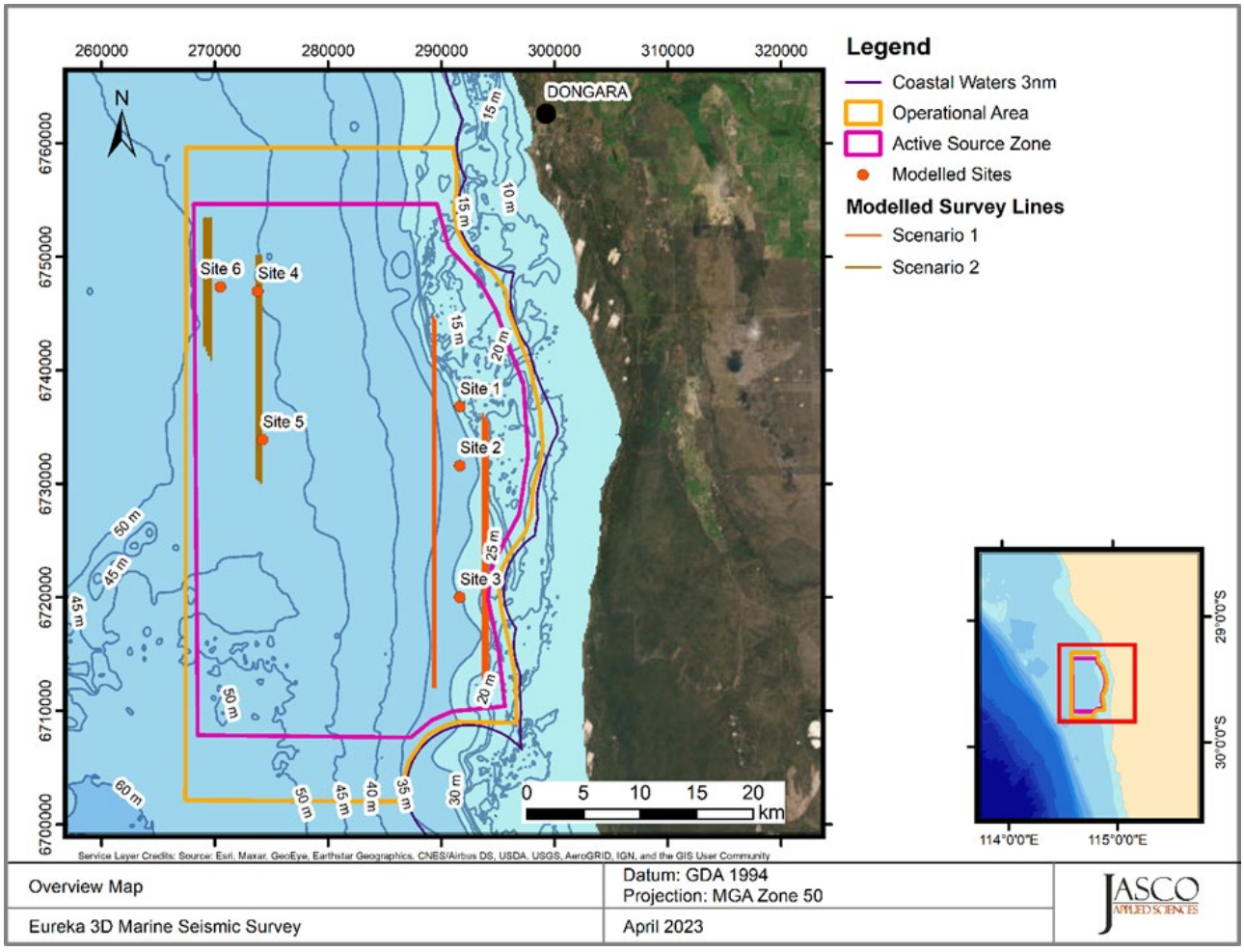


Figure 7-2: Overview of key survey features, modelling locations and the two survey scenarios (Appendix G(i))

The single impulse sites and accumulated SEL scenarios were chosen to be representative of the range of water depths and the potential sound propagation characteristics within the ASA. Sea floor sound levels were assessed at eight different representative water depths within the ASA (10, 12.5, 15, 20, 25, 30, 40, and 50 m).

Contours of the modelled underwater sound fields were computed, sampled either as the maximum value over all modelled depths (maximum-over-depth: MOD) or at the sea floor for the six single pulse locations, and for the two cumulative SEL_{24h} scenarios. The modelled distances to each of the sound exposure thresholds for marine fauna were computed from these contours. Two distances relative to the source are reported for each sound level:

- R_{max} – the maximum range to the given sound level over all azimuths
- $R_{95\%}$ – the range to the given sound level after the 5% farthest points were excluded.

The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment. In some environments a sound level contour might have small anomalous isolated fringes in which case the use of R_{max} can misrepresent the area of the region exposed to such effects. In these instances, $R_{95\%}$ is considered more representative. In environments that have bathymetric features that affect sound propagation then the $R_{95\%}$ may neglect to account for these and therefore R_{max} might better represent the region of effect in specific directions. For this impact assessment the R_{max} values have been considered. In many of the impact assessments, the maximum R_{max} values resulting from the various modelling sites have been referenced (unless specified) which provides a further level of conservatism to the assessment.

The results of the acoustic modelling are presented in relation to the sound exposure thresholds relevant to each receptor group assessed below. The detailed results are provided in the acoustic modelling report (Koessler & McPherson 2023; Appendix G(i)).

Due to changes in seismic data acquisition plans in the nodal area, Pilot commissioned JASCO to undertake additional modelling in the nodal area, the full report available to view in Appendix G(ii). This modelling includes an additional acquisition scenario that reflects the acquisition plan within the nodal area, i.e., a smaller 1440 in^3 airgun array towed in a double array configuration at an assumed speed of ~5 knots with a 50 m shot point interval and 50 m line spacing. This secondary modelling study also included a new single pulse site at a depth of 15 m located between several reef exclusion zones relevant to the activity (Figure 7-3). The accumulated SEL over 24 hours of seismic source operation was modelled considering representative scenarios with realistic acquisition patterns for shallow sections of the Eureka 3D MSS. Compared to the original acoustic modelling, a smaller array volume and larger inter-pulse intervals reduced the maximum ranges to all relevant SEL24h thresholds.

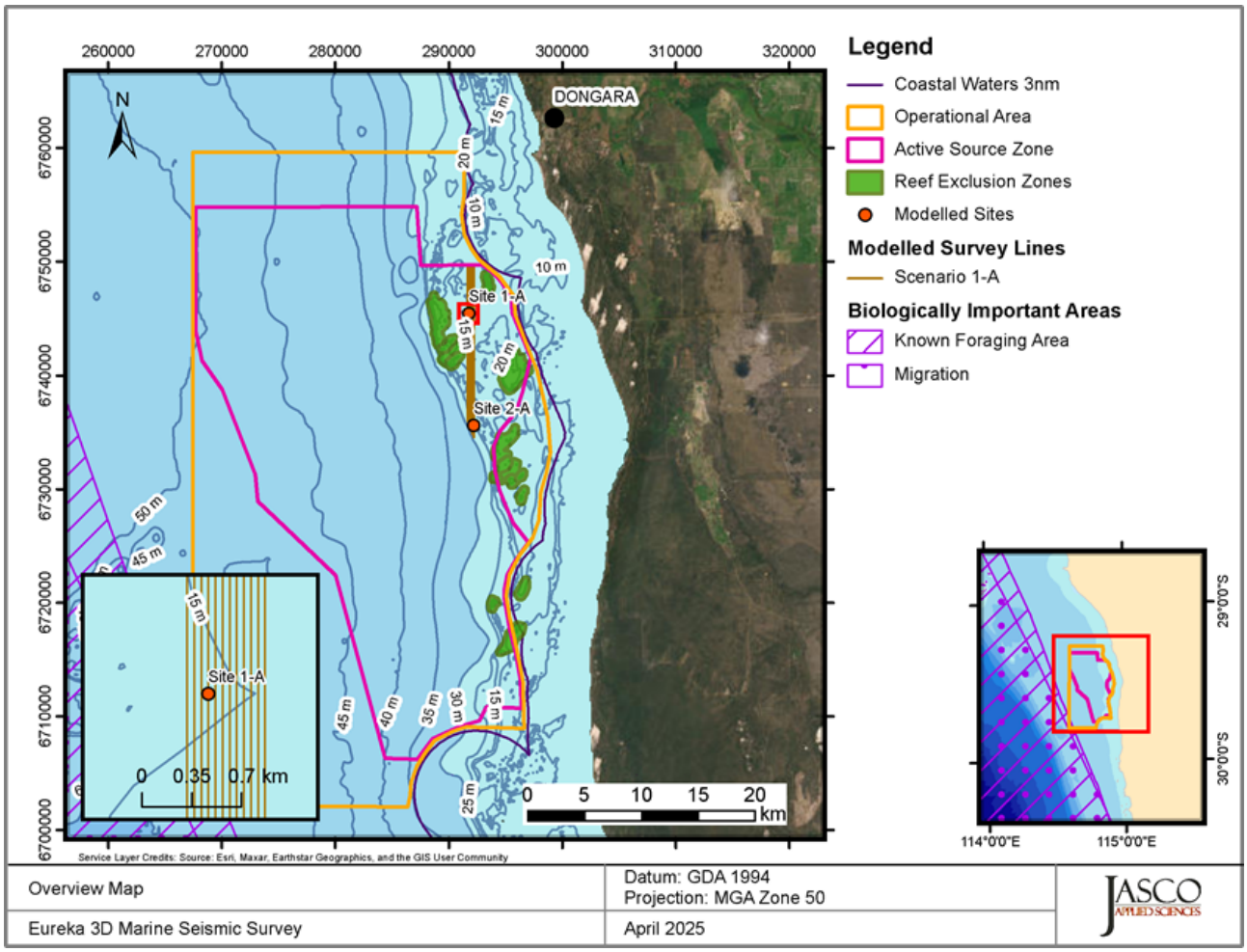


Figure 7-3: Overview of key survey features, modelled locations, and the survey scenario (Appendix G(ii))

The National Marine Fisheries Service (NMFS) recently released an updated version of its technical guidance titled "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 3.0)" (NMFS, 2024). This guidance provides revised underwater and in-air criteria for the onset of auditory-related impacts to marine mammals exposed to anthropogenic sound and includes the introduction of a new approach for assessing injury. The thresholds for permanent (PTS) and temporary (TTS) threshold shifts have been updated to reflect the onset of auditory injury for different marine mammal hearing groups. Auditory injury, as defined by NMFS, includes but is not limited to PTS and TTS. TTS is described as a temporary, reversible elevation in the hearing threshold at a specific frequency or within a portion of an animal's hearing range, relative to a baseline level. While TTS is acknowledged in the guidance,

NMFS does not classify it as a true auditory injury. This position is supported by studies indicating that TTS falls within normal physiological variability and does not cause structural damage. The temporary hearing reduction following exposure to loud noise is attributed primarily to fatigue of cochlear hair cells and supporting structures rather than cell loss, and is fully reversible (Ward, 1997; Southall et al., 2007, 2019, as cited in NMFS 2024).

Among the key changes, for Otariid Pinnipeds, both the peak sound pressure level (PK) and the cumulative sound exposure level (SELcum) thresholds for this group have been slightly lowered, indicating the potential for greater sensitivity to both immediate and prolonged noise exposure at greater distances from the sound source.

By contrast, the cumulative sound exposure level (SELcum) injury thresholds for the HF and VHF cetacean groups have been slightly lowered in the updated technical guidance. The peak sound pressure level (PK) thresholds for both groups have remained unchanged in the 2024 update. As a result, the revised SELcum criteria may theoretically result in a slightly reduced modelled effect distances for cumulative exposure scenarios, where animals are exposed repeatedly or over extended periods. The distances based on PK exposure, which are central to protecting marine mammals from immediate auditory injury, remain unchanged and therefore unaffected. To summarise, the modelled SELcum distances for HF and VHF cetaceans are likely more conservative than they would be if based on the updated thresholds.

Cumulative sound exposure level (SELcum) thresholds have remained unchanged for LF cetaceans, and the PK thresholds for this group have increased. As a result, the modelled PK distances for LF cetaceans are likely more conservative than they would be if based on the updated thresholds.

The changes to auditory injury and TTS thresholds introduced in this new guidance introduce an element of uncertainty regarding the effectiveness of control measures established in the Eureka EP. Adjustments to exposure levels, particularly for the Otariid Pinniped group, may alter the modelled distances at which relevant thresholds are exceeded. This uncertainty highlighted the need for Pilot's revision and consideration of the updated criteria in impact assessments and relevant control measures. Despite these revisions, Pilot is confident that existing control measures remain robust. Under the previous NMFS thresholds, no peak sound pressure level (PK) exposures approached auditory injury/PTS thresholds. Consequently, any recalculated distances using the updated 2024 thresholds are expected to be minor — likely within tens of meters. Given this scale, any such adjustments would be operationally insignificant and would not materially affect the overall effectiveness of Pilot's mitigation strategy, with Pilot's approach continuing to provide sufficient and conservative protection for marine mammals.

7.1.4.1 Animal movement and exposure modelling (animat modelling)

In addition to the propagation modelling outlined above, Pilot commissioned JASCO to perform an acoustic exposure analysis study for pygmy blue whales (*Balaenoptera musculus brevicauda*) within the migration and foraging BIAs to investigate any potential effects on pygmy blue whale northbound migration and foraging from the Eureka 3D MSS, based on use of the 2495 in^3 source with a 12.5 m shotpoint interval.

The ASA is adjacent to the known foraging BIA for pygmy blue whales, as well as to the pygmy blue whale migratory BIA (Figure 4-11 and Figure 4-12). Therefore, animat modelling was undertaken for both foraging and migrating behaviours. Fine-scale data on foraging behaviour are not currently available for pygmy blue whales. Therefore, data from multi-sensor tags deployed on blue whales (*B. musculus*) in the North Pacific were used to inform the feeding behaviours. Using intermediate-duration archival tags (SPLASH MK10) attached to eight blue whales off the coast of California, Irvine et al. (2019) determined two primary feeding behaviours: shallow and deep feeding. These two feeding behaviours differed between male and female blue whales, with females generally diving deeper than males during both shallow and deep feeding. To account for these differences, foraging female and male pygmy blue whales were modelled separately, with values derived from Irvine et al. (2019). The remaining parameters for feeding behaviour were primarily sourced from Goldbogen et al. (2011), who deployed 25 multi-sensor suction cup tags (DTAGs) on blue whales off the coast of California. The exceptions were the values for travel speed, which was derived from satellite tags deployed on pygmy blue whales off southern Australia (Möller et al. 2020), and surface interval, which was derived from a satellite tag deployed on a pygmy blue whale off western Australia (Davenport et al. 2022).

The migratory pygmy blue whale behaviour profile was not split by gender as there is no evidence for sex related differences in migratory behaviour. The migratory profile included both migratory and exploratory dives (i.e., shallow

dives with no indication of feeding) based on detailed information from Owen et al. (2016), who equipped a sub-adult pygmy blue whale with a multi-sensor tag off Western Australia. Migrating pygmy blue whales were not modelled undertaking feeding behaviour, as per the findings of Owen et al. (2016). In the migratory profile, the two dive types were modelled together such that the animats were migrating 95% of the time and engaged in exploratory dives 5% of the time (Owen et al. 2016). Using data from Owen et al. (2016), the approximate length of a bout of exploratory dives could be determined, as well as the average (±SD) depth of this dive type. The analysis of the dive data showed that the depth of migratory dives was highly consistent over time and unrelated to local bathymetry. The mean depth of migratory dives was 14 ± 4 m while the mean maximum depth of exploratory dives was 107 ± 81 m. Additional parameters regarding pygmy blue whale behaviour were derived from sources that used multi-sensor tags to record fine-scale dive and movement data (Owen et al. 2016; Möller et al. 2020). Where information was unavailable for pygmy blue whales, parameters were derived from blue whale tagging data (Goldbogen et al. 2011), as per the foraging profile.

The behaviour of migrating pygmy blue whales was modelled to reflect animats transiting through the modelling area on a 334° track during the northbound migration. This represents the animals migrating along the west coast of Australia to Indonesia (Double et al. 2014). The speed of travel for migratory behaviour (1.17 ± 0.60 m/s) and exploratory dives (0.88 ± 0.14 m/s) were calculated from data presented in Möller et al. (2020).

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict the exposure of animats to sound arising from the seismic activity. JASMINE integrates the predicted sound field with biologically meaningful movement rules for each marine mammal species (pygmy blue whales for the current analysis) that results in an exposure history for each animat in the model. In JASMINE, the sound received by the animats is determined by the proposed seismic operations. Animats are programmed to behave like the marine animals that may be present in an area. The parameters used for forecasting realistic behaviours (e.g., diving and foraging depth, swim speed, surface times) are determined and interpreted from marine mammal studies (e.g., tagging studies) where available or reasonably extrapolated from related or comparable species. For cumulative metrics, an individual "animats" sound exposure levels (SEL) are summed over a 24-hour duration to determine its total received energy and then compared to the relevant threshold criteria. For single-exposure metrics, the maximum exposure is evaluated against threshold criteria for each 24-hour period.

The exposure criteria for impulsive sounds (described in Koessler & McPherson 2023) were used to determine the number of animats that exceeded thresholds. To generate statistically reliable probability density functions, model simulations were run with animat sampling densities of four animats per square kilometre. The modelling results are not related to real-world density estimates for pygmy blue whales within BIAs or known core range area, as the density of animals is not known. To evaluate PTS and TTS, exposure results were obtained using detailed behavioural information for pygmy blue whales (refer above).

The seismic source was modelled as a vessel towing an airgun array at a speed of 4.5 knots, with an impulse interval of 12.5 m. The simulated source tracks followed a racetrack configuration with no acquisition occurring during turns. At the time and location of each seismic pulse, the modelled source location with the closest distance was selected for exposure modelling. The track lines, along with the acoustic modelling locations, are shown in Figure 7-2 above (Scenario 2).

The results from the animal movement and exposure modelling provided a way to estimate radial distances to effect thresholds. The distance to the closest point of approach (CPA) for each of the animats was recorded. The $ER_{95\%}$ (95% Exposure Range) is the horizontal distance that includes 95% of the animat CPAs that exceeded a given effect threshold. Within the $ER_{95\%}$, there is generally some proportion of animats that do not exceed threshold criteria. This occurs for several reasons, including the spatial and temporal characteristics of the sound field and the way in which animats sample the sound field over time, both vertically and horizontally. The sound field varies as a function of range, depth, and azimuth based on a variety of factors such as bathymetry, sound speed profile, and geoacoustic parameters. The way the animats sample the sound field depends upon species-typical swimming and diving characteristics (e.g., swim speed, dive depth, surface intervals, and reversals). Furthermore, even within a particular species definition, these characteristics vary with behavioural state (e.g. feeding, migrating). As this results in some animats not exceeding threshold criteria even within the $ER_{95\%}$, the probability that an animat within that distance was exposed above threshold within the $ER_{95\%}$ was also computed (Pexp) to provide additional context.

Acoustic ranges are reported for both $R_{95\%}$ and R_{max} (see Appendix G, Koessler & McPherson 2023), however, exposure ranges are reported for $ER_{95\%}$ only since, statistically, ER_{max} is not defined. JASMINE is a Monte Carlo simulation, and the results are probabilistic in nature. This is in contrast with acoustic modelling, where there is a specific maximum isopleth range for a given source/environment set-up.

7.1.4.2 Marine fauna noise effect criteria

The underwater noise effect criteria that have been used to predict the impact ranges (distances from the source) for injury and/or disturbance to marine fauna, include peer-reviewed and accepted thresholds and guideline levels based on the best available science for received sound levels. These criteria cover a range of effects from behavioural disturbance to injury or physiological damage. In the absence of peer-reviewed or recognised criteria, such as for plankton and some invertebrates, the modelling has used reported effects levels from scientific publications. In the absence of directly relevant criteria for some taxa, conservative criteria have been adopted based on international convention and from pile-driving impact studies, which are based on extended exposure to high intensity sound pulses and make no allowance for the receptor to leave the area if the sound level becomes uncomfortable.

7.1.5 Impact analysis and evaluation

This section describes the impacts that may occur on significant marine environmental receptors identified in Section 4 that are known to be sensitive to underwater sound discharges from seismic airgun arrays. This part of the impact assessment method is described in Section 6. Each of the subsequent sections then undertakes the impact analysis as defined in Section 6.

Sensitive receptors/ values	Review of the environmental resources described in Section 4, indicates that discharge of the acoustic source in the Eureka 3D MSS ASA has the potential to affect adversely the following environmental receptors, values and sensitivities, to varying degrees: • Plankton (including fish and benthic invertebrate eggs and larvae) • Benthic invertebrates • Fishes and elasmobranchs • Fish spawning • Transient marine turtles • Marine mammals (whales, dolphins, pinnipeds) • Seabirds • Commercial and recreational fisheries • Tourism and recreation (diving, snorkelling, spearfishing, sea lion tours).
Potential impacts	Potential environmental impacts to these environmental receptors include: • Physical injury to auditory tissues or other air-filled organs • Hearing loss; either temporary threshold shift (TTS) or permanent threshold shift (PTS) • Direct behavioural effects through disturbance or displacement and consequent disruption of natural behaviours or processes, e.g., Migration, feeding, resting, calving • Indirect behavioural effects by impairing/masking the ability to navigate, find food or communicate or by affecting the distribution or abundance of prey species • Indirect effects on the catchability of commercial fish stocks. The area over which seismic sound may adversely impact marine species depends upon multiple factors including the extent of sound propagation relative to the location of receptors, and the sensitivity and range of spectral hearing of different species (Slabbekoorn et al. 2010; Hawkins & Popper 2012). The potential for impact on individual animals depends on several factors, including the presence of the animal during the survey period, its proximity to the noise source, its ability to avoid the sound field generated by the airgun array, its specific physiological tolerance and the overlap between its hearing range and the seismic frequency range. Most of the sound energy of the seismic airgun pulses is in the low frequency range of 10 to 200 Hz (McCauley 1994;

OGP/IAGC 2011). The marine species most at risk from the low frequency acoustic emissions from seismic operations within the OA are cetaceans, particularly baleen whale species that hear and communicate in a similar low frequency range.

7.1.5.1 Zooplankton

7.1.5.1.1 Species sensitivity and sound exposure thresholds

Plankton is a collective term for all marine organisms that are unable to swim against a current. This group is diverse and includes phytoplankton (plants) and zooplankton (animals), as well as fish and invertebrate eggs and larvae, including coral eggs and larval stages. There is no scientific information on the potential for noise-induced effect in phytoplankton and no functional cause-effect relationship has been established. Noise-induced effects on zooplankton, such as copepods, cladocerans, chaetognaths and euphausiids, have been investigated in several sound exposure experiments.

Zooplankton includes invertebrate and fish eggs and larvae that are transported by currents and winds and hence cannot take evasive behaviour to avoid seismic sources. With respect to the Eureka 3D MSS, key spawning areas for commercially targeted fish species (assessed under "Fish spawning" below) have been identified as areas where zooplankton populations may be more important.

Larval fish species studied appear to have hearing frequency ranges like those of adults and similar acoustic startle thresholds (Popper et al. 2014). Swim bladders may develop during the larval stage and may render larvae susceptible to pressure-related injuries such as barotrauma. Effects of sound upon eggs, and larvae containing gas bubbles, is focused on barotrauma rather than hearing (Popper et al. 2014). Larval stages are often considered more sensitive to stressors than adult stages, but exposure to seismic sound reveals no differences in larval mortality or abundance for fish, crabs or scallops (Carroll et al. 2017).

Parry et al. (2002) studied the abundance of plankton after exposure to airgun sounds but found no evidence of mortality or changes in catch-rate at a population-level. Other studies have also noted limited negative impacts on zooplankton, fish eggs, larvae or fry, and most have reported that impacts occur within a few metres or tens of metres from the source (Kostyuchenko 1973; Dalen & Knutsen 1987; Holliday et al. 1987; Kosheleva 1992; Pearson et al. 1994; Turnpenny & Nedwell 1994; Booman et al. 1996; Payne 2004; Payne et al. 2009). These studies included exposures to sound pressures up to approximately 242 dB re 1 µPa, comparable to those predicted in close range to the Eureka 3D MSS seismic source. Based on these studies, physical impacts to planktonic organisms have typically been found to be limited to within approximately 10 m of the seismic source.

Using this 10 m impact range, a study by McCauley (1994) calculated the impact in a seismic survey area, assuming plankton mortality of 100% within 10 m of a seismic source. This suggested that the total mortality due to seismic testing would impact less than 1% of plankton in the survey area. DNV Energy (2007) and Hawkins & Popper (2012) conducted comprehensive reviews of a number of scientific studies, including those by Kostyuchenko (1973), Dalen & Knutsen (1987), Booman et al. (1996) and Sætre & Ona (1996); the effects of seismic activities on eggs and larvae were predicted to result in average and worst-case mortality rates of 0.0012% and 0.45% per day respectively, which were not deemed significant when compared to a natural mortality rate of 5–15% per day, as applicable to most species during early life stages. Natural mortality rates in larvae can be much higher than this — exceeding 50% per day in some species and commonly exceeding 10% per day (Tang et al. 2014). For example, in a review of mortality estimates (Houde & Zastrow 1993), the mean mortality rate for marine fish larvae was M = 0.24, a rate equivalent to a loss of 21.3% per day.

Impacts to scallop larvae have been identified following intense and lengthy periods of exposure to low-frequency sound. Tank experiments by Aguilar de Soto et al. (2013) showed evidence of morphological abnormalities in early-stage scallop larvae from simulated seismic signals for a 6920 in^3 seismic source. However, the lengthy exposure period of three second pulse intervals for an exposure duration of 90 hours and at 1 m distance from sound source is not realistic of an actual survey. Christian et al. (2003) found major developmental differences between control and treatment groups of snow crab eggs exposed to a peak pressure level of 216 dB SPL every 10 seconds for 33 minutes. Again, the exposure to a constant peak pressure level for a prolonged period is not realistic of an actual survey where the source is moving and so does not remain in one place.

Hawkins (2014) used continuous sonar to record zooplankton layers, comprising copepods, cladocerans, decapod larvae, gastropod larvae, and bivalve larvae, exposed to playback of pile driving sound (pile driving sound typically has a more rapid rise time, more frequent strike rates and therefore a greater sound exposure regime than a seismic survey). Zooplankton layers responded to sound by showing a 'dent' in the top of the layer at the onset of the sound sequence, although the change in depth often did not persist for the whole duration of the sound exposure and zooplankton distribution quickly returned to normal.

Day et al. (2016a, 2016b) found no effects on the mortality, abnormality, competency, or energy content of lobster larvae after exposure of early embryonic stages to seismic exposure. In this study, egg-bearing female southern rock lobsters (*Jasus edwardsii*) were exposed to signals from three airgun configurations, all of which exceeded SEL of 185 dB re 1 $\mu Pa^2 \cdot s$ (209-212 dB PK-PK). Lobsters were maintained until their eggs hatched and the larvae were then counted for fecundity, assessed for abnormal morphology using measurements of larval length and width, tested for larval competency using an established activity test and measured for energy content. Overall, there were no differences in the quantity or quality of hatched larvae, indicating that the condition and development of spiny lobster embryos were not adversely affected by airgun exposure. Day et al. (2016a, 2016b) detailed that the results suggest that embryonic spiny lobster are resilient to airgun signals and highlight the caution necessary in extrapolating results from the laboratory to real world scenarios or across life history stages.

McCauley et al. (2017) found that after exposure to airgun sounds generated with a single airgun (150 in^3) zooplankton abundance decreased and mortality in adult and larval zooplankton increased two-to three-fold when compared with controls. In this large-scale field experiment on the impact of seismic activity on zooplankton, a sonar and net tows were used to measure the effects on plankton, and a maximum effect-range of horizontal 1.2 km was determined. The findings contradicted the conventional idea of limited and very localised impact of intense sound in general, and seismic airgun signals in particular, on zooplankton, with the results indicating that there may be noise-induced effects on these taxa and that these effects may even be negatively affecting ocean ecosystem function and productivity.

The study measured zooplankton abundance and the proportion of the population that was dead at three distances from a single 150 in^3 airgun - 0, 200 and 800 m. The experiment estimated the proportion of the zooplankton that was dead, both before and after exposure to airgun noise, using net samples to measure zooplankton abundance, and bioacoustics to identify the distribution of zooplankton. In this study, copepods dominated the mesozooplankton (0.2–20 mm), and impacts were not assessed on microzooplankton (0.02–0.2 mm) or macrozooplankton (>20 mm). However, there was movement of water through the experimental area, which made interpreting their results more difficult (Richardson et al. 2017).

McCauley et al. (2017) provide three findings from the experiment to show that zooplankton were affected by the seismic source:

- The proportion of the mesozooplankton community that was dead increased two- to three-fold
- The abundance of zooplankton estimated by net samples declined by 64%
- The opening of a "hole" in the zooplankton backscatter observed via acoustics.

They found that exposure to airgun noise significantly decreased zooplankton abundance and increased the mortality rate from a natural level of 19% per day to 45% per day (on the day of exposure, and that these impacts were observed out to the maximum range assessed (1.2 km) (Richardson et al. 2017).

Scientists from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Oceans and Atmosphere Business Units were contracted by APPEA to undertake a desktop study that: a) critically reviewed the methodologies and findings of the McCauley et al. (2017) experiment; and b) simulated the large-scale impact of a seismic survey on zooplankton in the North West Shelf region, based on the mortality rate associated with airgun noise exposure reported by McCauley et al. (2017).

The CSIRO review of the McCauley et al. (2017) study found that there were three primary questions raised by the results of the experiment, all of which warrant further investigation (Richardson et al. 2017):

- Why was there no attenuation of the impact with distance? There is no consistent decline in the proportion of zooplankton that are dead with increasing distance away from the airgun. The energy of the sound waves at 1.2 km is substantially lower than at the source.
- Why was there an immediate decline in abundance? It is unclear why there would be a near immediate drop in zooplankton abundance as measured by net samples and acoustic data. If zooplankton were killed, they would not immediately sink from the surface layers or be rapidly eaten. A drop in abundance would be more likely once the dead zooplankton either sunk to the bottom or were removed by predation. Richardson et al (2017) conclude it is difficult to explain this immediate decline in zooplankton abundance.
- Was there sufficient replication to be confident in the study findings?

The conclusions were based on a relatively small number of zooplankton samples. A total of 24 samples were collected – two tows each sampling time × three distances from the gun (0 m, 200 m, 800 m) × two levels (Control, Exposed) × two replicate experiments (Day 1, Day 2). This means that there were only 12 samples collected under conditions exposed to the airgun, six on each day of the two experiments. The main potential confounding explanation in the study would be that a different water mass entered the area on each day of the experiment and had lower abundance and higher quantities of dead zooplankton. Richardson et al. (2017) conclude that: "although this is relatively unlikely it cannot be discounted because of the relatively few samples collected and only two replicate experiments conducted".

Independently of the APPEA/CSIRO study, the International Association of Geophysical Contractors (IAGC) conducted its own review of the McCauley et al. (2017) paper. This review came to the following conclusion: "While we found the study interesting, we are also troubled by the small sample sizes, the large day-to-day variability in both the baseline and experimental data, and the large number of speculative conclusions that appear inconsistent with the data collected over a two-day period. Both statistically and methodologically, this project falls short of what would be needed to provide a convincing case for adverse effects from geophysical survey operations." (IAGC 2017).

The second component of the CSIRO study was to estimate the spatial and temporal impact of seismic activity on zooplankton on the North West Shelf from a large-scale seismic survey, considering mortality estimates of McCauley et al. (2017), and accounting for typical growth rates, natural mortality rates, and the ocean circulation in the region The approach modelled a hypothetical 3D survey (2900 km^2 in size, over a 35-day period, in water depths of 300–800 m) on the edge of the North West Shelf during summer. To simulate the movement of zooplankton by currents, the researchers used a hydrodynamic model that seeded 0.5 million particles into CSIRO's Ocean Forecast Australia Model. Zooplankton particles could be hit multiple times by airgun pulses if they were carried by currents into the future survey path. The greatest limitation in this approach was accurate knowledge of the natural growth and mortality rates of zooplankton, and to address this the CSIRO researchers tested the sensitivity of the model to different recovery (growth-mortality) rates, and the sensitivity of the results to ocean circulation by undertaking simulations with and without water motion (Richardson et al. 2017).

The results of the simulations that included ocean circulation showed that the impact of the seismic survey on zooplankton biomass was greatest in the Survey Region (defined as the survey acquisition area with a 2.5 km impact zone around it) (22% of the zooplankton biomass was removed) and declines as one moves beyond it to the Survey Region + 15 km (14% of biomass removed), and the Survey Region + 150 km (2% of biomass removed). The time to recovery (to 95% of the original level) for the Survey Region and Survey Region + 15 km recovery was 39 days (38-42 days) after the start of the survey and three days (2–6 days) after the end of the survey (Richardson et al. 2017).

The major findings of the CSIRO study were that there was substantial impact of seismic activity on zooplankton populations on a local scale within or close to the survey area, however, on a regional scale the impacts were minimal and were not discernible over the entire North-West Shelf bioregion. Additionally, the study found that the time for the zooplankton biomass to recover to pre-seismic levels inside the survey area, and within 15 km of the area, was only three days following the completion of the survey. This relatively quick recovery was due to the fast growth rates of zooplankton, and the dispersal and mixing of zooplankton from both inside and outside of the impacted region (Richardson et al. 2017).

CarbonNet (2018) assessed zooplankton communities in Australia's Gippsland Basin before and after a seismic survey. Ten sites were sampled during the pre-survey period, consisting of six sites occurring within the survey area and four

reference sites. During the post-survey period, three sites were sampled near the survey line, as well as three reference sites. Post-survey sampling occurred within three days of acquiring the last survey line. Copepods, cladocerans and salps dominated the pre-survey samples, whereas the dinoflagellate *Noctiluca scintillans* dominated the post-survey samples. There was a high level of variance among samples and no lobster or scallop larvae occurred in any of the samples. Mortality rates were high in both pre- and post-survey samples and the high proportion of dead cladocerans was contributed to their delicate structure being destroyed by the sampling process rather than attributable to any MSS impacts.

A study by Fields et al. (2019) exposed zooplankton (copepods) to seismic pulses at various distances up to 25 m from a seismic source. The source levels produced were estimated to be 221 dB re $\mu Pa^2 \cdot s$. The study observed an increase in immediate mortality rates of up to 30% of copepods in samples compared to controls at distances of 5 m or less from the airguns. Mortality one week after exposure was significantly higher by 9% relative to controls in the copepods placed 10 m from the airguns. Fields et al. (2019) also reported no sub-lethal effects of seismic exposure to the copepods. The findings of the study are consistent with numerous other field studies, as referenced previously, indicating that the potential effects of seismic pulses to zooplankton are limited to within approximately 10 m from the seismic source. Fields et al. (2019) note that the findings of the McCauley et al. (2017) study are difficult to reconcile with the body of available research. The findings of the McCauley et al. (2017) study may, therefore, provide an overly conservative estimate of the potential effects of seismic pulses to zooplankton.

Day et al. (2021, 2023) undertook a study to determine whether early development and recruitment of southern rock lobsters puerulus and juveniles might be affected by exposure to seismic sound by assessing mortality rates following exposure; impairment of the righting reflex, and development through assessment of progression through the moult cycle. This study also undertook to respond to the finding by McCauley et al. (2017) of increased mortality in zooplankton following exposure to airgun signals that suggests that planktonic, early life stages of marine invertebrates may be more vulnerable than adults or developing embryos. Outcomes of this study are detailed in the section below on crustaceans.

Vereide et al. (2023) conducted a field experiment to assess mortality and naupliar body length of the calanoid copepod *Acartia tonsa* when exposed to the discharge of two 40-inch airguns nauplii were placed in plastic bags and attached to a line at a depth of 6 m, and at 50 m from the nearest transect line. For each treatment, three bags of nauplii were exposed to one of three treatments for 2.5 hours: Airgun array discharge, a boat control, or a silent control. After exposure, nauplii were kept in filtered seawater in the laboratory without food. Immediate mortality in the nauplii was approximately 14% compared to less than 4% in the silent and boat control. Similarly, there was higher mortality in the airgun exposed nauplii up to six days after exposure compared to the control treatments. Nearly all the airgun exposed nauplii were dead after four days, while >50% of the nauplii in the control treatments were alive at six days post-exposure. There was an interaction between treatment and time on naupliar body length, indicating lower growth in the nauplii exposed to the airgun discharge (growth rates after four days: 1.7, 5.4, and 6.1 $\mu m\ d^{-1}$ in the airgun exposed, silent control, and boat control, respectively). These experiments indicate that the output of two small airguns affected mortality and growth of the naupliar stages of *Acartia tonsa* in close vicinity to the array (50 m).

Vereide et al. (2023) concluded:

- The results of this study suggest that airgun array discharges affected the growth and mortality of *Acartia tonsa* in early naupliar stages. However, the degree of impact is likely to be stage- and species-specific and may be difficult to separate from background mortality.
- The results observed are consistent with many previous studies that show small effects of airgun discharges on zooplankton mortality. For example, no effects were detected in bivalve larvae sampled 2 km away from the source after exposure to airgun discharges (Parry et al. 2002) or in adult scallops sampled up to 1 km from the source shortly after exposure (Harrington et al. 2010). Similarly, Fields et al. (2019) reported that the mortality of the copepod *Calanus finmarchicus* adults to a two-airgun array discharge increased (<5%) compared to that of the control groups, but only at <10 m from the airguns and no effects at distances from 10 to 50 m.
- There were notable differences in these results from previous studies. For example, in contrast to Fields et al. (2019), this study found significantly higher mortality in the exposed animals compared to the controls at distances of 50–~1,200 m. Although the sound exposure levels were higher in Fields et al. (2019) than those in

this study, the animals in this study were exposed to multiple airgun discharges that resulted in a cumulative exposure that lasted much longer. The cumulative exposure of multiple blasts coupled with the younger stage used in this study may help to explain the higher mortality.

- Despite the higher mortality, the immediate mortality observed in this study is much lower than the 50% mortality in zooplankton at >1 km from the source (McCauley et al. 2017). Even though the absolute immediate mortality was lower than that reported by McCauley et al. (2017), the relative increase in mortality compared to the controls was somewhat greater in this study (greater than three-fold increase) than in McCauley et al. (2017) (two-to three-fold increase). However, in McCauley et al. (2017), the mortality in the controls was ~20% compared to less than 4% in this study.
- In this study, the mortality rate in nauplii directly after exposure was lower than the natural mortality rates observed in *Acartia* nauplii (up to 0.35 per day), although this is dependent on temperature, season, and region (Elliott & Tang 2011). This indicates that the population-level effect of airgun exposure might not be detectable from the background mortality.
- The airgun array exposed nauplii grew less and developed slower over four days than the boat and silent control groups. The slower development in the airgun array treatment nauplii was correlated with decreased growth. The progression through developmental stages and increase in body length observed in the control groups in this study is more similar to the development of naturally observed in *Acartia tonsa* nauplii cultured in 10–15°C water than is the development in the airgun array exposed nauplii. Slowed or arrested development at naupliar stages can reduce fitness or cause death. Thus, mortality could be affected long after seismic exposure. The population-level effects that this might have are uncertain.

Guideline thresholds for mortality to eggs and larvae have been proposed based on the sound exposure guidelines by the ANSI-Accredited Standards Committee S3/SC 1, Animal Bioacoustics Working Group (Popper et al. 2014). These guidelines represent the Working Group's efforts to establish broadly applicable guidelines for ichthyoplankton (fish eggs and larvae). The criteria that Popper et al. (2014) suggest for mortality in eggs and larvae are based on levels measured in the study by Bolle et al. (2012) that indicated no damage was caused by simulated repeated pile driving at 207 dB re 1 µPa SPL_{peak} or 210 dB re 1 µPa SEL_{cum}.

7.1.5.1.2 Impact assessment

For this impact assessment the sound exposure thresholds for mortality/potential mortal injury (PMI) to fish eggs and larvae from Popper et al. (2014) were applied and consider both PK and SEL_{24h} metrics (Table 7-2). The thresholds were based on limited data and were selected on the basis that Popper et al. (2014) note that they are likely to be conservative. While research generally suggests limited impacts to plankton beyond approximately 10 m distance from seismic sources, the precautionary Popper et al. (2014) thresholds for larval mortality / PMI have been selected to indicate the magnitude and extent of potential impacts from acquisition of the survey.

Table 7-2: Maximum predicted distances (R_{max}) to mortality/PMI thresholds in the water column for fish eggs and larvae, and zooplankton

Sound exposure threshold	R_{max} distance (km) – Streamer Acquisition	R_{max} distance (km) – Nodal Acquisition
210 dB re 1 µPa².s (SEL_{24h})	0.06	0.07
207 dB re 1 µPa (PK)	0.27	0.28

As shown in Table 7-2, the maximum distance (R_{max}) to mortality/PMI thresholds for fish eggs and larvae, and zooplankton, applying the single pulse (PK) threshold from Popper et al. (2014) was 270 m for streamer acquisition and 280 m for nodal acquisition.

Any potential mortality/PMI impacts to zooplankton communities have to be assessed in the context of natural mortality in these populations. Any mortality or mortal injury effects to zooplankton (including fish eggs and larvae) resulting from seismic noise emissions are likely to be inconsequential compared to natural mortality rates, which are very high — refer discussion above.

The magnitude of such localised impacts is negligible and is not expected to be discernible at the regional scale when considering the large natural spatial and temporal variability and scale of plankton and spawning biomass in the SWMR. In particular, phytoplankton and zooplankton biomass in the oceans can vary significantly at spatial scales ranging from hundreds of metres to hundreds of kilometres and temporal scales of hours, days, seasons and inter-annually, due to tidal and large-scale currents, bathymetry, temperature, salinity, water chemistry parameters and other environmental factors (Gibbons & Hutchings 1996; Holliday et al. 2011; McKinnon et al. 2008; Pearce et al. 2000; Sutton & Beckley 2017). Therefore, changes in zooplankton abundance are likely to be replenished and indistinguishable from natural levels and distributions within hours of a seismic survey vessel passing.

7.1.5.1.3 Coral spawning

The OA includes areas of patch reef and emergent reef habitat that are characterised by tropical and subtropical scleractinian (hard coral) species. The dominant mode of coral reproduction is broadcast spawning; however, the spawning period and the degree of synchrony varies between tropical and temperate regions.

As described in Section 4.3.2.1, the primary period of coral spawning in WA, including in the mid-west and around the Abrolhos Islands, is in autumn, often culminating in the mass spawning of many species and colonies during March and/or April (Gilmour et al. 2016). In the temperate southwest, where corals are near their geographical limit, coral spawning occurs around summer and autumn from approximately January to May (Gilmour et al. 2016).

Coral spawn may be present in the water column around reef habitat, and within the ASA from being transported by currents, following mass spawning events in March and/or April. As there have been no studies on impacts to coral spawning from seismic surveys this evaluation applies the information for zooplankton detailed above. As for plankton, coral spawn will be spatially and temporally variable throughout a seismic survey and potential mortality or mortal injury effects to coral spawn must be assessed in the context of natural mortality rates, which as per plankton is high and thus mortality rates caused by exposure to the seismic source would be low compared to natural mortality and unlikely to result in the lack of replenishment of coral populations.

As shown in Table 7-2, the maximum predicted distance to mortality/PMI thresholds in the water column for zooplankton (including coral eggs and larvae) is 270 m for streamer acquisition and 280 m for nodal acquisition. Pilot has proposed seismic source exclusion zones of 300 m around Leander Reef, Big Horseshoe Reef and around a further 13 unnamed reef areas in water depths shallower than 12 m. The seismic source will not be operated within 300 m horizontal distance of the 12 m contour of Leander Reef and Big Horseshoe Reef or within 300 m horizontal distance of the 12 m contour of the other unnamed reef area within the eastern part of the ASA. The 300 m exclusion distance provides some additional conservatism against the reported R_{max} for mortality/PMI for coral eggs and larvae.

7.1.5.1.4 Zooplankton – impact assessment conclusion

The potential impacts of noise emissions from the seismic source on zooplankton during the seismic acquisition are 'localised' and 'short-term', and the activity is not likely to result in any ecologically significant impacts at a population level for any zooplankton, fish eggs or larvae that may be present in the water column within the OA.

7.1.5.2 Benthic invertebrates

7.1.5.2.1 Species sensitivity and sound exposure thresholds

Research is ongoing into the relationship between sound and its effects on benthic invertebrates, including the relevant metrics for both effect and impact. Marine invertebrates lack a gas-filled bladder and are unable to detect the pressure component of sound waves (Parry & Gason 2006; Carroll et al. 2017) or "hear" sound in the way that mammals and fish can. Instead, invertebrates detect sound by sensing the particle motion component of sound in water and seabed sediments through physiological structures such as sensory hairs, statocysts and muscles, and therefore detect sound at close range (McCauley 1994; Parry & Gason 2006; André et al. 2016; Roberts et al. 2016; Edmonds et al. 2016; Carroll et al. 2017; Popper & Hawkins 2018).

Statocysts, found in a wide range of invertebrates, are utilised by animals to maintain their orientation, direct their movements through the water and may play a key role in controlling the behavioural responses of invertebrates to a wide range of stimuli. Although directly sensitive to particle motion and not to sound pressure, most available research on seismic impacts to invertebrates characterises received sound levels in terms of the sound pressure. Consequently, particle motion, rather than sound pressure, is likely to be a more important factor for benthic invertebrates such as crustacean and molluscs. Water depth and seismic source size are related to the particle motion levels at the sea floor, with larger arrays and shallower water being related to higher particle motion levels, thus more relevant to effects on crustaceans and bivalves (Koessler & McPherson 2023; Appendix G(i)).

A range of physiological responses have been identified in some studies, and these are summarised below.

7.1.5.2.2 Crustaceans

Studies by Christian et al. (2003), Department of Fisheries and Oceans Canada [DFO] (2004) and Payne et al. (2007, 2008) exposed snow crabs (*Chionoecetes opilio*) to seismic sound levels of approximately 197–237 dB re 1 µPa PK-PK. No acute or chronic lethal or sub-lethal effects were observed in the weeks to months following exposure, except for Payne et al. (2007, 2008) who noted a decrease in serum enzymes and an increase in food consumption in the weeks to months post exposure, which may indicate stress effects or potential osmo-regulatory disturbance.

As part of a collaborative, multi-disciplinary study conducted offshore on the continental slope (depth range of 107–162 m), Morris et al. (2018) and Cote et al. (2020) compared catch rates and used positioning telemetry in a Before-After-Control-Impact (BACI) study design to assess the behavioural responses of snow crab to exposure from industry seismic vessels. While effects of seismic exposure on snow crab movement could not be ruled out completely, effects were at most small relative to natural variation. In contrast, snow crab exhibited much clearer responses to handling, temperature and time of day. Overall, their results suggest that the effects of seismic exposure at this depth (>100 m), specific to the behaviour of adult male snow crab, are at most subtle and are not likely to be a prominent threat to the fishery (Morris et al. 2018; Cote et al. 2020).

7.1.5.2.2.1 Rock lobster

Research undertaken by Day et al. (2016a, 2016b) in Australian waters, exposed captive southern rock lobster (*Jasus edwardsii*) to multiple passes of a seismic source element in 10-12 m water depths. Maximum received sound exposures were 209-212 dB re 1µPa PK-PK, 186 to 190 dB re 1 $\mu Pa^2 \cdot s$ per-pulse SEL, and SEL_{cum} of 192 to 199 dB re 1 $\mu Pa^2 \cdot s$. Exposed and control lobsters were housed in a laboratory for up to a year post-exposure to allow monitoring of longer-term impacts. The findings of the study were published in a report, as well as several scientific articles. These are summarised below.

Mortality:

- Exposure to seismic sound did not result in any mortalities to adult lobsters (Day et al. 2016a, 2016b).

Righting time and statocysts damage:

- Airgun exposure caused damage to the righting reflex and statocysts in southern rock lobsters (Day et al. 2019). Following exposure equivalent to a full-scale commercial array (3100 in^3) passing within 100–500 m, lobsters showed impaired righting and significant damage to the sensory hairs of the statocyst. Reflex impairment and statocyst damage persisted for at least 365 days post exposure and did not improve following moulting. For this study, maximum measured received noise levels were 209–213 dB re 1 µPa (PK-PK).
- In a group of lobsters with pre-existing statocyst damage (assumed to be caused by exposure to high levels of anthropogenic noise), seismic exposure did not cause further statocyst damage, nor was there an increase in righting time (Day et al. 2020).

Stress:

- Increased tail gape (an indication of stress) was present in the summer experiments only, which may be a result of higher temperatures exacerbating a stress response (Day et al. 2016a, 2016b).

Haemolymph physiology and nutritional condition:

- Examination of the impact of seismic acoustic exposure on the haemolymph physiology and nutritional condition of this species and found no effect of seismic exposure on 24 haemolymph biochemical parameters, hepatopancreas index or survival. However, this study did report evidence of a chronic negative impact on immune competency for up to 120 days post-exposure, a potential immune response to infection after 365 days post-exposure; and chronic impairment of nutritional condition 120 days post exposure (Fitzgibbon et al. 2017).These authors concluded that the biochemical haematological homeostasis of rock lobster is reasonably resilient to seismic acoustic signals; however, exposure may negatively influence the rock lobster's nutritional condition and immunological capacity. The impact of these results at an ecological level is not known.

Eggs:

- Increased mortality, delayed development or abnormal development to the egg mass carried by any ‘berried’ females, if present, or larvae produced from those eggs, is highly unlikely. The condition or development of eggs carried by female lobsters at the time of exposure, even at proximity directly beneath the seismic source, were not affected (Day et al. 2016b). However, these eggs were in an early embryonic developmental stage, just after extrusion and prior to eye development, and were thus entirely soft tissue with no large internal density differences. Later spiny lobster larval developmental stages have developed sensory systems including arrays of pinnate setae along the flagella of the antennae and mechanosensory statocyst organs which they may use for navigation during the critical onshore migration and settlement phase. As such, the experimental results found here may not necessarily be the same for spiny lobsters exposed later in development (including later stage embryos and larvae) and is an area which requires further research to determine the potential impacts of seismic surveys on lobster populations.

The significance of the seismic exposures and whether the sub-lethal effects, such as increased righting times, may have wider ecological implications (e.g., ability to feed, avoid predators and resist disease) warrants further consideration.

Day et al. (2020) reported that some of the control lobsters used in the experiments were collected from a marine reserve and were found to have a high level of pre-existing impairment to statocysts like that induced by the seismic exposure experiments. The source of the damage in the lobsters in this study could not be ascertained, but the soundscape comparisons of the collection sites showed that the noisy site had a 5–10 dB greater level of noise, equivalent to a three to ten times greater intensity, in the 10–700 Hz range than was found at the remote collection site. Therefore, this statocyst impairment was the result of long-term exposure to shipping noise. The lobsters with pre-existing statocyst damage showed no significant differences in righting times between control and exposed lobsters; however, as a group these lobsters had the slowest right times of all experiments. It is unclear why exposure to the seismic surveys did not cause additional damage to the statocysts in these animals. Monitoring of the lobster population at the same reserve

where the lobsters with pre-existing statocyst impairment were taken from showed that the rock lobster population within the reserve was thriving and at carrying capacity (Green & Gardner, 2009; Kordjazi et al. 2015). Therefore, the levels of statocyst impairment reported in the Day et al. (2016a) study appear to not be impacting on the survival of this lobster population. However, it should be noted that these lobsters were not subject to any fishing pressure and the same aquatic noise that damages the lobster statocysts may also reduce the level of predation they face.

Day et al. (2021, 2022, 2023) examined the potential impacts of seismic surveys on the larval stages of southern rock lobster to determine whether early development and recruitment may be affected. Lobster puerulus (post-larval stage) and juveniles were held in baskets and exposed to multiple passes of a seismic source element in 10–12 m water depths. Maximum received sound exposures were 203-219 dB re 1µPa PK-PK, 181 to 190 dB re 1 µPa²·s per-pulse SEL, and SEL_{cum} of 201 to 205 dB re µPa²·s, comparable to Day et al. (2016a) (Day et al. 2021, 2022, 2023). Lobster puerulus were randomly assigned to control (not exposed to airgun signals) or E0 (exposed to airgun signals at a nominal range of 0 m from the sail line), and juveniles were assigned to control, E0 and E500 (exposed to airgun signals at a nominal range of 500 m from the vessel sail line). The findings of the study are as follows:

- Righting was significantly impaired for all exposure treatments immediately after exposure, indicating that the range of impact extended to at least 500 m from the source (maximum range tested in the study).
- Although exposure did not result in any elevated mortality for puerulus or juveniles, increased righting times likely indicated impaired predator avoidance and defence, which may therefore result in indirect mortality because of seismic exposure.
- Puerelus and juvenile E0 treatment lobsters did not show the capacity for recovery, while juvenile E500 lobsters recovered from impairment after the first moult, providing evidence of a range threshold for recovery.
- Intermoult period was significantly increased in E0 juvenile lobsters, and appeared to be increased in puerulus, while juvenile E500 treatment lobsters show a moderate, non-significant increase in moult duration.
- Increased intermoult duration suggested impacted development and potentially slowed growth, and physiological stress.

Impairment resulting from close range (0 m) exposure appeared to be persistent, as previously reported in adults, whereas juveniles exposed at a more distant range (500 m) showed recovery, indicating that exposure at a range of 500 m may not cause lasting impairment to righting (Day et al. 2022, 2023).

A more recent study by de Lestang et al. (2024) investigated the short, medium- and long-term effects of seismic exposure on wild western rock lobster, *Panulirus cygnus,* in a similar environment to the proposed Eureka MSS. Two hundred and twenty lobsters (carapace lengths ranging from 64 to 78 mm) were collected from commercial lobster vessels fishing in shallow waters (0 – 20 m) in the Fremantle region. Lobsters in the intermoult phase were retained, marked with anchor tags and held in aquaria for ~30 days prior to being transported to the seismic survey location. One hundred of these lobsters were exposed at a depth of ~5 m, to an 80 in^3 sleeve gun array, with an operating pressure of 2000 psi. The treatment lobsters were held in a line of eight or nine plastic baskets (four lobsters per basket), with the seismic source towed at a depth of 2 m over the middle of the line. Therefore, the minimum exposure range for lobsters in the baskets in the centre of the line was ~3 m. Sound exposure levels received by the treatment lobsters were not measured, as a hydrophone was deployed in the centre of the survey area, ~2 km away from the treatment location. However, recorded sound levels when the hydrophone was deployed directly under a firing location (equivalent to position of treatment lobster baskets) are likely to replicate the sound level received by the treatment lobster. The sound levels recorded in these instances were ≳220 dB re 1 µPa peak-to-peak sound pressure level.

An additional 100 control lobsters were held in the same conditions 10 km north of the survey area in similar habitat, depth and swell conditions. All baskets of treatment lobsters were retrieved ~30 minutes after direct exposure and baskets of control lobsters were retrieved immediately after this. All baskets of lobsters were then suspended in the water column above their final release location for 20 hours (overnight). The final release was located ~5 km offshore and central to the control and treatment locations over an isolated patch reef of ~0.5 km^2. This reef was surrounded by a sand habitat in ~ 14 m water depth.

Of the 200 lobsters deployed for the trial, only six died during the trials, four from the treatment group and two from the control group and this difference was not statistically significant. The surviving lobsters were examined for leg loss, righting time, blood protein concentration and release behaviour. Most lobsters examined after the trial had all legs present (77 and 76 % of control and treatment lobsters, respectively). However, more treatment lobsters than control lobsters had lost one or more legs, and this result was statistically significant. Like studies on southern rock lobster, treatment lobsters took significantly longer to right themselves (average of 13.6 s and 6.5 s for treatment and control lobsters, respectively). (Appendix H). No significant difference was observed in blood protein concentrations but there was a statistically significant difference in release behaviour. Release behaviour was classified on a scale of 1 – 3, with 1 representing very slow descent (no attempt by the lobster to expedite its descent); 2 representing slow descent (lobster made some attempt to speed up its descent); and 3 representing normal descent (lobster immediately tail-flicked and descended). The differences in release behaviours were as follows:

- 27% of treatment lobsters were classified as very slow, compared to 16% of control lobsters.
- 36% of treatment lobsters were classified as slow, compared to 27% of control lobsters.

Following these initial tests, all lobsters were then released at the same reef location (described above) and subject to the same commercial fishing activity. Of the 190 lobsters released, only 35 lobsters were recaptured by commercial fishers resulting in a small sample size for comparisons. This may have partly been due to some lobsters being below legal size and able to evade pots via escape gaps and the paper states there were equal numbers of undersize lobsters within the treatment and control groups. Nineteen lobsters were initially caught (11 control and 8 treatment) and 10 of these were retained by the fisher (3 control and 7 treatment). There were no further recorded instances of tagged lobsters being retained. The recapture rate from commercial fishing rapidly declined after this initial fishing effort with all subsequent fishing trips at this location yielding between zero and four tagged lobsters.

Analysis of the recapture data showed a lower recapture rate for lobsters exposed to seismic signals for the first month post seismic survey. Based on this recapture data, a model estimated an initial mortality experienced by the treatment lobsters of 22.1 %. However, the 95% confidence interval associated with this mortality estimate (0.06 – 0.68) indicates a low precision for this estimate. The cause of this reduction was not determined by the study, but reduced survival is put forward as the most likely cause. It is suggested that this mortality is associated with slower release behaviours for treatment lobsters making them more vulnerable to predation. Recapture rates for treatment and control lobsters after the first month did not indicate any long-term effects on lobster survival or catchability.

de Lestang et al. (2024) state that the 22% reduction in recapture of exposed lobsters should be measurable through a reduction in catch rates following the seismic survey. However, potential impacts on commercial fishing catch rates were not able to be examined as part of this study due to:

- Lack of fishing activity prior to the survey to serve as a baseline for comparison with post survey catch rates.
- The high abundance of small lobster that can escape commercial lobster pots.
- The highly variable nature of catchability within the WRL fishery.

To put the above analysis of potential effects of seismic survey noise on western rock lobster (WRL) into context it is important to understand the spatio-temporal overlap of the proposed Eureka MSS with rock lobster habitat and life stages. The proposed Eureka MSS is planned to be undertaken between February and March and although the OA overlaps a KEF for WRL the areas of suitable WRL habitat within the OA are likely to be primarily limited to shallow reef habitats. In recognition of this, Pilot have committed to seismic source exclusion zones of 300 m (see below for rationale for this zone size) around Leander Reef, Big Horseshoe Reef and a further 13 unnamed reef areas in water depths shallower than 12 m. These exclusion zones are designed to minimise the potential for close range sound exposure as experienced by treatment lobsters in the de Lestang et al. (2024) study. There is also potential for adult WRL to be exposed to seismic noise levels that may elicit sub-lethal effects in deeper parts of the ASA during the 'whites' migration when ~4-year-old WRL migrate from shallow inshore waters to spawning grounds in offshore waters up to 100 m deep. In the first period of the migration between late November and mid-December, the 'whites' occur in the shallower waters <40m. From late December to late February, the migration continues, however in waters >40m out to around 100m deep. The survey will occur outside the period when 'whites' are in the shallowest waters <40m (de Lestang et al 2022). As a

result, it is expected that adult WRL exposed to harmful levels of seismic noise will largely be limited to a small number of individuals that may be present outside of reef exclusion areas. It should also be noted that the natural reef ledge habitat of WRL will afford some protection from transmission loss before sound reaches the lobster.

Mating of WRL occurs in August – September and the females generally release fertilised eggs between September and February. These eggs hatch within 4-8 weeks releasing phyllosoma larvae that are carried offshore by nightly wind-driven currents as far as 1500 km from the mainland. Hatching is generally completed by the end of February or March (Gray 1992). The phyllosoma larvae spend 9-11 months in the open ocean before metamorphosing into pueruli which swim across the continental shelf with help from the prevailing currents to settle on inshore reefs. The settlement of puerulus larvae on inshore reefs can occur throughout the year (Miller et al. 2023), but peaks in spring and summer (Gray 1992). There is therefore some potential for the MSS to overlap with the hatching period and the period of puerulus settlement on inshore reefs.

Most of the puerulus/phyllosoma larvae spawned in the months leading up to the seismic survey will be highly dispersed once the survey is undertaken. Estimates of puerulus and phyllosoma larval densities in the water column are highly variable and change diurnally and with water column depth. Density estimates range from 0.04 – 0.7/1000m^3 for phyllosoma and 0.04 – 0.1/1000m^3 for puerulus (Ritz 1972). This is also likely to vary among years with changes in metocean conditions and spawning stock.

The science on noise impacts to plankton indicates that within the area of ensonification there will be a highly variable and sliding scale of impacts which will range from mortality to those individuals very close to the seismic source through to minimal disturbance to those individuals farthest from the source and/or exposed to seismic for a minimal time period. .. There are no specific studies on impacts to puerulus/phyllosoma from seismic surveys hence the assessment is informed from multiple studies on other invertebrates/crustaceans . Our assessment is further informed by the highly variable and inconsistent effects of seismic surveys on individuals, the spatially and temporally variable patterns of recruitment and settlement of WRL and the panmictic nature of the WA Rock Lobster population.

Larval distribution extends across a broad area of the west coast of Western Australia (Figure 7-4), from Exmouth to Augusta (de Lestang et al. 2016), encompassing oceanic and coastal waters far exceeding the spatial footprint of the proposed survey. Based on this range and the relatively small survey area, the overlap between the modelled phyllosoma distribution and the survey footprint is expected to be less than 1% of the total range. This greatly limits the proportion of the larval population potentially exposed to elevated sound levels.

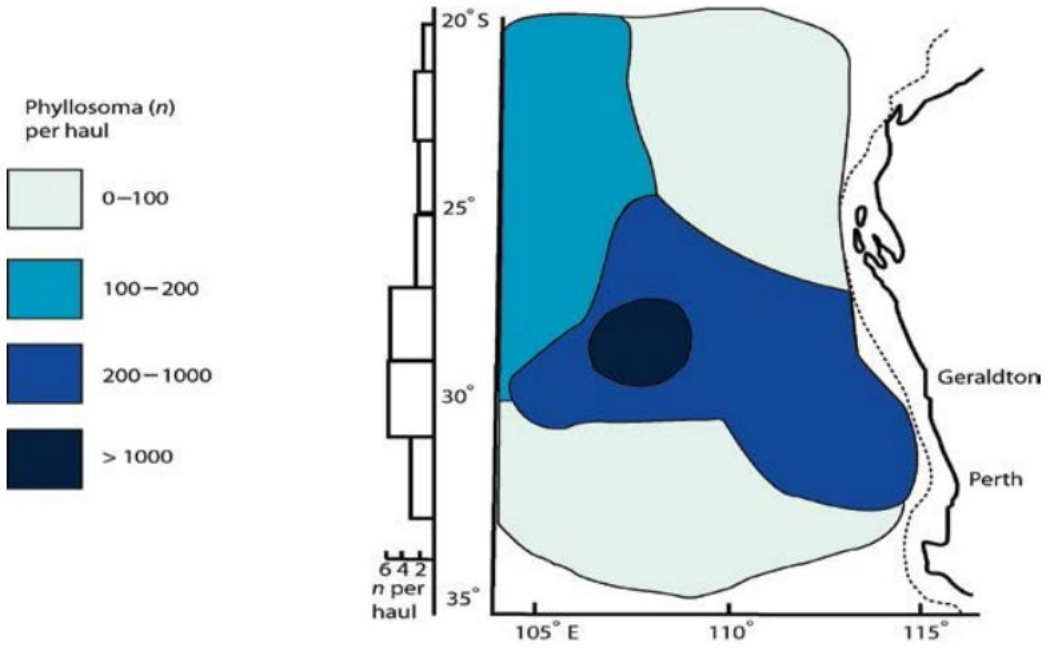


Figure 7-4: Distribution of western rock lobster phyllosoma larvae (Figure 5-7 in de Lestang et al. 2016)

The timing of the proposed survey (February–March) occurs after the main period of WRL puerulus settlement, which peaks during late spring to early summer and is largely complete by this time of year (Figure ; de Lestang 2016). These data have changed in recent years with the 2024 Stock Assessment report indicating a shift in settlement to later in the year, though the peak settlement still occurs well before the proposed survey window. Consequently, most puerulus will have already settled before the commencement of seismic operations, reducing the potential for exposure during this sensitive life stage.

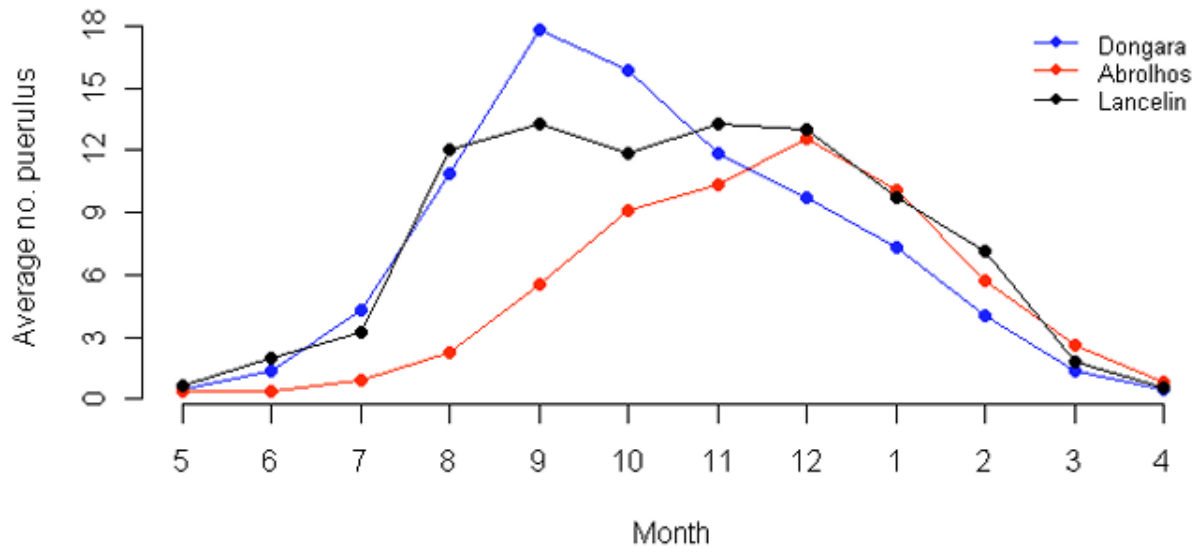


Figure 7-5: Average long-term (per 2007) puerulus settlement by month for sites in the northern (Dongara), southern (Lancelin) and offshore (Abrolhos Islands) zones of the WRL fishery (Figure 8-9 from de Lestang 2016).

Long-term puerulus monitoring shows that inter-annual settlement variability at Dongara, and at other monitoring sites along the coast, is substantial. For example, Figure 3.1 of the 2024 Stock Assessment report indicates that annual average

settlement has ranged from well below 20 to over 200 puerulus per collector at Dongara in different years — more than a tenfold difference — with similar variability observed elsewhere. Despite these large fluctuations in settlement, effects on subsequent biomass, egg production, landed catch, and catch rates have been comparatively muted, indicating resilience to variation at the settlement stage. Furthermore, the 2024 Stock Assessment notes that there is currently no stock–recruitment relationship known for this stock, and that variation in puerulus settlement is primarily driven by environmental factors (de Lestang 2024).

Given the survey's timing outside the main settlement period, the very small spatial overlap with the larval distribution range, the naturally high inter-annual variability in settlement, and the absence of a demonstrated stock–recruitment relationship, any reduction in larval abundance potentially associated with the proposed survey is expected to be negligible in the context of the WRL population.

As per the analysis of available science above, there is some potential for increased mortality in puerulus larvae (indirectly through impaired predator avoidance). However, the area and timeframe over which these effects might occur is small relative to the spawning range and protracted period of hatching, larval dispersal and settlement on inshore reefs. It is expected that most egg hatching will be in water deeper than the ASA, with breeding grounds typically in 40-100 m water depth (de Lestang et al., 2016) and the prevailing dispersal will be offshore away from the ASA. Further, the temporal overlap of the MSS with the peak period of puerulus settlement on inshore reefs is low, i.e., potential for 1 month overlap (30 days of acquisition) within a 6-month peak period (spring -summer). During this period of overlap, there is potential for sub-lethal impairment to puerulus moving within ~ 500 m of the airgun array but due to the protracted settlement period and the mobile nature of the MSS this will only be a small proportion of individuals recruiting to this location.

The analysis of seismic activity in the Dongara area and rates of puerulus settlement over the past 13 years shows that no relationship exists between the level of seismic activity and rates of settlement (Figure 7-6). Nine seismic surveys have been conducted in fishing area A and the southern half of fishing area B over the past 13 years. A scatter plot analysis of the rate of survey frequency against the rate of settle shows a very weak but insignificant positive correlation (i.e., rate of settlement increases with rate of surveys). Puerulus settlement is highly variable among years and is likely influenced by many biotic and abiotic environmental factors, but seismic activity does not appear to influence puerulus settlement.

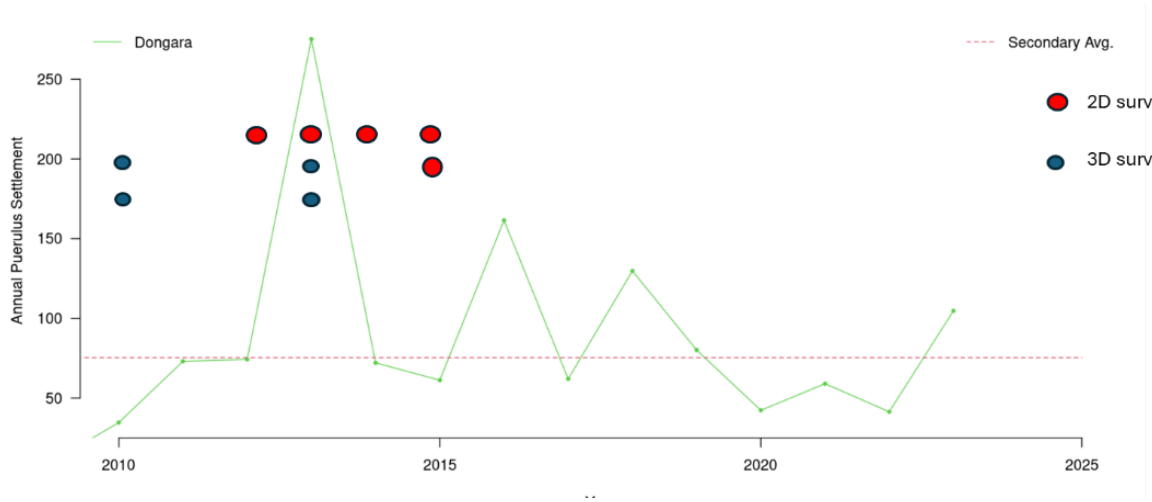


Figure 7-6: Rates of puerulus settlement and 2D and 3D seismic activity between 2010 and 2023

Finally, the above impact assessment draws heavily on research conducted on the effects of seismic noise on southern rock lobster (SRL). Stakeholders raised concerns regarding the applicability of these studies for assessing potential impacts of seismic noise on western rock lobster. Therefore, Pilot commissioned a study by the University of Tasmania's Institute for Marine and Antarctic Studies to assess the transferability of the knowledge between the two species for the purposes of the impact assessment (Peinado et al. 2024). While the study found that species specific data is preferable where

feasible., it did highlight several similarities between the species in relation to hearing anatomy and susceptibility to noise impacts. These include:

- While there is significantly less information available for WRL on the potential impacts of seismic signals compared to SRL, one similarity is that air guns signals cause righting impairments for both species (Day et al., 2019; Day et al., 2022; de Lestang et al., 2024)
- In crustaceans, the basic structure of the statocyst is similar across species, consisting of a sac-like epidermal invagination of the cuticle (Finley and MacMillan, 2000). However, the location of the statocyst varies between groups; for example, in lobsters, it is in the basal segment of each antennule. To the best of our knowledge, the statocyst in WRL has not yet been examined. However, due to the similarities across different crustacean species, as well as the similarities between lobsters, it is likely that the WRL and SRL statocysts are similar. This suggests that the seismic impact observed on the SRL statocyst could be extrapolated to WRL.

In the absence of specific studies on WRL, the use of data from studies on SRL is considered a reasonable surrogate. However, further research specific to WRL would assist in greater certainty in the impact assessment.

7.1.5.2.2.2 Molluscs

Kosheleva (1992) identified no detectable effects to marine bivalves and gastropods (mussels and periwinkles) after exposure to a single seismic source element of source level 233 dB re 1µPa at 0.5 m or greater from the source. Conversely, Matishov (1992) reported a single scallop shell splitting in a sample of three scallops, but this was located 2 m beneath a seismic source element and therefore exposed to maximum sources levels (which is not representative of a typical commercial seismic survey).

Several Australian studies (Przeslawski et al. 2016a, 2018; Day et al. 2017) have focussed on commercial scallops (*Pecten fumatus*). Przeslawski et al. (2016a, 2018) examined the short-term impacts on scallops and other marine invertebrates from a 2,530 cubic inch seismic array and found no evidence of mortality or change in condition following exposure to a seismic survey. Analysis of images and samples revealed some site-specific differences in scallop abundance, size, condition and assemblages, but these were not related to seismic operations. Day et al. (2017) exposed scallops to maximum received sound exposures of up to 213 dB re 1µPa PK-PK, 181 to 188 dB re 1 µPa².s per-pulse SEL, and SEL_{cum} of 188 to 198 dB re 1µPa².s. The study also predicted ground acceleration of up to 37.57 m/s². Day et al. (2017) concluded that exposures did not result in any immediate mass mortalities, however, repeated exposures resulted in a chronic increase in mortality over timeframes of approximately four months post-exposure, though not beyond naturally occurring rates of mortality. Separate experiments undertaken in 2013 and 2014 yielded mortalities of 3.6–3.8% in control scallops (no seismic exposure), 9.4–11.3% mortality in scallops exposed to a single pass of the seismic source, 11.3–16.1% mortality in scallops exposed to two passes of the seismic source, and 14.8–17.5% mortality in scallops exposed to four passes of the seismic source. The mortality rates were at the low end of the range of naturally occurring mortality rates documented in the wild, which range from 11–51% with a six year mean of 38% (Day et al. 2017). A third experiment in 2015 resulted in 100% mortality to both control scallops and exposed scallops and accordingly was attributed to other causes and not to seismic exposure (Day et al. 2017).

Sub-lethal effects to exposed scallops were also observed by Day et al. (2017) indicating a compromised capacity for homeostasis and potential immunodeficiency over acute (hours to days) and chronic (months) timescales post exposure. Exposures did not elicit energetically expensive behaviours (i.e., extensive swimming or long periods of valve closure), but scallops showed significant changes in some behavioural patterns during exposure (e.g., “flinch” response) and an increase in recessing into sediment following exposure (Day et al. 2017).

Published sound exposure criteria do not currently exist for acoustic impacts to invertebrates but the available literature above provides an indication of the sound levels and distances within which some impacts may occur. A range of sound levels, from 202 dB re 1 µPa PK-PK to 212 dB re 1 µPa PK-PK, based on the findings of the Payne et al. (2008) and Day et al. (2016a, 2016b, 2017) studies, were applied in the assessment. The Payne et al. (2008) 202 dB re 1 µPa PK-PK is associated with no impacts to benthic crustaceans (such as prawns, scampi and lobsters), whereas the 209-212 re 1 µPa PK-PK thresholds could be associated with some level of sub-lethal effects in these animals (Koessler & McPherson 2023;

Appendix G). A 213 dB re 1 µPa PK-PK level is considered as representative of levels that may result in sub-lethal effects and chronic mortality in molluscs and some other invertebrates based on Day et al. (2017).

The responses of squid to airgun signals were investigated by Fewtrell & McCauley (2012). The authors conducted several experiments and examined the received per–pulse SEL for caged squid (*Sepioteuthis australis*). They found that in one trial, where the received level of the first airgun impulse was 162 dB re 1 µPa²·s, the squid inked. This response was not observed again within this trial; however, the authors stated that it was unknown whether this was due to depleted ink reserves or habituation. In two other trials, the initial received levels were lower (132 and 146 dB re 1 µPa²·s per–pulse SEL), and although the cumulative received levels did exceed 162 dB re 1 µPa^2 s, no inking behaviour was observed. The authors hypothesised that the results also suggest that a gradual increase in received levels and prior exposure to airgun impulses decreases the severity of the alarm responses in this species. This aligns with findings of general habituation in response to predators in squid (Long et al. 1989). Recent work (Jones et al. 2020) supports these findings as well, indicating potential rapid, short–term habituation by squid to impulsive noise; however, similar response rates were seen 24 hours later, which indicated that squid might re-sensitise to the noise.

The results presented in by Fewtrell & McCauley (2012) were stated by the authors to be preliminary, and while they stated that while it is possible that noise levels greater than 147 dB re 1 µPa²·s are required to induce avoidance behaviour, the level associated with inking, of 162 dB re 1 µPa²·s per–pulse SEL, has been considered as a startle response level for squid. In the absence of additional studies and thresholds this level may be considered for other cephalopods; however, it may be limited when applied to other species.

Solé et al. (2017) conducted offshore noise-controlled exposure experiments on common cuttlefish (*Sepia officinalis*), at three different depths and distances from the source and particle motion and sound pressure measurements were performed at each location. Scanning electron microscopy revealed injuries in statocysts, which severity was quantified and found to be proportional to the distance to the transducer. These findings are the first evidence of cephalopods sensitivity to anthropogenic noise sources in their natural habitat. From the measured received power spectrum of the sweep, it was possible to determine that the animals were exposed at levels ranging from 139 to 142dB re 1µPa^2 and from 139 to 141 dB re 1µPa^2, at 1/3 octave bands centred at 315 Hz and 400 Hz, respectively. These results could therefore be considered a coherent threshold estimation of noise levels that can trigger acoustic trauma in cephalopods.

Given the similarities in physiology between squid and octopus, octopus are not thought to be at risk of physical injury even if individuals are exposed to several passes as noted by Fewtrell & McCauley (2012). There is limited information on the hearing sensitivity of octopus to sound stimuli. Kaifu (2008) studied *Octopus ocellatus* and concluded that the statocyst was responsible for the observed responses kinetic sound energy (particle motion). It is unknown how octopuses will respond behaviourally, but since they are benthic and territorial it is thought more likely that they will retreat into their lair as they normally do to perceived threats. They may also freeze and camouflage themselves if out in the open. Octopus are not expected to move very far from their territory and therefore will not be exposed to repeat close passes in short period of time since subsequent survey lines are about 4 km apart. If they remain in the same area, they may be exposed to sounds shown to elicit strong responses two to three times throughout the survey period and these events will be several days apart allowing the individual animals to recover.

Day et al. (2023) examined the potential effects of seismic surveys on the octopus (*Octopus pallidus*). Exposure to seismic air gun signals did not result in mortality in either males or female octopus. Both exposed male and female octopus demonstrated impacts to behaviour, with exposed males showing reduced “adventurousness” through a reduced rate of escaping from their tanks and depressed feeding in E0 octopus when compared to their feeding rates later in the study. In female octopus, exposure was correlated to a reduction in maternal care of eggs, particularly as the eggs neared hatching. There was some indication of a reduced number of eggs in the E0 and E500 treatments, which may have been an indication of removal of dead or poorly developing eggs, though it was not conclusive as the number of eggs laid (by individual) prior to the start of the study was unknown. There was no indication of harm to the offspring, with hatches generally completing fully with live, competent hatchlings (Day et al. 2023).

In the haemolymph the pH in males was initially low in all treatments compared to expected levels for octopus with the E0 treatment significantly lower than controls, suggesting that handling stress was evident in all treatments but was synergistically exacerbated by exposure. This was followed by alkalosis (rise in pH) in E0 and E500 treatments compared

to controls and the E1000 treatment in subsequent weeks, a response that was also observed in the female octopus (Day et al. 2023).

Immune parameters showed several impacts, with phagocytosis (cellular process for ingesting and eliminating foreign cells or particles) significantly elevated in female and male octopus in the E0 and E500 treatments. In females, haemocyte vitality was significantly reduced at five days post exposure. The impact of exposure on the phenoloxidase system, an enzyme system responsible for melanisation important for killing pathogens and repairing wounds, was equivocal with some substantial (12–40%) but non-significant increases in activity observed in male octopus at days 1 and 5 post exposure followed by a significant increase of 40–60% over Control activity in the E0 and E500 treatments at day 47 post exposure. In females, a non-significant 15% reduction in activity level at day 5 was followed by a non-significant 100% increase in mean activity at day 17. These results suggest that there was a high degree of variation between individuals, making it difficult to conclude whether there was an impact from seismic exposure to octopus that may be detected with more robust sample sizes or whether the variability in activity is characteristic of this enzyme, making it unsuitable for measuring impact (Day et al. 2023).

Along similar lines, several oxidative stress enzymes showed non-significant differences between treatments that make it impossible to determine whether activities were impacted but sample sizes were not robust enough to draw conclusions. Catalase and superoxide dismutase were generally 20–30% and 5–7% higher, respectively, in exposed E0 and E500 treatments than in Controls early in the study, but these differences lacked statistical significance. Male octopus in all exposed treatments showed a non-significant 10–15% decrease in nitric oxide concentration early in sampling (Days 1 and 12), whereas females showed a significant 100% increase in the E0 treatment compared to Controls at day 5 post exposure. Both malondialdehyde and comet assays were used to investigate DNA damage, with the results of both assays showing no indication of damage in either sex. The glutathione system (acts to prevent/limit damage to important cellular components caused by ROS) showed moderate levels of impact, with no differences observed in any of the three enzymes at day 1 post exposure and a non-significant decrease observed in glutathione reductase and glutathione peroxidase at day 5 post exposure in E0 and E500 octopus. In females, glutathione reductase was significantly elevated in E0 octopus at day 5 and glutathione s-transferase significantly elevated at day 17. The neurotransmitter acetylcholine esterase was significantly reduced in E0 and E500 treatments of day 1 post exposure males and in E500 treatment females at day 17 post exposure (Day et al. 2023).

Overall, Day et al. (2023) concluded that the implications of these findings concerning potential effects in octopus were as follows:

- The results from this study showed no evidence of mortality in either the short- or long-term.
- There was potential that impacted neurotransmitter activity levels underpinned observed behavioural changes in “adventurousness,” feeding and maternal care, raising concerns over impact to other behaviours octopus use to interact with their environment that rely on neuromuscular coordination.
- The observed impacts to the immune function and oxidative stress systems were not likely to be severe or persistent enough on their own to suggest long-term damaging effects or impairment.
- Based on the sound and physiology metrics measured here, the overall level of impact was negligible at 500 m and almost non-existent at 1000 m, establishing an exposure threshold range for minimising impact.

Parsons et al. (2024) exposed ≈11,000 silverlip pearl oyster (*Pinctada maxima*) to a four-day experimental seismic survey, plus one vessel-control day. After exposure, survival rates were monitored throughout a full two-year production cycle, and the number and quality of pearls produced at harvest were assessed. This large scale experimental seismic survey exposed adult pearl oysters to received SEL up to 209 dB re 1 $\mu Pa^2 \cdot s$. Oysters from two groups, on one sampling day, exhibited reduced survival and pearl productivity compared to controls, but 14 other groups receiving similar or higher exposure levels did not. The seismic source alone was determined to be very unlikely to cause mortality of *P. maxima*. There was no correlation and little effect of sound levels on *P. maxima* cultured pearl productivity. Reduced survival/pearl retention on one sampling day was determined to be unlikely to be driven by seismic exposure. Therefore, Parsons et al. (2024) found no conclusive evidence of an impact of the seismic source survey on oyster mortality or pearl production.

In the absence of noise effect criteria on abalone, the body of research described above for other molluscs has been used to assess impacts of seismic noise form the Eureka survey. Therefore, noise levels capable of producing sub-lethal effects to abalone could extend approximately a few hundred meters from the source. Hart et al (2017) shows that Roe's abalone on the west coast predominantly inhabit waters between 1-40m depth and are generally limited to rocky reef habitats within those depths. As such, there is the potential that abalone on the reef areas, in waters less than 40m depth within the survey area, could be exposed to sub-lethal levels of seismic noise.

The ASA is in Abalone Management Area 8 for Roe's abalone, and in 2010/2011 a marine heat wave significantly reduced the population. The level of reduction/mortality in areas south of Port Gregory were uncertain, but likely less than waters further north where mortality levels were up to 99.9% north of Kalbarri and were between 20%-90% in waters between Port Gregory and Kalbarri (Strain et al 2019, Figure 3.6). This is most likely due to waters further south being cooler (Strain et al 2019, Figure 3.5) and therefore it logical to predict that mortality levels were lower in the ASA than further north.

Furthermore, Sandoval-Castillo et al. (2015) showed that Roe's abalone have three genetically distinct population clusters, which shows each population can repopulate through breeding and dispersal of larvae within its defined geographical range. The abalone in the ASA are in cluster two which occupies the coastal waters between Greenough and Augusta. This cluster likely suffered less depletion than cluster one to the north (Kalbarri Cliff to Lucky Bay) where waters were warmer and given their genetic connectivity, are likely to have greater recovery potential than abalone further north in Abalone Management Area 8.

Approximately, 51% of the active source area has waters less than 40m deep and the survey is restricted to waters deeper than 15m, but not all that area contains the rocky habitat used by abalone. Without a dedicated benthic habitat survey of the ASA, it is not possible to quantitatively assess the amount of rocky habitat in the ASA. However, the proportion of habitat within the ASA is only a very small proportion of the habitat available to abalone within the greater bioregion and fishery. Since the survey is scheduled to occur during the summer/autumn period, concerns have been raised regarding the combined effect of elevated water temperatures and noise exposure if another marine heatwave occurred during the survey. Unfortunately, no studies have been conducted to evaluate the effects of simultaneous seismic noise and elevated water temperatures on abalone. Therefore, for the purpose of this impact assessment, it is conservatively assumed that all the abalone could die due to cumulative exposure (noting that an extreme heatwave alone could cause significant mortality). The ASA is within genetic cluster two, which extends south to Augusta, occupies less than 1% of the geographical range of this genetic cluster. Even if there was complete mortality of abalone on the rocky reef areas in the ASA, most of the population, including those further south that have been less affected by historical marine heat waves, could potentially re-populate the abalone in the ASA. The evidence from previous marine heat waves shows that mortality rates can be extremely high, and if similar extreme temperatures were repeated during the survey, any additional stress from seismic noise exposure is unlikely to have significant additional mortality when the heat alone has caused near total mortality. Conversely, if temperatures are only slightly elevated and the combined effect of elevated temperature and noise exposure induce some additional mortality in the ASA, the evidence from genetic analysis shows that abalone from the surrounding waters can repopulate the ASA. As such, there is not expected to be any long-term or large spatial scale impacts on the Roe's abalone population within genetic cluster two because of the seismic survey.

Roe's abalone are known to reproduce through the winter months in the waters around Perth and have an estimated larval duration of about 10 days (Hart et al 2017). Since the survey will be conducted in February to March there is not anticipated to be a direct impact on reproductive behaviour, larvae or settlement. Other molluscs have exhibited physiological changes that are consistent with a stress response (as described above). For abalone exposed to noise levels that elicit a sub-lethal response it is possible that an associated stress response could alter reproductive performance or fecundity. In the worst-case scenario if reproduction is impacted, this will only occur for the few abalone within the ASA, which is a very small proportion of the spawning population and is unlikely to affect the broader population merely because the numbers impacted would be too small. However, there is great uncertainty in this prediction and any sublethal effects may have no effect on reproduction at all.

7.1.5.2.3 Sponges and corals

A PK sound level of 226 dB re 1 µPa PK was applied for sponges and corals, based on a study where corals received maximum sound pressure levels of 226-232 dB re 1µPa PK-PK, but no mortality, damage to soft tissue or skeletal integrity,

visible signs of stress, change in abundance or community structure was detected immediately after, and up to four months following exposure (Heyward et al. 2018).

7.1.5.2.4 Seagrasses

Little is known about the potential effects of underwater noise on other sessile benthos, for instance seagrasses (flowering aquatic plants). In a recent study, Solé et al. (2021) examined morphological and ultrastructural changes in seagrass, after exposure to sounds in a controlled environment. This research focused on rhizome cortical cells and root cap collumella cells in the seagrass *Posidonia oceanica*, both of which contain amyloplasts. Amyloplasts have evolved as analogues of the invertebrate statocysts, sensory organs responsible for gravity perception, which have been shown to be sensitive to noise. The amyloplasts operate like statocysts in *P. oceanica* roots and rhizomes and probably have evolved to have a role in sound and vibration reception. Solé et al. (2021) observed that low-frequency sounds produced alterations in *P. oceanica* root and rhizome amyloplasts, which sense gravity and process sound vibration. Nutritional processes of the plant were affected as well: the study observed a decrease in the number of rhizome starch grains, which have a vital role in energy storage, as well as a degradation in the specific fungal symbionts of *P. oceanica* roots. Given that these effects were most probably associated with the particle motion component of the sound waves generated in the experiment, it is likely that any effects from seismic survey noise on seagrasses in shallow water marine environments would be limited to very close ranges from the source (i.e., <10 m).

7.1.5.2.5 Impact assessment

7.1.5.2.5.1 Sound pressure

A range of sound exposure levels from 202 dB re 1 µPa PK-PK (a no effect threshold) to 213 dB re 1 µPa PK-PK were applied in the acoustic modelling study for benthic invertebrates. Sound levels of 209-212 re 1 µPa PK-PK thresholds are potentially associated with some level of sub-lethal effects. As shown in Table 7-3, at a sound exposure threshold of 209 dB re 1 µPa PK-PK, the maximum predicted R_{max} distance was 167 m for streamer acquisition, and 103 m for nodal acquisition. The maximum predicted R_{max} distance associated with the 213 dB re 1 µPa PK-PK level for sub-lethal effects (Day et al. 2019) was 103 m at 40 m water depth for streamer acquisition, and 70 m at 10 m water depth for nodal acquisition. Maximum distances to this sound level in shallower waters supporting suitable reef habitat for western rock lobster (< 20 m) is 90 m.

The PK sound level at the sea floor directly underneath the seismic source was estimated at the modelled sites and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); the threshold was reached at a maximum range of 15 m (20 m water depth) for streamer acquisition and 4 m (15 m water depth) for nodal acquisition. Additionally, the 226 dB re 1 µPa PK reported in Heyward et al. (2018) is not a threshold above which impacts are expected to occur, but a level at which no short-term or long-term effects were observed. Impacts to corals and sponges are not expected until significantly higher levels are exceeded, which are not predicted to occur during this survey. Therefore, no measurable impacts to corals and sponges are expected.

Table 7-3: Maximum predicted distances (R_{max}) to effect thresholds for benthic crustaceans at the sea floor

Sound exposure threshold (PK-PK)	R_{max} distance (m) – Streamer Acquisition	Water depth (m)	R_{max} distance (m) – Nodal Acquisition	Water depth (m)
213 dB re 1 µPa	103	40	**70**	**10**
212 dB re 1 µPa	121	50	**75**	**10**
210 dB re 1 µPa	136	30	**93**	**10**
209 dB re 1 µPa	167	50	**103**	**10**
202 dB re 1 µPa	292	15	**212**	**15**

At received noise levels of 209 dB re µPa (PK-PK), the maximum predicted R_{max} distance for sub-lethal impacts to crustaceans is approximately 167 m for streamer acquisition and 103 m for nodal acquisition, and therefore there is the

potential for some crustaceans to experience sound levels that could result in some low-level, sub-lethal effects (e.g., impairment of reflexes, damage to statocysts and reduction in numbers of haemocytes). These sub-lethal effects could result in a reduction in fitness to some individuals; however, as demonstrated by the research studies on both crustacean and mollusc species, it is unlikely that this would occur to most individuals. The area of western rock lobster habitat exposed to sound levels that may elicit sub-lethal effects is very small relative to the West Coast Rock Lobster Managed Fishery (WCRLMF) that extends from Shark Bay to Cape Leeuwin and is considered a single connected stock. Therefore, impacts at a population level due to reduced fitness would be unlikely as there would be sufficient unaffected individuals to maintain the population. Further to this, the area of this proposed MSS is subject to some of highest levels of recruitment within the fishery (Miller et al. 2023) indicating a recovery potential from settlement of puerulus larvae into these coastal reef habitats.

Chronic mortality may also occur in a small number of organisms (e.g., bivalve molluscs) within the weeks and months following exposure to sound levels equal to or greater than 213 dB re 1 µPa PK-PK (Day et al. 2017), within a maximum R_{max} of up to approximately 103 m from the seismic source for streamer acquisition and 70 m from the source for nodal acquisition.

The distance to the per–pulse SEL startle (inking) response level of 162 dB re 1 μPa^2 s for squid (Fewtrell & McCauley 2012) was reached between 2.90 and 2.03 km for streamer acquisition and between 2.3 and 2.56 km for nodal acquisition.

7.1.5.2.5.2 Particle motion

At the sea floor interface, crustaceans and bivalves are subject to particle motion stimuli from several acoustic or acoustically induced waves. These include the particle motion associated with an impinging sound pressure wave in the water column (the incident, reflected, and transmitted portions), substrate acoustic waves, and interface waves of the Scholte type. However, it is unclear which aspect(s) of these waves is/are most relevant to the animals, either when they normally sense the environment or their physiological responses to loud sounds, and as such there is not enough information to establish similar criteria and thresholds as done for marine mammals and fish. Including recent research, such as Day et al. (2016a, 2016b, 2017), current literature does not clearly define an appropriate metric or identify relevant levels (pressure or particle motion) for an assessment. This includes the consideration of what particle motion levels lead to a behavioural response, or mortality. Therefore, at this stage, authoritative thresholds to inform the impact assessment are not defined. However, levels can be determined for pressure metrics presented in literature to assist the assessment (Koessler & McPherson 2023; Appendix G(i)).

As described above, for crustaceans, a PK-PK sound level of 202 dB re 1 µPa (Payne et al. 2008) is associated with no impact and therefore applied in the assessment. Additionally, for context, the PK-PK sound levels determined for crustaceans in Day et al. (2016b), 209–212 dB re 1 µPa, are also included.

For bivalves, literature does not present a sound level associated with no impact, and as particle motion is the more relevant metric, particle acceleration from the seismic source has been modelled for comparison with the results of Day et al. (2017). The maximum particle acceleration assessed for bivalves, associated with chronic mortality in some individuals, was 37.57 m/s^2 (Koessler & McPherson 2023; Appendix G). The maximum particle acceleration and velocity, as a function of horizontal range from the centre of the array in broadside directions (which generate the higher amplitude results) was modelled. For the streamer acquisition modelling, the distance to no effect was reached between 58 and 7 m, based on a particle acceleration limit of 37.57 m/s^2 at the sea floor, with the maximum distance of 58 m being reached at 10 m water depth. For the nodal acquisition modelling, a maximum distance of 42 m was reached at 10 m water depth.

7.1.5.2.6 Reef exclusion zones

Noting the maximum distance to no effect for western rock lobster was 292 m, based on the conservative 202 dB re 1 µPa PK-PK threshold level from Payne et al. (2008), Pilot has proposed seismic source exclusion zones of 300 m around Leander Reef, Big Horseshoe Reef and around a further 13 unnamed reef areas in water depths shallower than 12 m. The seismic source will not be operated within 300 m horizontal distance of the 12 m contour of Leander Reef and Big

Horseshoe Reef or within 300 m horizontal distance of the 12 m contour of the other unnamed reef areas within the eastern part of the ASA (Figure 7-7).

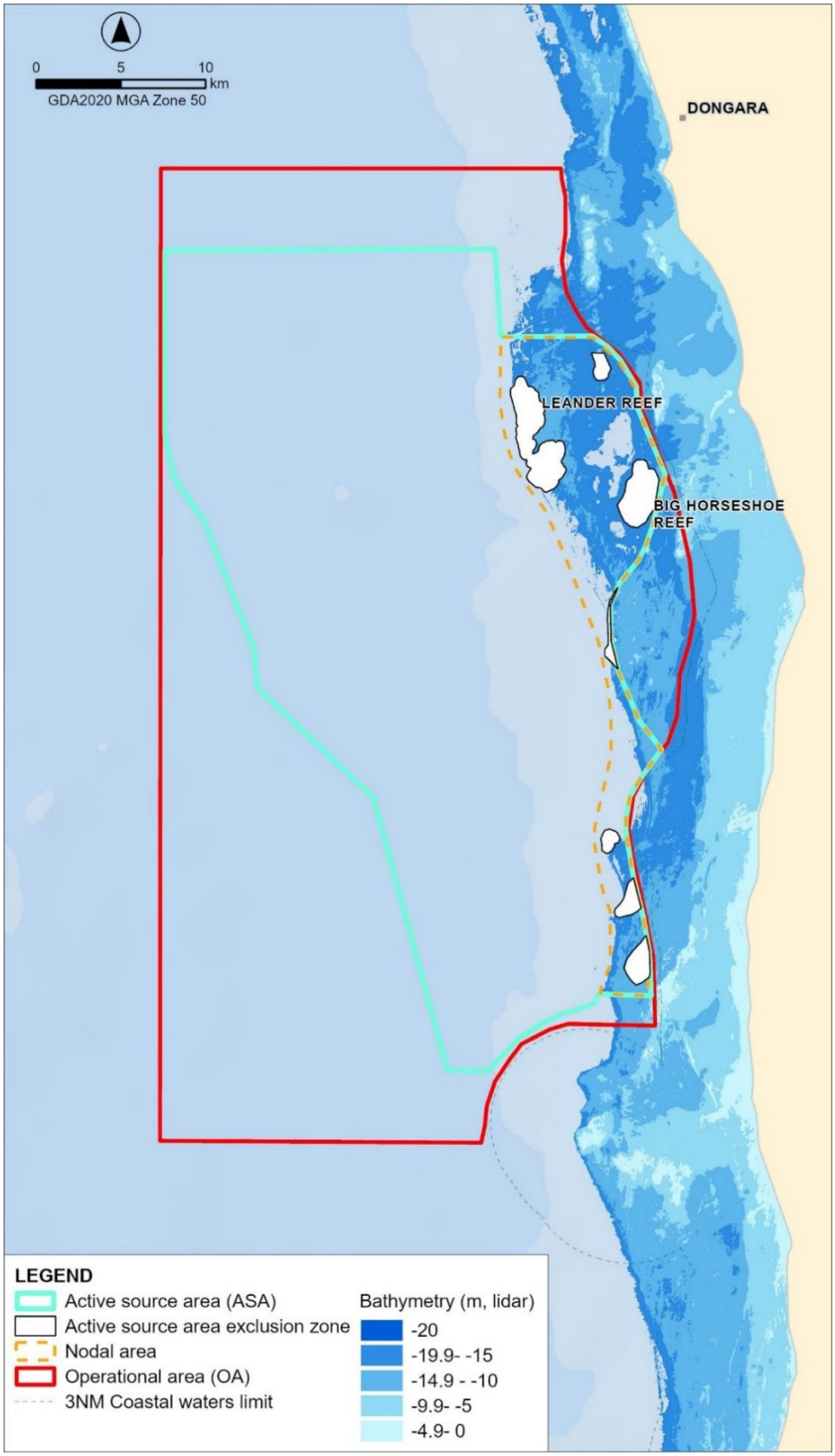


Figure 7-7: Proposed seismic source exclusion zones

7.1.5.2.7 Benthic invertebrates – impact assessment conclusion

Based on the above body of research and risk assessment, some benthic invertebrate species may experience sub-lethal effects or a small increase in mortality rates in the weeks or months following seismic exposure within tens or hundreds of metres from the seismic source. Should this occur, the continuous natural cycle of death, recovery and recruitment of invertebrates from adjacent areas will occur in parallel over these same timescales, and therefore it is questionable whether any impacts from seismic exposure would be detectable from natural fluctuations in relative abundance, benthic community composition and structure. Day et al. (2017) and Payne et al. (2007, 2008) acknowledge that the changes observed in their research are likely within the range of variation that can occur from other common natural and anthropogenic stressors. The ecological implications of such impacts on benthic invertebrate communities are not expected to be significant or long-term.

Therefore, the potential impacts of noise emissions from the seismic source on benthic invertebrates during the acquisition of the survey are 'localised' and 'short-term', as the activity is not likely to result in any ecologically significant impacts at a population level for any species of invertebrate that may be present on the sea floor within or adjacent to the ASA.

7.1.5.3 Fishes and elasmobranchs

7.1.5.3.1 Species sensitivity and sound exposure thresholds

Every species of fish studied to date can hear. Fish produce sounds in a wide range of context such as feeding, mating or fighting, and as a result anything that inhibits the detection of these sounds can have a negative effect on their fitness and survival (Popper & Hawkins 2019). Most fish species detect sounds from <50 Hz up to 500–1500 Hz (Popper & Hawkins 2019). A smaller number of species can detect sounds over 3 kHz, while very few species can detect ultrasound over 100 kHz (Ladich & Fay 2013). The critical issue for understanding whether an anthropogenic sound will affect the hearing of a fish is whether it is within the hearing frequency range of the fish and loud enough to be detectable above background ambient noise.

The hearing sensitivity of fish varies depending upon the auditory structures in the inner ear (otoliths surrounded by an epithelium of hair cells) and, if present, the swim bladder (Finneran & Hastings 2000; Nedwell et al. 2004). Otoliths are sensitive only to particle motion, while the swim bladder may provide an indirect route for sound pressure to reach the inner ear. The other main mechano-reception system in fish is the lateral line system, which runs along the side of the body and is more pronounced in some groups of fish than others. The lateral line system responds to particle motion produced in the near field of a sound source, as well as to tiny water currents set up by the motions of the fish (Nedwell et al. 2004), therefore all fish are sensitive to the particle motion component of sound at close range from a sound source. Particle motion is the most relevant metric for perceiving underwater sound for most species, but except for a few species (Popper & Fay 2011; Popper et al. 2014), there is an almost complete lack of relevant data on particle motion sensitivity in fish (Popper & Hawkins 2018). Some more specialised fish with a swim bladder that they use for hearing are sensitive to sound pressure and can detect less intense noise and a wider range of frequencies, compared to less-specialised groups of fish (Popper et al. 2014; Carroll et al. 2017; Hawkins & Popper 2017). The susceptibility of fish to injury from noise exposure varies depending on the species and the presence and possible role of a swim bladder in hearing.

In marine fish, the connection with the swim bladder and ability to detect sound pressure is understood to be present to some varying degree in the families Clupeidae (e.g. herrings, sardines, pilchards and shads), Gadidae (e.g. true cods such as Atlantic cod and whiting), and some nearshore/reef species relevant to tropical Australia, including some species in the families Pomacentridae (e.g. damsel fishes and clown fishes), Holocentridae (soldierfishes and squirrelfishes) and Haemulidae (e.g. grunters and sweetlips) (Nedwell et al. 2004; Braun & Grande 2008; Popper et al. 2014; Popper & Hawkins 2018, 2019). However, most marine fish species do not have this hearing specialisation.

A great many fishes possess a swim bladder or other gas-filled cavity but do not have a connection with their hearing, for example various demersal scalefish targeted by the West Coast Demersal Scalefish Managed Fishery (e.g., baldchin groper, snapper, redthroat emperor). Of these demersal scale fish, dhufish are an interesting exception, in that they have a mechanical connection (bi-lateral sonic muscles) between the otic region and the swim bladder, which appear to be

used for sound production (Parsons et al. 2012, 2013). Fish species that lack a gas-filled cavity altogether, include elasmobranchs (e.g., sharks and rays), some flat fishes, some tunas, and mackerels (Casper et al. 2012; Popper et al. 2014).

The sound exposure thresholds applied for fish and elasmobranchs (sharks and rays) in the acoustic modelling study and in this impact assessment are summarised in Table 7-4 and explained in more detail in the acoustic modelling report (Koessler & McPherson 2023; Appendix G(i)). The modelling study assessed the ranges for quantitative threshold criteria based on the Popper et al. (2014) guidelines for three types of immediate effects to fish:

- Mortality, including injury leading to death
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma
- TTS.

The modelling study considered single pulse (PK) and multiple pulse (SEL_{24h}) metrics for both the entire water column and sea floor in the following categories reflective of the different hearing mechanisms and sensitivity to sound:

- I - Fish without a swim bladder (also appropriate for sharks in the absence of other information)
- II - Fish with a swim bladder that do not use it for hearing
- III - Fish that use their swim bladders for hearing.

For this impact assessment, it is assumed that all fish can detect signals below 500 Hz and so can 'hear' the seismic source.

Table 7-4: Thresholds for seismic sound exposure for fish, adopted from Popper et al. (2014)

Type	Mortality and potential mortality injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
I Fish: No swim bladder (particle motion detection)	>219 dB SEL_{24h} or >213 dB PK	>216 dB SEL_{24h} or >213 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
II Fish: Swim bladder not involved in hearing (particle motion detection)	>210 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
III Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	186 dB SEL_{24h}	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate

Notes: Peak sound level (PK) dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s. All criteria are presented as sound pressure, even for fish without swim bladders, since no data for particle motion exist. Relative risk (high, moderate, or low) is given for animals at three distances from the source defined in relative terms as near (N – tens of metres), intermediate (I – hundreds of metres), and far (F – thousands of metres).

7.1.5.3.2 Mortality/injury

It is noted that while thresholds for fish mortality have been included for consideration in this assessment based on the Popper et al. (2014) guidelines, no studies to date have demonstrated direct mortality of free-swimming adult fish in response to airgun emissions, even when fired at close proximity (within 1–7 m) (DFO 2004; Boeger et al. 2006; Popper et al. 2016; Carroll et al. 2017). Although some fish deaths have been reported during cage experiments, these were more likely caused by experimental artefacts of handling fish or confinement stress (Hassel et al. 2004). For free-swimming fish that can move away from seismic sources as they approach, the potential for lethal physical damage from airgun emissions is even further nullified. However, reef or bottom-dwelling fish that show greater site attachment may be less inclined to flee from a seismic sound source and experience greater effects.

Despite mortality being a possibility for fish exposed to airgun sounds, Popper et al. (2014) did not reference an actual occurrence of this effect. At the time of developing the guidelines, no quantified data on injury and mortality from seismic sources on fish had been reviewed by the Working Group. Therefore, the Popper et al. (2014) exposure guidelines for mortality/potential mortal injury and recoverable injury for fish exposed to seismic source emissions are based solely on data from pile driving conducted on predominantly temperate, freshwater fish species. Although seismic surveys and pile driving both produce impulsive sound, their sound characteristics are markedly different; pile driving impulses result in a more rapid rise time in sound pressure than seismic pulses and it is this rapid rise time that has the greatest potential for trauma (Caltrans 2001, 2004; Hastings & Popper 2005; Popper et al. 2006).

Environmental Resources Management Australia (ERM) undertook a detailed literature review of potential fish mortality and physical injury because of exposure to seismic sources (ERM 2017). Of the 28 studies reviewed, only three observed direct mortality and in each case, mortalities occurred to caged fish at very close proximity to the seismic source (<2 m), which is not representative of real-life exposures from seismic surveys because fish are free-swimming and are not typically exposed at such close range. The received sound levels that resulted in mortality ranged from 220 to 241 dB re 1 µPa PK; however, other studies reported no mortality or injury at levels as high as 246 dB re 1 µPa PK. Therefore, the sound exposure criteria proposed by Popper et al. (2014) for mortality and injury are highly conservative and provide a precautionary approach in the assessment of potential injury and mortality effects to fishes from exposure to underwater noise from marine seismic surveys.

7.1.5.3.3 Temporary threshold shift

Temporary hearing impairment (TTS) can occur due to fatigue and temporary changes to the epithelium (hair cells) of the inner ear and/or damage to auditory nerves innervating the ear, which has the potential to occur in some fishes exposed to intense sound pressures for prolonged periods of time (Smith et al. 2006; Popper et al. 2014; Liberman 2015). While experiencing TTS, fishes may have a decrease in fitness in terms of communication, detecting predators or prey, and/or assessing their environment. The period over which normal hearing ability returns following the termination of a sound that causes TTS is variable, and dependent on many factors including the intensity and duration of sound exposure (e.g., Popper & Clarke 1976; Scholik & Yan 2001; Amoser & Ladich 2003; Smith et al. 2004a, 2004b, 2006, 2011; Popper et al. 2005, 2007).

The impact threshold of 186 dB re 1 $\mu Pa^2 \cdot s$ proposed by Popper et al. (2014) in Table 7-4 is based on exposure of a freshwater fish species with a connection between the swim bladder and inner ear (i.e. more specialised hearing than the majority of demersal and pelagic fish species likely to occur in the Eureka 3D MSS OA – the dhufish being an exception) (Popper et al. 2005). Fish that showed TTS recovered to normal hearing levels within 18–24 hours. Given that reliable auditory frequency weightings have not been defined for the three categories of fish in the way they have for cetaceans, the 186 dB re 1 $\mu Pa^2 \cdot s$ SEL_{24h} criteria in Table 7-4 includes a level of conservatism as:

- Most fish that are likely to occur in the OA do not possess a direct connection between the swim bladder and the inner ear; they are therefore sensitive primarily to particle motion rather than sound pressure and may be less sensitive than the types of fish upon which the 186 dB re 1 $\mu Pa^2 \cdot s$ threshold is derived
- Modelled SELs are based on broadband sounds and may therefore account for more sound energy associated with frequencies that are not within the auditory ranges of the fish species likely to occur in the OA
- The main contribution of sound energy to the onset of TTS will occur over just a few hours when the source is at the closest point of approach; the 24-hour modelled accumulation period accounts for additional sound energy accumulated while the seismic source is at greater distances and potentially not audible to fishes.

It is also noted that many of the available studies on TTS are based on captive fish, whereas free-swimming fishes in the wild are likely to make some effort to avoid the intense sound pressures that contribute the most to the onset of TTS. If TTS does occur, the effects will be temporary and recoverable (Popper et al. 2005).

Popper (2018) in his expert peer review of TTS effects in demersal fishes for the Santos Bethany 3D MSS, located in the Timor Sea, noted:

- It is highly unlikely that there would be physical damage to fish because of the survey unless the animals are very close to the source (perhaps within a few metres).
- If TTS takes place, its level is likely to be sufficiently low that it will not be possible to easily differentiate it from normal variations in hearing sensitivity. Even if fish do show some TTS, recovery will start as soon as the most intense sounds end, and recovery is likely to even occur, to a limited degree, between seismic pulses. Based on very limited data, recovery within 24-hours (or less) is very likely.
- Nothing is known about the behavioural implications of TTS in fish in the wild. However, since the TTS is likely very transitory, the likelihood of it having a significant impact on fish fitness is very low.

Therefore, while TTS effects in site-attached fishes may occur, the potential for impacts to individuals' fitness and survival is limited and impacts to fish community structures are not expected (Popper 2018).

7.1.5.3.4 Behavioural effects

Behavioural effects of noise on fish will vary depending on the circumstances of the fish, hearing sensitivity, the activities in which it is engaged, its motivation, and the context in which it is exposed to sounds (Hawkins & Popper 2017). Responses may include avoidance behaviours, startle reactions, increased swimming speed, change in orientation, change in position in the water column, changes to schooling behaviour (e.g., tightening of school structure), and temporary avoidance of an area (Simmonds & MacLennan 2005; McCauley et al. 2000a; Fewtrell & McCauley 2012; Popper et al. 2014; Carroll et al. 2017). Changes in movement patterns may also temporarily divert efforts away from feeding, egg production and spawning success (Hawkins & Popper 2017). The potential extent and duration of behavioural effects based on studies of seismic exposure are summarised below.

A degree of caution should be given when interpreting behavioural studies, given that many are conducted on captive fish which may not provide an accurate representation of responses in free-swimming fish in the wild (Popper et al. 2014; Salgado Kent et al. 2016; Carroll et al. 2017). Behavioural studies are also highly subjective. Extrapolation of observed effects on fish should also be undertaken with caution (Carroll et al. 2017). This is particularly the case given that many exposure-experiments report received SPL or SEL, even though the most relevant metric for most fish species is particle motion (Popper & Hawkins 2018, 2019). Many exposure experiments are undertaken using a single airgun and it is not clear how transferrable the behaviours and received SPL/SEL levels are to a full commercial-sized seismic array, particularly if observed behaviours are in response to particle motion close to the sound source rather than to sound pressure.

Pearson et al. (1992) exposed captive demersal rockfish to multiple 10-minute periods of seismic sound from a seismic source towed at distances of less than 215 m, which is not representative of real-life exposures to a seismic survey. Schools of rockfish were observed to exhibit a 'startle' response (shudders, flexions of the body followed by rapid swimming) at sound levels above 200–205 dB re 1µPa SPL. An 'alarm' response (change in vertical position in the water column to be closer to the seabed, short-term post-exposure behavioural changes) was found to occur above approximately 180 dB re 1µPa SPL, although it was suggested that some individuals may begin to exhibit subtle changes in behaviour and position in the water column at sound levels above 161 dB re 1µPa SPL. Changes in behaviour were found to return to normal before the end of the sound exposure or within just minutes of the sound ceasing, indicating only very short-term, transient effects and potential habituation to the disturbance.

Santulli et al. (1999) exposed caged European sea bass (a demersal species) to a 2500 in^3 seismic source. Limited response was observed at 2.5 km distance, a startle response was observed when the array was at approximately 800 m, but after passing within 180 m, fish behaviour appeared to return to normal within one hour.

The Scott Reef Study associated with the Woodside Maxima 3D MSS reported in McCauley et al. (2008) and Miller & Cripps (2013) and summarised in Salgado-Kent et al. (2016), included a component that examined how the behaviour of caged fish exposed to seismic signals changed. The study examined the effects to fish species in the Holocentridae family, which have adaptations linking the swim bladder to the otolith system of the inner ear, as well as to bluestripe snapper, a demersal species without such a hearing adaptation, like the demersal species that are most likely to occur within the Eureka 3D MSS OA. Fish were exposed to either one or two passes of the active source at three distance categories (45–

74 m, 105–131 m, 475–807 m). Alarm responses (including the startle response and behavioural avoidance) occurred within less than 200 m either side of the pass by, but responses were too infrequent to include in analyses. Less significant agitation levels (defined by changing swim direction) in Holocentridae increased with increasing received sound level above 155–165 dB re 1 uPa².s SEL, but agitation levels did not seem to increase with increasing received sound levels for the less sensitive bluestripe snapper (McCauley et al. 2008). Fish began to feed and behave normally again within 20-minutes after the passage of the seismic source (McCauley et al. 2008; Miller & Cripps 2013).

McCauley et al. (2000a, 2003) reported that trials involving captive fish (of various species, including snappers, emperors, groupers, trevally, bream, herring, dhufish, mullet, trumpeter and wrasse) exposed to seismic sound showed a common 'startle' response (C-turns), 'alarm' responses (e.g. swimming faster, darting movements and sudden changes in school structure), or less obvious changes such as moving closer to the seabed or huddling closer together. Subtle responses such as moving closer to the seabed or changes in schooling behaviour were suggested to commence when sound levels exceeded approximately 147-151 dB re 1 µPa² s SEL. Similar behaviours in pink snapper and trevally were noted by Fewtrell & McCauley (2012) in response to comparable sound levels. These are minimal reactions that are likely to be an indication of awareness and perception of the sound rather than a response that could result in significant ecological impacts. More obvious startle and alarm responses were apparent in trials when received sound levels were in the order of 159-172 dB re 1 µPa² s SEL. In situations where a behavioural response was observed, fish were considered to have resumed normal behaviour within 4–31 minutes after cessation of the seismic activity (McCauley et al. 2000a, 2003). Startle and alarm responses reduced with time, indicating some habituation to the sound. No statistically clear trends in physiological stress response were observed following exposure (McCauley et al. 2000a, 2003).

Behavioural observations of two tropical snapper species and another coral reef fish species, spadefish, in field enclosures before, during and after exposure to seismic sound showed that repeated exposure resulted in increasingly less obvious startle responses (Boeger et al. 2006). This is consistent with the potential habituation suggested by McCauley et al. (2000a) and by Fewtrell & McCauley (2012).

McCauley & Salgado Kent (2007) observed the behaviour of goldband snapper in fish traps in the Timor Sea using cameras placed inside the fish traps. A seismic vessel towed two 3090 in^3 seismic sources. Maximum signals reached at the closest trap to each seismic pass-by were 200, 202 and 212 dB re 1 µPa PK-PK (equivalent to approximately 194, 196 and 206 dB re 1 µPa PK). No dramatic behavioural responses of fish to the passing seismic source were observed. Fish generally displayed increased activity immediately after entering a trap presumably as they searched for a way out, with this activity reducing with time. Fish that had been in a trap for some time showed increased activity levels as the operating seismic source approached but were 'quiet' when the array passed at the point of closest approach.

Bruce et al. (2018) tagged tiger flathead and two shark species, which were monitored during a seismic survey undertaken in Australian waters. Sharks moved freely in and out of the study area and exposed sharks did not show any indication of differences in behaviour or distribution compared with control areas. Minor behavioural effects were observed in exposed tiger flathead, which increased their swimming speed during the seismic survey and changed daily movement patterns after the survey but showed no significant displacement. Overall, there was little evidence for consistent behavioural responses (Bruce et al. 2018).

Paxton et al. (2017) observed temperate reef fish, including snapper and grouper species, in 33 m water depths located 7.9 km from a seismic survey line using video recordings. The authors observed fish abundance and habitat use during the evening hours for three days prior to a seismic survey and then during the evening of the day when seismic activity occurred. The authors attempted to measure sound at two other reefs in closer proximity to the survey, but the hydrophones malfunctioned. No video recordings were made at the other reefs where hydrophone measurements were attempted. No hydrophone measurements were made at the reef where video recordings took place, but maximum sound levels were estimated to be more than 170 dB re 1 µPa SPL. Despite no clear visual evidence of behavioural responses in fish during the seismic survey, the authors noted a 78% decline in abundance in the evening following the survey. No further recordings were made to assess when fish abundance returned to pre-exposure levels or how far they may have moved. Therefore, with limited data, it is not clear from this study if reduced abundance is attributed to the seismic sound or other natural factors such as tidal influence or food availability. However, the study may indicate a possible avoidance response and change in local abundance and distribution.

Meekan et al. (2021) undertook a large-scale experiment that quantified the impacts of exposure of an assemblage of tropical demersal emperors (family Lutjanidae), snappers (family Lethrinidae) and groupers (family Epinephelidae) targeted by commercial fisheries to a commercial-scale seismic source on the North West Shelf off Western Australia. Dominant species included bluespotted emperor (*Lethrinus punctulatus*), red emperor (*Lutjanus sebae*), and brownstripe snapper (*L. vitta*). A combination of Baited Remote Underwater Video Systems (BRUVS) and acoustic tagging methods were used to measure the behaviours and movements of fishes at high, medium and low exposure sites, as well as at control sites. The high, medium and low exposure sites were located at horizontal distances from the path of the seismic source of approximately 0–300 m, 2–10 km and 11 km, respectively. The maximum modelled SEL values received at the high, medium and low exposure sites were in the order of 180–200 dB re 1 $\mu Pa^2 \cdot s$, 130–160 dB re 1 $\mu Pa^2 \cdot s$ and 115–125 dB re 1 $\mu Pa^2 \cdot s$, respectively. There were no short-term (days) or long-term (months) effects of exposure on the composition, abundance, size structure, behaviour, or movement of fishes at any exposure sites. The authors suggest that it is a reasonable assumption that the behavioural responses of demersal fishes to the bait cue provided by the BRUVS are a realistic proxy of the likely response of the same species to baited hooks or traps used by the commercial fisheries that target them. The acoustic tags and telemetry found little evidence that fish were displaced by the exposure to the seismic source. Movements of tagged fish occurred over a limited area focused on two or three acoustic receivers, and there was no evidence for the departure of tagged fish after exposure. These multiple lines of evidence suggest that seismic surveys have little impact on the behaviours of demersal fishes in this environment.

Some other studies looking at the behavioural response of sound pressure-sensitive Gadidae and Clupeidae species, such as whiting, Atlantic cod and herring, have reported changes in vertical position in the water column, potential avoidance responses and short-term changes in distribution. Chapman & Hawkins (1969) observed that the depth distribution of free-ranging whiting changed in response to an intermittently discharging stationary seismic source, which resulted in fish being exposed to an estimated SPL of 178 dB re 1 µPa. The fish school responded to the sound by shifting downward, forming a more compact layer at greater depth although temporary habituation was observed after one hour of continual sound exposure (Chapman & Hawkins 1969).

Hawkins et al. (2014) exposed free-swimming sprat (a sound pressure-sensitive Clupeidae species with a swim bladder connected to the inner ear) and Atlantic mackerel (a particle motion detecting species without a swim bladder) to playback of impulsive sound. Sprat schools were more likely to disperse laterally in response to received sound levels of approximately 135 dB re 1 μPa^2 s SEL. Mackerel schools were more likely to alter their depth in the water column in response to approximately 142 dB re 1 μPa^2 s SEL. Hawkins et al. (2014) note how the two different species seemed to respond to the sound playback at similar sound levels despite the differences in sound sensitivity of the two species, but suggested that mackerel were simply more “flighty” than sprat and therefore more likely to react. The tests were also undertaken using low sound level playback in very close proximity to the schools of fish and it is not clear how relevant the sound pressure and sound exposure levels are in relation to mackerel given that their response was likely driven by particle motion. The study location, a very small, enclosed, quiet, coastal sea lough, where fish were not accustomed to heavy disturbance from shipping and other intense sound sources is also very different from an open ocean location.

Slotte et al. (2004) monitored the effects of a 3090 in^3 seismic array on migrating herring (Clupeidae) and whiting (Gadidae), mapping their distribution and abundance in relation to the seismic survey lines. There was no significant evidence of immediate, near-field scaring reactions on the horizontal scale in response to acquiring survey lines, but there was some evidence that fish changed position in the water column, moving closer to the seabed. Some short-term changes in distribution were observed but were not statistically significant; fish consistently remained within the immediate vicinity of the survey area, but in a limited number of measurements there was an indication that fish abundance was lower near to the survey area and increased with distance out to a maximum range of 37 km. However, results were inconsistent, and clear trends were not observed in all cases. Slotte et al. (2004) concluded that it was not possible to determine how much abundance and distribution were attributed to the seismic survey or to the natural migration patterns and food availability of the fish, or other natural factors. Herring and whiting were found to be abundant in the survey area again after a pause in seismic acquisition and monitoring of fishes for three to four days, indicating that if any displacement did occur because of seismic sound exposure, the displacement was temporary (i.e. less than 3–4 days) (Slotte et al. 2004).

In similar studies, Engås et al. (1996) and Engås & Løkkeborg (2002) reported on the effects of seismic surveys on Atlantic cod and haddock (Gadidae) and found that the abundance of fish was lower in the survey area compared with areas

outside of the survey area, which the authors hypothesize may be the result of an avoidance response. Some differences in abundance were still detectable within the survey area five days after the survey was completed (Engås et al. 1996; Engås & Løkkeborg 2002).

Conversely, Peña et al. (2013) described the real-time behaviour of herring schools exposed to a full-scale 3D seismic survey, observed using sonar. No changes were observed in swimming speed, swimming direction, or school size that could be attributed to a transmitting seismic vessel as it approached from 27 km to 2 km, over a six-hour period. The unexpected lack of a response to the seismic survey was interpreted as a combination of a strong motivation for feeding by the fish, a lack of suddenness of the onset of sound, and an increased level of tolerance to seismic pulses.

Davidsen et al. (2019) investigated the effects of seismic sound exposure on the physiology and behaviour of captive Atlantic cod (*Gadus morhua*) and saithe (*Pollachius virens*) using a combination of biologgers and acoustic tags, as well as video monitoring. Experimental sound exposures were 18–60 dB above ambient. Fish were held in a large sea cage and exposed over a three-day period. The cod exhibited reduced heart rate in response to the particle motion component of the sound from the airgun, indicative of an initial flight response. No behavioural startle response to the airgun was observed; both cod and saithe changed both swimming depth and horizontal position more frequently during sound exposure. The saithe became more dispersed in response to the elevated sound levels. The fish seemed to habituate both physiologically and behaviourally with repeated exposure. The authors concluded that sound exposures induced over the timeframes used in this study appear unlikely to be associated with long-term alterations in physiology or behaviour.

Hubert et al. (2020) exposed captive Atlantic cod to one hour of playback of seismic airgun sound pulses with a ten-second shot point interval. Cod were placed in a net pen positioned 7.8 m from the speaker. The mean peak sound pressure and particle acceleration levels at 9.7 m from the speaker were 164 dB re 1 µPa and 101 dB re 1 nm/s^2, respectively. At 16.4 m form the speaker, the mean peak sound pressure and particle acceleration levels were 158 dB re 1 µPa and 99 dB re 1 nm/s^{2,} respectively. These levels compare with a mean SPL of the ambient conditions in the pen of 113 dB re 1 µPa and a mean sound particle acceleration of 61 dB re 1 nm/s^2. Results indicated no strong overall pattern of change in swimming patterns or immediate, short-term behaviours during the exposure, compared to baseline periods without playback. However, several individuals changed their time spent in several behavioural states during the 1-hour sound exposure. Several individuals spent more time transiting and less time being locally active or inactive. This may be indicative of changes in energy expenditure, which may be relevant if sound exposure occurs over the long-term. However, due to experimental design limitations, it was not possible to test the significance of these behavioural state trends (Hubert et al. 2020).

van der Knaap et al. (2021) investigated the effect of a 3.5-day, full-scale, seismic survey exposure on the movement behaviour of free-swimming Atlantic cod, using acoustic telemetry. The closest point of approach to the tagging location was 2.25 km. The study found that during the experimental survey, cod did not leave the detection area more than expected from baseline data. However, cod left more quickly than expected, from two days to two weeks after the seismic survey. Furthermore, behavioural analyses indicated that during the exposure cod decreased their activity, with time spent being locally active (moving over small distances, showing high body acceleration) becoming shorter, and time spent being inactive (moving over small distances, having low body acceleration) becoming longer. Additionally, diurnal activity cycles were disrupted with lower locally active peaks at dusk and dawn—periods when cod is known to actively feed.

The following conclusions are made regarding behavioural effects to fish from seismic airguns, based on the literature above:

- Different fish may exhibit different behavioural responses when exposed to seismic survey noise, depending on their activities, motivation and the context in which they receive sound.
- Fish may change position in the water column (i.e. move closer to the seabed) as a response to becoming aware of approaching seismic sound (e.g. Pearson et al. 1992; McCauley et al. 2000a, 2003; Slotte et al. 2004; Fewtrell and McCauley, 2012; Miller and Cripps, 2013; Davidsen et al. 2019).
- Exposure to higher sound levels at close range to a seismic source may begin to result in more noticeable startle or alarm responses, such as changes in school structure, increased swimming speed and avoidance of the sound

source (e.g. Simmonds & MacLennan 2005; McCauley et al. 2000a, 2003; Fewtrell & McCauley 2012; Popper et al. 2014; Carroll et al. 2017).

- Many exposure experiments are undertaken using a single airgun and it is not clear how transferrable the behaviours and received SPL/SEL levels are to a full commercial-sized seismic array, particularly if observed behaviours are in response to particle motion close to the sound source rather than to sound pressure.
- There is some evidence that fish may also tolerate gradual increases in sound levels and habituate to repeated sound exposures (Chapman & Hawkins 1969; McCauley et al. 2000a; Boeger et al. 2006; Fewtrell & McCauley 2012; Peña et al. 2013; Davidsen et al. 2019).
- Many studies indicate that fishes resume normal behaviour shortly after cessation of the acoustic disturbance (within minutes / less than an hour), with no evidence of long-term changes (e.g. Wardle et al. 2001; Pearson et al. 1992; Santulli et al. 1999; McCauley et al. 2000a, 2003; Fewtrell & McCauley 2012; Miller & Cripps 2013; Davidsen et al. 2019).
- Meekan et al. (2021) found no short-term (days) or longer-term (months) effects of seismic sound exposure on the behaviour and movement of tropical demersal snapper, emperor and grouper species on the North West Shelf.
- There is some evidence that changes in distribution may persist for longer than the initial change in behaviour, i.e. position in the water column, schooling behaviours and swim speeds may return to normal relatively quickly (within minutes or hours), but their distribution may not return to normal for hours or days. Potential changes in distribution of fish have been observed in some studies for approximately five days following sound exposure, although such changes are limited to studies that focused primarily on migrating sound pressure-sensitive types of fish with a swim bladder-ear connection (e.g. Clupeidae, Gadidae). These studies also acknowledge that it is difficult to attribute these changes in distribution directly to the seismic survey or to natural migration patterns, food availability or other natural factors (Slotte et al. 2004; Engås et al. 1996; Engås & Løkkeborg 2002). However, it is possible that changes to the behaviour and distribution of some sound-sensitive prey species (e.g. herring, sardines) may have some indirect influence on the distribution of larger predatory fishes during the days following exposure and disturbance.
- Small changes in behaviour or disruption to diurnal activities of pressure-sensitive species of fish (Gadidae) with a swim bladder-ear connection may indicate that activities such as feeding and energy expenditure can be affected if exposed long-term (Davidsen et al. 2019; Hubert et al. 2020; van der Knaap et al. 2021), although these species of fish may also habituate to the sound with repeated exposure (Davidsen et al. 2019).

Given the limited convergence in results from the available studies, the subjective nature of many assessments and the context under which fish received sound, the Popper et al. (2014) ANSI-Accredited Standards Committee Sound Exposure Guidelines for Fishes and Turtles determined that it is not possible to define exact sound level thresholds for changes in fish behaviours. Instead, Popper et al. (2014) applies relative risk criteria (Table 7-4). The criteria reflect the potential for substantial changes in behaviour for a large proportion of the animals exposed to a sound, which may alter distribution, and moving from preferred sites for feeding and reproduction. The criteria do not include effects on single animals or small changes in behaviour such as a startle response or minor movements. As such, Popper et al. (2014) indicate that fish without a swim bladder or with no connection between the swim bladder and the inner ear may experience substantial changes in behaviour within tens or hundreds of metres of a seismic source. These peer-reviewed and accredited sound exposure criteria are reflected in this risk assessment. It is acknowledged that some fishes with swim bladders may show varying levels of awareness of sound pressure at greater distances from the seismic source, but it is important to recognise changes in behaviour that may be of ecological significance from those that are not.

7.1.5.3.5 Impact assessment

As described in Section 4.3.3, the OA and surrounding waters represent habitat for a range of bony fishes (teleosts) and elasmobranchs (sharks and rays), including benthic, demersal, and pelagic assemblages. These fish assemblages include various demersal scalefish targeted by the West Coast Demersal Scalefish Managed Fishery (e.g. dhufish, baldchin groper,

snapper, redthroat emperor). Behavioural impacts potentially affecting 'catchability' of target species, and hence catch rates, for this commercial fishery are assessed in Section 7.1.5.5.

The OA overlaps with large areas of patch and emergent reef habitat. These areas of hard substrate represent significant habitat for both demersal and benthic fish assemblages, including "site-attached" fish assemblages. For this assessment, site-attached fishes are defined as fish that rely on the benthic habitat and demonstrate a very high degree of site fidelity to the extent that they are unlikely or unable to flee an approaching seismic source and are instead likely to remain/seek refuge within habitat structures.

The EPBC Protected Matters Search identified eight shark species (including the white shark, whale shark and grey nurse shark), one sawfish species and two ray species that may potentially occur within the OA (see Section 4 and Appendix B).

Without appropriate control measures in place, noise emissions from the seismic source have the potential to impacts fish and elasmobranchs by causing mortality/potential mortal injury (PMI), recoverable injury and hearing impairment (TTS and masking) because of high sound levels at close range to the seismic source, or behavioural disturbance impacts at greater distances.

Table 7-5 presents the results of the acoustic modelling study for maximum predicted distances to mortality/ PMI, recoverable injury and TTS onset in fish and fish eggs and larvae. Data is presented for both the entire water column (MOD) and at the sea floor.

Table 7-5: Summary of maximum distances to mortality/PMI, recoverable injury and TTS onset in fish, fish eggs and larvae for single pulse and SEL_{24h} modelled scenarios

Marine fauna group	Potential impact	Sound exposure threshold		Rmax distance (km) – Streamer Acquisition		Rmax distance (km) – Nodal Acquisition	
				MOD	Sea floor	MOD	Sea floor
I Fish: No swim bladder	Mortality/PMI	219 dB re 1 µPa2·s (SEL24h)	<0.06	<0.06	0.06		0.06
		213 dB re 1 µPa (PK)	0.15	0.07	0.11		0.045
	Recoverable injury	216 dB re 1 µPa2·s (SEL24h)	<0.06	<0.06	0.07		0.07
		213 dB re 1 µPa (PK)	0.15	0.07	0.11		0.045
	TTS	186 dB re 1 µPa2·s (SEL24h)	4.66	4.66	2.46		2.46
II Fish: Swim bladder not involved in hearing	Mortality/PMI	210 dB re 1 µPa2·s (SEL24h)	<0.06	<0.06	0.07		0.07
		207 dB re 1 µPa (PK)	0.27	0.13	0.28		0.094
	Recoverable injury	203 dB re 1 µPa2·s (SEL24h)	0.10	0.10	0.07		0.07
		207 dB re 1 µPa (PK)	0.27	0.13	0.28		0.094
	TTS	186 dB re 1 µPa2·s (SEL24h)	4.66	4.66	2.46		2.46
III Fish: Swim bladder involved in hearing	Mortality/PMI	207 dB re 1 µPa2·s (SEL24h)	<0.06	<0.06	0.07		0.07
		207 dB re 1 µPa (PK)	0.27	0.13	0.28		0.094
	Recoverable injury	203 dB re 1 µPa2·s (SEL24h)	0.10	0.10	0.07		0.07
		207 dB re 1 µPa (PK)	0.27	0.13	0.28		0.094
	TTS	186 dB re 1 µPa2·s (SEL24h)	4.66	4.66	2.46		2.46

The following fish types have been identified for this assessment:

- Site-attached fish assemblages
- Demersal fish species, including key commercial indicator species such as dhufish, snapper, baldchin groper and redthroat emperor
- Pelagic fish species, including species targeted by commercial and recreational fishers, such as mackerels, samson fish, tuna species and trevally
- Shark species, including EPBC Act-listed sharks.

7.1.5.3.6 Site-attached fish assemblages and demersal fish species

Within the ASA, key bathymetric features that are expected to provide habitats (hard substrate with epibenthos communities) with the potential to support site-attached or habitat dependent fish assemblages are the larger emergent reefs (e.g. Leander Reef, Big Horseshoe Reef) and smaller scattered patch reef areas. These reefs and the seagrass beds or sand patches that separate them will be occupied by a range of demersal scalefish, including several species targeted by commercial and recreational fishers—dhufish, snapper, baldchin groper and redthroat emperor. The inshore lagoons in the OA are important for the recruitment of commercially and recreationally important species (and it is assumed many other fish species; Fairclough 2021; Parker et al. 2019; Shalders et al. 2018). The Commonwealth marine environment within and adjacent to the west coast inshore lagoons KEF is regarded as an important nursery area for many recreational and commercial fish species including western rock lobster, dhufish and snapper. Many juvenile demersal species use inshore, seagrass or sandy habitats for feeding and protection, before migrating offshore as adults to reefs or other habitats.

As shown in Table 7-5, the maximum predicted R_{max} distances to exceedance of mortality/PMI and recoverable injury thresholds of 213 dB re 1 µPa (PK) and 207 dB re 1 µPa (PK) at the sea floor for all hearing groups of fish range from approximately 70 – 130 m for streamer acquisition, and 45 – 94 m for nodal acquisition, from a single impulse. Further detailed modelling of SEL_{24h} levels received at the sea floor was undertaken by Koessler & McPherson (2023; Appendix G), including acquisition in shallow areas where the seismic source may be operated in proximity to reefs. The predicted R_{max} distances to exceedance of mortality/PMI and recoverable injury SEL_{24h} thresholds for all hearing groups of fish at both the sea floor and in the water column was <60 m for streamer acquisition, and 70 m for nodal acquisition (refer Table 7-4).

There is the potential for recoverable injury to occur in site-attached fishes in the water column up to a maximum range of approximately 270 m (streamer acquisition) and 280 m (nodal acquisition) from the seismic source (refer Table 7-5). The seismic source will not be operated within 300 m horizontal distance of the 12 m contour of Leander Reef and Big Horseshoe Reef or within 300 m horizontal distance of the 12 m contour of the other unnamed reef areas within the eastern part of the ASA. The 300 m exclusion distance provides some additional conservatism against the reported R_{max} for recoverable injury for fishes in the water column (270 m and 280 m), noting that the Popper et al. (2014) thresholds for recoverable injury are already considered to be highly conservative, as described above. Further to this, as the survey vessel will need to deviate around these reef exclusion zones multiple times there is potential for increased cumulative sound exposure. To minimise this, the survey vessel will not activate the seismic source within 200 m of the reef exclusive zone unless 24 hours has elapsed since the source was last operated within 200m of the exclusion zone for a particular reef feature. This 24-hour interval is expected to reduce the cumulative noise exposure to site-attached fish species based on the reported recovery period of 18 – 24 hours for TTS observed in fish (Popper et al., 2005).

7.1.5.3.7 Pelagic fish species

Pelagic fish species likely to be present in OA include mackerels, samson fish, trevally and several species of tuna. Some species (e.g. mackerels) do not possess a swim bladder (Group I fish), while other species do (Group II and III fish). These species may be targeted in the region by recreational fishers.

As shown in Table 7-5, the maximum predicted R_{max} distances to mortality/PMI and recoverable injury for fish with no swim bladder (Group I fish) within the entire water column was within 150 m (streamer acquisition) or 110 m (nodal acquisition). For all fish with a swim bladder (Group II and III fish) the maximum predicted R_{max} distance to mortality/PMI within the entire water column was within 270 m (streamer acquisition) or 280 m (nodal acquisition). The maximum distance to the TTS threshold in the water column for all fish hearing groups (Group I, II, III) was within 4.7 km for streamer acquisition, or 2.5 km for nodal acquisition. Large, pelagic, fast-swimming fish species such as mackerel, tuna and trevally are highly unlikely to experience TTS effects as they can swim away from a seismic source. Individuals would have to remain within ranges of approximately 4.7/2.5 km of the operating seismic source for 24-hours to be exposed to sound levels that could cause TTS.

Pelagic fishes are most likely to exhibit behavioural responses (avoidance) by moving away from an operating seismic source that approaches within a few tens of metres of them. Behaviour may return to normal within minutes. However, it is acknowledged that the behaviours and distributions of the pelagic species could be affected for hours or days following exposure because of potential disturbance to more sound-sensitive prey species, such as herrings, sardine's, sprat and shads.

7.1.5.3.8 Shark species

The EPBC Protected Matters Search identified eight shark species (including the white shark, whale shark and grey nurse shark), one sawfish species and two ray species that may potentially occur within the OA.

No sound exposure thresholds currently exist for acoustic impacts from seismic sources to sharks and sawfishes, which are sensitive only to particle motion. As a conservative and precautionary approach, the Popper et al. (2014) exposure guidelines for fish with no swim bladder for injury; 213 dB re 1 µPa (PK) and 219 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h}); and TTS (186 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h}), have been used for this assessment.

As shown in Table 7-5, the maximum predicted R_{max} distances to mortality/PMI/recoverable injury for fish with no swim bladder (incl. sharks) within the entire water column was within 150/110 m. TTS thresholds across the water column for fish without a swim bladder could be reached within 4.7/2.5 km. It is important to appreciate that individual sharks would have to remain within a range of 4.7/2.5 km of the operating seismic source (which is also moving) for 24-hours to be exposed to sound levels that could cause TTS.

It is expected that the potential effects to sharks associated with acoustic noise will be the same as for other pelagic fish species, resulting in minor and temporary behavioural change such as avoidance. This aligns with the Popper et al. (2014) guidelines, which detail that there is the potential for high risk of behavioural impacts in fish species near the seismic source (tens of metres), moderate risk within hundreds of metres, and low risk at thousands of metres from the seismic source.

7.1.5.3.9 Fishes and elasmobranchs – impact assessment conclusion

The potential impacts of noise emissions from the seismic source on fish and elasmobranchs during the acquisition of the survey are 'localised' and 'short-term' and restricted to temporary behavioural changes (avoidance) in any isolated individuals that may transit the area near the operating seismic source. Based on the timing and duration (up to 40 days) of seismic acquisition, and the proposed control measures, predicted noise levels from seismic acquisition are not considered likely to cause mortality/PMI, recoverable injury or significant TTS effects to fish communities or result in any ecologically significant impacts at a population level.

7.1.5.4 Fish spawning

High intensity impulsive sound emitted from the seismic source has the potential to result in behavioural changes in fish or masking of fish vocalisation, which may temporarily divert efforts away from spawning aggregations, egg production and recruitment success (Hawkins & Popper 2017), or potentially cause displacement resulting in fish abandoning spawning grounds. Anecdotal evidence from previous seismic programs appeared to show immediate effects on fish behaviour and longer-term localised stock depletion.

A recent study examined behavioural responses in spawning Atlantic cod in Norway (McQueen et al. 2022, 2023). Atlantic cod (*Gadus morhua*) may be especially vulnerable to sound disturbance during spawning, as it is a soniferous fish species, with acoustic communication playing an important role in the cod mating system, and a low frequency hearing range (10–650 Hz). During the spawning period, male cod produce low frequency grunts (~50 Hz) that have been associated with aggressive and courtship behaviours. Low frequency noise associated with ship traffic has been found to reduce the effective communication range of spawning cod (Stanley et al. 2017; as cited in McQueen et al. 2023), and low frequency anthropogenic noise can elicit stress responses in cod resulting in reduced egg production and fertilization rates (Sierra-Flores et al. 2015). Additionally, cod tend to demonstrate high site fidelity to spawning areas. There have been reports that free-ranging cod move away from an area in immediate or delayed response to seismic surveys (Engås et al. 1996; van der Knaap et al. 2021).

To investigate whether airgun sound causes cod to leave their spawning grounds, McQueen et al. (2022, 2023) deployed acoustic telemetry arrays were on two cod spawning grounds: test and a reference site. From 2019 to 2021, 136 mature cod from the test site and 45 from the reference site were tagged with acoustic transmitters. Intermittent seismic shooting of two 40 in^3 airguns for 1-week during the spawning periods of 2020–2021 resulted in fluctuating SELs at the test site, comparable to a full-scale industrial survey 5–>40 km away. Residency and survival of tagged cod were analysed with capture–mark–recapture models fitted to the detection and recapture data. Departure rate of the mature cod varied between spawning seasons but was similar between the test and reference sites. Cod demonstrated only weak responses to the disturbance from repeated three-hour treatment periods over five days, swimming on average slightly deeper during seismic exposure compared to silent control periods. This response varied between individuals. Longer-term effects of seismic exposure on swimming depth were not detected. No changes in swimming acceleration, displacement, or area use occurred. Neither survival nor departure significantly differed between seismic exposure and baseline periods. The results indicated that exposure to airguns at received SEL of up to ~145 dB re 1 μPa^2 s, comparable to a seismic survey occurring several kilometres away, did not displace tagged cod from spawning grounds. These results suggest that relatively distant seismic surveys do not substantially alter cod behaviour during the spawning period at received sound exposure levels varying between 115 and 145 dB re 1 μPa^2 s over a five-day period (McQueen et al. 2022, 2023).

7.1.5.4.1 Impact assessment

This impact assessment is focused on fish spawning and recruitment for relevant key indicator commercial fish stocks.

Sections 4.3.4 and 4.4.4 describe the key indicator species that are relevant to the Eureka 3D MSS, which include demersal species targeted by the West Coast Demersal Scalefish Managed Fishery (WCDSMF), and Spanish mackerel targeted by recreational fishers. The reproductive biology of the key demersal indicator fish species results in a very broad distribution of eggs and larvae, and consequently genetic connectivity over a wide geographic range. Multiple batches of millions of pelagic eggs are released during multiple, frequent spawning events and throughout extended spawning periods (Gaughan et al. 2018a).

The following assessment considers the potential magnitude of effects to fish spawning behaviours, and therefore the potential influence of the Eureka 3D MSS on recruitment success and the sustainability of key indicator fish species. The assessment considers:

- Spatial-temporal analysis – to provide context on the proportion of the spawning biomass that may be exposed during the survey
- The natural variability in fish distribution, spawning biomass and recruitment
- The sustainability status of the fish stocks and fisheries.

While the focus of this assessment is on the key indicator species, the status of these stocks is used by fisheries managers as an indicator of the sustainability status within the broader suite of scalefish species exploited in the region.

7.1.5.4.2 Spatial-temporal analysis

A spatial-temporal analysis has been conducted to determine the overlap between the Eureka 3D MSS and the principal spawning ranges and periods of key commercial indicator species. The analysis provides an indication of the proportion of the spawning area and the proportion of the spawning period for each species that may be exposed to sound from the survey.

The following assessment focuses on the following commercial key indicator fish species:

- WA dhufish
- Snapper (Mid-west/Kalbarri)
- Redthroat emperor
- Spanish mackerel (no commercial take in area of Eureka 3D MSS but targeted by recreational fishers).

Other key commercial indicator species for the WCDSMF are baldchin groper, hapuku, blue-eye trevalla, eightbar grouper and bass groper. However, the spatial-temporal analysis was not conducted for these species there is either no overlap between peak spawning period and the proposed acquisition windows for the survey (baldchin groper), or there is no spatial overlap between the principal depth range for the species and water depths across the survey area (i.e. the deeper water indicator species – hapuku, blue-eye trevalla, eightbar grouper and bass groper).

The following spatial-temporal analysis is not intended to provide an exact estimate of how much each species' spawning success rate will be impacted. Instead, this method demonstrates how the proportion of fishes that may be affected is relatively small compared to the larger overall adult spawning biomass, spawning area and spawning periods of each stock, which is important context for the assessment. It is important to note that several assumptions have been applied to the analysis to address uncertainty about behavioural effects to spawning fishes and provide a conservative and more precautionary estimate of the proportion of spawning fish stocks that may be exposed and potentially affected during the survey. These assumptions are outlined below:

The spatial overlap with each stock is represented by 24-hours of 3D acquisition with a 10 km buffer applied to account for possible uncertainty about the exact range to disturbance to fish.

This approach accounts for an area that may be subject to sound exposure from the seismic source. Accounting for the entire ASA or the entire acquisition line plan is overly conservative as it is likely to be significantly larger than the area where fish may be exposed to sound and subjected to disturbance. The 24-hour timeframe is precautionary to account for scientific uncertainty in relation to the duration and recovery of behavioural disturbances in fishes. Behavioural changes in the demersal fish species and mackerel in the OA may return to normal within minutes or hours following exposure (e.g. Pearson et al. 1992; Santulli et al. 1999; McCauley et al. 2000a, 2003; McCauley & Salgado Kent 2007; Woodside 2011; Fewtrell & McCauley 2012; Miller & Cripps 2013; Bruce et al. 2018). Meekan et al. (2021) found no short-term (days) or longer-term (months) effects of seismic sound exposure on the behaviour and movement of tropical demersal snapper, emperor and grouper species off northern Australia, including groups of fishes exposed within tens of metres of the passing seismic source.

McQueen et al. (2022, 2023) found that relatively distant seismic surveys do not substantially alter behaviour in a fish hearing specialist species (Atlantic cod) during the spawning period at received sound exposure levels varying between 115 and 145 dB re 1 μPa^2 s.

To apply an additional level of conservatism and account for possible uncertainty about the exact range over which fish may be disturbed, a 10 km buffer has been applied to the acquisition lines to account for potential variability in the hearing of different fish species and to broadly represent where some fishes may have some awareness of sound pressure changes, noting that the key indicator demersal and pelagic fish species are primarily sensitive to particle motion effects more so than sound pressure and significant behavioural effects are more likely to be limited to within tens or hundreds of metres of the seismic source (Popper et al. 2014). The 10 km buffer also accounts for the predicted R_{max} distance to TTS onset in all fish hearing groups (4.66 km; refer Table 7-5 above) and provides an

additional 5km buffer as a conservative measure that aligns with the upper limit of the qualitative threshold for behaviour set by Popper et al. (2014) (Table 7-6).

Therefore, this 24-hour scenario provides a conservative reflection of the spawning area that may be exposed at any time during the survey. For example, depending upon the actual line sequence acquired, the seismic survey vessel may sail past groups of fishes at a particular location, with disturbance occurring for less than an hour, and then may sail tens of kilometres beyond this point, turning to acquire another line, and may not pass near the same location again until days later; given the 'racetrack' acquisition approach, the same area of seabed and same group of fishes may not be exposed to significant disturbances again during the entire survey.

The spatial extent of the spawning areas for each key indicator fish species has been estimated based on each species' principal depth range and the West Coast Bioregion fisheries management area.

Genetic connectivity and the biological stocks have been confirmed across significantly larger areas (hundreds of thousands of square kilometres compared with the tens of thousands of square kilometre spawning areas considered in the analysis). The biological stocks of the key indicator species generally extend across the entire west coast region of WA. The biological stock areas may be more relevant to the impact assessment from a biological perspective; however, the boundaries of the biological stocks are not clearly defined, and it is noted that genetic connectivity and recruitment within the biological stock ranges occurs over multiple years of spawning and dispersion of eggs and larvae (Martin et al. 2014; Gaughan et al. 2018b). In any given year or a single spawning season, the genetic connectivity between the area of seabed exposed to disturbances from the survey depends on the duration of the egg and larval dispersion phase and the oceanographic currents; connectivity and recruitment in a single season may therefore occur within and well beyond the limits of the West Coast Bioregion fishery management area, but potentially not across the entire biological stock area.

Therefore, to address any potential uncertainty in the biological stock ranges, the West Coast Bioregion fishery management area has been selected to provide a conservative indication of the proportion of the stocks that may be affected in a single spawning season. As a result, the spatial overlaps accounted for in the spatial-temporal analysis are likely to significantly overestimate the percentage of spawning area of each species that may be exposed to sound from the acquisition of the Eureka 3D MSS.

The spatial-temporal analysis is a simplistic approach that assumes that fish spawning in the area and period of exposure will be compromised.

It is possible that fishes may continue to spawn regardless of exposure and disturbance, may move away from the seismic source and spawn at another location nearby, or, given that fish behaviours may return to normal within minutes or hours of exposure, spawning may be delayed but may occur a short time later. In either of these cases, the impact on spawning success may be negligible. However, given uncertainty about how the spawning behaviours of individual fishes and populations may be affected in response to seismic sound exposure, it is conservatively assumed that cessation of spawning could occur.

Therefore, the following analysis provides a conservative indication of the proportion of each indicator fish stock that may be exposed during a 24-hour period of 3D acquisition. This provides useful context for the impact assessment, but the extent and duration of actual impacts will likely be significantly smaller.

Table 7-6 presents the spatial overlap with the spawning areas of key indicator species based on each species' principal depth range and the West Coast Bioregion fisheries management area.

Table 7-6: Spatial overlap with spawning ranges of key indicator fish species

Acquisition scenario	Spatial overlap			
	Dhufish (10–150 m)	Snapper (1–200 m)	Redthroat emperor (5–100 m)	Spanish mackerel (1–50 m)
24-hours 3D + 10 km buffer (maximum 620 km^2)	3.9%	2.4%	3.0%	1.4%

Spawning areas have been estimated based on each species' depth range and the West Coast Bioregion fishery management area. It is important to note that genetic connectivity and the biological stocks have been confirmed across significantly larger areas; however, the West Coast Bioregion fishery management area is a useful and conservative indicator for assessment purposes and is consistent with the fisheries management approach.

A temporal (duration) analysis has also been conducted to determine the maximum overlap between the timing and total potential duration of the Eureka 3D acquisition and the spawning times of key commercial indicator fish species (refer to Table 7-7). It is important to note that the temporal overlap may also over-represent what will likely be a disturbance to one out of many spawning events for a very small proportion of fish effected by the passing seismic source at the time of a spawning event. For example, the above demersal fish species are serial/multiple batch broadcast spawners, releasing multiple batches of eggs into the water column over a wide area, and spawn multiple times throughout the spawning period (Newman et al. 2008; Gaughan et al. 2018).

Table 7-7: Temporal overlap with peak spawning periods of key indicator fish species

Acquisition scenario	Temporal overlap			
	Dhufish (Dec–Mar / 122 days)	Snapper (Jun–Aug / 92 days)	Redthroat emperor (Dec–Feb / 91 days)	Spanish mackerel (mid-Sep–mid-Dec / 91 days)
Maximum 30-day duration Feb–Mar survey period	24%	0%	33%	0%

The combined spatial-temporal overlap with the spawning areas and times of the key commercial indicator fish species is presented in Table 7-8.

Table 7-8: Combined spatial-temporal overlap with spawning periods and ranges of key indicator fish species

Acquisition scenario	Spatial / temporal overlap			
	Dhufish (10–150 m) (Dec–Mar / 122 days)	Snapper (1–200 m) (Jun–Aug / 92 days)	Redthroat emperor (5–50 m) (Dec–Feb / 91 days)	Spanish mackerel (1–50 m) (mid-Sep–mid-Dec / 91 days)
24-hours 3D + 5 km buffer Maximum 30-day duration	0.94%	0%	0.99%	0%

As described above, the proposed timing of the Eureka 3D MSS (February to March) avoids the peak spawning periods for baldchin groper, and so spawning adults of this species will not be affected.

The spatial-temporal overlap with the dhufish, snapper and redthroat emperor stocks is less than 1.0% of their WA stock range and spawning period. The spatial overlap with the Spanish mackerel stock is less than 0.2% of its WA stock range and does not overlap with the spawning period.

7.1.5.4.3 Natural variability in spawning biomass and recruitment

To provide further context, the natural levels of variability in spawning and recruitment have been considered. Spawning biomass and recruitment rates fluctuate annually; for example, long-term monitoring data for indicator species show interannual variation in recruitment and biomass indices of more than an order of magnitude (Fisher et al. 2023; DPIRD 2023), with years of elevated or reduced recruitment influencing the overall stock population (Marriott et al. 2012). Newman et al. (2003) and Marriott et al. (2012) suggest that both spawning, and recruitment success can vary depending upon both environmental (e.g. water temperature, cyclones, El Niño-La Niña cycles) and anthropogenic influences (e.g. fisheries catch levels over and above natural mortality rates).

Extended periods of high exploitation by fisheries can result in decreases in the spawning stock biomass and number of effective spawnings (Newman et al. 2003). As reported in the latest WA State of the Fisheries Report (Fisher et al. 2023), the most recent stock assessment of demersal scalefish targeted by the WCDSMF indicates that while there are some signs of recovery of dhufish in the south of the West Coast Bioregion, indicators for the northern management areas are unlikely to meet recovery milestones by 2030 unless further management action is taken to reduce total fishing mortality (i.e. retained catches and post-release mortality). Accordingly, the biological stock of dhufish is thus classified as inadequate (Fisher et al. 2023). Similarly, the stock assessment for snapper indicates that while the decline of spawning biomass has been halted, recovery milestones are unlikely to be met unless further management action is taken to reduce total fishing mortality (i.e. retained catches and post-release mortality); therefore, the biological stock of snapper is also classified as inadequate (Fisher et al. 2023).

In the context of large natural variability driven primarily by environmental factors and fishing pressure (Marriott et al., 2012; Newman et al., 2003; Fisher et al., 2023) and fisheries catch levels over and above natural mortality rates, the potential for approximately <1.0% of the dhufish or snapper spawning biomass in the West Coast Bioregion fishery management area to be disturbed is expected to have a negligible effect (i.e. no discernible impacts to recruitment and populations). DPIRD (ID 4682) highlighted that dhufish pair spawn and published studies show that waters of 10 to 150 m are inhabited by recently spawned dhufish (Hesp et al. 2002), suggesting their spawning could occur in these depths. In the absence of further studies delineating the specific locations or depths of spawning dhufish, they are assumed to be capable of spawning at any depth within their range where there is suitable habitat. Furthermore, the distribution of spawning fish is unlikely to be evenly distributed either within or outside the seismic survey area. Given the survey area spans a representative depth range of their natural distribution, the proportional level of impact (<1%) is considered a conservative and representative assessment.

The effects of the survey are unlikely to be discernible from natural variation, given that it is only the groups of fishes exposed at a particular site and point in time that may be affected; spawning will continue undisturbed elsewhere throughout the stocks' ranges and most spawning groups in the region at any point in time will be undisturbed. For species with high dispersal and connectivity, such spatially and temporally restricted disturbances are within the range of population fluctuations observed under natural conditions (Fisher et al., 2023; Hesp et al., 2002). The affected groups of fishes will also spawn again at multiple other times during the spawning season and so discernible impacts to recruitment and populations are not expected.

The serial, broadcast spawning strategies of the indicator demersal fish species, by their very nature, offsets potential high natural embryo and larval mortality because of predation or other environmental factors and thereby spreads the risk or potential opportunity for larval settlement over large areas and long timeframes. Subsequent recruitment of fishes to the adult stock also occurs over extended timeframes and is ongoing. Therefore, in comparison, the occasional, short-term, transient and localised disturbances to groups of fish because of a seismic survey would have impacts many orders of magnitude smaller than regional scale environmental/climatic events that would affect entire stocks and are within the bounds of the year-to-year variability documented for these fisheries (Fisher et al., 2023; DPIRD 2023).

7.1.5.4.4 Commercial fish spawning – impact assessment conclusion

Based on the above information and the highly conservative assessment, potential disturbance to a small proportion (up to 1.0%) of the indicator fish stocks in the West Coast Bioregion fisheries management area within one season is not expected to result in any population level impacts, and any such effect would be indistinguishable from natural variation

in spawning and recruitment observed over the long term (Fisher et al., 2023; DPIRD 2023), both in the context of natural variability in spawning and recruitment and inadequate stock levels for dhufish and snapper from fishing mortality.

7.1.5.5 Commercial fisheries

Increased sound levels associated with seismic acquisition may modify the behaviour, local abundance and distribution of fish species, and therefore affect commercial fisheries catch rates within the ASA and in adjacent waters. Additionally, seismic acquisition has the potential to affect commercial fisheries via displacement or exclusion of fishers from areas where they normally operate for all or part of the period during which the survey is being acquired. This potential impact is assessed in Section 7.3.

As described in Section 4.4.2, a review of catch and effort data shows that the following WA-managed commercial fisheries were active in the OA within the past ten years:

- Marine aquarium managed fishery (MAMF)
- Octopus interim managed fishery (OIMF)
- Open access fishery (OAF)
- Specimen shell managed fishery (SSMF)
- Tour operator fishery west coast (TOFWC)
- West Coast Demersal Gillnet and Demersal Longline Managed Fishery (WCDGDLMF)
- West coast demersal scalefish managed fishery (WCDSMF)
- West coast rock lobster managed fishery (WCRLMF).

7.1.5.5.1 Crustaceans

The primary commercially targeted crustacean species in the OA is the western rock lobster. The WCRLMF targets the western rock lobster (*Panulirus cygnus*), off the west coast of Western Australia between Shark Bay and Cape Leeuwin. An analysis of fishing catch and effort data for this fishery shows that the OA only overlaps a very small percentage (1.94 %) of the fished area. In addition, this analysis as well as surveys of commercial rock lobster fishers reflected in Miller et al. (2023) indicate that there is currently low fishing effort in the OA relative to adjacent areas.

Commercial and recreational catch rates in this fishery have been maintained at consistently high levels. These high catch levels and the results of fishery-independent egg production monitoring across the fishery indicate that western rock lobster biomass and egg production in all locations of the WCRLMF are at record-high levels based on nearly three decades of fisheries surveys. The breeding stock is therefore considered sustainable-adequate (Newman et al., 2023).The healthy stock status of the western rock lobster indicates a level of resilience to localised sub-lethal effects to a small number of individuals and these effects are not expected to impact catch rates beyond the immediate survey area. Noise modelling results indicate that sub-lethal effects would be limited to less than 200 m from the airgun array. Further to this, any localised effects are expected to recover due to either recovery of exposed individuals or stock replenishment from recruitment. This is supported by a review of relevant literature on effects of seismic noise on crustacean fisheries.

Parry & Gason (2006) undertook a statistical analysis of catch per unit effort (CPUE) data collected over nearly 30 years in the Victorian southern rock lobster fishery (in southwest Victoria) that showed no influence of historical 2D and 3D MSS activity. Analyses looked at short-term (weekly) and long-term variations (up to seven years) in CPUE to determine whether changes were correlated with the MSS. The surveys occurred in water depths ranging from 10 m to 150 m. The study included surveys occurring during the southern rock lobster spawning period as well as during the lobster fishing season and so would have interacted with adult lobsters and larvae in a similar way to what the proposed Eureka 3D MSS may. This study found no evidence that catch rates were affected in the weeks or years following the surveys; however, Day et al (2016a) suggest that catch rates would have had to decrease by around 50% for this study to detect a result.

Morris et al. (2018) investigated the effects of 2D seismic on the snow crab fishery along the continental slope in Canada in a BACI study over a period of two years. Crabs were exposed to received levels of 187 dB re 1µPa^2 s (single shot) and 200 dB re 1µPa^2 s (cumulative over 24-hours). There were no negative effects on the catch rates in the shorter term (days) or longer term (weeks), and the authors concluded that seismic effects on snow crab harvest (if they do exist) would be smaller than changes related to natural spatial and temporal variation.

Morris et al. (2020) conducted a field experiment to apply a series of comparisons conducted within a BACI study design to investigate the effect of prolonged 3D seismic airgun exposure on the catch rates of snow crab over nine weeks in 2017 and five weeks in 2018. Changes in catch rates at 3D seismic surveying sites were inconsistent across years, with reduced catches in 2017 and increased catches in 2018. Catch rates were similar at experimental and control sites within two weeks after exposure, and the potential effect of seismic surveying was not measured at 30 km. The large variation in catch rates across small temporal and spatial scales coupled with the absence of notable mechanistic responses of snow crab in past studies to seismic noise in associated snow crab movement behaviour, gene expression and physiology, the authors concluded that the observed differences owing to seismic surveying in their study design are likely a result of stochastic processes external to their manipulation (Morris et al. 2020).

7.1.5.5.2 Molluscs

Day et al. (2023) conducted an octopus fishery analysis using a BACI analysis of logbook data to determine whether there was an impact on CPUE from the CGG Gippsland 3D MSS. BACI analysis showed that there was no impact of the seismic survey on the octopus fishery CPUE at the fishing block level. However, independent of this study, short-term declines in CPUE were evident in individual fishers' catch histories reported and analysed through the CGG Gippsland 3D MSS Fisheries Displacement Mitigation plan. This suggests that the fishery logbook CPUE data calculated at the level of fishing block, was not sensitive enough to capture localised changes.

7.1.5.5.3 Fishes

Some fishers believe there is a longer-term effect on fish catchability or presence in fished areas; however, it is not possible to isolate possible seismic survey effects from confounding factors such as fishing pressure, climatic changes and variation in natural population dynamics. A series of studies have been undertaken to determine the effects of seismic surveys on fish catches and distribution, primarily in the United States and Europe (e.g., California: Greene et al. 1985; Pearson et al. 1992; Norway: Dalen & Knutsen 1987, Engås et al. 1993; UK: Pickett et al. 1994). While the conclusions from these studies are largely ambiguous, due to the inherently high levels of variability in catch statistics, one study noted that pelagic species appear to disperse, resulting in a decrease in reported catches during the surveys (Dalen & Knutsen 1987).

Engås et al. (1996) and Engås & Løkkeborg (2002) looked at the effects of a seismic exploration on fishing success for haddock (*Melanogrammus aeglefinus*) and Atlantic cod (*Gadus morhua*). They found that, compared to pre-seismic catches, there was a significant decline in the long line catch rate during and after the seismic study. The catch rate did not return to normal for five days after the end of the seismic study, although evidence of this decline being related solely to the survey is inconclusive. More recently, the same group used sonar to observe the behaviour of blue whiting and Norwegian spring spawning herring during a seismic operation and observed that fish would dive from the seismic source and not return until after the activity had stopped (Slotte et al. 2004).

A study undertaken by the CSIRO and Geoscience Australia (Thomson et al. 2014) examined fisheries catches (10 species of interest) and catch rates for potential effects from 183 seismic surveys undertaken in the Gippsland Basin (Bass Strait). The authors found that there were no clear or consistent relationships between seismic surveys and subsequent fisheries catch rates in their study. However, they cautioned that the results did not imply that such impacts do not exist, but that data was lacking. In terms of duration since a seismic survey occurred, significant positive and negative effects were found but could not be distinguished from inter-annual changes in stock size or availability to fishing gear resulting from other dynamics (Thomson et al. 2014).

In natural situations, most fish are expected to be able to avoid the approaching noise source before it reaches injurious or potentially lethal levels through horizontal or vertical movements. Evidence that fish can actively avoid the source

comes from studies of caged fish actively swimming away from the approaching noise source and temporarily reduced catchability in commercial fisheries. Wardle et al. (2001) conducted a field study, using a video camera to document the behaviour of fish in response to noise levels equivalent or greater than those in the proposed survey. This study showed that the resident fish on the site did not evade the active source until it was within a few metres. No direct mortality was observed at sound levels of up to 218 dB (SPL_{pk}).

Not all studies have resulted in behavioural alteration. Feeding Atlantic herring (*Clupea harengus*) schools off northern Norway showed no changes in swimming speed, direction or school size in response to a transmitting seismic vessel as it approached from 27 km to 2 km, over a 6-hour period (Peña et al. 2013). As fishing areas are large and commercial fish species are free-swimming, if fish are 'scared' temporarily from an area, based on evidence presented, it is likely they will be displaced temporarily to another area still within the fishing zone and so able to be caught.

There is little research undertaken on what effect seismic surveys have on fish catchability. Salgado Kent et al. (2016) acknowledge that there has been some effort to relate fisheries catch data to seismic survey effort, but to date none of the Australian efforts to relate finfish catch rates with seismic surveys have yielded results of any meaning. The Gippsland Marine Environmental Monitoring (GMEM) project provided no clear evidence of adverse effects on scallops, fish, or commercial catch rates due to the 2015 seismic survey (Przeslawski et al. 2016b):

'Catch rates in the six months following the seismic survey were different than predicted in nine out of the 15 species examined across both Danish Seine and Demersal Gillnet sectors. Across both fishing gear types, six species (tiger flathead, goatfish, elephantfish, boarfish, broadnose shark and school shark) indicated increases in catch after the seismic survey, and three species (gummy shark, red gurnard, sawshark) indicated decreases in catch. These results support previous work in which the effects of seismic surveys on catch seem transitory and vary among studies, species, and gear types.'

Research to date has identified some negative effects, some positive effects, and no effects from seismic surveys on catch rates and abundance. This is likely due to the importance of the context of exposure. In many instances, fish may move away from an area when a seismic survey is being undertaken. This could impact on the catchability and catch rates for the target species of any commercial fisheries occurring in the same area at the same time.

Haddon (2017) further investigated the effect of the 2015 seismic survey in the Gippsland Basin on deepwater flathead catches and concluded that the significant drop in catch per unit effort (CPUE) was very likely negatively influenced by the seismic survey. However, Haddon (2017) went on to add that the seismic survey did not appear to have had a lasting impact on deepwater flathead CPUE, which returned to typical values in the first month following the seismic survey.

A critical review of the potential impacts of marine seismic surveys on fish and invertebrates (Carroll et al. 2017) found that other studies on fish have positive, inconsistent, or no effects from seismic surveys on catch rates or abundance. A desktop study of four species (gummy shark, tiger flathead, silver warehou, school whiting) in the Bass Strait found no consistent relationships between catch rates and seismic survey activity in the area, although the large historical window of the seismic data may have masked immediate or short-term effects which cannot therefore be excluded (Przeslawki et al. 2016b). Przeslawki et al. (2016b) concluded that "These results support previous work in which the effects of seismic surveys on catch seem transitory and vary among studies, species, and gear types". The body of peer-reviewed literature does not indicate any long-term abandonment of fishing grounds by commercial species, with several studies indicating that catch levels returned to pre-survey levels after seismic activity had ceased (Carroll et al. 2017). As noted by Przeslawski et al. (2016b), it is possible that fish may be displaced from a survey footprint to adjacent areas, however the total number of fish within the fishery stock remains unchanged.

Meekan et al. (2021) found no short-term (days) or longer-term (months) effects of seismic sound exposure on the behaviour and movement of tropical demersal snapper, emperor and grouper species off northern Australia including groups of fishes exposed within tens of metres of the passing seismic source. The authors suggest that the behavioural responses of demersal fishes to the bait cue during the study are a realistic proxy of the likely response of the same species to baited hooks or traps used by the commercial fisheries that target them. Therefore, no long-term impacts on the catchability of demersal fish species are expected.

Effects will be temporary as the seismic vessel traverses each survey line, and fish may move away as the airgun array approaches. As described above, significant behavioural responses in the key indicator demersal fish species (which

primarily detect particle motion, with limited, or no sensitivity to sound pressure changes at distance from a seismic source) will likely be limited to distances of a few hundreds of metres from the operating seismic source.

Section 4.4.2 includes an analysis of the area of overlap between the area of historic fishing activity (effort) and the OA for the Eureka 3D MSS. The potential area of disturbance generally represents less than 5% of the areas fished by each fishery (refer Table 4-15) and limited impacts are expected.

It is acknowledged that localised and temporary disturbances to fishing activities from seismic survey activities may occur. However, noting that behavioural impacts to target fish species will likely be limited to distances of a few hundreds of metres from the operating seismic source, with behaviours and distributions returning to normal minutes or hours (or potentially days) after, the potential acoustic disturbance to commercial fisheries and their target species is not expected to exceed the areas and durations of displacement due to the physical presence of the survey. Once the survey is complete, fish behaviours and distributions are expected to return to normal within days, if not hours.

It is likely that alternative and viable fishing grounds are available to fishers during the survey. If viable catch levels can be maintained from other areas, overall annual catch rates and fishery performance are not expected to be significantly impacted. If fishers experience impacts, Pilot has developed a set of compensation principles relevant to commercial fishing activities. In summary, Pilot will consider claims from commercial fishing licence holders where:

- There is genuine displacement from undertaking normal fishing activities that results in economic loss.
- Fishing equipment has been lost or damaged by any activities under Pilot's control.
- Loss of catch that can be demonstrated by licence holders.
- The commercial fisheries compensation principles will be consistent with the loss adjustment principles described in *Guidance framework: Supporting cooperative coexistence of seismic surveys and commercial fisheries in Australia's Commonwealth marine area* (Australian Government 2022).

7.1.5.5.4 Commercial fisheries – impact assessment conclusion

The potential impacts of noise emissions from the seismic source on commercial fisheries during the acquisition of the survey are 'localised' and 'short-term', based on behavioural disturbance of target species potentially affecting 'catchability' and hence and catch rates for weeks- months following completion of the survey.

7.1.5.6 Marine turtles

7.1.5.6.1 Species sensitivity and sound exposure thresholds

Acute noise, or temporary exposure to loud noise, may result in the avoidance of important habitats and in some situations physical damage to turtles. However, there is a scarcity of data regarding the responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. Marine turtles have the best hearing sensitivity and low frequencies in the range of 100-700 Hz (Bartol & Musick 2003; Finnernan et al. 2017) and are known to have poor auditory sensitivity (Bartol & Ketten 2006; Dow Piniak et al. 2012). Accordingly, PTS and TTS thresholds for turtles are likely more similar to those of fishes than to marine mammals (Popper et al. 2014).

McCauley et al. (2000b) observed the behavioural response of caged sea turtles — green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) — to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the turtles increased their swimming activity and above 175 dB re 1 µPa (SPL) they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural response to sea turtles by NMFS and applied in the Arctic Programmatic Environmental Impact Statement (PEIS) (NSF 2011) and the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017). The 175 dB re 1 µPa level from McCauley et al. (2000b) is recommended as the threshold for behavioural disturbance.

Some additional data suggest that behavioural responses occur closer to an SPL of 175 dB re 1 µPa, and TTS or PTS at even higher levels (Moein et al. 1995), but the received levels were unknown and the NSF (2011) PEIS maintained the earlier NMFS criteria levels of 166 and 180 dB re 1 µPa (SPL) for behavioural response and injury, respectively. Popper et al. (2014) suggested injury to turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h}). Sound levels defined by Popper et al. (2014) show that animals are very likely to exhibit a behavioural response when they are near an airgun (tens of metres), a moderate response if they encounter the source at intermediate ranges (hundreds of metres), and a low response if they are far (thousands of metres) from the airgun.

The sound exposure thresholds applied for marine turtles in the acoustic modelling study, and in this impact assessment, are summarised in Table 7-9. The peak pressure levels (PK) and frequency-weighted accumulated sound exposure levels (SEL) presented in Table 7-9 are as reported in Finnernan et al. (2017) for PTS and TTS effects in turtles. The behavioural response threshold presented in Table 7-9 is the 166 dB re 1 µPa (SPL) as applied by the NMFS (NSF 2011), and the 175 dB re 1 µPa (SPL) reported in McCauley et al. (2000b).

Table 7-9: SPL, SEL_{24h}, and PK thresholds for acoustic effects on marine turtles

Effect type	Criterion	Unweighted SPL (dB re 1 µPa)	Weighted SEL_{24h} (dB re 1 $\mu Pa^2 \cdot s$)	PK (dB re 1 µPa)
Behavioural response	NSF (2011)	166	N/A	
	McCauley et al. (2000a, 2000b)	175		
PTS onset thresholds* (received level)	Finneran et al. (2017)	N/A	204	232
TTS onset thresholds* (received level)			189	226

* Dual metric acoustic thresholds for impulsive sounds; Use whichever results in the largest isopleth for calculating PTS and TTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered. L_p denotes sound pressure level period and has a reference value of 1 µPa. $L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa. L_E denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 $\mu Pa^2 s$.

7.1.5.6.2 Impact assessment

Without appropriate control measures in place, noise emissions from the seismic source have the potential to impact marine reptiles by causing changes to hearing (PTS and TTS) because of high sound levels at close range to the seismic source, or behavioural disturbance impacts.

As described in Section 4.3.10.1, the OA does not overlap any marine turtle BIA, and the nearest nesting beaches are in Shark Bay, approximately 350 km to the north. There are anecdotal records of loggerhead and leatherback turtles (deceased animals) in proximity to the OA in the Atlas of Living Australia database, and the seagrass habitats of the Commonwealth marine environment within and adjacent to the west coast inshore lagoons KEF may provide valuable feeding grounds for green and leatherback turtles. Therefore, it is possible that transient individuals could be present in the area during acquisition of the Eureka 3D MSS.

Table 7-10 presents the results of the acoustic modelling study for the maximum R_{max} distances to PTS (injury), TTS, behavioural response and behavioural disturbance thresholds in turtles, for all modelled source scenarios. The results for the thresholds applied for PTS and TTS consider both metrics (single pulse PK and multiple pulse SEL_{24h}).

Table 7-10: Maximum predicted horizontal distances (R_{max}) to PTS, TTS, behavioural response and behavioural disturbance thresholds in turtles, for all modelled scenarios

Hearing group	Sound effect threshold	R_{max} distance (km) – Streamer Acquisition	R_{max} distance (km) – Nodal Acquisition
Marine turtles	**Behavioural response**		
	166 dB re 1 µPa (SPL)	4.90	3.37
	175 dB re 1 µPa (SPL)	1.58	1.28
	PTS		
	232 dB re 1 µPa (PK)	-	-
	204 dB re 1 µPa².s (SEL_{24h})	0.06	0.07
	TTS		
	226 dB re 1 µPa (PK)	-	-
	189 dB re 1 µPa².s (SEL_{24h})	2.10	1.72

A dash indicates that the threshold is not reached within the limits of the modelling resolution (20 m).

Marine turtle PTS thresholds could be reached within 60 m for streamer acquisition and 70 m for nodal acquisition. based on the application of the multiple pulse SEL_{24h} threshold as the single pulse PK PTS threshold was not reached within the limits of the modelling resolution. TTS thresholds could be reached within 2.1 km for streamer acquisition and 1.72 km for nodal acquisition, based on the application of the multiple pulse SEL_{24h} threshold as the single pulse PK PTS threshold was again not reached.

The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24-hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position and represents an unlikely scenario. More realistically, transient marine turtles moving through the OA would not stay in the same location for 24-hours, but rather a shorter period, depending upon their behaviour and the proximity and movements of the source. There are no indications that the OA and adjacent waters include any significant foraging areas for turtles. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine reptiles travelling within this radius of the source will be impaired, but rather that an animal could be exposed to the sound level associated with impairment (either PTS or TTS) if it remained in that location for 24-hours (Koessler & McPherson 2023; Appendix G(i)).

The likelihood of PTS and TTS occurring to marine turtles is reduced to a degree by the implementation of control measures including an observation zone of 500 m and a shut-down zone of 100 m under Part A of the EPBC Policy Statement 2.1, which reduces the potential for close range sound exposures where the greatest sound contribution is received.

Based on the 166 dB re 1 µPa SPL behavioural threshold criterion a behavioural response could occur within 4.9 km for streamer acquisition and 3.37 km for nodal acquisition. Based on the 175 dB re 1 µPa SPL behavioural threshold criterion a behavioural disturbance could occur within 1.58 km for streamer acquisition and 1.28 km for nodal acquisition. Accordingly, turtles approaching the operating seismic source are likely to exhibit a behavioural response (avoidance) such that they would not approach the source close enough to incur a TTS.

7.1.5.6.3 Marine turtles – impact assessment conclusion

Based on the assessment above and the implementation of controls, the potential impacts of noise emissions from the seismic source on marine reptiles (turtles) during the acquisition of the survey are ‘localised’ and ‘short-term’. Impacts are likely to be restricted to temporary behavioural changes (avoidance) to transient turtles that may pass within 4.9/3.37 km (streamer/nodal acquisition) of the seismic source. Such behavioural changes are expected to only last for the duration of a survey pass with normal behaviour anticipated to resume when the vessel has moved this distance or more away along the seismic sail line.

7.1.5.7 Marine mammals

7.1.5.7.1 Species sensitivity and sound exposure thresholds

Marine mammal species differ in their hearing capabilities, absolute hearing sensitivity and their frequency band of hearing (Richardson et al. 1995; Wartzok & Ketten 1999; Southall et al. 2007). Accordingly, Southall et al. (2007, 2019) proposed relatively broad hearing groups based on their known hearing sensitivity and sound production parameters, as well as common auditory anatomical features. For this assessment, four functional hearing groups are included: low-frequency (LF) cetaceans (baleen whales), high-frequency (HF) cetaceans (dolphin, sperm whale, beaked whale species), very high-frequency (VHF) cetaceans (*Kogia sp*.) and otariid pinnipeds in water (ASL).

NMFS (2016) recommend dual marine mammal criteria for the prediction of PTS and TTS from underwater sound modelling – peak SPL 'unweighted' criteria and cumulative exposure weighted criteria (Table 7-11). Both sets of criteria are applied in the assessment for marine mammals within this EP.

The marine mammal behavioural threshold is based on the current (NOAA 2019) root mean square (rms) sound pressure level (SPL) criterion for marine mammals. The NOAA (2019) sound level criterion for potential disturbance to marine mammals (cetaceans and pinnipeds) is 160 dB re 1 µPa SPL for impulsive sounds, which is peer reviewed and accepted by the scientific community, and has therefore been used for the assessments in this EP. Whilst the newly published Southall et al. (2021) provides recommendations and discusses the nuances of assessing behavioural response, the authors do not recommend new numerical thresholds for the onset of behavioural response for marine mammals.

Table 7-11: Summary of relevant injury and behavioural criteria for marine mammals

Marine mammal hearing group	NOAA (2019)	Southall et al. (2019)			
	Behaviour	PTS		TTS	
	Unweighted SPL (dB re 1 uPa)	PK (dB re 1 uPa)	Weighted SEL_{24h} (dB re 1 $uPa^2 \cdot s$)	PK (dB re 1 uPa)	Weighted SEL_{24h} (dB re 1 $uPa^2 \cdot s$)
Low frequency cetaceans	160	219	183	213	168
High-frequency cetaceans		230	185	224	170
Very high-frequency cetaceans		202	155	196	140
Otariid pinnipeds in water		232	203	226	188

7.1.5.7.2 Impact assessment - cetaceans

Biologically important periods for key cetaceans in the region are shown in Table 7-12.

Table 7-12: Biologically important periods for cetaceans

Species	January	February	March	April	May	June	July	August	September	October	November	December	Notes
Survey timing													
Humpback whale													September to October – cows/calves
Pygmy blue whale													Species typically prefers deeper waters
Southern right whale													Occasional sightings north of Geographe Bay

Peak period		Shoulder period	

Marine mammals use sound for foraging, orientation, communication, navigation, echolocation of prey and predator avoidance (Richardson et al. 1995, Reckendorf et al. 2023) and therefore are sensitive to underwater noise. High levels of anthropogenic underwater sound can have negative impacts; ranging from changes in their acoustic communication, displacing them from an area, and in more severe cases causing physical injury or mortality (Richardson et al. 1995, Gordon et al. 2003, Brandt et al. 2018, Palmer et al. 2021).

Impulse sounds from an airgun array are considered capable of causing instantaneous auditory injury resulting in a permanent threshold shift (PTS) that persists once sound exposure has ceased (Southall et al. 2019). PTS may also result from prolonged exposure at lower levels. Hearing loss may be considered permanent if hearing does not return to normal after several weeks. Lower noise levels or shorter exposures to noise have the potential to cause a temporary threshold shift (TTS) where animals would experience temporary auditory injury, and from which they would recover fully, particularly as they move away from the source (Southall et al. 2019).

Behavioural responses to low frequency acoustic sound in baleen whales range from tolerance at low–moderate acoustic levels (McCauley et al. 2000a) to graduated behavioural responses including shifts in respiratory and diving patterns (McCauley, 1994) at higher levels. It has been observed that the behaviour of cetaceans to differing sound levels depends on their activity at the time of exposure and is variable between and within species (Richardson et al. 1995, Weilgart 2007, Southall et al. 2021). Cetaceans tend to be less responsive to sound when migrating or feeding than when suckling or resting with calves or socialising.

The key marine mammal species within the Eureka 3D MSS OA and adjacent waters that may be affected by underwater noise from seismic operations have been classed into the functional hearing groups as follows:

- LF cetaceans (baleen whales): humpback whales (HBWs), pygmy blue whales (PBWs), southern right whales (SRWs), and potential presence of other species (e.g., fin, sei and Bryde's whales)
- HF cetaceans: limited to transiting individuals for larger dolphins, beaked whales, sperm and killer whales
- VHF cetaceans: limited to occasional transiting individuals of *Kogia sp*.

Underwater noise modelling carried out for the Eureka 3D MSS for an airgun array source of 2495 in^3/1440 in^3 (in nodal areas) predicted distances to received sound levels compared with noise effect criteria threshold levels in Table 7-13.

Table 7-13: Summary of modelled impact ranges for cetaceans

Hearing group / effect	Sound effect threshold	R_{max} distance (km) – Streamer Acquisition	R_{max} distance (km) – Nodal Acquisition
LF cetaceans			
PTS	219 dB re 1 uPa (PK)	0.06	0.06
	183 dB re 1 $uPa^2 \cdot s$ (SEL_{24h})	3.08	1.72
TTS	213 dB re 1 uPa (PK)	0.15	0.11
	168 dB re 1 $uPa^2 \cdot s$ (SEL_{24h})	43.0	11.9
HF cetaceans			
PTS	230 dB re 1 uPa (PK)	-	-
	185 dB re 1 $uPa^2 \cdot s$ (SEL_{24h})	-	-
TTS	224 dB re 1 uPa (PK)	-	-
	170 dB re 1 $uPa^2 \cdot s$ (SEL_{24h})	0.06	0.1
VHF cetaceans			
PTS	202 dB re 1 uPa (PK)	0.41	0.45
	155 dB re 1 $uPa^2 \cdot s$ (SEL_{24h})	0.06	0.07
TTS	196 dB re 1 uPa (PK)	0.84	0.85
	140 dB re 1 $uPa^2 \cdot s$ (SEL_{24h})	0.44	0.07
All cetaceans			
Behavioural response	160 dB 1 uPa (SPL)	9.2	5.53

Note: A dash indicates no exceedance of threshold within the limits of the modelling resolution (20 m).

While these modelling results are based on recommendations from relevant guidance, the cumulative PTS and TTS (SEL_{24h}) exposures are not expected to occur in reality; a whale is unlikely to remain stationary while a seismic vessel traverses an area, and mitigation controls such as the low-power and shut down zones would be triggered.

7.1.5.7.2.1 Injury, permanent and temporary threshold shifts

While intense impulse waves from underwater point sources of sound can cause injury to fauna through barotrauma (Richardson et al. 1995; NMFS 2018), airgun arrays are not strictly point sources (DEWHA 2008a) due to the multiple airguns arranged in a specific pattern which spreads the sound energy over a larger area reducing the intensity of the sound pressure waves at any given point compared to a single point source, and therefore less likely than explosives or piling to create sound pressure waves intense enough to cause such injury. Furthermore, as the sound pressure wave propagates away from the source, its duration increases, and peak reduces. This transformation into a non-impulsive sound reduces its potential to cause injury in the far-field (NMFS 2018). No instances of instantaneous injury to marine mammals from seismic airguns have been recorded (DEWHA, 2008a) and there is no reason to consider that the Eureka 3D MSS will do so.

Modelled peak pressure noise levels from a single shot of the airgun array on full power indicate that LF cetaceans could suffer PTS within 60 m (for both streamer and nodal acquisition) of the airguns and VHF cetaceans within 410 m (streamer acquisition) or 450 m (nodal acquisition). The PTS onset threshold was not reached within the limits of the model (20 m) for HF cetaceans (Table 7-13). PTS is considered highly unlikely throughout the duration of the survey because the standard control measures of the EPBC Act Policy Statement 2.1 (pre-start-up visual observations, soft start, low-power zone and shut down zone) will help ensure that whales are detected if in close proximity to the airgun array before the array is activated, and if they are detected, the airguns will not be started or will be powered down or shut down. The

timing of the survey (early February to end of March) is prior to the period of known presence of high densities of whales in the OA, and therefore the presence of whales during this time is expected to be limited to occasional, transient individuals. This acquisition window avoids the peak migration periods for PBW, HBW and SRW in the region.

Outside of these ranges, individual animals may still sustain PTS but only through prolonged exposure to the airgun signals. The noise modelling for LF cetaceans predicted that prolonged exposure over 24 hours could cause PTS out to a maximum of 3.08 km (streamer acquisition) or 1.72 km (nodal acquisition) of the source (Table 7-13). This prediction included close exposure whereby most of the sound energy "dose" would have occurred, and the range to cumulative PTS onset is likely to be much closer than this. PTS through cumulative exposure is considered unlikely because of the behavioural responses of individual animals (e.g., move away from the source) or the application of the mitigation measures when whales are spotted. Cetaceans that are susceptible to these sound levels comprise all the baleen whales that may be encountered in the OA (Section 4.3.8). Therefore, the standard mitigation measures in the EPBC Act Policy Statement 2.1 Part A apply.

As for a single shot, HF cetaceans are not expected to receive injurious levels if exposed to the seismic source for a 24-hour period (Table 7-13). The noise modelling for VHF cetaceans predicted that prolonged exposure over 24-hours could cause PTS out to a maximum of 60 m (streamer acquisition) or 70 m (nodal acquisition) of the source (Table 7-13). It is considered highly unlikely that a cetacean would remain so close to the source due to the probable behavioural responses to the noise of the airguns. Furthermore, *Kogia sp*. are not likely to be exposed to prolonged airgun noise in this short range given the implementation of a low-power zone of 2 km and shut-down zone of 500 m as required under EPBC Policy Statement 2.1. It is therefore highly unlikely that any VHF cetaceans will suffer PTS through prolonged exposure to the seismic survey.

Instantaneous TTS can be caused by a single airgun shot if a cetacean is close enough or through repeated exposure to the airgun shots if further away. Instantaneous TTS (PK) for LF cetaceans was predicted to occur within 150 m (streamer acquisition) or 110 m (nodal acquisition) of the airgun array and within 840 m (streamer acquisition) or 850 m (nodal acquisition) for VHF cetaceans. The PTS onset threshold was not reached within the limits of the model for HF cetaceans. This is not considered very likely because the airgun array will only be started after the observation zone has been thoroughly searched by MFOs and if cetaceans have escaped detection, will not be exposed to full power because the airgun array will be started on low power (soft start). This is likely to alert cetaceans to the disturbance and encourage them to move away before full power is achieved. Should cetaceans come within 2 km or 500 m of the airguns on full power, the airgun array will be powered down or stopped, respectively.

Prolonged exposure to seismic shots has the potential to cause TTS (SEL_{24h}) at greater ranges than single shots. The range to potential cumulative TTS for LF cetaceans was 43 km (streamer acquisition) or 11.9 km (nodal acquisition), 60 m (streamer acquisition) or 100 m (nodal acquisition) for HF cetaceans and 440 m (streamer acquisition) or 70 m (nodal acquisition) for VHF cetaceans (Table 7-13). Realistically, a whale will not remain stationary in a fixed position for a 24-hour period (unless it is engaged in foraging within a spatially confined area) and therefore ranges to cumulative TTS are highly conservative.

While no physical injury is expected, any significant avoidance or prolonged disturbance of whales can carry energetic consequences. New bioenergetics research shows that higher activity levels measurably reduce fasting endurance in right whales. A lactating female or an individual in marginal condition may have little capacity for extra energy expenditure. Therefore, even a temporary displacement or increased travel distance to evade seismic noise could erode a whale's energy reserves, potentially affecting its condition, survival or reproductive success if feeding opportunities are delayed. This risk is highest for mother-calf pairs and any whales already in poor body condition or entangled (Christensen et al. 2025.

The timing of the survey (early February to end of March) is prior to the period of known presence of whales adjacent to the OA, and therefore the presence of whales is expected to be limited to occasional, transient individuals. Based on the published literature regarding the timing of migration and foraging, significant numbers of whales are not expected to be in the region. EPBC Policy Statement PS 2.1 Parts A and B are being implemented as precautionary measures in case some individuals are encountered, and due to the uncertainty about presence for rarer species.

Animat modelling

A summary of radial distances to exposure thresholds for pygmy blue whales, along with probability of exposure for modelled Scenario 2 (refer Section 7.1.4) are included in Table 7-14, which shows results for scenarios for foraging and migrating pygmy blue whale animats. Results include $ER_{95\%}$ exposure ranges calculated for the SEL_{24h} thresholds for both TTS and PTS, and the probability of an animat being exposed above the threshold within the $ER_{95\%}$.

Table 7-14: Summary of animat simulation results for pygmy blue whales for Scenario 2, showing 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (Pexp [%])

Noise effect criteria	Foraging				Migrating	
	Male		Female			
	ER95%	Pexp	ER95%	Pexp	ER95%	Pexp
PTS (SEL24h)1	0.89	63	0.82	66	0.63	54
TTS (SEL24h)2	14.5	57	13.7	59	8.47	70

[1] LF-weighted SEL_{24h} (183 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2019)

[2] LF-weighted SEL_{24h} (168 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2019)

Exposure ranges from animal movement modelling for PTS and TTS criteria are typically shorter than those predicted using acoustic propagation modelling because moving animats generally accumulate sound energy over a shorter time ('dwell time'). In this study, PTS and TTS exposure ranges were substantially shorter than acoustic ranges to threshold.

All considered scenarios with unrestricted animat seeding resulted in exposures above the PTS and TTS thresholds. The maximum $ER_{95\%}$ for PTS and TTS were 0.89 and 14.5 km, respectively, with corresponding exposure probabilities for animats travelling within that range of 63% and 57%, indicating that 37% and 43% of animats that travelled within the 95th percentile range were not exposed above threshold. This is because the modelled animats move in and out of the ensonified area and change their vertical position in the water column, thereby influencing the length of time they are within the exposure radius. For example, an animat might approach within the predicted exposure range but if they are traveling more quickly on average than other animats, they may not accumulate as much sound exposure, or they may spend more time at depths where sound levels are lower.

The animal movement and exposure modelling presented herein is a more realistic estimate of the dosimetric impact potential for accumulated sound exposure compared to static receiver accumulated sound exposure modelling scenarios presented in Koessler & McPherson (2023).

Based on the results of the animat modelling there will be no overlap between the maximum TTS onset range for migrating pygmy blue whales and the migration BIA, which is located at least 17 km from the ASA at the closest point. There is a marginal TTS onset overlap for both males and females within the known foraging BIA, which is located at ~13 km from the ASA (based on a maximum $ER_{95\%}$ of 14.5 km for males and 13.7 km for females). However, the ASA is located at least 35 km from the most important foraging area in the region (refer Figure 4-11), as calculated by Thums et al. (2022) from the overlap between three metrics of pygmy blue whale spatial use.

It is important to note that the acquisition of the Eureka 3D MSS will not overlap shoulder or peak periods for either the northbound or southbound pygmy blue whale migration, based on the planned acquisition window of February–March 2025 or February–March 2026. Similarly, acquisition of the survey will not overlap the defined migration periods for southern right whales (April to October) or humpback whales (June to November) in the region.

To account for the potential presence of pygmy blue whales within and adjacent to the known foraging BIA outside of migration periods, an additional control and adaptive management procedures will be implemented to manage potential impacts to pygmy blue whales to ensure the activity is not inconsistent with the Conservation Management Plan for the Blue Whale (refer Section 9).

The additional control will be the deployment of two dedicated and trained MFOs on the support vessel during acquisition within the western section of the ASA (blue lines on Figure 3-3) – designated as the Extended Observation Zone for PBW. During acquisition within the Extended Observation Zone for PBW, the support vessel will be positioned 10 km to the west of the survey vessel, and the MFOs will implement the same observation and shut-down zones as described in Table 7-20 below. Based on an approximate bridge height of 4m above sea surface for the support vessel, and 20m for the seismic vessel giving viewable distances to the horizon of 7km and 16km respectively. These combined distances provide observation distances more than the 14.5km required (Figure 7-8). The MFOs aboard the support vessel will be in direct communication with the lead MFO aboard the survey vessel and will have the authority to request a shut-down if a positively identified (certain or probable confidence level) pygmy blue whale or large unidentified whale is observed within the limits of visibility from the support vessel (refer PS 1 Table 7-19).

If the support vessel has to leave the Extended Observation Zone for any reason (e.g. for resupply) the survey vessel will stop acquisition and move to lines within the eastern section of the ASA (red lines on Figure 3-3) Acquisition within the Extended Observation Zone will only recommence when the support vessel is available to re-commence the role of additional spotter vessel.

To account for the limitation that visual monitoring for pygmy blue whales will be limited to daylight hours only, additional adaptive management measures will be implemented throughout the survey, in accordance with Part B.6 of EPBC Policy Statement 2.1. As described in Table 7-20. If there are three or more shut-downs for pygmy blue whales within a 24-hour period (including shut-downs triggered by sightings by the support vessel MFOs within the Extended Observation Zone), then the seismic operations must not be undertaken thereafter at night-time or during low visibility conditions.

Seismic operations cannot resume at night-time or during low visibility conditions, until there has been a cumulative 24-hour period of seismic operations (daylight hours with good visibility) during which there has been ≤1 shut-down for pygmy blue whales.

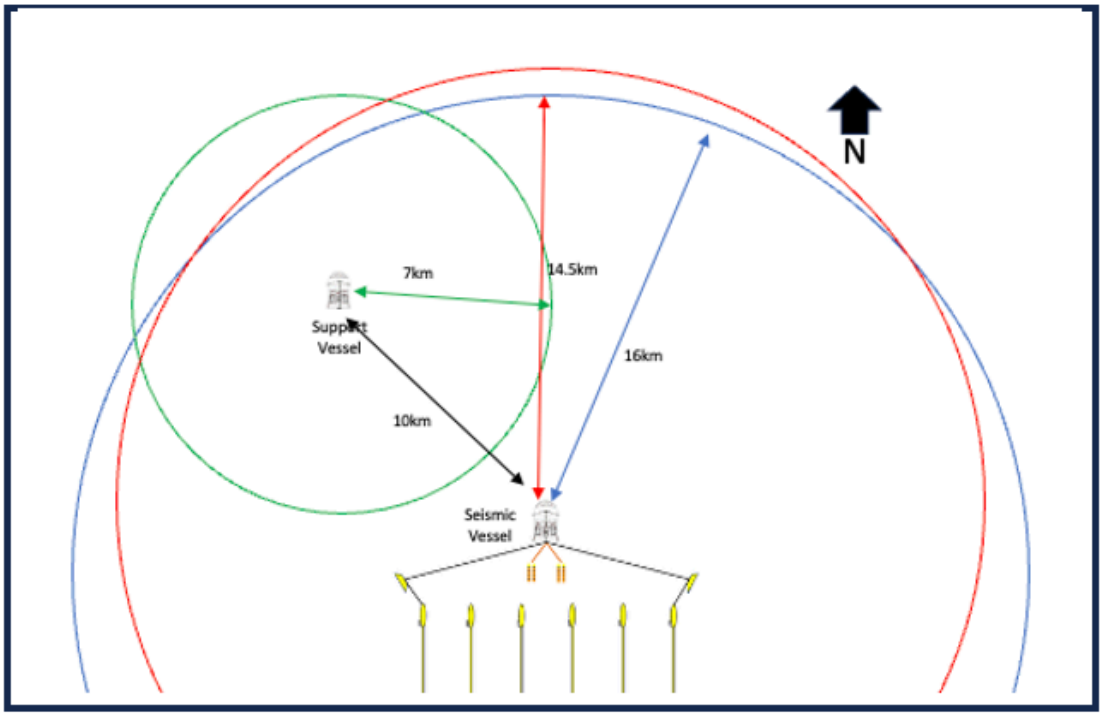


Figure 7-8: Dual-Vessel MFO Deployment Ensures >14.5 km PBW Coverage

7.1.5.7.2.2 Behavioural disturbance

Behavioural responses to low frequency acoustic sound in baleen whales range from tolerance at low–moderate acoustic levels (McCauley et al. 2000a) to graduated behavioural responses including shifts in respiratory and diving patterns

(McCauley 1994) at higher levels. It has been observed that the behaviour of cetaceans to differing sound levels depends on their activity at the time of exposure and is variable between and within species (Richardson et al. 1995). Cetaceans tend to be less responsive to sound when migrating or feeding than when suckling or resting with calves or socialising.

Strong behavioural disturbance from a single shot of the airgun array for all marine fauna groups including cetaceans is predicted to occur out to a maximum distance of 9.2 km (streamer acquisition) or 5.53 km (nodal acquisition) from the source (Table 7-13). Southall et al. (2007, 2021) noted that certain marine mammal species and certain marine mammals in specific behavioural modes appear to be significantly more sensitive to noise exposure.

The species most sensitive to behavioural disturbance that may occur in or around the OA are the PBW, SRW and HBW due to the overlap with the BIAs. The timing of the survey (early February to end of March) is outside of the recognised migration periods for all three species, and therefore the presence of individuals is expected to be unlikely, or in the case of PBW, limited to transient individuals during this time. In particular, the OA is extending toward the northern extremity of SRW distribution with only a few recorded sightings and strandings north of Perth. These records all fall within the expected temporal scale of SRW migration and reproduction within Australian waters and do not extend into the period of the survey. There is a lack of temporal overlap for SRWs, and the closest reproduction BIAs are approximately 100 km south of Perth (400 km south of the OA), and 1000 km north of the OA in Exmouth Gulf,-SRW presence is considered unlikely in the areas adjacent to the OA at this time of year.

Other whales that may be encountered during the survey in the OA include the minke, sei, fin and Bryde's whale. These species may also exhibit a behavioural response out to the modelled ranges of 9.2/5.53 km. Should individuals or groups of these whales be encountered, they may be displaced temporarily as the seismic vessel passes, but their behaviour is likely to return to normal quickly and recommence their natural activities.

HF cetaceans including sperm whales and dolphins, and VHF cetaceans such as *Kogia sp*. may be present in the region; however, there are no known BIAs or important areas for feeding, migration, resting, breeding in or close to the OA. Behavioural disturbance may occur up to 9.2/5.53 km. Observers and MFOs on seismic vessels regularly see dolphins and other small-toothed whales in the vicinity of seismic surveys. In general, dolphins avoid operating seismic vessels (Stone & Tasker 2006), and in most cases, the avoidance radii for dolphins are small (1 km or less), with some individuals showing no apparent avoidance (Holst et al. 2006; Moulton & Miller 2005; Stone 2003; Stone & Tasker 2006; Weir 2006). Underwater noise impacts resulting in behavioural effects to HF and VHF cetaceans will be short-term as the vessel traverses sail lines within the acquisition zones and recoverable.

7.1.5.7.2.3 Indirect impacts on baleen whales

Indirect impacts on baleen whales could occur through the loss of zooplankton as a food resource through the airgun sound sources. As concluded in Section 7.1.5.1, the impacts on zooplankton are expected to be localised and will recover rapidly once the vessel moves to other seismic lines and zones. Impacts to zooplankton will be limited to a maximum range of 280 m from the ASA, and consequently these effects will not extend into the PBW foraging BIA.

7.1.5.7.3 Impact assessment - pinnipeds

The Australian sea lion (ASL) is the only pinniped with a known breeding site and/or haul-out site in the vicinity of the Eureka 3D MSS OA and EMBA, with the closest breeding colony located ~10 km away from the ASA on Beagle Island, adjacent to the southeast corner of the OA. This is a defined breeding BIA. Additionally, as described in Section 4.3.8, ASL foraging BIAs extend along the western coast of Australia, south of Geraldton down to Perth. The OA overlaps both foraging BIAs (Figure 4-14). As central placed foragers, ASLs forage year-round within the OA.

ASLs are otariids (sea lions and fur seals). Based on the review by NOAA (2013a) the functional hearing range of otariid pinnipeds has been estimated as 100 Hz to 40 kHz. The airgun array proposed for the Eureka 3D MSS will produce pulses across a frequency range of 0–150 Hz, i.e., largely below the functional hearing range of otariids such as the ASL, which are better adapted to detecting higher frequency underwater sounds. Underwater audiograms for some sea lions and fur seals indicate that their greatest sensitivity lies in the range 2–32 kHz and these pinnipeds are therefore likely to be less sensitive to low frequency (<1 kHz) sounds than to higher frequency (>1 kHz) sounds. The low frequency sounds (10–

300 Hz) produced by seismic airgun arrays appear to fall below the range of otariid pinniped greatest hearing sensitivity (McCauley 1994). This interpretation must be treated with caution, as little data exists for low frequency thresholds and hearing sensitivities of Australian pinnipeds. However, it is recognised that seismic activity will only be a potential threat to pinnipeds if it takes place close to them (Shaughnessy 1999).

ASLs make underwater sounds including barks, whinnies and buzzing associated with social interactions. It has been measured that the projected energy for these sounds is between 0.25 and 2 kHz frequency (Richardson et al. 1995), and their hearing range is approximately between 0–4 kHz (Pidcock et al. 2003), in comparison to the airgun array proposed for the Eureka 3D MSS, which will produce pulses in the range of 0–150 Hz. Richardson et al. (1995) reported that an airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975a; cited in Richardson et al. 1995). Gray seals exposed to noise from airguns reportedly did not react strongly (J. Parsons, in G.D. Greene et al. 1985; cited in Richardson et al. 1995). Seals in both water and air sometimes tolerate strong noise pulses from nonexplosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Richardson et al. 1995). Thus, Richardson et al. (1995) concluded that "we might expect seals to be rather tolerant of, or habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to an area".

Monitoring studies conducted in 1996–1997 for an open-water seismic programme in the Alaskan Beaufort Sea indicated that seals (mainly ringed seals) usually tolerate strong sound pulses from nearby seismic vessels (Richardson 1999). Numbers, distance, and behaviour of ringed seals, bearded seals, and spotted seals were investigated during seismic operations offshore northern Alaska (July–September 1996; 11 Bolt 1900LX airguns with a total array volume of 1320 in^3; Harris et al. 2001). About 79% were first seen within 250 m of the seismic vessel, and the sighting rate declined rapidly at lateral distances >50 m. Seals tended to stay farther away during full-array seismic. There was partial avoidance of the zone <150 m from the boat during full-array seismic, but seals apparently did not move much beyond 250 m.

Southall et al. (2007) found that, based on the limited data on pinnipeds in water exposed to multiple pulses, exposures in the ~150 to 180 dB re 1 µPa range (rms values over the pulse duration) generally have limited potential to induce avoidance behaviour in pinnipeds. Received levels exceeding 190 dB re 1 µPa were determined by Southall et al. (2007) to be likely to elicit responses, at least in some ringed seals, which are phociids (Harris et al. 2001; Blackwell et al. 2004b; Miller et al. 2005; cited in Southall et al. 2007). Based on the modelled sound pressure levels (SPL) for the 2495 in^3 proposed for use during the Eureka 3D MSS, SPLs >190 dB re 1 µPa would only occur within ~280 m of the operating array (Koessler & McPherson 2023).

Lalas & McConnell (2016) recorded the responses of New Zealand/long-nosed fur seals (*Arctocephalus forsteri*) during daylight hours during a 3D seismic survey (two identical airgun arrays with a volume of 3090 in^3) offshore southern New Zealand. Results were not conclusive since the sighting rate and the distance also decreased with deteriorating sea state and the survey vessel and the towed instruments created obstacles that elicited a response.

In the case of pinnipeds exposed to sequences of airgun pulses from an approaching seismic vessel, most animals may show little avoidance unless the received levels are high enough for mild temporary threshold shift (TTS) to occur. Southall et al. (2019) proposed injury (i.e., TTS onset) criteria for pinnipeds in water of 226 dB re 1 µPa (SPL), or an SEL of 188 dB re 1 μPa^2 s (refer Table 7-11). SPL / SEL of these magnitudes would only be experienced at extremely close range (e.g., <50 m or so) from an operating array of the size proposed for the Eureka 3D MSS, particularly for otariid species such as Australian sea lions. The noise created during seismic surveys is generally considered to be outside of the hearing range of ASLs and is therefore not considered to be a great source of disturbance, and the species is mobile and can exhibit avoidance behaviour if disturbed.

Underwater sound modelling was carried out for both single shot sites and for 24-hour cumulative exposure scenarios. Single shot (PK) and cumulative thresholds (SEL_{24h}) for PTS were not reached within the limits of the model (Table 7-15). Single shot TTS effects were not predicted to occur within the limits of the model, and cumulative TTS effects were predicted to occur within 60 m (streamer acquisition) or 980 m (nodal acquisition) of the source (Table 7-15). A sea lion would not remain in a fixed position for a full 24-hour period, and therefore no PTS or TTS impacts to sea lions are expected to occur.

However, it is possible that sea lions could exhibit some behavioural disturbance within 9.2 km (streamer acquisition) or 5.53 km (nodal acquisition) of the seismic vessel (based on the NOAA 2019, 160 dB re 1µPa threshold). This is considered a potentially overly conservative threshold (and distance) given the much lower sensitivity of otariids to seismic sound compared with cetaceans.

Table 7-15: Summary of modelled impact ranges for pinnipeds

Effect	Sound effect threshold	R_{max} distance (km) – Streamer Acquisition	R_{max} distance (km) – Nodal Acquisition
PTS	232 dB re 1 uPa (PK)	-	-
	203 dB re 1 $uPa^2 \cdot s$ (SEL_{24h})	-	-
TTS	226 dB re 1 uPa (PK)	-	-
	188 dB re 1 $uPa^2 \cdot s$ (SEL_{24h})	0.06	0.98
Behavioural response	160 dB 1 uPa (SPL)	9.2	5.53

Note: A dash indicates no exceedance of threshold within the limits of the modelling resolution (20 m)

There is also the potential for impacts to pinnipeds relating to prey displacement. An assessment of the potential acoustic impacts to pinniped prey from an operating array (i.e., mainly fish, western rock lobster, octopus and cuttlefish) has been undertaken in sections 7.1.5.2 and 7.1.5.3. The key findings from these are:

- Fishes and elasmobranchs (section 7.1.6.3): Four main fish types were identified in the OA, site attached fish, demersal fish species, pelagic fish species and shark species. The hard substrate and epibenthos communities around the emergent reefs are key bathymetric features that support site attached and demersal fish species, however these areas will mostly be avoided due to a 300m exclusion area at the 12m depth contour. The pelagic fish and sharks are fast swimming species that will exhibit behavioural avoidance response while the seismic source is nearby, but behaviour is expected to return to normal within minutes to hours once the source is removed.
- Cephalopods (section 7.1.6.2): Cephalopods are a sound sensitive species and behavioural responses to the seismic source would be expected. Octopus, one of the ASLs key prey items, are benthic and territorial so are not expected to move far as the source passes by them. This means that they will only be exposed to the source 2-3 times with days in between these occurrences to recover.
- Invertebrates (section 7.1.6.2): Benthic invertebrates such as WRL cannot move large distances in response to acoustic sound. Sub-lethal impacts to WRL may be observed because of exposure to the seismic source however the exclusion areas around reefs will limit this impact and any affected WRL will remain available as prey to ASLs. In summary, it is expected that any impacts on ASL prey species will be 'localised' and 'short-term' and restricted to temporary behavioural changes (avoidance) in any isolated individuals that may transit the area near the operating seismic source. The area of temporary prey displacement for more mobile species will be small relative to the large BIA for foraging.

As described in Section 9, there are no action areas, objectives or actions in the Recovery Plan for the Australia Sea Lion (DSEWPC 2013a) that relate to potential impacts from anthropogenic noise on ASLs. The issues paper for ASL's (2013) does identify noise as a secondary threat that requires more research, with potential to impact on behaviour of the ASL and their prey species. Similarly, the South-west Marine Bioregional plan states that the effect of seismic activity on pinnipeds is not well understood and could possibly impact prey availability if not adequately managed (Commonwealth of Australia, 2007).

7.1.5.7.4 Marine mammals – impact assessment conclusion

Based on the assessment above, and the implementation of a temporal control to avoid acquisition during northbound and southbound PBW migration, and during the SRW migration period, the potential impacts of noise emissions from the seismic source on cetaceans during the acquisition of the survey are 'localised' and 'short-term'. Impacts are likely to be restricted to temporary behavioural changes (avoidance) in individuals moving through the OA, with predicted noise levels from the seismic acquisition not considered likely to cause injury effects.

7.1.5.8 Seabirds

7.1.5.8.1 Species sensitivity and sound exposure thresholds

There is very little known about the effects of intense underwater sound (i.e., seismic surveys) on marine birds. However, impacts have not been observed during previous seismic surveys (Turnpenny & Nedwell 1994), and it is generally thought that noise produced from activities associated with seismic surveys may impact only those species of birds that spend large quantities of time underwater, either swimming or plunge diving while foraging for food, for example penguins. Pichegru et al. (2017) found that penguins showed a strong avoidance of their preferred foraging areas during seismic activities, foraging significantly further from the survey vessel when in operation and increasing overall foraging effort. However, little penguins are rarely observed north of Perth, and the OA is not an important foraging area for this species. The primary foraging habitats are south of Perth, in Cockburn Sound.

7.1.5.8.2 Impact assessment

A total of 27 species of marine birds were identified as potentially occurring in the OA (Section 4.3.11), with foraging BIAs for eight species overlapping with the OA.

Birds foraging within the OA may be exposed to increased sound levels generated by the operating seismic source during foraging dives near the sea surface, and in response they may exhibit a startle response. Birds resting at the surface have limited potential to be affected by the noise emissions underwater due to the limited transmission of sound energy between the water and air interface, though they may also exhibit a startle response if resting in waters near to the operating seismic source. However, given the likely avoidance response of prey species (e.g., fish) in waters immediately surrounding the seismic source, it is unlikely that birds would forage in proximity to the seismic source. In the unlikely event that birds to forage in proximity to the source, this is likely to be limited to individuals only, with these birds expected to temporarily move away from the area as a result.

7.1.5.8.3 Seabirds – impact assessment conclusion

The behaviour and distribution of some fish may be affected for short periods during and after exposure to the seismic source, which may result in 'localised' and 'short-term' changes in the distribution of target prey species for some bird species. However, it is expected that the behaviours and distribution of prey at any one time will remain largely unaffected within the OA. Therefore, impacts to seabird populations are extremely unlikely to occur.

7.1.5.9 Impacts on protected area values and management

Pilot has undertaken the impact assessment in accordance with the management strategies and objectives of the South-west Marine Reserves Network Management Plan and consistent with Australia's IUCN Principles (Table 7-16). Protected areas and their conservation values that could be affected by seismic sound from the Eureka 3D MSS are summarised in Table 7-16. There are no known sites of cultural heritage significance in the OA (Section 4.4) nor has there been any objection from cultural heritage stakeholders during consultation (Section 0).

Table 7-16: Protected areas potentially directly or indirectly affected by the Eureka 3D MSS

Protected area	Conservation values that may be affected by the survey	Impacts from survey
Commonwealth protected areas		
Abrolhos AMP	Important breeding area for lesser noddies Important feeding and nesting ground for many other seabird species Important migratory pathway for humpback whales Breeding and foraging area for the ASL Diverse benthic and pelagic fish communities Important rock lobster habitat	The Abrolhos AMP is located 20 km west of the Eureka 3D MSS OA and will not be affected by the survey. The impact assessment for environmental receptors provided throughout this section demonstrates that the survey will not have significant impact on the values of the area for migration, feeding, resting and breeding/nesting. Pilot has adopted a 'zoned' approach to the Eureka 3D MSS and will implement control measures to avoid impacts to migrating cetaceans (see Section 7.1.5.7).
Jurien AMP	Important migratory pathway for humpback whales and pygmy blue whales Important breeding area for ASLs Important nesting ground for seabirds Important foraging area for white sharks Shallow seagrass lagoons supporting large biodiversity of marine species Valued recreational activities including fishing and diving	The Jurien AMP is located 40 km south of the Eureka 3D MSS OA and will not be affected by the survey. The impact assessment for environmental receptors provided throughout this section demonstrates that the survey will not have significant impact on the values of the area for migration, feeding, resting and breeding/nesting. Pilot has adopted a 'zoned' approach to the Eureka 3D MSS and will implement control measures to avoid impacts to migrating cetaceans (see Section 7.1.5.7).
State protected areas		
Jurien Bay Marine Park	Important breeding area for ASLs Important breeding area for seabirds including fairy terns and osprey Recreational fishing area Recreational area for swimming, diving, snorkelling and kayaking	The Jurien Bay Marine Park is located 40 km south of the Eureka 3D MSS OA and will not be affected by the survey. The impact assessment for environmental receptors provided throughout this section demonstrates that the survey will not have significant impact on the values of the area for migration, feeding, resting and breeding/nesting.
Key ecological features		
Commonwealth marine environment within and adjacent to the west coast inshore lagoons KEF	Regionally and nationally important for high benthic productivity and aggregations of marine life Unique diversity of marine species Seagrass habitats provide valuable feeding grounds for protected species including green and leatherback turtles Important nursery area for many recreational and commercial fish species including western rock lobster, dhufish and snapper	The marine environment within and adjacent to the west coast inshore lagoons KEF is located within the Eureka 3D MSS OA. No management objectives set. Refer to assessments in: Section 7.1.5.1 (plankton) Section 7.1.5.2 (benthic invertebrates) Section 7.1.5.5 (commercial fisheries) Section 7.1.5.6 (marine turtles)
Western rock lobster KEF	Important area for western rock lobster	The western rock lobster KEF is located within the Eureka 3D MSS OA. No management objectives set. Refer to assessments in: Section 7.1.5.1 (plankton) Section 7.1.5.2 (benthic invertebrates) Section 7.1.5.5 (commercial fisheries)

7.1.5.10 Impact analysis on tourism and recreation

Scuba divers and snorkelers

The human auditory system is significantly less sensitive underwater than in air and is further degraded if diving equipment obstructs the ears or face (e.g., diving with a hood or full facemask). Under water, the human ear is about 20 dB less sensitive than it is in air at low frequencies (20 Hz), increasing to 40 dB at mid-frequencies (less than 1 kHz), and increasing to 70–80 dB less sensitive at higher frequencies (Parvin 1998). Divers who wear neoprene hoods have even higher hearing thresholds (lower sensitivity) above 500 Hz because the hood material absorbs high-frequency sounds (Sims et al. 1999). Exposure studies related to divers have typically focused on military sonar exposure, with little information on seismic survey operations, and as such care is required when considering thresholds for non-military divers, particularly for impulsive sounds such as seismic source impulses (Ainslie 2008).

Underwater auditory threshold curves indicate that the human auditory system is most sensitive to waterborne sound at frequencies between 400 Hz to 1 kHz (Parvin et al. 1994), and these frequencies have the greatest potential for damage. Within the literature (all as cited in Ainslie 2008), there is some variation in acceptable SPLs for divers.

The auditory threshold of hearing under-water was lowest at 1 kHz (70 dB re 1 µPa SPL) and increased for lower and higher frequencies to around 120 dB re 1 µPa at 20 Hz and at 20 kHz (Parvin 1998). Fothergill et al. (2000) and Fothergill et al. (2001) conducted controlled acoustic exposure experiments on military divers under fully controlled conditions at a US Ocean Simulation Facility and an US Open water test facility. The following exposure limit for both military and recreational divers was suggested as a conservative measure: For frequencies between 100 and 500 Hz, the maximum SPL should be 145 dB re 1 µPa over a maximum continuous exposure of 100 seconds or with a maximum duty cycle of 20 per cent and a maximum daily cumulative total of three hours. The trading relation between the maximum SPL and duration was 4 dB per doubling of duration (e.g., 141 dB SPL for a 200 second exposure) (Pestorius et al. 2009).

In alignment with these studies, and considering only frequencies between 100 and 500 Hz, Parvin (2005) suggested 145 dB re 1 µPa as a safety criterion for recreational divers and swimmers. Seismic airgun sources are broadband sources, and therefore, for this assessment the most precautionary and conservative diver acoustic impact threshold is the 145 dB re 1 µPa SPL suggested by Parvin (2005). This does not imply that this level is associated with the onset of injury but represents a conservative level for protection against prolonged sound exposure for health and safety purposes.

Pilot has compared the predicted received levels from the sound modelling with the human health assessment threshold of 145 dB re 1 µPa (SPL) proposed by Parvin (2005) for recreational divers and swimmers. Based on this threshold, divers are predicted to hear underwater noise from the seismic survey at up to 24.1–36.4 km from the source depending on the modelled site. However, these maximum ranges are orientated offshore (i.e., in a westerly direction into deeper waters) and should not be considered an offset distance to the coast (Koessler & McPherson 2023; Appendix G(i)). Maximum ranges to the 145 dB re 1 µPa (SPL) threshold in an easterly direction (i.e., inshore into shallower waters) are in the order of 7.1–8.7 km.

Guidance note issued by the UK Diving Medical Advisory Committee (DMAC) “Safe Diving Distance from Seismic Surveying Operations” (DMAC 2020) have suggested that adverse effects may be experienced by divers at distances of up to 27 km from a seismic source, similar to the 145 dB re 1 µPa SPL isopleth in an offshore direction considered above, but do not provide any further details. DMAC (2020) recommends that where diving and seismic activity occur within 30 km of each other, a joint risk assessment should be conducted, and planning/mitigation agreed between parties. Where diving and seismic activities occur within 45 km of each other, all parties should be made aware of the planned activity. These ranges include areas around banks and shoals where divers may be present.

There are known commercial diving operations that periodically occur in the OA as part of the commercial fishing activities for the Marine Aquarium Managed Fishery and the Specimen Shell Managed Fishery, typically diving at depths of 10-50m, in addition to recreational diving activities likely limited to shallow nearshore water depths (<30 m) (Section 4). In the event of diving operations planned within or within 10 km of the OA, specific dive procedures will be defined in the concurrent operations (CONOPS) / simultaneous operations (SIMOPS) Plan, including an extension of the Cautionary Zone to 10 km, and the requirement for a joint risk assessment in advance of any SIMOPS. Pilot will develop a SIMOPS Plan for the Eureka 3D MSS and affected diving operation in agreement with the affected relevant operator(s). As part of the

SIMOPS Plan, Pilot will establish a communications protocol outlining all key contacts, confirming schedules and identifying constraints and buffer distances that need to be observed. No impacts to human divers are predicted.

Tourism Operations

No tourism activities are known to take place specifically within the OA; however, tourism activities do take place in the surrounding region.

Relevant tourism operators will be kept informed of survey activities to ensure that they avoid the area in which the survey vessels are active, with ongoing notification communication happening 7 to 10 days prior to the survey commencement, and ongoing communication happening daily during the survey period, as described in Section 0.

7.1.5.11 Cumulative impacts from seismic airgun discharges

Potential cumulative impacts associated with the Eureka 3D MSS may occur if the survey is undertaken:

- At the same time as another seismic survey within the area, there is an overlap in the areas ensonified by each survey and there are noise sensitive receptors in the overlap zone (concurrent surveys)
- Within an area where previous seismic surveys have occurred, the affected marine biota are still in the same area and have not fully recovered (sequential surveys).

It should be noted that this section does not assess cumulative impacts from future seismic surveys within the area that may occur after the Eureka 3D MSS validity, as this is the responsibility of that titleholder as part of their cumulative impact assessment.

7.1.5.11.1 Concurrent surveys

All currently submitted and approved EPs for seismic surveys have been investigated on the NOPSEMA website and no surveys are planned (EP submitted or accepted) that overlap with the Eureka 3D MSS OA.

In the event of a survey planned at the same time as the Eureka 3D MSS, the industry best practice and conservative 40 km buffer between seismic vessels will keep sound levels below the level at which physiological impacts could occur. CONOPS will be prepared at least one month prior to the planned survey commencement (where necessary) and the seismic vessel will adhere to specific CONOPS procedures when operating within the Cautionary Zone around another the other vessel.

Following acceptance of this EP and as part of the pre-survey planning and notification process, the NOPSEMA website will be monitored for newly accepted EPs for marine seismic surveys which could contribute to cumulative noise in the survey area. If a survey is permitted within 40 km of the Eureka 3D MSS OA, and scheduling for both surveys may overlap, the relevant titleholder will be contacted, and arrangements made to ensure that the potential cumulative impacts will be reduced to ALARP. As a minimum, Pilot will not acquire seismic data within 40 km of another actively acquiring seismic vessel.

Given the very low probability of two seismic surveys occurring simultaneously and the controls that will be implemented to establish and maintain communications prior to and during the survey to ensure such simultaneous activities would maintain an adequate separation distance (40 km), there is very little risk of cumulative impacts to marine receptors. No cumulative impacts are predicted from concurrent surveys.

7.1.5.11.2 Sequential surveys

Cumulative impacts can occur when the timing between activities is less than the recovery rate of any potential impacts to receptors.

The US National Marine Fisheries Service (NMFS) applies a "resetting" of SEL_{cum} after 12 hours of non-exposure (Stadler & Woodbury 2009). Whereby, if there is a 12-hour period between the end of one pile driving operation and the start of the next, the SEL_{cum} for a fish during the pile driving operation is reset to zero for the next set of exposures. In addition, recent work has shown that fish can recover from the startle response of acoustic disturbance within minutes (Bruintjes et al. 2016) and that repeated exposure can lead to habituation and reduced response within weeks (Nedelec et al. 2016). Applying a pile-driving management measure to a seismic survey is highly conservative, given the much lower number of sound pulses associated with seismic surveys and the ability of most fish and other receptors to move away from the source. Populations would be more resilient due to immigration and recruitment of unaffected individuals. Popper (2018) lends weight to the likelihood of recovery and concluded in a recent peer review of a seismic EP that effects in fish are recoverable once the seismic vessel has passed overhead and expected to occur within 24 hours.

Localised changes in zooplankton abundance (including eggs and larvae) are expected to be replaced and indistinguishable from natural levels within hours of exposure to seismic sound, and certainly within a few days of the seismic survey being completed (McCauley et al. 2017; Richardson et al. 2017). Sublethal and chronic lethal effects to some benthic invertebrates could occur for weeks or several months after exposure to seismic sound (Day et al 2017), however overall changes in benthic community composition and structure are expected to be negligible in the context of natural variability in mortality and recruitment (Parry and Gason 2006, Blanchard et al 2022).

Behavioural changes for migrating or foraging marine fauna (e.g., cetaceans, sea lions and white sharks) are expected to return to normal within hours or days of the seismic survey being completed.

There have been no seismic activities undertaken in the region in recent times. The last MSS undertaken in the area was over ten years ago in February to May 2013 — the Geelvink 3D MSS and the Turtle Dove Ridge 3D MSS for Murphy Australia Oil (refer NOPIMS). Therefore, no cumulative impacts from sequential seismic surveys are predicted for the Eureka 3D MSS.

7.1.5.12 Inherent impact evaluation

Using the above discussions, the impact evaluation is summarised in the following and is defined as part of the impact assessment method in Section 6.4.2. Where multiple risks or impacts have been identified on a given group of receptors with differing rankings, the worst case is quoted. Where risk ranking is Low, the potential impacts are deemed to be ALARP and acceptable and are not considered further unless additional treatments can be applied that have conservation benefits. Where risk ranking results are Moderate or higher, ALARP and acceptability will be discussed and demonstrated below.

Inherent impact	Consequence	Likelihood	Risk ranking
	Minor – Plankton	Possible – Plankton	Moderate – Plankton
	Minor – Invertebrates	Unlikely – Invertebrates	Low – Invertebrates
	Minor – Lobster/octopus	Possible – Lobster/octopus	Moderate – Lobster/octopus
	Minor – Fishes	Possible – Fishes	Moderate – Fishes
	Minor – Fisheries	Possible – Fisheries	Moderate – Fisheries
	Minor – Turtles	Possible – Turtles	Moderate – Turtles
	Minor – Cetaceans	Possible – Cetaceans	Moderate – Cetaceans
	Minor – Pinnipeds	Unlikely – Pinnipeds	Low – Pinnipeds
	Minor - Seabirds	Unlikely - Seabirds	Low - Seabirds
	Minor – Protected areas	Unlikely – Protected areas	Low – Protected areas
	Minor – Divers/snorkellers	Possible – Divers/snorkellers	Moderate - Divers/snorkellers

7.1.6 Impact treatment

Taking the above evaluations, treatments for each of the impacts deemed to be Moderate or higher are identified in the following as described in Section 0 as part of the impact assessment method.

7.1.6.1 Demonstration of ALARP

The impacts to marine fauna from seismic noise are relatively well understood for some marine fauna groups (e.g., marine mammals) and less well understood for others (e.g., invertebrates, plankton and fish). While none of the risks or impacts demonstrated above have been shown to be significant, there is still some uncertainty in the actual levels of intensity of the sounds or duration of exposure required before injury occurs to some marine taxa. Because of the impacts and the potential consequences identified in Section 7.1.5, and uncertainty of the distribution and abundance of some fauna groups, recognised good practice control measures are not considered appropriate on their own to manage the potential impacts to ALARP and Acceptable levels. Therefore, Pilot is implementing additional control measures.

This assessment also considers the environmental impact to the location specific environmental values and sensitivities of the OA. The potential impacts on cetaceans have been considered in the planning of the survey adjustments to the activity schedule made to avoid impacting biologically important periods as follows:

- Conduct the survey between early February to end of March, to avoid encountering migrating pygmy blue whales, southern right whales and humpback whales when these species are passing through the region on their annual northbound/southbound migrations.

Pilot considers the adopted controls to be appropriate in reducing the environmental impacts associated with underwater sound from seismic operations on marine fauna to ALARP (Table 7-17). There are no other controls or measures that may practicably or feasibly be adopted to further reduce the impacts without disproportionate costs compared to the benefit of the potential impact reduction (Table 7-17).

Table 7-17: Demonstration of ALARP – underwater sound from seismic operations

Control measures	Cost benefit analysis	Impact reduction	Control adopted
ALARP assessment technique – good practice, legislative requirements and recovery plans			
Implementation of all Part a Standard Management Procedures described in EPBC Policy Statement 2.1 relating to the following: Pre-start-up visual observation Soft start Start-up delay Operational visual monitoring Power-down and stop work Night-time and low visibility	Benefits outweigh cost, legal requirement	Yes	Yes
Implementation of EPBC Policy Statement 2.1 Part B.4 increased precaution zones and buffer zones for whales: Observation zone: 3 km+ to the limits of visibility for large unidentified whales 2 km to 3 km for all other whales Shut-down zone: To limits of visibility for positively identified (certain or probable confidence level) pygmy blue whales, and large unidentified whales 2 km for all whales	Benefits outweigh cost, legal requirement	Yes	Yes
Implementation of the following precautionary zones for ASLs: Observation zone to 1 km Shut-down zone to 500 m	Benefits outweigh cost	Yes	Yes
Application of EPBC Policy Statement Part B Additional Management Procedures			

Control measures	Cost benefit analysis	Impact reduction	Control adopted
Implementation of EPBC Policy Statement 2.1 Part B.1 Additional Management Procedures – MFOs: Four dedicated trained Marine Fauna Observers (MFOs) will watch for whales and ASLs during seismic operations in daylight hours, throughout the duration of the survey Two MFOs will be deployed on the survey vessel Two MFOs will be deployed on the support vessel during acquisition within the western section of the ASA (blue lines on Figure 3-3)–the Extended Observation Zone for PBW. During acquisition within the Extended Observation Zone, the support vessel will be positioned 10 km to the west of the survey vessel, and the MFOs will implement the same observation and shut-down zones as described in PS 1 above. The MFOs aboard the support vessel will be in direct communication with the lead MFO aboard the survey vessel, and will have the authority to request a shut-down if a positively identified (certain or probable confidence level) pygmy blue whale or large unidentified whale is observed within the limits of visibility from the support vessel If the support vessel has to leave the Extended Observation Zone for any reason (e.g., for resupply) the survey vessel will stop acquisition and move to lines within the eastern section of the ASA (red lines on Figure 3-3). Acquisition within the Extended Observation Zone will only recommence when the support vessel is available to re-commence the role of additional spotter vessel. At least one dedicated MFO undertaking observations during daylight hours per observing vessel (survey vessel and support vessel). If required, the additional MFO will be used during times of increased whale sightings.	Benefits outweigh cost	Yes	Yes
All MFOs engaged for the Eureka 3D MSS will have previous experience observing for marine mammals at sea, and be competent at identifying marine mammals, estimating distance, implementing mitigation actions and recording data. All MFOs will have completed relevant training detailing marine fauna identification and EPBC Act Policy Statement 2.1 requirements.	Benefits outweigh cost	Yes	Yes

Control measures	Cost benefit analysis	Impact reduction	Control adopted
All marine fauna detection personnel (MFOs, trained crew) will attend the environmental induction presentation, which will include the environmental sensitivities of the survey area, environmental management strategies, EPO, and EPS as detailed in the EP. At crew changes, this information will be communicated to on-coming personnel during handover.	Benefits outweigh cost	Yes	Yes
Implementation of EPBC Policy Statement 2.1 Part B.6 Adaptive Management Measures to minimise the minimum potential impacts to pygmy blue whales from seismic noise. The following adaptive management measures will be implemented: If there are three or more shut-downs for pygmy blue whales within a 24-hour period (including shut-downs triggered by sightings by the support vessel MFOs), then the seismic operations must not be undertaken thereafter at night-time or during low visibility conditions Seismic operations cannot resume at night-time or during low visibility conditions, until there has been a cumulative 24-hour period of seismic operations (daylight hours with good visibility) during which there has been ≤1 shut-down for pygmy blue whales.	Benefits outweigh cost	Yes	Yes
Additional control measures for pygmy blue whales			

Control measures	Cost benefit analysis	Impact reduction	Control adopted
Use of passive acoustic monitoring (PAM) to detect vocalising whales	Pilot Energy has implemented a mitigation strategy that reduces risks to baleen whales through a combination of seasonal timing, visual monitoring, and adaptive management. The survey is scheduled for February to March, outside the peak migration periods for humpback, pygmy blue, and southern right whales in the Dongara region. This timing aligns with known seasonal whale movements and relevant EPBC Act guidance. Although Passive Acoustic Monitoring (PAM) could, in theory, help detect whales at night, its practical value is limited in this context. Furthermore, the cost and operational complexity of PAM are not justified given the seasonal timing of the survey. The high cost and operational burden of PAM make it a disproportionate and unnecessary measure. Pilot Energy's current approach achieves appropriate protection without unjustified expenditure.	`Yes	No
Reduce size of ASA to minimise potential for injury to PBW within the foraging BIA	Given the implementation of adaptive management measures and minimal overlap of maximum TTS onset range with the PBW foraging BIA, the potential impacts of noise emissions from the seismic source on pygmy blue whales are likely to be restricted to temporary behavioural changes (avoidance) in individuals moving through the OA, with predicted noise levels from the seismic acquisition not considered likely to cause injury effects. Based on the evidence presented in Thums et al. (2022), the likelihood of encountering foraging PBW is considered low. An additional control of a two additional MFOs deployed aboard the support vessel during acquisition within the Extended Observation Zone increases the ability to detect PBW.	No	No
EPBC Act Policy Statement 2.1 Part B.3 – Use of spotter aircraft to detect presence of cetaceans	Increases potential likelihood of environmental impacts, health and safety impacts to personnel due to aircraft in the field. Unacceptable risk to personnel in operating aircraft offshore. Disproportionate cost of aircraft and personnel.	Limited	No

Control measures	Cost benefit analysis	Impact reduction	Control adopted
Use of unmanned aerial vehicles (UAVs – drones) to detect presence of cetaceans	Unproven technology in monitoring PBW in offshore marine environments. Dependent on suitable weather conditions (low wind speeds and good visibility). Significant cost of commercial drones and licensed pilots.	Limited	No
Use of alternative acoustic monitoring techniques (sonobuoys, fixed moorings, AUVs)	Unproven technology in monitoring PBW in offshore marine environments. Significant technical challenges in providing real time data on PBW detections to the survey vessel. Logistical and health and safety risks in deploying and retrieving equipment. Disproportionate cost for additional vessels, personnel and equipment hires.	Limited	No
Other control measures			
If another vessel is acquiring seismic data in the region, the survey vessel shall not acquire data simultaneously within 40 km of the other seismic vessel to avoid cumulative impacts to marine fauna.	Benefits outweigh cost	Yes	Yes
An exclusion zone of 9.2 km horizontal distance around the Beagle Islands has been removed from the ASA	Benefits outweigh cost	Yes	Yes

Control measures	Cost benefit analysis	Impact reduction	Control adopted
Reduce size of ASA by extending the buffer zone from the Beagle Islands during the potential ASL breeding season from February – September 2025 or revise survey timing to avoid ASL breeding season	Breeding and pupping are land-based activities and will not be directly impacted because of the seismic survey. Potential indirect impacts associated with disturbance to foraging ASLs or displacement of their prey are considered negligible due to: Small disturbance ranges for ASLs and their prey relative to the broad foraging areas. The low sensitivity of otariid pinnipeds to seismic noise, i.e., noise largely below their functional hearing range. The seismic vessel and ASLs will be mobile so impacts will be limited to the short time frame before the seismic vessel moves away. Breeding and pupping are a protracted event (approx. 7 months) and the seismic survey is limited to 40 days. The survey timing has been optimised to avoid overlap with more noise sensitive species, particularly the blue whale (refer Table 4-11).	No	No
No seismic acquisition during the pygmy blue whale northbound or southbound peak migration periods (i.e., April to July; and October to January).	Benefits outweigh cost	Yes	Yes
No seismic acquisition during the southern right whale migration period (i.e., April to October).	Benefits outweigh cost	Yes	Yes
No seismic acquisition during the humpback whale migration period (June to November).	Benefits outweigh cost	Yes	Yes

Control measures	Cost benefit analysis	Impact reduction	Control adopted
No seismic acquisition during the peak commercial fishing periods and peak sensitive periods for fish and invertebrates	Pilot Energy has scheduled the seismic survey for February and March to minimise environmental and operational risks. This timing avoids peak periods for whale migration, foraging, and Australian sea lion breeding, based on current observations for 2026. It also reduces the likelihood of weather-related delays that could prolong operations and increase risk. Environmental assessments support the low likelihood of ecological impact during this period. Western Rock Lobster hatching mostly occurs outside the seismic area, and only one month of the six-month puerulus settlement period overlaps with the survey. Fish spawning overlap is minimal—less than 1% for key species such as dhufish, snapper, red throat emperor, and Spanish mackerel—making population-level impacts unlikely when considering natural variability and fishing pressures. To minimise disruption to commercial fishing, Pilot Energy will maintain regular communication with fishers, provide forward notice of survey vessel movements, and support access to alternative fishing areas. A compensation protocol is in place to address any losses incurred.	No	No
Seismic source validation: If a seismic source is selected for the Eureka 3D MSS that is any larger size (see Table 3-2) to the modelled source, additional acoustic source modelling will be undertaken using the JASCO AASM model to confirm that the far-field horizontal source level specifications of the seismic source selected for the survey are comparable to those assessed in this EP.	Benefits outweigh cost	Yes	Yes
All discharges of the seismic source (including soft starts and bubble tests) will occur only within the ASA.	Benefits outweigh cost	Yes	Yes

Control measures	Cost benefit analysis	Impact reduction	Control adopted
Seismic vessel will adopt lowest possible seismic source size while still achieving operational outcomes	The chosen source sizes (2495 cu.in. in deeper areas and 1440 cu.in. in the nodal area areas) are the minimum necessary to achieve required data quality for operational objectives, thereby reducing potential impacts on marine fauna. Further reduction in source size would compromise data quality and operational objectives.	Yes	Yes
Where potential concurrent operations with diving and/or snorkelling activities are identified, adhere to the following recommended requirements of the DMAC 12 guidelines: Where diving and seismic activity are scheduled to occur within 45 km, Pilot will notify divers/snorkellers of the planned activity where practicable. Where diving and seismic activity will occur within 30 km a joint risk assessment should be conducted, between the divers/snorkellers involved and Pilot and the seismic contractor in advance of any simultaneous operations.	Benefits outweigh cost	Yes	Yes
In addition to the requirements of EPBC Policy 2.1, Pilot Energy will initiate a power-down or shut-down of the seismic source if dolphins' approach within 500 m of the source, except for those observed bow riding.	Measure adopted from consultation. (Event 2888).	Yes	Yes
Nodal Source and Reef Exclusion Zones ALARP Analysis			
No operation of the seismic source within 300 m horizontal distance of the 12 m contour of Leander Reef and Big Horseshoe Reef or within 300 m horizontal distance of the 12 m contour of the other unnamed reef areas within the eastern part of the ASA.	Benefits outweigh cost	Yes	Yes
An interval of 24 hours will be applied to subsequent passes during acquisition and infill of areas 200 m from the exclusion zones in the nodal area	Benefits outweigh cost	Yes	Yes

Control measures	Cost benefit analysis	Impact reduction	Control adopted
Complete the nodal source lines no closer than 300m from the reef during day and night.	This control reduces the acquisition area which reduces the quality of the geophysical data, however the data collected will still be sufficient to meet the survey objectives. There is no additional survey costs associated with this control. This control provides protection to adult lobsters that reside in the reef habitats where lobsters are potentially at greatest densities. This control has been adopted because the cost is not grossly disproportionate to the environmental benefit gained.	Yes	Yes
Complete the nodal source lines within 500m of the 300m exclusion zone only during daylight hours to provide protection to nighttime foraging lobsters.	This control adds significant cost to the survey due to an additional week required to conduct the survey and approximately $3 million in additional survey costs. The additional 500m exclusion zone excludes 1.3 times the area of the 300m zone alone. Other costs associated with extending the duration of the survey include greater seismic noise exposure to other environmental receptors and revision of the entire EP to extend the survey. The evidence shows that seismic exposure is not lethal to adult lobsters, but sublethal effects may occur. While foraging may be impacted for the few nights that acquisition is active in the 500m zone, the impacts to lobster health and foraging behaviour are temporary. Therefore, the additional commercial costs to the survey are grossly disproportionate to the small sublethal protections that the control would provide.	Yes	No

Control measures	Cost benefit analysis	Impact reduction	Control adopted
Complete the nodal source lines no closer than 800m from the reef structures at any time (day and night).	Though this is more protective for all life cycle stages of lobsters, this would result in the geophysical data objectives for the survey not being completed and invalidate survey. As a result, the survey would not be commercial viability. The environmental benefit gained would be the reduction in sublethal effects on a small number of foraging lobsters. Therefore, the additional commercial costs to the survey are grossly disproportionate to the small sublethal protections that the control would provide.	Yes	No

Control measures	Cost benefit analysis	Impact reduction	Control adopted
No operation of the seismic source over areas of seabed with seagrass to protect the puerulus that may be residing in the seagrass.	This control would result in the survey not being economically feasible because the full extent of seagrass in the OA is not known. A dedicated seabed mapping study would be required that would cost millions of dollars and months of additional work prior to the seismic survey commencing. These areas would then be excluded from the survey area and would likely result in the geophysical data objectives for the survey not being completed and invalidate the survey. The evidence shows that puerulus exposed at very close proximity to seismic noise resulted in sublethal effects (Day et al. 2021, 2022, 2023). Therefore, excluding seismic acquisition over seagrass beds is not going to prevent large mortality events of peurulus and at most may reduce some sublethal effects and some possible mortality. As such, the environmental benefit of adopting this control is consider minor, especially in the context of the broader peurulus recruitment. Therefore, the additional commercial costs to the survey are grossly disproportionate to the small sublethal protections that the control would provide	Yes	No

7.1.6.2 Residual impact evaluation

Residual impact	Consequence	Likelihood	Risk ranking	Decision type
	Low – Plankton	Possible – Plankton	Low – Plankton	B
	Minor – Invertebrates	Unlikely – Invertebrates	Low – Invertebrates	
	Low to Minor – Lobster/octopus	Unlikely to Possible – Lobster/octopus	Low to Moderate – Lobster/octopus	
	Minor – Fishes	Unlikely – Fishes	Low – Fishes	
	Minor – Fisheries	Unlikely – Fisheries	Low – Fisheries	
	Low – Turtles	Possible – Turtles	Low – Turtles	
	Minor – Cetaceans	Unlikely – Cetaceans	Low – Cetaceans	
	Minor – Pinnipeds	Unlikely – Pinnipeds	Low – Pinnipeds	
	Minor - Seabirds	Unlikely - Seabirds	Low - Seabirds	
	Minor – Protected areas	Unlikely – Protected areas	Low – Protected areas	
	Minor – Tourism/Divers/snorkellers	Unlikely – Tourism/Divers/snorkellers	Low – Tourism/Divers/snorkellers	

7.1.6.3 Demonstration of acceptability

The Activity is consistent with Pilots corporate policies, culture, processes, standards, structure and system as outlined in the Demonstration of ALARP and Environmental Performance Outcomes including:

- Alignment with Pilots Environmental and Sustainability Policy for the Eureka 3D MSS described in Appendix A.
- Alignment with Pilots Hazard Identification and Risk Management Procedure.
- Adherence to Pilots impact/risk treatment (section 0).

These principles are integral to Australia's environmental legislation, including the federal Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). They guide the evaluation of projects, ensuring that they align with the principles of ESD, protect biodiversity, and promote sustainable development. Consistent adherence to these principles is essential for responsible and sustainable environmental management in Australia. ESD is a foundational concept in environmental decision-making and management, with its principles deeply rooted in international agreements and enshrined in Australian legislation. The core tenet of ESD is to ensure that the needs of the present generation are met without compromising the ability of future generations to meet their own needs. There follows and assessment of each principle of ESD having regard to the Eureka MSS and the preparation process of the EP. The impact assessment has considered the following relevant principles of ESD:

- The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making.
- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.

Impacts are considered consistent with these principles given controls adopted, and that impacts will be limited to a range of low-moderate indicating ether ‘negligible impact’ to ‘short term effect with recovery from months to one year’ (See section 6.4.2). Other principles of ESD were not considered relevant to underwater noise emissions from seismic source.

The proposed activity and control measures are not inconsistent with the requirements of recovery plans or wildlife conservation plans/advice. The impact/risk is being managed in accordance with industry good practice (APPEA Code of Environmental Practice and IAGC/IOGP guidelines), and national and international standards (ISO 31010:2018 Risk

Management, Standards Australia / Standards New Zealand Risk Management Guidelines). The impact assessment and control measures are also consistent with NOPSEMA Acoustic Impact Evaluation and Management Guideline (N-04750-IP1765 Rev 2 Dec 2018). Extensive consultation has been undertaken, and all stakeholder concerns and feedback has been assessed and addressed appropriately.

The newly published southern right whale aerial survey report (Smith et al., 2025) reinforces that calving continues to occur in southern Western Australia and that population growth rates in those areas have slowed in recent years. This information does not change the assessment for the Eureka 3D MSS, as the survey area lies approximately 350 km north of Perth and outside of known calving habitat. The primary protective measure for SRW in this EP remains the February–March timing of the activity, which avoids periods when SRWs are present in Western Australian waters.

Additionally, to the criteria presented above, Table 7-18 below further exhibits the reasonings why predicted impacts to relevant receptors, and by extension the activity, will be conducted in an environmentally acceptable manner, and impacts will be reduced to an acceptable level.

Table 7-18: Statement of Acceptability

Statement of Acceptability		
Receptor	**Acceptability Criteria & Assessment Summary**	**Environmental Performance Considerations**
Plankton, Fish, Invertebrates (incl. spawning)	The predicted level of impact for Plankton, fish and invertebrates (including spawning) is of an acceptable level because: Claims that seismic surveys pose a risk of impact to certain fish and crustacean species has some merit to individual animals. Controls to limit this impact have been applied and are considered ALARP. Claims were raised that the use and application of scientific papers that referenced the Southern Rock Lobster were not reflective of potential impacts to the Western rock lobster. Pilot's focus was that both species have a mechanosensory organ called a statocyst that is potentially impacted by the particle motion component of underwater noise and that, as research in all scientific fields is limited it is common practice to draw on similar case studies for impact assessment. As there is uncertainty Pilot has adopted a control measure that precludes operation of the seismic source within the nodal area of the survey with a 300m buffer applied to identified reefs to minimise noise levels in these areas. Impacts to adult and juvenile lobster are expected to be sublethal and recoverable and are therefore not expected to have population and ecosystem level effects. The survey will not result in changes to spawning biomass or changes in recruitment of important species that may be discernible from normal natural variation and will therefore not have population or ecosystem level effects. The survey will be managed in a manner that is consistent with management objectives for relevant AMPS's, recovery plans and conservations plans/advice. Localised changes to zooplankton expected to be replaced and indistinguishable from natural levels within hours, and certainly within a few days based on McCauley et al. (2017) and Richardson et al. (2017). Recovery of fish expected within 12 to 24-hours based on Stadler & Woodbury (2009) and Popper (2018).This demonstration of acceptability meets acceptable levels AL 1,2,3,5,6,7,8,9, 10, 11, 12, and 13.	EPO 2 - Undertake seismic acquisition in a manner that reduces potential cumulative impacts resulting from the Eureka 3D MSS and other seismic survey operations as far as reasonably practicable. EPO 3 - Undertake seismic acquisition in a manner that prevents injury and reduces the potential for TTS in site-attached fishes and invertebrates.

Statement of Acceptability		
Receptor	**Acceptability Criteria & Assessment Summary**	**Environmental Performance Considerations**
Marine Fauna (turtles, cetaceans, ASL, seabirds)	The predicted level of impact for migratory and threatened cetaceans is of an acceptable level given the following: Claims were raised that the seismic activity may impact on the foraging area of the ASL. No TTS or PTS impact is likely in foraging ASL, however as an added precaution Pilot have extended the EPBC Policy statement 2.1, for whales, to also extend to ASL and initiated a 1km observation zone and 500m shutdown zone for MFO observation of ASL. Additionally, an exclusion area of 9.2km was placed on the Beagle Islands. The survey will be managed in a manner that prevents physical injury or displacement of PBW, HBW, SRW and ASL from migration and foraging BIA's. Additionally, it will be managed in a manner that reduces potential biologically significant behavioural disturbances to PBW, SRW, HBW, ASL and other cetacean species. The survey will be managed in a manner that is consistent with management objectives for relevant AMPS's, recovery plans and conservations plans/advice. The predicted level of impact has been reduced to ALARP. By scheduling the seismic survey between early February to end of March, the migration periods for PBWs, SRWs and HBWs are avoided. This demonstration of acceptability meets acceptable levels AL 1,2,3,4, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 and 31.	EPO 1 - Undertake seismic acquisition in a manner that prevents injury and biologically significant behavioural disturbance to whales and ASLs. Implementation of EPBC Policy Statement 2.1 Part B.6 Adaptive Management Measures to minimise the minimum potential impacts to pygmy blue whales. EPBC Policy Statement 2.1 Part A Standard Management Procedures applied throughout duration of survey. Implementation of EPBC Policy Statement 2.1 Part B.4 increased precaution zones and buffer zones for whales. Implementation of EPBC Policy Statement 2.1 Part B.1 Additional Management Procedures – MFOs. Two MFOs will be deployed on the support vessel during acquisition within the Extended Observation Zone for PBW.

Statement of Acceptability		
Receptor	**Acceptability Criteria & Assessment Summary**	**Environmental Performance Considerations**
KEFs & Protected Areas	The predicted level of impact for KEF's and protected areas is of an acceptable level because: The survey will be undertaken in a manner that is consistent with the principles and management objectives of the south-west marine reserves network management plan. The survey will be undertaken in a manner that is consistent with the objectives of the commonwealth and (Abrolhos and Jurien AMP) and state protected areas (Jurien Bay Marine Park). This demonstration of acceptability meets acceptable levels AL 37, 38, 39, and 40.	EPO 1 - Undertake seismic acquisition in a manner that prevents injury and biologically significant behavioural disturbance to whales and ASLs.

Statement of Acceptability		
Receptor	**Acceptability Criteria & Assessment Summary**	**Environmental Performance Considerations**
Commercial & Recreational Fisheries	The predicted level of impact for commercial and recreational fisheries is of an acceptable level given the following: Claims were raised that there may be future financial impacts to commercial fishing because of the Seismic activity. Pilot found that it was unlikely that catch rates would be impacted outside of the short-term impacts from displacement, however in the unlikely event of impacts to catch rates Pilot has put forward a commitment to implement a Commercial Fishing Industry Adjustment Protocol. This will formally manage claims by commercial fishers for lost/damaged gear, costs due to displacement/relocation and loss of catch because of survey activities. Impacts of the survey on commercial or recreational fishery catch rates will be limited to short term and localised effects. The potential impacts of noise emissions from the seismic source on spawning of key indicator commercial fish species are slight and short-term, and the activity is not likely to result in any ecologically significant impacts at a population level for any key indicator commercial fish species that may be spawning within or adjacent to the OA during acquisition activities. The proposed control measures are consistent with key mitigation strategies for seismic surveys published in the WA Department of Fisheries Guidance statement on undertaking seismic surveys in Western Australian waters (DoE 2013) – e.g., use of soft starts; minimise the sound intensity and exposure time of surveys. Pilot has also considered DPIRD's ecological risk assessment of seismic impacts to marine finfish and invertebrates (Webster et al. 2018) during the assessment of impacts and risks to fish spawning and commercial fisheries, noting that the DPIRD risk assessment considers worst-case potential impacts to individual finfish and invertebrates assuming they do not move to avoid an approaching seismic source. This is not representative of real-life sound exposures and does not represent impacts at a population level. Pilot has, therefore, considered additional information to assess impacts to fish spawning and fish stock populations. Ongoing consultation will address any outstanding or arising issues with relevant stakeholders. This demonstration of acceptability meets acceptable levels AL 32, 33, 34, 35, and 36.	EPO 2 - Undertake seismic acquisition in a manner that reduces potential cumulative impacts resulting from the Eureka 3D MSS and other seismic survey operations as far as reasonably practicable. EPO 3 - Undertake seismic acquisition in a manner that prevents injury and reduces the potential for TTS in site-attached fishes and invertebrates. EPO 6 - Activities are carried out in a manner that does not interfere with other marine users to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties. PS - Implementation of the Eureka Marine Seismic Survey Commercial Fisher Compensation Protocol (EMSSCFCP) to formally manage claims by commercial fishers for lost/damaged gear, costs due to displacement/relocation and loss of catch because of survey activities.

Tourism & Recreation	The predicted level of impact for tourism and recreation is of an acceptable level given the following: The proposed controls and consequence level are consistent with the DMAC 12 (Rev 2) guidelines. No tourism operations were identified as being active in the OA, however if this changed any Impacts to tourism and recreation activities would be limited to the time frame to undertake the seismic acquisition. This demonstration of acceptability meets acceptable levels AL 41 and 42.	EPO 2 – Undertake seismic acquisition in a manner that reduces potential cumulative impacts resulting from the Eureka 3D MSS and other seismic survey operations as far as reasonably practicable. PS - Where potential concurrent operations with diving and/or snorkelling activities are identified, adhere to the following recommended requirements of the DMAC 12 guidelines: Where diving and seismic activity are scheduled to occur within 45 km, Pilot will notify divers/snorkellers of the planned activity where practicable. Where diving and seismic activity will occur within 30 km a joint risk assessment should be conducted, between the divers/snorkellers involved and Pilot and the seismic contractor in advance of any simultaneous operations. PS - Direct communication with local dive shops and Port Denison Volunteer Sea Search & Rescue will be used to identify and notify the public of planned survey operations. Local newspaper advertisements and signs posted at local boat ramps and beaches will also be used to notify the public of the planned survey operations.

Statement of Acceptability		
Receptor	Acceptability Criteria & Assessment Summary	Environmental Performance Considerations
		EPO 4 - Undertake seismic acquisition in a manner that prevents injury to any scuba divers or snorkellers. EPO 6 - Activities are carried out in a manner that does not interfere with other marine users to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties. PS - Pilot will take reasonable steps to avoid or minimise conflict with other marine users, should such a conflict be identified during ongoing discussions with relevant persons. PS - Survey timing will be limited to February – March 2026.

7.1.6.4 Environmental performance outcomes, standards and measurement criteria

The environmental performance outcomes, standards and measurement criteria appropriate to measure performance of the adopted control measures for underwater sound from seismic operations are presented below in Table 7-19.

Table 7-19: Environmental performance outcomes, standards and measurement criteria for underwater sound from seismic operations

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 1 Undertake seismic acquisition in a manner that prevents injury and biologically significant behavioural disturbance to whales, dolphins, and ASLs EPO 2 Undertake seismic acquisition in a manner that reduces potential cumulative impacts resulting from the Eureka 3D MSS and other seismic survey operations as far as reasonably practicable.	PS 1 Implementation of EPBC Policy Statement 2.1 Part A Standard Management Procedures relating to the following: Pre-start-up visual observation for minimum 30 minutes Soft start for minimum 30 minutes Start-up delay for a minimum of 30 minutes Operations monitoring Power-down and stop work Night-time and low visibility. Implementation of EPBC Policy Statement 2.1 Part B.4 increased precaution zones and buffer zones for whales: Observation zone: 3 km+ to the limits of visibility for large unidentified whales 2 km to 3 km for all other whales Shut-down zone: To limits of visibility for positively identified (certain or probable confidence level) pygmy blue whales, and large unidentified whales 2 km for all whales Implementation of the following precautionary zones for ASLs: Observation zone to 1 km Shut-down zone to 500 m Dolphin shut-down – The seismic source will be powered down if any dolphin enters the 500 m shut-down zone.	MC 1 MFO data sheets/report confirms EPBC Policy Statement 2.1 is available aboard the seismic vessel and all Part A Standard Management Procedures have been implemented throughout seismic data acquisition. MC 2 Records demonstrate compliance with Policy Statement 2.1 Part A Standard Management Procedures and Part B.4, including application of precautionary zones for ASLs.
	PS 2 Implementation of EPBC Policy Statement 2.1 Part B.1 Additional Management Procedures – MFOs: Four dedicated trained Marine Fauna Observers (MFOs) will watch for whales and ASLs during seismic operations in daylight hours, throughout the duration of the survey	MC 3 Records demonstrate two dedicated MFOs per observing vessel (survey vessel and support vessel) are

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	Two MFOs will be deployed on the survey vessel Two MFOs will be deployed on the support vessel during acquisition within the western section of the ASA (blue lines on Figure 3-3) – the Extended Observation Zone for PBW. During acquisition within the Extended Observation Zone, the support vessel will be positioned 10 km to the west of the survey vessel, and the MFOs will implement the same observation and shut-down zones as described in PS 1 above. The MFOs aboard the support vessel will be in direct communication with the lead MFO aboard the survey vessel, and will have the authority to request a shut-down if a positively identified (certain or probable confidence level) pygmy blue whale or large unidentified whale is observed within the limits of visibility from the support vessel If the support vessel has to leave the Extended Observation Zone for any reason (e.g., for resupply) the survey vessel will stop acquisition and move to lines within the eastern section of the ASA (red lines on Figure 3-3). Acquisition within the Extended Observation Zone will only recommence when the support vessel is available to re-commence the role of additional spotter vessel At least one dedicated MFO undertaking observations during daylight hours per observing vessel (survey vessel and support vessel). If required, the additional MFO will be used during times of increased whale sightings.	aboard and undertake observations in accordance with EPBC Act Policy Statement 2.1. MC 4 MFO data sheets/report demonstrates watch maintained during daylight acquisition MC 5 CVs for MFOs demonstrates competency and experience
	PS 3 All MFOs engaged for the Eureka 3D MSS will have previous experience observing for marine mammals at sea, and be competent at identifying marine mammals, estimating distance, implementing mitigation actions and recording data. All MFOs will have completed relevant training detailing marine fauna identification and EPBC Act Policy Statement 2.1 requirements.	
	PS 4 All marine fauna detection personnel (MFOs, trained crew) will attend the environmental induction presentation, which will include the environmental sensitivities of the survey area, environmental management strategies, EPO, and EPS as detailed in the EP. At crew changes, this information will be communicated to on-coming personnel during handover.	MC 6 MFO commitments presentation; attendance sign-off sheets MC 7 Pre-survey inspection verifies MFO procedures located on bridge.
	PS 5 Implementation of EPBC Policy Statement 2.1 Part B.6 Adaptive Management Measures to minimise the minimum potential impacts to pygmy blue whales from seismic noise. The following adaptive management measures will be implemented:	MC 8 Records demonstrate compliance with pygmy blue whale adaptive management measures as described

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	If there are three or more shut-downs for pygmy blue whales within a 24-hour period (including shut-downs triggered by sightings by the support vessel MFOs), then the seismic operations must not be undertaken thereafter at night-time or during low visibility conditions. Seismic operations cannot resume at night-time or during low visibility conditions, until there has been a cumulative 24-hour period of seismic operations (daylight hours with good visibility) during which there has been ≤1 shut-down for pygmy blue whales.	
		MC 10 Records confirm no incidents when vessels less than 40 km apart and actively acquiring data
	PS 6 No seismic acquisition during the pygmy blue whale northbound or southbound migration periods (i.e., April to July; and October to January)	MC 11 Records demonstrate acquisition of the survey confined to period 1 February to 31 March 2025, or 1 February to 31 March 2026.
	PS 7 No seismic acquisition during the southern right whale migration period (i.e., April to October)	
	PS 8 No seismic acquisition during the humpback whale migration period (June to November)	
	PS 9 Seismic source validation: If a seismic source is selected for the Eureka 3D MSS that is a larger size (see Table 3-2) to the modelled source, additional acoustic source modelling will be undertaken using the JASCO AASM model to confirm that the far-field horizontal source level specifications of the seismic source selected for the survey are comparable to those assessed in this EP	MC 12 Acoustic modelling (source modelling) for selected seismic source.
	PS 10 If another vessel is acquiring seismic data in the region, the survey vessel shall not acquire data simultaneously within 40 km of the other seismic vessel in order to avoid cumulative impacts to marine fauna	MC 9 Communication records show that any geophysical contractors operating other seismic survey vessels have been consulted two weeks prior to the survey start and agreed to 40 km separation distance MC 13 Records demonstrate compliance with the 40 km separation distance.

Environmental performance outcomes	Environmental performance standards	Measurement criteria
		MC 14 Record demonstrate consultation with other titleholders with acreage within 40 km of the OA, and with other geophysical companies, prior to commencement of the activity.
	PS 11 All discharges of the seismic source (including soft starts and bubble tests) will occur only within the ASA	MC 15 Seismic vessel gun logs will contain the seismic observers acoustic log of all instances the acoustic source was activated, including the acoustic source sequence activated during soft start procedures. MFO weekly reports to concur with seismic logs regarding number and timing of soft starts.
EPO 3 Undertake seismic acquisition in a manner that prevents injury and reduces the potential for TTS in site-attached fishes and invertebrates	PS 109 No acquisition within a 9.2 km horizontal distance around the Beagle Islands	MC 16 Survey records demonstrate that the seismic source has not been operated within the described exclusion zones.
	PS 12 No operation of the seismic source within 300 m horizontal distance of the 12 m contour of Leander Reef and Big Horseshoe Reef or within 300 m horizontal distance of the 12 m contour of the other unnamed reef areas (Figure 3-2) within the eastern part of the ASA.	
	PS 106 The seismic survey vessel will not deviate around the reef exclusion zones (within 200 m) with the seismic source activated unless at least 24-hours has passed since the previous line was acquired.	MC 104 Survey records demonstrate that the seismic source was not operated within 24 hours of an area that had been acquired or infilled in the preceding 24 hours, in the nodal area, 200m from the exclusion zones.
	PS 37 Implementation of the Eureka Marine Seismic Survey Commercial Fisher Compensation Protocol (EMSSCFCP) to formally manage claims by commercial fishers for lost/damaged gear, costs due to displacement/relocation and loss of catch because of survey activities.	MC 43 Commercial Fishing Industry Adjustment Protocol implemented with relevant commercial fishers prior to commencement of survey activities.

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	This Protocol originated from the National Energy Resources Australia (NERA) Commercial Fishing Industry Adjustment Protocol (NERA, 2021). The Protocol has been amended following feedback from fishers and fishing associations who Pilot Energy have consulted with. The (EMSSCFCP) will have the following features: As a minimum, claims processes for direct losses from: Accidental damage or loss of deployed fishing equipment caused by the presence of the seismic vessel (either repair or replace). Displacement for increased transit times, which result in increased fuel and crewing costs from moving fishing locations, Reduced catch per unit effort if survey acquisition timing directly overlaps a previously fished area, within the fishing season, demonstrated by the reported data. The claims process will require a fisher to provide evidence (or authorisation to access evidence) for claimed losses that enables a calculation of how much compensation may be due. Details about the role, responsibilities, and instructions for nominated claims assessors who will be third parties to the titleholder. An assessment report on each claim will be provided by the claim assessor to the titleholder and the claimant. The assessment report will include the details and methodology used to conclude the claim and an Outcome Notification. There will be a dispute mechanism requiring additional assessment by a different assessor. Applies to fishing cooperatives who can provide evidence of commercial losses because of the survey. A loss of adjustment claim can be lodged up to 6 months s after the completion of the activity. Subject to a claim being lodged, a suitably experienced/qualified independent person/organisation will be engaged by the titleholder as the assessor of the claim, in consultation with the claimant. Appropriately documented claims will be assessed, in accordance with the processes outlined in the protocol, and a report will be provided to the claimant within 30 days of the lodgement date of the claim Successful claims will receive compensation within 10 working days of the Outcome Notification being executed. The claim assessor(s) will be suitably experienced and qualified and is defined as a person or organisation with proven demonstrated experience in data analysis and data auditing processes and procedures	

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	within the fishing industry. Nominees for claims assessors can be made by titleholders and claimants and then agreed upon before the commencement of a claim. There is a claims process specified in the protocol, which will be followed by the titleholder and the claims assessor. If a claimant disagrees with a claim assessment outcome, and an agreement cannot be reached between the titleholder and the claimant, the claimant may, within 30 days of receipt of the Outcome Notification, request that a suitably experienced/ qualified independent third-party is engaged to review and determine the outcome of the claim. The independent expert reviewer must provide a view as to whether the claim assessment process has been conducted in line with the requirements of the protocol. The independent expert reviewer may also consider any additional information deemed appropriate by them, including information provided by either the claimant or the titleholder. An independent expert review decision may differ from the initial assessment outcome. A copy of the Protocol has been included in Appendix C.	
EPO 4 Undertake seismic acquisition in a manner that prevents injury to any scuba divers or snorkellers	PS 13 Where potential concurrent operations with diving and/or snorkelling activities are identified, adhere to the following recommended requirements of the DMAC 12 guidelines: Where diving and seismic activity are scheduled to occur within 45 km, Pilot will notify divers/snorkellers of the planned activity where practicable. Where diving and seismic activity will occur within 30 km a joint risk assessment should be conducted, between the divers/snorkellers involved and Pilot and the seismic contractor in advance of any simultaneous operations.	MC 17 Records demonstrate that relevant DMAC 12 guidelines followed where potential concurrent diving/ snorkelling activities are identified.

7.2 Impact 2: Underwater sound – vessel operations

In accordance with the Pilot Energy risk assessment methodology (Section 6) this impact is classified as lower order.

7.2.1 Identification of the hazard and extent

Hazard	The seismic vessel(s) and the support/chase vessel(s) will generate low levels of machinery noise, especially when using propulsion thrusters. This noise will be at a much lower level than the noise emitted from the active airgun array. Seismic data acquisition will occur on a continuous basis (24-hours a day) throughout the survey (maximum duration of 40 days), with limited periods of time when the seismic source is not operational. While the seismic source is operational, the underwater noise generated by vessels will be a negligible addition to the cumulative noise levels. The assessment of underwater vessel noise below is therefore limited to the periods when underwater noise levels from vessel operations are dominant, and periods when the airgun array is not operational (e.g., line turns, during maintenance / repairs and marine fauna shutdowns). The area is already subject to frequent noise from vessels due to its proximity to relatively busy shipping routes.
Extent	OA
Duration	Duration of survey – up to 40 days in early February to the end of March.

7.2.2 Defined acceptable level

For lower-order impacts and risks, Pilot Energy defines the acceptable level as the point at which the residual impact or risk has been reduced to ALARP. This means that all relevant control measures have been identified and implemented to the extent that no additional practicable measures are available without costs being grossly disproportionate to the environmental benefit gained. In this context, the acceptable level is inherently linked to the ALARP outcome, recognising that residual impacts and risks at this level are tolerable, consistent with legislative requirements, and aligned with relevant environmental and stakeholder expectations.

7.2.3 Impact analysis and evaluation

This section describes the impacts that may occur on significant marine environmental receptors identified in Section 4 that are potentially sensitive to underwater sound from vessel activities. On conclusion of the impact analysis, the inherent impacts from the hazards are evaluated. This part of the impact assessment method is described in Section 6.4.

Potential impacts	The potential risks and impacts to marine fauna from increased underwater noise associated with normal vessel operations are reasonably well understood limited to behavioural disturbance rather than direct physiological injury. Vessel operations in the region are widely acceptable to the community (due to the existing usage for other marine activities e.g., shipping and fishing), therefore the potential for adverse impacts from vessel noise is considered low. The greatest source of noise during the activity will be from operation of the airgun array, therefore the impact assessment for the effects of increased noise from vessel operations on marine fauna is put into the context in terms of the limited periods during which this could be the dominant noise source—i.e., when the seismic source is not operational. Noise emissions from the seismic and support/chase vessels will be influenced by the activity being conducted by the vessels, for example, the seismic vessel generates less noise when drifting and more when towing the streamer array using the azimuth thrusters. Source levels from typical seismic vessels are approximately 165 to 180 dB re 1 µPa (root mean squared (rms) @ 1 m for vessels <100 m long and 180 to 190 dB re 1 µPa (rms) @ 1 m for vessels >100 m long (Richardson et al. 1995; Kipple & Gabriel 2004; Heitmeyer et al. 2003). Marine fauna at distance from the vessel will be exposed to much lower noise levels due to attenuation of the sound energy as it travels through the water.
Predicted effects	Pygmy blue whales, southern right whales and humpback whales have BIAs that overlap the OA. The timing of the survey (early February to end of March) is outside of the recognised peak migration periods for all three of these

	species, and therefore the presence of individuals is expected to be limited to occasional, transient individuals during this time. Other whales that may be encountered include the fin, sei and Bryde's whale. The white shark could also be present in the OA, having a wide distribution across the region and a foraging BIA overlapping the OA. There is a haul-out site and breeding colony for the ASL at the Beagle Islands, located ~10 km south of the OA. Additionally, ASLs may forage in the waters of the OA, which are overlapped by foraging BIAs for both males and females. Therefore, it is possible that individual sea lions may be encountered within the OA during the survey. It is also possible that other species of marine fauna that are not regionally significant may transit through the OA, e.g., dolphins and marine turtles. Underwater noise emissions from vessel operations are generally within or below the range of natural noise levels experienced by marine fauna, and therefore not expected to cause any physiological damage to fauna (McCauley 1998, 2003; McCauley & Jenner 2001; Richardson et al. 1995). The primary auditory effect of vessel noise on marine fauna is the potential masking of biologically significant sounds (Southall et al. 2007). Potential behavioural effects on marine fauna due to underwater noise from vessels also include changes in vocalisation characteristics and disturbance to foraging, navigation and reproductive activities. Most acoustic energy radiated from large commercial vessels is below 1 kHz, and so the greatest potential for masking exists for marine fauna that produce and receive sounds within this frequency band; primarily baleen whales, pinnipeds, fish, and possibly some toothed whales (Southall et al. 2007). Acoustic masking at higher frequencies (1 to 25 kHz) may affect toothed whales (beaked whales, sperm whales, dolphins and porpoises) near the vessels. There has been relatively little behavioural observation of cetaceans exposed to continuous, low-level underwater noise, such as from vessels. An experimental study involving acoustic tagging and controlled exposure experiments with North Atlantic right whales (*Eubalaena glacialis*), showed no effect of vessel noise on the whales. Five of the six individual whales responded strongly (interrupted dive pattern and swam rapidly to the surface) to the presence of an artificial alarm stimulus (series of constant frequency and frequency modulated tones and sweeps) but ignored playbacks of vessel noise (Nowacek et al. 2004). Small cetaceans are commonly observed swimming near vessels; this attraction indicates that the noise is not having a detrimental effect on the animals. The frequency range of vessel noise overlaps the hearing ranges of many fish species (Amoser & Ladich 2003). Hearing impairment (i.e., TTS) has been recorded for fish exposed to continuous noise from small boats and ferries for two hours (Vasconcelos et al. 2007). However, recovery was observed on cessation of vessel noise. In summary, marine fauna that may be present within the OA are mobile and would be expected to actively avoid the seismic and support/chase vessels, especially during data acquisition. When the airguns are not operational, there may be localised behavioural disturbance of fauna in the immediate vicinity of the vessel during operations. However, this would be limited to a temporary change in behaviour due to avoidance of the area but no injury or lasting impact. No injury or mortality of marine fauna because of exposure to vessel noise in an already high vessel usage area; and no effects at a population level are predicted.

Inherent impact	Consequence	Likelihood	Risk ranking
	Minor	Unlikely	Low

7.2.4 Impact treatment

Using the impact evaluations in Section 6.4.2, treatments for each of the impacts are identified in the following as part of the impact assessment methodology described in Section 0.

7.2.4.1 Demonstration of ALARP

Complete elimination of the impact is not possible as there is no practical alternative to the use of vessels which allow Pilot to undertake the activity. The impact assessment has determined that, with the implementation of the adopted control measures, underwater noise from vessel operations will not result in a potential impact greater than a localised area of avoidance and short-term effect on marine fauna species. Behavioural disturbance effects are expected to return to cease once the vessels are removed from the area.

The application of recognised good practice is considered appropriate to manage these risks (Table 7-20), specifically those relating to operating seismic vessels and procurement of chase vessels to ensure the noise levels generated by the working vessels are at their lowest levels. The relevant EPBC Regulation managing interactions between vessels and cetaceans is also considered good practice.

However, this risk assessment recognises the survey-specific nature of risks associated with the Eureka 3D MSS and the challenges in predicting the use of the OA by other marine users. To augment decision making, a precautionary approach is applied where uncertainty continues to exist.

Pilot is committed to ensuring continual risk reduction and identifying if additional control measures may be applied that are not disproportionate to the sacrifice (e.g., cost) of implementation. Pilot considers the adopted controls to be appropriate in reducing the environmental impacts associated with underwater sound from vessel operations on marine fauna to ALARP. There are no other controls measures that may practicably or feasibly be adopted to further reduce the impacts without disproportionate costs compared to the benefit of the potential impact reduction.

Table 7-20: Demonstration of ALARP – underwater sound from vessel operations

Control measures	Cost benefit analysis	Impact reduction	Control adopted
ALARP assessment technique – legislative requirements, good practice			
All internal combustion engines on-board the vessels will be maintained in accordance with the manufacturer's specifications and hence noise emissions will be typical of vessels in the region.	Benefit outweighs cost	Yes	Yes
Interaction between survey vessel and marine mammals (whales, dolphins and pinnipeds) within the OA will be consistent with EPBC Regulations 2000 – Part 8 Division 8.1 and Australian National Guidelines for Whale Watching and Dolphin Watching 2017 (Commonwealth of Australia 2017): Vessels will not knowingly travel faster than six knots within 300 m of a whale or 150 m of a dolphin or pinniped Vessels will not knowingly get closer than 100 m of a whale or 50 m of a dolphin or pinniped Survey vessel and support/chase vessels will not intentionally approach within 150 m of a dolphin calf or sea lion pup or within 300 m of a whale calf (Reg 8.06(2)) If a marine mammal approaches the vessel within the above zones, the vessel should avoid rapid changes in engine speed or direction.	Benefit outweighs cost; legal requirement	Yes	Yes
ALARP assessment technique – EIA			
Do nothing – survey not acquired	The survey is critical in providing data to fill in data gaps in the region and to replace existing poor quality seismic data already reprocessed by Pilot. Minimal benefit given the precautionary control measures to be implemented. Costs disproportionately higher than benefits.	Yes	No

Residual impact evaluation				
Residual Impact	Consequence	Likelihood	Risk ranking	Decision type
	Low	Unlikely	Low	A

7.2.4.2 Demonstration of acceptability

The impact assessment has concluded that, with the implemented control measures, project vessel noise disturbance is expected to result in no more than localised and temporary disruption to a small proportion of the population. These impacts are anticipated to have no lasting effects and no impact on critical habitats or activities.

Pilot has thoroughly evaluated additional opportunities to further mitigate impacts and risks associated with vessel noise. The adopted control measures are in line with good industry practice and fully comply with the requirements set forth in Part 8 (Division 8.1) of the EPBC Regulations 2000.

The planned seismic activity has been assessed to be consistent with relevant Recovery and Threat Abatement Plans and aligns with the principles of ESD. No specific concerns regarding underwater sound impacts from project vessels have been raised by relevant stakeholders.

Given these factors, Pilot believes the adopted control measures are appropriate and sufficient to manage the impacts and risks of underwater sound from project vessels to a level that is broadly acceptable.

7.2.4.3 Environmental performance outcomes, standards and measurement criteria

The environmental performance outcomes, standards and measurement criteria appropriate to measure performance of the adopted control measures for underwater sound from vessel operations are presented below in Table 7-21: Environmental performance outcomes, standards and measurement criteria for underwater sound from vessel operations

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Table 7-21: Environmental performance outcomes, standards and measurement criteria for underwater sound from vessel operations

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 5 Minimise impacts of underwater sound from vessel operations during the Eureka 3D MSS on EPBC listed Threatened and Migratory marine mammal species in the OA.	PS 14 All internal combustion engines on-board the vessel will be maintained in accordance with the manufacturer's specifications.	MC 20 Records and training matrix demonstrate that a qualified marine engineer is on-board throughout survey
	PS 15 Interaction between survey vessels and marine mammals (whales, dolphins and pinnipeds) within the OA will be consistent with EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans: Vessels will not knowingly travel faster than 6 knots within 300 m of a whale or 150 m of a dolphin or pinniped Vessels will not knowingly get closer than 100 m of a whale or 50 m of a dolphin or pinniped Survey vessel and support/chase vessels will not intentionally approach within 150 m of a dolphin calf or sea lion pup or within 300 m of a whale calf (reg 8.06(2)). If a marine mammal approaches the vessel within the above zones, the vessel should avoid rapid changes in engine speed or direction.	MC 18 MFO report demonstrates no breaches of EPBC Regulations 2000 Part 8. MC 19 Compliance and marine mammal sighting reports will be completed and provided to NOPSEMA/DCCEEW within three months of completion of the survey.

7.3 Impact 3: Interactions with other marine users

In accordance with the Pilot Energy risk assessment methodology (Section 6) this impact is classified as higher order. Therefore, an additional assessment and detail is required to demonstrate this impact is of an acceptable level.

7.3.1 Identification of hazard and extent

Hazard	The survey vessel and support/chase vessels will operate 24-hours a day for the duration of the survey (up to 40 days). During the survey there will be one survey vessel, one support vessel, and at least one chase vessel to manage interactions with other vessels and hazard avoidance duties ahead of the survey vessel (e.g., fishing gear), to assist with streamer deployment and recovery (if required), and other activities as required (e.g., resupply). There may also be additional vessels assisting with the ocean bottom node (OBN) deployment and recovery. Other marine users such as commercial and recreational fishing, charter and dive vessels and commercial shipping may be temporarily displaced by the presence of the survey vessel and the streamers extending up to 7 km behind the vessel. These also present a navigational hazard to other marine users. Data in shallower waters within the Node Survey Area may be acquired using OBN. The nodes will be deployed from the vessel and placed on the sea floor by commercial divers or ROVs. Nodes are expected to be placed in a grid of 250 m × 250 m which would result in the deployment of approximately 1500–2000 nodes. The Node Survey Area where equipment will be deployed covers approximately 119 km² (Figure 3-2). The nodes would be placed at the start of the survey and collected at the end of the survey timeframe. The location of the activity potentially intersects with marine cultural heritage values for the Southern Yamatji and Yued group of Traditional Owners (TOs) and potentially other TO groups.
Extent	OA
Duration	Duration of survey – up to 40 days in early February to the end of March.

7.3.2 Defined acceptable levels

Pilot Energy's risk assessment methodology for demonstrating that impacts and risks are at an acceptable level distinguishes between higher-order and lower-order impacts and risks. For lower-order impacts and risks, acceptability is demonstrated when the impact or risk has been shown to be reduced to as low as reasonably practicable (ALARP). However, for the interactions with other marine users, an additional demonstration is required. Before the assessment, acceptable levels of impact are defined (below). Once the assessment is complete, the predicted impact levels are compared with these predefined acceptable levels. If the predicted levels are lower than the defined thresholds, the impact is at an acceptable level.

AL 41. Survey activity and equipment are limited to within the OA and only during the survey period

AL 42. Relevant person concerns/objections received have been merit assessed, and control measures developed to address merited claims/objections, where required. There are no outstanding merited objections or claims

AL 43. Vessel operations will be compliant with relevant legislation and guidelines relating to navigation and safety at sea

AL 44. Third parties are always made aware of the presence and movements of the seismic and support/chase vessels through the ongoing relevant person notification program

AL 45. Fishers receive sufficient notification of survey operations in each zone through the ongoing relevant person notification program for planning of fishing trips

AL 46. Disruption to fishing activities is limited to that required for safe passage of the survey vessel and its towed array whilst it is restricted in its ability to manoeuvre.

AL 47. Towed seismic array does not snag/entangle with set fishing gear, such as rock lobster pots and octopus traps, after providing notification.

7.3.3 Impact analysis and evaluation

Potential impacts	Temporary and intermittent displacement of other marine users such as transiting vessels (including shipping and fishing vessels), boaters, divers/snorkellers and other recreational users Disruption of fishing activities due to entanglement of fishing gear (trawl nets, fish traps/pots, gillnets and long lines) with the seismic streamers.
Predicted effects	Commercial and recreational fishing activities Consultation with relevant persons identified concern over the loss of access to fishing grounds (displacement) and interference with fishing gear (e.g., entanglement). A description of Commonwealth and WA state-managed fisheries with jurisdictional boundaries overlapping the OA is provided in Section 4.4.2. An assessment of the amount of activity by each fishery is provided in Table 4-15 and Table 4-16 Recreational fishers onboard charter and private vessels operating off the WA coast and around the Abrolhos Islands typically target large pelagic and west coast demersal scalefish species. There were 59 licensed tour operators active in 2019/2020 (Newman et al. 2021a), though only 1-2 licences per year in waters within the OA. It is likely that some activity by recreational fishers will occur within the OA, though this is expected to be short-term and intermittent. This may be impacted by the recent extension to banned fishing periods for demersal scalefish, which overlaps with the period of the survey; however, there is no information to advise how long this extension may apply for. It will be necessary for areas in the immediate vicinity of the survey vessel and towed array to be prohibited to recreational and commercial fishing vessels in accordance with maritime regulations relating to safety of navigation. However, only minor disruption to fishing activities is expected for fishers who may set their fishing gear for several hours and/or who are mobile and can move away from the survey vessel whilst still fishing (for example rock lobster and octopus fishers). This is because the survey vessel will be travelling at a slow speed (4.5 knots) and occupies a small space relative to the broader survey area which will remain open to fishing activity. Activities within the Node Survey Area may also temporarily restrict fishing activities. Given the relatively small area where nodes will be deployed (119 km²) in comparison to the area of historical fishing effort, impacts to commercial and recreational fishing are expected to be negligible. Pre-survey notifications will commence four weeks prior to the start of the survey for this purpose, with notification 7 to 10 days prior to the survey commencement, and ongoing communication happening daily during the survey period, as described in Section 0. Tourism activities (e.g., recreational divers/snorkellers, sea lion tours) No tourism activities are known to take place specifically within the OA; however, tourism activities do take place in the surrounding region. Relevant tourism operators will be kept informed of survey activities to ensure that they avoid the area in which the survey vessels are active, with ongoing notification communication happening 7 to 10 days prior to the survey commencement, and ongoing communication happening daily during the survey period, as described in Section 0. Commercial shipping The western side of the OA potentially intersects with a shipping fairway; however, there is limited traffic through the OA (Figure 4-42). Vessels transiting the region during the proposed survey will primarily include bulk carrier ships (primarily iron ore, grain, mineral sands and alumina), general cargo ships, and smaller vessels transiting in to and out of Port Denison. The presence of the survey vessels and towed array in the OA has the potential to present a navigational hazard to other vessels; however, third parties will be made aware of the survey and support/chase vessels presence and movements at all times (via Notice to Mariners issued by the Australian Hydrographic Office) and ongoing notification of the survey timing/location, and survey vessel position during the survey will be implemented to manage any potential interactions (refer Section 0). Oil and gas activities

	It is not considered feasible that other seismic surveys will take place in the region concurrently with acquisition of the Eureka 3D MSS. If other oil and gas activities take place, Pilot will develop a Simultaneous Operations (SIMOPS) Plan (or Concurrent Operations (CONOPs) Plan) where required. As part of the SIMOPS Plan, Pilot will establish a communications protocol outlining all key contacts, confirming schedules and identifying constraints and buffer distances that need to be observed for all known concurrent operations. Cultural heritage values Consultation has not found any specific potential impacts within the OA relating to cultural heritage however discussions have revealed that some marine animals in the region are significant to some TO groups, but those details are not able to be recorded publicly. Consultation also found that there is cultural heritage related to the Irwin River mouth and adjacent Sea Country, but it is not clear whether this extends into the OA and consultation has not identified any explicit impacts of the survey on these values. Potential impacts are predicted on the value of these cultural features, particularly songlines, but no spatial or temporal impacts are predicted.

Inherent impact evaluation				
Inherent impact	**Consequence**	**Likelihood**	**Risk ranking**	**Decision type**
Rock lobster, octopus and demersal scale fish fishers	Minor	Probable	Significant	B
Other commercial fishers	Low	Probable	Moderate	
Commercial shipping	Low	Possible	Low	
Recreational fishers	Minor	Possible	Moderate	
Tourism activities	Minor	Possible	Moderate	

The potential for interference with commercial and tourism fishing activities has been assessed on a fishery-by-fishery basis, focusing on operational interactions that may arise. For State managed fisheries this assessment includes only those where both the fisheries licensed area and historical commercial catch data directly overlap with the Eureka MSS operational area. This dual-filter approach was the requested consultation approach by the Western Australian Fishing Industry Council ensuring that the analysis is focused on fisheries with a demonstrable and spatially relevant history of activity in proximity to the proposed survey, thereby reducing consultation fatigue for fishers and prioritising resources and consultation efforts where there is a reasonable potential for operational interaction. This filtering method is applied using Table 4-15 (Commonwealth-managed fisheries) Table 4-16 (WA State-managed fisheries).

However, there are some limitations of employing this methodology. Historical fishing effort is only a snapshot of past activity and may not fully capture the dynamic nature of commercial fishing operations, particularly for mobile fisheries or those with flexible effort distribution across their licence area. In theory, some operators could choose to relocate into the MSS area in the future, even if they have not done so historically. Furthermore, the spatial granularity at which the fishing effort is reported, prevents the identification of effort within and adjacent to the MSS. Therefore, comprehensive consultation was undertaken to identify fishers that could be affected by the survey. The consultation has revealed some fishers that could be affected which is analysed and evaluated below.

7.3.3.1 Western Tuna and Billfish Fishery (WTBF)

This line-based fishery is mobile and operates across broad offshore zones throughout northern, western and southern Australia. Historical effort within the MSS area is very low with no known recent fishing activity within the OA. Therefore, fishing effort and CPUE is unlikely to be affected. Consultation did not identify any active fishing in the OA. This combined with the lack of historical fishing in the OA, means it is highly unlikely that the seismic gear could be entangled with a long-line or that fishers will be displaced. The MSS will be conducted in a way that avoids unnecessary interference and has ongoing control measures to minimise loss to fishers.

7.3.3.2 Marine Aquarium Fish Managed Fishery (MAFMF)

This small-scale, dive-based fishery operates primarily in inshore reef environments. Although historical fishing effort has occurred within the MSS area, consultation identified one active fisher who has historically fished in the MSS. Pilot continues to consult with this fisher through the ongoing consultation process and impacts will be managed through the measures provided in Section 7.3.4.3(e.g. the look ahead notification procedure and compensation protocol). As such, there is potential for some impacts to an individual fisher, these impacts are expected to be low.

7.3.3.3 Octopus Interim Managed Fishery (OIMF)

This pot-based fishery operates in inshore and shelf waters. The pots use a triggered trapdoor and are generally deployed for up to 11 days and are retrieved and re-deployed in similar locations. While some effort has occurred near the OA area in past years, these gear types are easily relocated, and current fishing intensity in the area is limited. Outside the MSS, 96.7% of the fishery remains available to fishers and with relatively mobile fishing pots the gear can be relocated with sufficient notice to fishers. Consultation did not identify the OA as being intensively fished or as being a more important area than the rest of the fishery, however some fishers routinely fish the MSS area with their pots remaining deployed for long periods of time. As such, there is the potential for engagement with their pots or the potential to displace these fishers during the survey period. Pilot has identified mitigation options that include notifications to enable fishers to remove pots prior to the survey and redeployment post survey with appropriate compensation or the seismic contractor removes and redeploys pots on behalf of the fishers with appropriate compensation or fishers could move pots outside of the OA with appropriate compensation. Pilot continues to consult with affected fishers and will manage impact to acceptable levels through the ongoing consultation process.

7.3.3.4 Open Access Fishery (OAF)

This category includes small-scale commercial single drop wet-line fishing activities with variable spatial effort. Historical data shows minimal fishing in the OA area, though it is acknowledged that fishing locations may shift over time. However, consultation did not identify any open access fishery likely to operate in the survey area during the MSS timeframe. Fishing is primarily conducted by small coastal vessels that can deploy their single drop wet-lines at a range of locations along the coast. Interference with fishing activity is not anticipated.

7.3.3.5 Specimen Shell Managed Fishery (SSMF)

This fishery involves hand collection of shells in shallow, reef-associated habitats. No historical effort has been recorded within the MSS area. Although effort could relocate, no intention to operate in the survey area was identified during consultation. Therefore, interference is not expected.

There has been one fisher identified who has previously fished in the area. Their lowest level of fishing effort is conducted in the OA during the time of year the survey period is scheduled. The SIMOPS plan will be used to manage impacts to divers, and the compensation plan will be used to offset any loss of fishing effort and therefore impacts are expected to be low.

7.3.3.6 Tour Operator Fishery West Coast (TOFWC)

This non-extractive fishery supports licensed tourism operations such as diving and marine wildlife tours. No tourism activity is known to occur in the MSS area. Consultation confirmed no tour operators will be affected, and advance notifications will be issued to ensure operations can continue without interference.

7.3.3.7 West Coast Demersal Gillnet and Demersal Longline Managed Fishery (WCDGDLMF) and West Coast Demersal Scalefish Managed Fishery (WCDSMF)

This fishery uses passive gear and targets demersal species and the WCDSMF is subject to recent management reforms and closely monitored for CPUE. Some historical effort has occurred near the MSS area and consultation has identified two fishers who claim to have historically fished in the OA. The extent and locations of historical fishing by these fishers has not been disclosed. The gear types used in these fisheries are typically relocated with ease, and consultation did not identify any expected interference. Pilot continues to consult with affected fishers and will manage impact through the ongoing consultation process, look ahead notification procedure and compensation protocol. Therefore, impacts to fishers due to physical interactions is expected to be low.

7.3.3.8 West Coast Rock Lobster Managed Fishery (WCRLF)

The West Coast Rock Lobster Managed Fishery (WCRLF) is a pot-based fishery that operates widely along the west coast. While some lobster pots may be set inside and near the OA area, they can be retrieved and redeployed with enough notice and planning. Consultation identified 12 fishers that could potentially be affected by the seismic survey. It is unclear as to the exact level of effort that these fishers have historically undertaken within the OA. There is the potential for both the streamers and seismic source to become entangled with the pot floats and lines, causing damage and loss to their gear. However, Pilot continue to consult with affected fishers through the ongoing consultation process and will manage impacts to fishers with the look ahead notification procedure and compensation protocol. Therefore, impacts to fishers due to physical interactions is expected to be low. .

7.3.3.9 Mackerel Managed Fishery (MMF)

During consultation, the Western Australian Fishing Industry Council (WAFIC) requested that the Mackerel Managed Fishery (MMF) be included in the list of WA State Fisheries with historical activity in the Operational Area (OA). However, no publicly available data has been identified to verify historical effort by the MMF within the OA. The manager of the MMF at DPIRD confirmed the fishery can be deemed historically inactive in the OA. Therefore, the MMF will be considered historically inactive in the OA for the purposes of this assessment.

7.3.4 Impact treatment

7.3.4.1 Demonstration of ALARP

The potential impacts to other marine users during seismic surveys are well understood. Seismic exploration surveys have been conducted along the Australian coast for decades and there are established practices to manage the more common risks. The application of recognised good practice is considered appropriate to manage these risks. These are encapsulated in AMSA Marine Orders specific to safety of navigation and prevention of collisions during seismic operations:

- Marine Order 30 - Prevention of collisions
- Marine Order 27 - Safety of navigation and radio equipment
- Marine Order 21 - Safety and emergency arrangements.

However, this risk assessment recognises the survey-specific nature of risks associated with the Eureka 3D MSS and the challenges in predicting the use of the OA by other marine users. To augment decision making, a precautionary approach is applied where uncertainty continues to exist. As the residual impact to certain commercial fishers is assessed as Moderate, Pilot has adjusted the seismic survey period to avoid acquisition over peak fishing periods for these fisheries as far as possible (Section 4.4.2). In addition, Pilot has undertaken a comprehensive re-assessment of survey design to reduce the overall size of the OA and ASA to avoid sensitive fishing areas and reduce disruption to fishing activities whilst

still maintaining survey objectives. This re-assessment has resulted in a reduction in OA and ASA size of approximately 20 per cent.

Pilot is committed to ensuring continual risk reduction and identifying if additional control measures may be applied that are not disproportionate to the sacrifice (e.g., cost) of implementation. Pilot considers the adopted controls to be appropriate in reducing the environmental risks associated with interactions with other marine users to ALARP. There are no other controls measures that may practicably or feasibly be adopted to further reduce the risks of impacts without disproportionate costs compared to the benefit of the potential risk reduction (Table 7-22).

Table 7-22: Demonstration of ALARP – interactions with other marine users

Control measures	Cost benefit analysis	Impact reduction	Control adopted
ALARP assessment technique – good practice			
Seismic acquisition will only occur during daylight hours.	There are substantial additional costs and impacts in limiting acquisition to daylight hours. This would double the survey duration. Interactions with fishing and shipping vessels would still potentially occur, therefore costs outweigh benefits.	Yes	No
In the event of SIMOPS, communications will be maintained with other facilities/vessels.	Reduced risk of adverse interaction with other vessels outweighs cost.	Yes	Yes
Vessel-to-vessel transfers will occur away from shipping lanes or other high traffic areas	Reduced risk of adverse interaction with other vessels outweighs cost.	Yes	Yes
AIS broadcast of the vessel type, location, virtual outer tail buoy locations, azimuth, and speed	Reduced risk of adverse interaction with other vessels outweighs cost.	Yes	Yes
Seismic acquisition in other titleholders' exploration permits will be undertaken in accordance with Ingress Agreements with the relevant titleholders and an Access Authority granted by NOPTA. A Special Prospecting Authority (SPA) will be in place for acquisition over open acreage.	Standard practice	Yes	Yes
ALARP assessment technique – EIA			
Pilot will consider evidence-based claims from Australian commercial fishing licence holders where: There is genuine displacement from undertaking normal fishing activities that results in demonstratable economic loss Deployed fishing equipment has been accidentally lost or damaged by any activities under Pilot's control There is a loss of catch due to the seismic activity that can be demonstrated.	Benefit to fishers' livelihoods and industry reputation outweighs the cost of compensation.	Yes	Yes

Control measures	Cost benefit analysis	Impact reduction	Control adopted
As part of the ongoing notification process, Pilot will notify all relevant persons four weeks prior to the start of the survey to provide details about the anticipated dates for commencement and completion of acquisition.	Early notification of activities will allow relevant persons, in particular fishers, to plan activities around the survey and avoid negative interactions. Benefit outweighs cost.	Yes	Yes
Commercial fishers actively operating in the OA will be issued a notification 7 to 10-days prior to activities commencing in the OA, including posting of survey notification at local boat ramps.	Ongoing notification will allow relevant persons to plan activities around the survey and avoid negative interactions. Benefit outweighs cost.	Yes	Yes
Where requested, commercial fishers actively operating in the OA will be kept informed of daily survey activities through Pilot's 24-hour look-ahead communication.	Short-term notification of activities during the survey will allow relevant persons to plan activities around the survey and avoid negative interactions. Benefit outweighs cost.	Yes	Yes
Provision of bathymetric survey data to commercial fishers who have requested the data.	Pilot will consult with fishers requesting data to determine the format required for supply of data.	Yes	Yes
Pilot will continue to advise relevant fishers of planned sail-lines and dates and if any issues are raised by fishing relevant persons, Pilot will make reasonable effort to avoid or minimise conflicts. Controls to be considered will include: Moving to another sail-line Allowing fishers to fish area prior to seismic acquisition Minimise survey activity in areas where there is known fishing activity.	Early notification of activities will allow fishers to plan activities around the survey and avoid negative interactions. Benefit outweighs cost.	Yes	Yes
Inform the Australian Hydrographic Office of relevant survey details prior to, during (if alterations occur) and on completion of the survey to ensure a Notice to Mariners informs all third parties of survey details and are updated as required.	Notices to Mariners are issued to correct and maintain navigational charts and hence inform other vessels of navigation issues related to the MSS. Benefit outweighs cost.	Yes	Yes
Pilot will take reasonable steps to avoid or minimise conflict with other marine users, should such a conflict be identified during ongoing notification with relevant persons.	Design of the survey to minimise interactions, avoid certain areas and allow early notification of activities to enable third parties including fishers to plan activities around the survey and avoid negative interactions. Benefit outweighs cost.	Yes	Yes
Seismic acquisition will only occur outside key fishing seasons.	Fishing occurs all year round in some region of the OA. Avoidance of all fishing seasons is not possible	Yes	No

Control measures	Cost benefit analysis	Impact reduction	Control adopted
No seismic acquisition during the peak commercial fishing periods and peak sensitive periods for fish and invertebrates	Pilot Energy has selected February and March as the timing for the seismic survey based on a range of overarching environmental and operational considerations. This period was chosen to avoid peak sensitivities for key marine species, such as whale migration and foraging patterns, and to minimise overlap with Australian sea lion breeding, which is expected to fall outside February and March in 2026 based on current observations. Operational constraints also played a role in this decision, as conducting the survey during other times of the year could increase risks associated with prolonged operations due to adverse weather conditions affecting acoustic acquisition. Specific temporal assessments of environmental sensitivities further support this timing. For Western Rock Lobster (WRL), egg hatching occurs predominantly in deeper waters, outside the area of seismic acquisition (ASA). Additionally, the overlap between WRL puerulus settlement and the survey period is limited to one month out of six. An analysis of spatial and temporal overlap with fish spawning for key indicator species is detailed in Section 7.1.5.4. The findings indicate minimal overlap: less than 0.50% of the Western Australian stock range and spawning period for dhufish and snapper, slightly higher at 0.53% for redthroat emperor, and less than 0.2% for Spanish mackerel. These highly conservative assessments conclude that potential disturbances to approximately 0.5% of indicator fish stocks within the West Coast Bioregion fisheries management area during one season are unlikely to result in population-level impacts. This conclusion considers natural variability in spawning and recruitment as well as stock depletion caused by fishing mortality. Regarding commercial fishing, Pilot Energy recognizes the importance of minimizing disruption to fishers during the survey period. To assist fishers in reducing impacts to their operations, constant communication will be maintained regarding the location of survey vessels, along with lookahead planning to provide advance notice of vessel movements. Additionally, alternative viable fishing grounds are expected to be available during the survey period. If losses are incurred by fishery groups because of the survey, a compensation protocol will be implemented to address them.	Yes	No

Control measures	Cost benefit analysis	Impact reduction	Control adopted
ALARP assessment technique – precautionary approach			
Do nothing – survey not acquired	Titleholders are required by NOPTA to acquire seismic data within specified time frames.	Yes	No
Avoid shipping routes	Shipping occurs throughout the region and within the OA. Avoiding the western side of the OA would compromise the survey objectives. Vessel interactions are manageable through the support vessel/chase vessels, and the cost (loss of survey data) outweighs the benefits.	Yes	No

Residual impact evaluation				
Residual impact	**Consequence**	**Likelihood**	**Risk ranking**	**Decision type**
Rock lobster, octopus and demersal scalefish fishers	Minor	Possible	Moderate	B
Other commercial fishers	Low	Possible	Low	
Commercial shipping	Low	Unlikely	Low	
Recreational fishers	Minor	Possible	Moderate	
Tourism activities	Minor	Unlikely	Low	

7.3.4.2 Demonstration of acceptability

The impact assessment has been conducted in alignment with the relevant principles of ESD and has that, with the implemented control measures, the physical interaction of project vessels and towed seismic equipment is expected to have no more than a moderate impact on rock lobster, octopus, and recreational fisheries. These impacts are anticipated to be localised and temporary, lasting from days to weeks. For other receptors, the impact is assessed as low with negligible effects. This will ensure AL 48 is met.

Pilot has thoroughly explored additional opportunities to further mitigate impacts and risks. All vessel operations will strictly adhere to relevant legislation and guidelines concerning navigation and maritime safety, including Marine Orders 21, 27, and 30, as well as the International Convention for the Safety of Life at Sea (SOLAS). This will ensure AL 45 is met.

The activity will be confined to the Operational Area and the survey timeframe. This will ensure AL 43 will be met.

Stakeholders have raised concerns about the potential displacement of commercial fishers during the survey period. While fishing activities will remain possible in areas of the survey zone where the seismic vessel is not currently operating, Pilot acknowledges the potential for displacement impacts. To address this, Pilot has implemented a Commercial Fishing Industry Adjustment Protocol to formally manage and address claims from affected commercial fishers. To minimise interactions with other marine users including entanglement in fishing gear, Pilot will provide ongoing notifications about vessel locations. This will ensure AL 44, 46, 47, and 49 are met.

The adopted control measures are in line with good industry practice and meet the expectations of the Australian Maritime Safety Authority (AMSA) and the Australian Hydrographic Office (AHO). Pilot believes these measures are appropriate and sufficient to manage the impacts and risks associated with physical interactions of project vessels to an acceptable level.

7.3.4.3 Environmental performance outcomes, standards and measurement criteria

The environmental performance outcomes, standards and measurement criteria appropriate to measure performance of the adopted control measures for physical interactions with other marine users are presented below in Table 7-23. Environmental performance standards and relevant measurement criteria have been developed for each control measure adopted above.

Table 7-23: Environmental performance outcomes, standards and measurement criteria for physical interactions with other marine users

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 6 Activities are carried out in a manner that does not interfere with other marine users to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties	PS 16 Vessel to maintain appropriate lighting, navigation and communication always to inform other users of the position and intentions of the survey vessel, in compliance with the *Navigation Act 2012*, COLREGS (International Regulations for Preventing Collisions at Sea 1972), Chapter IV (Radio communications) and Chapter V (Safety of Navigation) of SOLAS (International Convention on the Safety of Life at Sea 1974).	MC 21 Evidence that vessels comply with COLREGS and relevant chapters of SOLAS. Any records of failure to comply are documented.
	PS 17 Vessel navigational lighting and communication systems managed in accordance with Marine Orders 30, 27 and 21.	MC 22 Evidence that vessels have navigational lights and communication system that comply with relevant marine orders, including appropriate day shapes, lights and streamers, to indicate the survey vessel is towing and is therefore restricted in its ability to manoeuvre.
	PS 18 Continuous (24-hour) survey operations with multiple trained crew (STCW95/Elements of Shipboard Safety) and monitoring of vessel position (radar) and depth always during seismic acquisition.	MC 23 Records confirm bridge was manned continuously during survey operations, visual and radar watches always maintained, and that vessel crew have appropriate qualifications.
	PS 19 The Australian Hydrographic Office (AHO) advised of survey details (survey location, timing) four weeks prior to mobilisation and following demobilisation on completion or suspension of activities for issue of Notice to Mariners.	MC 24 Records of notification of survey details sent to the AHO four weeks prior to survey mobilisation and within two weeks of survey demobilisation (following completion or suspension).
	PS 20 The AHO advised of relevant alterations to survey details as required during the survey for issue of updated Notice to Mariners.	MC 25 Records of notification of survey details sent to the AHO during the survey in response to altered information
	PS 21 AMSA's JRCC will be advised at the start and/or re-start (after suspension for the season) of the survey vessel's details (including vessel name, call-sign and Maritime Mobile Service Identity (MMSI)), satellite communications details	MC 26 Records demonstrate that AMSA JRCC have been notified of the survey vessel details and movements 24 to 48-hours prior to the start of the survey

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	(including INMARSAT-C and satellite telephone), area of operation and requested clearance from other vessels.	
	PS 22 AMSA JRCC will be notified at the end of the survey when operations have been completed and/or suspended.	MC 27 Records demonstrate that AMSA JRCC have been notified of the end (completion and /or suspension) of survey operations.
	PS 23 Survey vessel will be equipped with Automatic Radar Plotting Aid (ARPA) and active AIS for detection of vessels, speed and heading. AIS broadcasts include vessel type, location, virtual outer tail buoy locations, azimuth, and speed.	MC 28 Records confirm ARPA and AIS active on survey vessels. MC 29 Records confirm AIS broadcast of the vessel type, location, virtual outer tail buoy locations, azimuth, and speed
	PS 24 Support and chase vessels will assist in managing interactions with other vessels and maintain communications with other vessels in the OA.	MC 30 Records demonstrate that dedicated support and escort vessel are employed for the duration of the activity.
	PS 25 Tail buoys clearly marked to identify streamer ends to other users.	MC 31 Records confirm all tail buoys marked to identify streamer ends.
	PS 26 In-water equipment lost will be recovered, if retrievable where safe and practicable to do so.	MC 32 Incident reports made for lost equipment show that recovery where possible. MC 33 Detailed records of equipment lost overboard will be maintained and reported to NOPSEMA as recordable environmental incidents (Section 10.8.2), and also reported via the Post-survey Environmental Review Report (PERR) (Section 10.8.1).
	PS 27 AMSA and AHO to be advised of the loss of large items of buoyant waste and lost equipment (potential navigational hazards).	MC 34 Response from AMSA and AHO confirms receipt of notification in event of lost object incident.
	PS 28	MC 35

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	An Access Authority (AA) will be agreed with the Titleholder for WA-31-L.	Records of AA for data acquisition in permit areas within the Operational Area.
	PS 29 A Special Prospecting Authority (SPA) will be in place for the areas of open acreage within the ASA.	MC 36 Records of granted SPA for data acquisition in open acreage areas within in the ASA.
	PS 30 Pre-planning search of NOPSEMA approvals data to identify potential for overlap with other seismic surveys and other Petroleum Operator activities	MC 37 All other submitted EPs for seismic surveys in the region will be reviewed at least one the month prior to the survey to ascertain potential overlap.
	PS 31 As part of the ongoing notification process, Pilot will notify all relevant persons four weeks prior to the start of the survey with survey details including, timing, location and duration.	MC 38 Relevant person consultation records show notification of survey details to all relevant persons four weeks prior to the start of the survey.
	PS 32 Commercial fishers actively operating in the OA and will be issued a notification 7 to 10-days prior to activities commencing in the OA, including posting of survey notification at local boat ramps.	MC 39 Copies of notifications to relevant fishers 7 to 10-days prior to activities commencing in the OA.
	PS 33 Commercial fishers actively operating in the OA will be kept informed of daily survey activities through Pilot's 24-hour look-ahead communication.	MC 40 Sighting records of 24-hour look-ahead communications with commercial fishers who have requested the data
	PS 34 The seismic vessel shall notify AMSA's Joint Rescue Coordination Centre (JRCC) for promulgation of radio-navigation warnings 24-48 hours before operations commence and on completion.	MC 41 AMSA's JRCC will require the vessel details (including name, call sign and Maritime Mobile Service Identity (MMSI)), satellite communications details (including INMARSAT-C and satellite telephone), area of operation, requested clearance from other vessels and need to be advised when operations start and end.
	PS 35 Provision of bathymetric survey data to commercial fishers who have requested the data.	MC 42 Consultation records confirm format and supply of ASA bathymetric data to commercial fishers who have requested the data.

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	PS 36 Implementation of the Eureka Marine Seismic Survey Commercial Fisher Compensation Protocol (EMSSCFCP) to formally manage claims by commercial fishers for lost/damaged gear, costs due to displacement/relocation and loss of catch because of survey activities.	MC 43 Commercial Fishing Industry Adjustment Protocol implemented with relevant commercial fishers prior to commencement of survey activities.
	PS 113 If another vessel is acquiring seismic data in the region, the seismic vessel shall not acquire data simultaneously within 40 km of the other seismic vessel to avoid cumulative impacts to marine fauna.	MC 9 Communication records show that any geophysical contractors operating other seismic survey vessels have been consulted two weeks prior to the survey start and agreed to 40 km separation distance. MC 10 Records confirm no incidents when vessels less than 40 km apart and actively acquiring data.
	PS 38 Pilot will continue to advise relevant persons (such as commercial fishers) of planned sail-lines and dates and if any issues are raised by relevant persons, Pilot will make reasonable effort to avoid or minimise conflicts. Controls to be considered will include: Moving to another sail-line Allowing fishers to fish area prior to seismic acquisition Minimise survey activity in areas where there is known fishing activity.	MC 44 Survey consultation records show merit assessment and consideration of controls in response to relevant person feedback prior to and during survey.
	PS 39 Resupplying sites will not be in shipping channels or high traffic areas	MC 45 Logs show all resupplying occur away from shipping lanes and high traffic areas
	PS 40 Pilot will take reasonable steps to avoid or minimise conflict with other marine users, should such a conflict be identified during ongoing discussions with relevant persons.	MC 44 Survey consultation records show merit assessment and consideration of controls in response to relevant person feedback prior to and during survey.

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	PS 41 Survey timing will be limited to February – March 2026.	MC 46 Records show no activity in months outside of February - March 2026.

7.4 Impact 4: Light emissions – vessels

In accordance with the Pilot Energy risk assessment methodology (Section 6) this impact is classified as lower order.

7.4.1 Identification of hazard and extent

Hazard	Lighting is required for safe navigation (under the *Navigation Act 2012* and Marine Order 30) and for safe work practices at night; however, these light emissions may have adverse impacts on photo-sensitive fauna. Lighting typically consists of bright white (metal halide, halogen, fluorescent) lights used for internal lighting, deck lighting and for navigational purposes. Lighting from the seismic survey vessels will be the largest source of artificial light emissions during the survey, which will be restricted to the OA (except for transiting to/from the mainland and in the event of an emergency). There will be smaller and insignificant light emissions from the support/escort vessels. Light can typically be seen from a horizontal distance = 3.57 x √ height above sea level. The survey vessel operational deck height may be as high as 16 m, thus visible at sea level from approximately 14.3 km (i.e., visible from the coast when in the eastern third of the OA) with decreasing intensity. The commercial fishing, other oil and gas activities and shipping vessel traffic in the area are discussed in Section 4.
Extent	OA
Duration	Duration of survey – up to 40 days in early February to the end of March

7.4.2 Defined acceptable level

For lower-order impacts and risks, Pilot Energy defines the acceptable level as the point at which the residual impact or risk has been reduced to ALARP. This means that all relevant control measures have been identified and implemented to the extent that no additional practicable measures are available without costs being grossly disproportionate to the environmental benefit gained. In this context, the acceptable level is inherently linked to the ALARP outcome, recognising that residual impacts and risks at this level are tolerable, consistent with legislative requirements, and aligned with relevant environmental and stakeholder expectations.

7.4.3 Impact analysis and evaluation

Potential impacts	Disorientation, attraction or repulsion of sensitive marine fauna (e.g., juvenile seabirds). Disruption to natural behavioural patterns and cycles, e.g., enabling nocturnal foraging and increased predation compared to unlit areas.
Predicted effects	Seabirds Artificial lighting has the potential to attract and/or disorientate birds and detrimentally impact dispersal, migration, foraging behaviour or when breeding adults return to colonies at night (Commonwealth of Australia 2020). Vessels are a dynamic source of light pollution in the marine environment, often brightly lit and temporarily increasing light levels in otherwise relatively dark areas (Austad et al.2023). Burrow-nesting Procellariiformes (petrels, storm-petrels and shearwaters) are the species most affected by artificial light through attraction and grounding. Fledglings are more commonly impacted during maiden flights as they disperse from their natal colonies (Rodríguez et al. 2017), particularly where light pollution sources occur at close range (Rodríguez et al. 2017; Atchoi et al. 2024). However, under specific meteorological conditions such as fog or light precipitation, lighting may increase the potential for attraction and/or disorientation of juvenile and/or adult seabirds. There are no records of surface nesting Procellariform seabird fallout or light attraction events at sea (Atchoi et al. 2020).

	There are up to 13 species of seabirds that may forage within or transit through the Eureka 3D MSS OA. Eight species have foraging BIAs that overlap the OA—the Caspian tern, bridled tern, roseate tern, Australian fairy tern, white-faced storm petrel, Pacific gull, wedge-tailed shearwater and little shearwater (described in Section 4.3.11). The nearest breeding colonies for these species occur within the Turquoise Coast Island Nature Reserve, including the Beagle Islands, located between Leeman and Dongara, and further south within the Jurien Bay Marine Park. Some of the most significant breeding colonies are at located at the Houtman Abrolhos Islands, situated 70km to the north-west of the OA. The four species of terns and Pacific gull are all diurnal and roost ashore at night, thus, are not likely to be adversely impacted by artificial light on vessels. The wedge-tailed shearwater, little shearwater and white-faced storm-petrel are locally breeding species that may be attracted to artificial light on vessels at night, become disorientated and become grounded on the vessel's deck. Given the short duration of the activity and distance from breeding and resting sites, light disturbance to birds is likely to be restricted to behavioural changes by a potentially small number of shearwaters in the immediate vicinity of the vessels. Any effect of exposure is not expected to impact on migration or other behaviours (nesting/forging) at a population level. Rescue programs of grounded birds offer an immediate and effective mitigation strategy to reduce vessel lighting impacts (Rodríguez et al. 2017). A protocol for the capture, handling and release of any grounded seabirds may be implemented to minimise impacts to seabirds (IAATO Guidelines to Minimize Seabirds Landing on Ships). Lighting impacts to shearwaters can be further reduced or avoided by undertaking surveys outside the fledging season for species likely to be attracted to artificial lights or under conditions of high humidity, cloud and fog that lead to poor visibility. For example, the peak fledging period is late October-early November for little shearwaters and late April-early June for wedge-tailed shearwaters (Marchant & Higgins 1990).		
	Marine turtles Artificial light on, or near, nesting beaches poses a threat to marine turtles because it can disrupt critical behaviours such as adult emergence and nesting, hatchling orientation, sea-finding and dispersal behaviour, which may reduce the overall reproductive output of a stock (Commonwealth of Australia 2017). There are no nesting beaches, Habitat Critical or BIAs for turtles anywhere in the mid-west region, Foraging, migrating and internesting turtles do no use light as a cue, and consequently any transient individuals moving through the OA during the survey would not be affected by vessel light emissions. Therefore, there are no impacts predicted to occur to marine turtles from vessel lighting emissions during the Eureka 3D MSS.		
	Other marine fauna Other marine life may also be attracted to the light spill from the vessel. Experiments using light traps have found that some fish and zooplankton species are attracted to light sources (Meekan et al. 2001), with traps drawing catches from up to 90 m (Milicich et al. 1992). The concentration of organisms attracted to light results in an increase in food source for predatory species, and marine predators are known to aggregate at the edges of artificial light halos. This could potentially lead to increased predation rates compared to unlit areas, but population recovery is predicted to be rapid through reproduction and migrations with the tide. Although this effect is expected to be greater in a stationary vessel, worms, squid, plankton and fish can aggregate directly under downward facing lights on the water. This in turn can attract predatory fauna such as seabirds, cetaceans, fishes and squid. There is minor potential for changes in inter-specific dynamics as some species are more able to exploit the longer foraging periods and to prey on phototropic prey species. The constant movement of the vessels will reduce this potential significantly. It is expected that any potential impact of increased predation would be undetectable at a population level, especially for plankton where recruitment is rapid, particularly given the short duration of the survey and the relatively small area potentially exposed to vessel light emissions. Cetaceans predominantly utilise acoustic senses to monitor their environment rather than visual sources (Simmonds et al. 2004), so light is not considered to be a significant factor in cetacean behaviour or survival.		
Inherent impact	Consequence	Likelihood	Risk ranking
	Minor	Unlikely	Low

7.4.4 Impact treatment

7.4.4.1 Demonstration of ALARP

There is no safe or practical alternative to the use of artificial lighting during the activity; therefore, the associated impacts cannot be eliminated. The use of lights for navigational purposes is a legislated requirement, and subsequently a well-practiced and understood activity. The performance standards outlined in this EP align with the requirements of *Navigation Act 2012* (Cth) Part 3 (Prevention of Collisions) and Marine Order 30 - Prevention of collisions.

Additional controls have been considered and adopted where they can further reduce risks to ALARP. Where the cost of implementing the additional control measures is disproportionate to the benefit gained, they have not been adopted (Table 7-24).

Table 7-24: Demonstration of ALARP – light emissions – vessels

Control measures	Cost benefit analysis	Impact reduction	Control adopted
ALARP assessment technique – good practice			
Non-essential lighting will be switched off when not in use.	Benefit outweighs cost	Yes	Yes
Use only long wavelength yellow and red light and extensive shrouding	Typically used more for light intensive activities in the vicinity of turtle nesting. Given that there are no nesting sites for light sensitive receptors near or in the OA, the cost of re-fit outweighs benefit	Limited benefit due to low likelihood of night-time encounters with sensitive receptors in OA	No
External lighting will be directed onto the deck, reducing light spill to the environment where practicable for safe operations.	Benefit outweighs cost	Yes	Yes
Guidelines to Minimize Seabirds Landing on Ships including seabirds landing on ships capture, handling and release procedure	Benefit outweighs cost	Yes. These guidelines provide information on how to help prevent birds from landing on the ships. They also provide information on how to safely handle any birds that do land which assists to minimise impacts to birds that have landed.	Yes
Design and implement a rescue program for grounded birds.	Evidence from previous seismic surveys indicates extremely low incidence of grounded seabirds, therefore the cost of establishing a rescue programme is grossly disproportionate to the minor benefit potentially gained.	Limited benefit due to very low incidence of grounded seabirds.	No
Prevent indoor lighting reaching outdoor environment by closing window blinds to shield internal lights.	Benefit outweighs cost	Yes	Yes
ALARP assessment technique – EIA			

Control measures	Cost benefit analysis	Impact reduction	Control adopted
No night-time operations.	Limiting seismic activities to daylight hours would significantly extend the time required to acquire data for individual activities. Most activities will take place more than 14 km from land which will reduce likelihood of attraction of shorebirds and seabirds/. There are no nesting sites for light sensitive receptors near or in the OA. Negligible environmental benefit in 12-hour operations, but significant increase in vessel charter costs and length of survey (i.e., double the survey duration). Sacrifice (additional vessel costs) disproportionately higher than benefit.	Limited benefit due to low likelihood of night-time encounters with sensitive receptors in OA	No

Residual impact evaluation				
Residual impact	Consequence	Likelihood	Risk ranking	Decision type
	Minor	Unlikely	Low	A

7.4.4.2 Demonstration of acceptability

The impact assessment has concluded that routine light emissions from project vessels may result in detectable but insignificant localised changes to ecosystems, habitats, and local species populations. These impacts are expected to be temporary, with full recovery anticipated within days to weeks.

Pilot has thoroughly explored opportunities to further reduce the impacts associated with light emissions, as discussed in previous sections. The assessment has given due consideration to relevant conservation advice, wildlife conservation plans, and the NLPG.

The impact assessment has been conducted in alignment with the relevant principles of ESD. No specific concerns regarding light emissions have been raised by relevant stakeholders. Given these factors, Pilot believes that operations conducted in accordance with the identified standards and implemented control measures are sufficient to manage the risks associated with light emissions to a level that is broadly acceptable.

7.4.4.3 Environmental performance outcomes, standards and measurement criteria

The environmental performance outcomes, standards and measurement criteria appropriate to measure performance of the adopted control measures for light emissions are presented below in Table 7-25. Environmental performance standards and relevant measurement criteria have been developed for each control measure adopted in Section 7.6.4.2.

Table 7-25: Environmental performance outcomes, standards and measurement criteria for light emissions

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 7	PS 42	MC 47
External vessel lighting conforms to that required by maritime safety standards	Light glow is minimised by managing external vessel lighting in accordance with: Marine Orders 30 - Prevention of collisions.	Vessel class certifications are current.

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 8 Minimise potential for adverse impacts on light sensitive marine fauna	PS 43 Non-essential vessel lighting will be switched off when not in use, and blinds will be shut at night.	MC 48 Inspection during survey confirms non-essential vessel lighting is switched off at night. MC 49 Induction material demonstrates that vessel crew has been inducted in light spill reduction protocols, especially switching off non-essential lights, and closing of blinds at night.
	PS 44 External vessel lighting will be directed onto the deck, reducing light spill to the environment where practicable for safe operations.	MC 50 Record of inspection during the activity to confirm orientation of all external work lights in use has been checked and adjusted where practicable.
	PS 45 Vessel crew to follow guidelines to Minimize Seabirds Landing on Ships including seabirds landing on ships capture, handling and release procedure: – Keep deck lights and ice lights at the minimum necessary for safety. – Use blackout blinds on all portholes and windows where possible. – Keep deck lights to a minimum when at anchor or close inshore overnight. – Check every morning to see if birds have landed on the ship. – When possible, let one person coordinate the handling and taking care of these birds. – Handle the birds as little as possible. – Keep the birds in a warm, dry, dark room until ready for release. – Use one box/container for each bird. If not, enough boxes are available, put same bird species in one box. Do not mix bird species. – Record the birds found and report the event to IAATO. – Release the birds when the deck lights are off, or at first light the next day. – Ensure there are no Skuas or Gulls around during the release. – To release, stand at the railing on the windward side of the ship. Sit the bird in the palms of the outstretched hands – if the bird does not take off on its	MC 128 Fauna interactions documented in MFO datasheets

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	own then gently throw the bird up in the air.	

7.5 Impact 5: Routine discharges – vessels

In accordance with the Pilot Energy risk assessment methodology (Section 6) this impact is classified as lower order.

7.5.1 Identification of hazard and extent

Hazard	Seismic survey and support/chase vessels routinely discharge small volumes of liquid and solid waste into the marine environment, such as putrescible wastes (food scraps), deck drainage), bilge water, sewage and grey water (such as water from showers, laundries and dishwashing), cooling water and brine. **Food waste:** Food waste from the vessel galleys will be macerated and discharged. The average volume of putrescible waste from each vessel depends largely on the number of Persons on-board (POB) and is anecdotally around 12 kg/person/day (NERA 2018), totalling 70-140 kg for the larger vessels spread over the day. **Deck drainage:** Comprising seawater from waves/spray, rainwater and deck wash-down water, may contain minor quantities of oil, grease and detergents that have been spilled on the decks. **Bilge waters:** Includes deck drainage captured in a closed-loop system (e.g., bunded areas) and machinery/engine space oily water that has been directed to the oil water separator (OWS) for removal of the oil prior to discharge of the treated water once the discharge is ≤15 ppm oil-in-water (OIW) as required by MARPOL. The oil is returned to shore for reuse/disposal. **Sewage and grey water:** The vessels are yet to be determined; however, a typical seismic vessel of the size required carries approximately 70 POB. Support/chase vessels will carry approximately 15 POB. The volume of discharges during the survey are expected to be approximately 170 L/day/person (United States Environmental Protection Agency 2011), yielding a total daily grey water volume of approximately 12,000 L for the seismic vessel. **Cooling water:** Seawater is used as a heat exchange medium for cooling machinery engines and other equipment. Seawater is drawn up from the ocean, where it is de-oxygenated and sterilised by electrolysis (release of chlorine from the salt solution) and then circulated as coolant for various equipment through the heat exchangers (in the process absorbing heat from the machinery) and is then discharged to the ocean and may contain low concentrations of residual biocide and scale inhibitors if used to control biofouling and scale formation. **Brine:** (Hyper-saline water) is created through the vessel's desalination process that creates freshwater for drinking, showers, cooking etc. This is achieved through reverse osmosis (RO) or distillation; both processes resulting in the discharge of seawater with elevated salinity. The freshwater produced is then stored in tanks on-board. The potential impacts of routine discharges to marine waters during seismic surveys are well understood with legislative requirements and standard marine industry agreed practices to manage risks. However, due to the proximity of parts of the OA to the shoreline and shallow water depths, no discharges of liquid and solid waste will occur within the nodal area of the OA.
Extent	OA
Duration	Duration of survey – up to 40 days in early February to the end of March

7.5.2 Defined acceptable levels

For lower-order impacts and risks, Pilot Energy defines the acceptable level as the point at which the residual impact or risk has been reduced to ALARP. This means that all relevant control measures have been identified and implemented to the extent that no additional practicable measures are available without costs being grossly disproportionate to the environmental benefit gained. In this context, the acceptable level is inherently linked to the ALARP outcome, recognising that residual impacts and risks at this level are tolerable, consistent with legislative requirements, and aligned with relevant environmental and stakeholder expectations.

7.5.3 Impact analysis and evaluation

Potential impacts	Temporary localised decline in water quality in the immediate vicinity of the discharge Localised increase in biological oxygen demand (BOD) Localised increase in turbidity of surrounding waters Temporary toxicity to marine flora and fauna (bilge water discharges) Temporary and localised increase in sea surface water temperature Temporary and localised increase in sea surface salinity
Predicted effects	Water quality **Food waste**: Food waste can cause temporary localised increases in the nutrient content of surface waters close to the discharge potentially affecting plankton, pinnipeds and pelagic fish and attracting scavenger seabirds. Rapid dispersion and biodegradation ensure potential impacts are negligible. **Sewage and grey water:** Discharges of treated sewage and grey water will be rapidly diluted in the surface layers of the water column and dispersed by currents. There is potential for phytoplankton uptake of the extra nutrients from sewage and localised, temporary increases in primary productivity. The BOD of the treated effluent is unlikely to lead to oxygen depletion of the receiving waters (Black et al. 1994), as it will be treated prior to release. On release, surface water currents will assist with oxygenation of the discharge. Woodside (2011) conducted monitoring of sewage discharges at their Torosa-4 Appraisal Drilling campaign which demonstrated that a 10 m^3 sewage discharge reduced to approximately 1% of its original concentration within 50 m of the discharge location. In addition to this, monitoring at distances 50, 100 and 200 m downstream of the platform and at five different water depths confirmed that discharges were rapidly diluted and no elevations in water quality monitoring parameters (e.g., total nitrogen, total phosphorous and selected metals) were recorded above background levels at any station. Heavier nutrient load, sedimentation and toxicity from sewage discharge can also impact on coral growth and repair. This impact is mostly observed with large quantities of effluent in poorly flushing areas such as bays and less-so in well flushed areas when the quantities are small (Alsabah, 2017) **Grey water** from galleys, showers/basins and laundries may include a range of pollutants of varying toxicities such as hydrocarbons, detergents, grease, particulates, chemicals, food waste and coliform bacteria. Grey water is also treated through the sewage treatment plant, so pollutants are largely removed from the discharge. Given the temporary intermittent nature of the discharges in any one location, the small volumes, treatment before discharge, the rapid dilution and dispersion in the open ocean, high biodegradability and low persistence of sewage and grey water no measurable increases in nutrient concentrations, oxygen demand, turbidity or effects to plankton are expected. **Bilge tanks** potentially containing small volumes of hydrocarbons, detergents, solvents and chemicals. The OWS then treats this water to MARPOL requirements before discharging overboard. The volume of treated water discharges is typically small and intermittent. The greatest risk is to corals, plankton and pelagic fish. These discharges will be rapidly diluted, dispersed and biodegraded to undetectable levels local to the discharge. The small volumes and low concentrations of oily water from bilge discharges may temporarily reduce water quality but are not expected to induce acute or chronic toxicity impacts to marine fauna or plankton through ingestion or absorption through the skin. In the event the OWS malfunctions and discharges of off-specification water, these impacts may occur, though this is only likely in a highly localised area and temporary (meaning that few individuals would be exposed). Decks that are not bunded and drain directly to the sea may result in the discharge of contaminated water which may cause temporary and localised reduction in surface water quality. **Cooling water:** The maximum cooling water discharge rate and temperatures for the vessels that may be used, are unknown but typically are several degrees above ambient, depending on design, efficiency and throughput. Once in the water column, cooling water will remain in the surface layer, where turbulent mixing and heat transfer with surrounding waters will occur rapidly. This will cause very localised and temporary increases in water temperature, potentially resulting in thermal stress to sensitive biota. Impacts on most marine organisms will be negligible given the buffering and dispersive capacities of the receiving seawater and as the vessels are constantly in motion, the impacts are considered negligible with full recovery in the short term.

	Brine: Brine discharge salinity typically ranges from 40 – 60 ppt (parts per thousand). It is denser than seawater (approximately 35 ppt). As such, discharged brine water will sink through the water column potentially exposing receptors that are sensitive to salinity to levels approximately 14-70% above ambient and to potential toxicity impacts from residual biocide and scale inhibitors used to prevent marine growth and corrosion. However, sinking through the water column will aid rapid mixing with receiving waters and dispersion by ocean surface currents. Modelling of continuous wastewater discharges by Woodside (2008, Torosa South -1) found discharge water temperature decreased rapidly to less than 1°C above background levels within 100 m (horizontally) of the discharge point, and within background levels within 10 m vertically. Seabirds, pinnipeds, cetaceans, plankton and pelagic fish may be in the immediate vicinity of the discharge. Increased temperatures may result in physiological changes such as avoidance (or attraction), stress or mortality depending in part on mobility and sensitivity. Walker and MacComb (1990) found that most marine species can tolerate short-term fluctuations of 20-30% in water salinity, so most pelagic species (other than plankton) passing through a denser saline plume would not suffer adverse impacts. Given the rapid, localised dispersion predicted by the modelling, such impacts are considered negligible. The biocides used in desalination are typically low concentrations when added, highly reactive, rapidly biodegradable and deactivate during the inhibition process, resulting in little or no residual toxicity on discharge (Black et al. 1994). Given the localised rapid dispersion, the small volumes and the constant movement of the vessels, there is low potential for adverse effects.		
	Protected areas and other marine habitats and communities Grey water, sewage, bilge water and putrescible waste discharges will be rapidly diluted and dispersed and the concentrations of any potential contaminant or nutrient will reach background levels quickly. No effects on communities are expected for pelagic or benthic receptors. Any reduction in water quality would be localised and temporary (short term) and unlikely to have any measurable impact on species diversity or abundance. Fisheries and fish resources will not be affected as impacts are localised and temporary. There are therefore no predicted effects to the Abrolhos and Jurien Bay Marine Parks in proximity (~40 km) to the OA. The maximum number of vessels in close contact at any time with each other will be two (e.g., re-supply) – as such, they are alongside for a short time and not discharging bilge or sewage, cumulative impacts are unlikely, and consequences rated negligible.		
Inherent impact	Consequence	Likelihood	Risk ranking
	Low	Unlikely	Low

7.5.4 Impact treatment

7.5.4.1 Demonstration of ALARP

The offshore disposal of sewage, grey water and putrescible wastes may cause a small, localised (immediate area), temporary (short-term) increase in the nutrient content in the water column in the immediate vicinity of the discharge. Discharges of brine and cooling water also have the potential to reduce water temperature and increase salinity in the immediate vicinity of the vessel. Due to the small volumes discharged and well-mixed open ocean environment within the OA, any changes to ambient water quality (including salinity and temperature), nutrient levels or dissolved oxygen in the receiving waters are expected to be negligible.

Pilot considers the adopted controls to be appropriate in reducing the environmental impacts associated with routine vessel discharges to the marine environment to ALARP. Additional controls have been considered and adopted where they can further reduce risks to ALARP. Where the cost of implementing the additional control measures is disproportionate to the benefit gained, they have not been adopted (Table 7-26).

Table 7-26: Demonstration of ALARP – routine discharges – vessels

Control measures	Cost benefit analysis	Impact reduction	Control adopted
ALARP assessment technique – legislative requirements, good practice			

Control measures	Cost benefit analysis	Impact reduction	Control adopted
Installation and use of sewage systems compliant with internationally recognised MARPOL 73/78 Annex IV (sewage) and Annex V (garbage) specifications	Benefit outweighs cost; legal requirement.	Yes	Yes
All waste holding tanks are to be fully operational prior to survey commencement	Benefit outweighs cost.	Yes	Yes
Vessel survey crew will be inducted in waste management and made familiar with the vessel Garbage Management Plan (GMP)	Benefit outweighs cost.	Yes	Yes
Installation and use of oily water separators compliant with MARPOL 73/78 Annex I and Marine Order 91–Marine pollution prevention specifications (i.e., treating OIW <15 ppm)	Benefit outweighs cost; legal requirement.	Yes	Yes
The vessel must not be stationary when undertaking discharge and OIW separator shut off value must be maintained and operational	Benefit outweighs cost. Industry standard	Yes	Yes
Deck drains scupper plugs available	Benefit outweighs cost.	Yes	Yes
Minor oil/lubricant spills will be mopped up immediately with absorbent materials that will be stored on-board and disposed of onshore as hazardous waste in accordance with the vessel SOPEP	Benefit outweighs cost.	Yes	Yes
ALARP assessment technique – EIA			
No discharge of liquid and solid waste within the nodal area	Benefit outweighs cost, legal requirement. Discharge of untreated food scraps and sewage is not permitted within 12 nm from the nearest land. However, discharge of treated and contaminated sewage is allowable within 3NM of land. Given the shallowness of the water and potential sensitive biota, Pilot will not have any vessel discharges whilst in the nodal area. Other waste outside of the nodal area will be treated as per Marine Orders.	Yes	Yes
Retain all or some waste streams on-board to avoid discharging at sea.	Additional storage on-board, increased handling and HSE implications and onshore disposal impacts result in disproportionate costs outweighing benefits.	Limited	No
Installation of a higher specification sewage treatment system	Likely to require refitting most vessels and has availability and schedule impacts	Yes	No
Requiring vessels to use alternative cooling devices such as fin fans	Fin-fan cooler systems typically require additional space and power, introducing additional environmental impacts	No	No
Residual impact evaluation			

Residual impact	Consequence	Likelihood	Risk ranking	Decision type
	Low	Unlikely	Low	A

7.5.4.2 Demonstration of acceptability

The impact assessment has determined that given the adopted controls, planned discharges from project vessels are unlikely to result in a potential impact great than a temporary contamination above background levels. Further opportunities to reduce risks have been explored above and Pilot has committed to an additional control in limiting discharges in the shallower nodal area of the OA. Therefore, the adopted controls are considered good industry practice, are aligned with the principals of ESD and meet the legislative requirements under Marine Orders 91, 95 and 96. With no specific relevant person concerns raised, Pilot considers that the controls will manage the impacts of discharges to a level that is broadly acceptable.

The impact assessment has concluded that, with the implemented control measures, planned discharges from project vessels are expected to result in no more than temporary contamination above background levels. These impacts are anticipated to be limited in both extent and duration.

Pilot has thoroughly explored additional opportunities to further mitigate risks associated with planned discharges. In response to these investigations, Pilot has committed to an additional control measure, specifically limiting discharges in the shallower nodal area of the OA.

The adopted control measures are in line with good industry practice and fully comply with the legislative requirements set forth in Marine Orders 91, 95, and 96. Furthermore, these measures align with the principles of ESD.

No specific concerns regarding planned discharges from project vessels have been raised by relevant stakeholders. Given these factors, Pilot believes the adopted control measures, including the additional commitment to limit discharges in sensitive areas, are appropriate and sufficient to manage the impacts of planned discharges to a level that is broadly acceptable.

7.5.4.3 Environmental performance outcomes, standards and measurement criteria

The environmental performance outcomes, standards and measurement criteria appropriate to measure performance of the adopted control measures for routine vessel discharges are presented below in Table 7-27. Environmental performance standards and relevant measurement criteria have been developed for each control measure adopted above.

Table 7-27: Environmental performance outcomes, standards and measurement criteria for routine vessel discharges

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 9 Meet legislated discharge requirements for permissible discharges	PS 46 Compliance with MARPOL 73/78 Annex IV (sewage) and Annex V (garbage), (as applied in Australia under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*)); and Marine Order 96–Marine pollution prevention–sewage, and Marine Order 95–Marine pollution prevention–garbage, as required by vessel class. Vessel will have a Garbage Management Plan (GMP) and Garbage Record Book for vessels >100 GRT or certified to carry 15 persons or more) that sets out the procedures for minimising, collecting, storing, processing and discharging garbage. Treated sewage discharged >3 nm from land (but not in the nodal area) or untreated sewage discharge >12 nm from land and at a speed of greater than 4 knots. In the event of a STP malfunction, untreated sewage and grey water is only discharged when the vessel is greater than 12 nm from shore in accordance with Regulation 11 of MARPOL Annex IV (enacted by Marine Order 96). Operational on-board sewage treatment plant approved by the International Maritime Organization (IMO) International Sewage Pollution Prevention (ISPP) Certificate.	MC 51 Records of any non-compliance with MARPOL are documented; and corrective actions identified and undertaken. MC 52 Maintenance records demonstrate regular maintenance undertaken of on-board STP / macerator MC 53 Survey-specific discharges and emissions register confirms that treated sewage is only discharged when the vessel is >3 nm from shore and outside of the nodal area MC 54 Survey-specific discharges and emissions register verifies that untreated sewage is only discharged when the vessel is >12 nm from shore. MC 55 Records demonstrate the vessels hold a valid ISPP certificate and verifies the installation of a MARPOL approved STP, as required by vessel class.
	PS 47 Operational on-board organic waste macerator compliant with MARPOL Annex V. All food waste is macerated to ≤25 mm in size prior to overboard discharge, any discharge must be at a speed of greater than 4 knots. Un-macerated putrescible waste is only discharged overboard when the vessel is greater than 12 nm from the coastline. Non-putrescible galley waste is returned to shore for disposal.	MC 56 A MARPOL compliant Garbage Record Book is in place (for vessels >400 GRT or certified to carry 15 persons or more) and verifies waste discharge volumes and locations MC 57 Records verify that the macerator is functional and regularly maintained. MC 58 A Garbage Record Book is in place that verifies non-macerated food waste is returned to shore

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	PS 48 All waste holding tanks are to be fully operational prior to survey commencement.	MC 59 Records demonstrate that the vessels waste holding tanks are fully operational prior to survey.
	PS 49 Vessel survey crew will be inducted in waste management and made familiar with the vessel GMP.	MC 60 Records show that the project induction includes information on waste management requirements and Garbage Management Plan, and sign-off register indicates all personnel on-board have received the induction.
	PS 50 Compliance with MARPOL 73/78 Annex I (as applied in Australia under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*)); and Marine Order 91–Marine pollution prevention–oil. Oil content of any discharged water to be <15 ppm. Bilge water contaminated with hydrocarbons must be contained and disposed of onshore, except if the oil content of the effluent without dilution does not exceed 15 ppm or an IMO approved oil/water separator (as required by vessel class) is used to treat the bilge water. The survey and support vessels have an International Oil Pollution Prevention (IOPP) certificate as appropriate.	MC 61 Oil Record Book confirms volume and concentration of discharge. MC 62 Records demonstrate the survey and support vessels holds a valid IOPP certificate, as required by vessel class. MC 63 Calibration records verify that the OWS is set to 15 ppm. MC 64 Vessel engineers / chief engineer to confirm that OIW is in good working order during vessel audit during the survey (inspection within the last 12 months).
	PS 51 The residual oil from the OWS is pumped to tanks and disposed of onshore.	MC 65 The Oil Record Book verifies that waste oil is transferred to shore.
	PS 52 The vessel must not be stationary when undertaking discharge and OIW separator shut off value must be maintained and operational.	MC 66 Records show vessel was moving (not stationary) when undertaking discharge and OIW separator shut-off valve was maintained and operational.

Environmental performance outcomes	Environmental performance standards	Measurement criteria
	PS 53 Minor oil/lubricant spills will be mopped up immediately with absorbent materials that will be stored on-board and disposed of onshore as hazardous waste in accordance with the vessel SOPEP.	MC 67 Records show that response measures for minor oil/lubricant spills were carried out in accordance with the SOPEP. MC 68 Records show that contaminated clean-up wastes stored on-board in covered bins prior to onshore disposal at a licensed waste management facility. MC 69 Records show spills and leaks are recorded and investigated; and corrective actions identified and undertaken.
EPO 10 Minimise discharges to ocean	PS 54 Scupper plugs or equivalent drainage control measures are readily available to the deck crew so that deck drains can be blocked in the event of a hydrocarbon or chemical spill on deck to prevent or minimise discharge to the sea.	MC 70 Site inspection verifies that scupper plugs (or equivalent) are available on the main deck of survey and support vessels.
	PS 55 No discharge of liquid and solid waste within the nodal area	MC 129 Records show location where liquid and solid waste discharged
EPO 11 Equipment that requires cooling by water, and the RO plant, will be maintained in accordance with the vessel PMS so that they are running within specified operating parameters	PS 56 Engines and associated equipment that require cooling by water will be maintained in accordance with the vessel PMS so that they are operating within accepted parameters.	MC 71 PMS records verify that the equipment is maintained to schedule.

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 12 The marine crew is competent in spill response and have appropriate response resources to respond to a spill.	PS 57 The vessel crew is competent in spill response and has appropriate response resources to prevent or minimise hydrocarbon or chemical spills discharging overboard.	MC 72 Training records verify that vessel crews receive spill response training.

7.6 Impact 6: Atmospheric emissions – vessels

In accordance with the Pilot Energy risk assessment methodology (Section 6) this impact is classified as lower order.

7.6.1 Identification of hazard and extent

Hazard	Atmospheric emissions of greenhouse gases and other pollutants will be produced through: Combustion of marine gas oil (MGO) or marine diesel oil (MDO) from the survey and support/chase vessel engines and fixed and mobile deck equipment during the survey Solid non-hazardous waste combustion within an incinerator if logistics do not allow for the timely removal of waste from the vessel. The main emissions that present an environmental impact are: • Nitrous oxides (NO_X) • Sulphurous oxides (SO_X) • Particulate matter <10 µm • Non-methane volatile organic compounds (VOCS) • Benzene, toluene, ethylbenzene and xylenes (BTEX) • Greenhouse gases (predominantly carbon dioxide).
Extent	OA and atmosphere
Duration	Duration of survey – up to 40 days in early February to the end of March

7.6.2 Defined acceptable levels

For lower-order impacts and risks, Pilot Energy defines the acceptable level as the point at which the residual impact or risk has been reduced to ALARP. This means that all relevant control measures have been identified and implemented to the extent that no additional practicable measures are available without costs being grossly disproportionate to the environmental benefit gained. In this context, the acceptable level is inherently linked to the ALARP outcome, recognising that residual impacts and risks at this level are tolerable, consistent with legislative requirements, and aligned with relevant environmental and stakeholder expectations.

7.6.3 Impact analysis and evaluation

Potential impacts	Localised and temporary decrease in air quality due to emission of gaseous and particulate matter from marine gas oil or diesel combustion Contribution to the global greenhouse gas (GHG) effect.
Predicted effects	The potential impacts of atmospheric emissions from vessels are well understood with legislative requirements and industry agreed good practices to manage impacts. The application of recognised good practice is considered appropriate to manage the impact. The combustion of MGO/MDO can create continuous or discontinuous plumes of particulate matter (soot or black smoke) and the emission of non-GHG, such as sulphur oxides (SO_x) and nitrous oxides (NO_x). Inhalation can cause or exacerbate health impacts to humans such as vessel personnel or coastal communities depending on the concentrations of particles inhaled. Similarly, the inhalation of particulate matter may affect the respiratory systems of fauna – in this case, limited to seabirds overflying the vessel/s.

	Particulate matter released from the source and support vessels will not impact on the health, cause smog or adversely affect the amenity of the nearest human coastal settlements (such as Port Denison and Dongara, and Leeman) as local and offshore winds will rapidly disperse and dilute particulate matter. This rapid dispersion and dilution will also ensure that seabirds are not exposed to concentrated plumes of particulate matter from any exhaust point. All GHG such as carbon dioxide, methane and nitrous oxide will add to the atmospheric GHG load which adds to global warming potential. The predominant source of emissions is the fuel use of the survey vessels. Conservative daily fuel use estimations have been undertaken with the assumption of one Seismic vessel, one supply vessel and three chase vessels. The survey will have one chase vessel however three have been calculated due to the uncertainty of vessel requirements for potential node placement. Using MGO fuel and the daily fuel use estimations the calculation for potential emissions is below in Table 7-28. The activity is like other industrial activities contributing to the accumulation of GHG in the atmosphere including local shipping and commercial fishing in the OA. Additional requirements by the IMO introduced in January 2023 for this class of vessel, require each ship to have a ship specific operational carbon intensity calculated with an expected cumulative improvement in carbon performance leading up to 2030. Given the short duration of the survey (up to 40 days), and constant movement of the vessel, emissions from the combustion of fuel on-board the vessels will not affect sensitive receptors in the vicinity of the OA (including the health or amenity of the nearest human settlements, which are more than 6.5 km from the Operational Area at the closest). Cumulative impacts from multiple vessels being in the same area are not predicted, as combined discharges will still be localised and disperse rapidly with little effects (ecologically or on visual amenity). There will be no refuelling of the survey vessel in the OA.		
Inherent impact	Consequence	Likelihood	Risk ranking
	Low	Unlikely	Low

Table 7-28: Potential emissions calculations for Eureka 3D MSS

Results	Volume in t CO2-e
Estimated emissions for five vessels used in marine navigation for 30 days of survey	3,684.85
Estimated emissions for five vessels used in marine navigation for 40 days of survey (30 plus 10 days of contingency)	4,913.13

7.6.4 Impact treatment

7.6.4.1 Demonstration of ALARP

The use of vessels and hence fuel cannot be eliminated. Alternative fuels (solar, wind, biofuels) have not been commercially proven. Pilot considers the adopted controls to be appropriate in reducing the environmental impacts associated with atmospheric emissions from vessels to ALARP. Additional controls have been considered and adopted where they can further reduce risks to ALARP. Where the cost of implementing the additional control measures is disproportionate to the benefit gained, they have not been adopted (Table 7-29).

Table 7-29: Demonstration of ALARP – atmospheric emissions - vessels

Control measures		Cost benefit analysis	Impact reduction	Control adopted
ALARP assessment technique –legislative requirements, good practice				
Compliance with equivalent requirements as those internationally defined in MARPOL 73/78 Annex VI and accepted by the wider international shipping industry		Benefit outweighs cost, legal requirement	Yes	Yes
A specific Ship Energy Efficiency Management Plan (SEEMP) will be in place for the Seismic vessel as per IMO guidelines		Benefit outweighs cost, legal requirement	Yes	Yes
Survey and supply/chase vessels only use MGO or MDO grade fuel as opposed to heavy fuel oil or bunker fuel		Benefit outweighs cost	Yes	Yes
All engines to be well maintained in accordance with manufacturers specifications		Benefit outweighs cost	Yes	Yes
ALARP assessment technique – EIA				
A MARPOL approved incinerator is used to incinerate solid waste (food waste, paper, cardboard, rags, plastics) if logistics do not allow for the timely removal of waste from the vessels.		Benefit outweighs cost	Yes	Yes
Oil and other noxious liquids and solids will not be incinerated.		Benefit outweighs cost	Yes	Yes
Residual impact evaluation				
Residual impact	Consequence	Likelihood	Risk ranking	Decision type
	Low	Unlikely	Low	A

7.6.4.2 Demonstration of acceptability

The impact assessment has determined that given the adopted controls atmospheric emissions during the seismic activity will not result in a potential impact greater than negligible impact to the localised area. Further opportunities to reduce the impacts and risks are investigated above. The adopted controls are considered, good industry practice, in line with the principles of ESD, and meet legislative requirements. Pilot has not received comments or concerns from relevant persons and considers that the adopted controls manage the impacts of atmospheric emissions in the OA to a level that is broadly acceptable.

The impact assessment has concluded that, with the implemented control measures, atmospheric emissions during the seismic activity are expected to result in no more than negligible impacts to the localised area. These impacts are anticipated to be minimal and limited in both extent and duration.

Pilot has thoroughly explored additional opportunities to further mitigate impacts and risks associated with atmospheric emissions, as discussed in previous sections. The adopted control measures are in line with good industry practice and fully comply with relevant legislative requirements. Furthermore, these measures align with the principles of ESD

Pilot has not received any comments or concerns from relevant stakeholders regarding atmospheric emissions from the project activities. Given these factors, Pilot believes the adopted control measures are appropriate and sufficient to manage the impacts of atmospheric emissions in the Operational Area to a level that is broadly acceptable.

7.6.4.3 Environmental performance outcomes, standards and measurement criteria

The environmental performance outcomes, standards and measurement criteria appropriate to measure performance of the adopted control measures for atmospheric emissions from vessels are presented below in Table 7-30. Environmental performance standards and relevant measurement criteria have been developed for each control measure adopted in Section 7.6.4.1.

Table 7-30: Environmental performance outcomes, standards and measurement criteria for atmospheric emissions

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 13 Combustion systems comply with MARPOL VI (Prevention of Air Pollution from Ships) requirements.	PS 58 Compliance with MARPOL 73/78 Annex VI as applied in Australia under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and Marine Order 97(Marine pollution prevention–air pollution), where applicable to vessel class including: • Survey and support vessel will hold a valid International Air Pollution Prevention (IAPP) Certificate. • Only fuel that contains less than 3.5% m/m sulphur will be bunkered. • Survey and supply/chase vessels only use MGO or MDO grade fuel. • Vessels >400 GRT must ensure that firefighting and refrigeration systems are managed to minimise Ozone Depleting Substances (ODS).	MC 74 Records demonstrate the vessel(s) hold a valid IAPP certificate, where applicable to vessel class MC 75 Inspection of bunkering records to confirm that the survey vessel is using fuel with <3.5% sulphur by mass MC 76 MSDS and vessel bunker receipts confirm the use of low-sulphur fuel and MGO or MDO or lighter grade fuel for main engines MC 77 ODS book is available and current
	PS 59 All combustion equipment will be maintained in accordance with the PMS to ensure they are operating to design specifications.	MC 71 PMS records confirm that combustion equipment is maintained to schedule.
	PS 60 A MARPOL approved incinerator is used to incinerate solid waste (food waste, paper, cardboard, rags, plastics) if logistics do not allow for the timely removal of waste from the vessel.	MC 78 IAPP certificate verifies the incinerator meets MARPOL requirements.
	PS 61 Incineration is only conducted when the vessel is >12 nm from the shore	MC 79 Survey-specific discharges and emissions register indicates no incineration within 12 nm of the shore.
	PS 62 Oil and other noxious liquids and solids will not be incinerated.	MC 80 The Oil Record Book and Garbage Record Book verify that waste oil and other noxious substances are retained on-board for transfer to shore.

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 14	PS 63	MC 81
Fuel use will be restricted to the minimum required to undertake the seismic survey	Fuel use will be measured, recorded and reported for abnormal consumption, and in the event of abnormal fuel use, corrective action is taken to minimise air pollution. Fuel use must be added to the ships Carbon Intensity Indicator (CII) calculation.	Fuel use is recorded in the daily operations reports.

7.7 Impact 7: Seabed disturbance – placement of ocean bottom nodes

In accordance with the Pilot Energy risk assessment methodology (Section 6) this impact is classified as lower order.

7.7.1 Identification of hazard and extent

Hazard	Shallower areas of the ASA have been delineated as the nodal area (Figure 3-2) as they will be better acquired using ocean bottom node (OBN) technology. The nodes have flexible placement and retrieval options including autonomous vehicles, nodes on a rope (NOAR) and commercial divers. The nodes would be placed on the seabed at the start of the survey and collected at the end of the survey timeframe. The placement and retrieval of these small, lightweight nodes on the seabed has the potential to cause minor physical damage to benthic habitats.
Extent	Node Survey Area
Duration	Duration of survey – up to 40 days in early February to the end of March.

7.7.2 Defined acceptable levels

For lower-order impacts and risks, Pilot Energy defines the acceptable level as the point at which the residual impact or risk has been reduced to ALARP. This means that all relevant control measures have been identified and implemented to the extent that no additional practicable measures are available without costs being grossly disproportionate to the environmental benefit gained. In this context, the acceptable level is inherently linked to the ALARP outcome, recognising that residual impacts and risks at this level are tolerable, consistent with legislative requirements, and aligned with relevant environmental and stakeholder expectations.

7.7.3 Impact analysis and evaluation

Potential impacts	The known and potential impacts of seabed disturbance are: Temporary smothering / displacement of a small area of seabed habitat Localised elevated turbidity Disturbance/damage to shipwrecks, pipelines and other oil and gas subsea infrastructure.
Predicted effects	OBNs may be placed on the seabed in water depths shallower than ~12 m. Nodes are expected to be placed in a grid of 250 m × 250 m, which would result in the deployment of approximately 2500 nodes. The Node Survey Area where equipment will be deployed covers approximately 119 km². The shallow waters of the OA partially overlap with the Commonwealth marine environment within and adjacent to the west coast inshore lagoons KEF, and the OA is entirely within the Western rock lobster KEF. The Commonwealth marine environment within and adjacent to the west coast inshore lagoons KEF is a chain of inshore lagoons containing extensive seabeds of macroalgae and seagrass with a unique diversity of marine species. The seagrass habitats provide valuable feeding grounds for protected species such as the ASL and are important nursery areas for many recreational and commercial fish species. There is one known historic shipwreck. the *Leander,* that may be within the Node Survey Area Figure 7-9, but exact location is unknown) This shipwreck is not listed as a Protected Place under the EPBC Act but is an underwater cultural heritage site protected by the Underwater Cultural Heritage Act 2018. The Cliff Head Development wellhead platform is located within the Node Survey Area, and part of the Node Survey Area is crossed by the two pipelines (production and water injection, along with associated power cable and umbilical) that connect the platform to the Arrowsmith stabilisation plant onshore (Figure 7-9). The pipelines run ~10 km along

	the sea floor from the wellhead platform to the shore crossing, and are unburied, using the concrete coating weight and rock bolting to provide stability. The temporary placement and retrieval of nodes on the seabed may result in negligible impacts to biota as a result of physical disturbance and elevated turbidity. However, given the localised area where the equipment will be placed and their small footprints, no significant impact to the values of the Commonwealth marine environment within and adjacent to the west coast inshore lagoons and Western rock lobster KEFs will occur. The temporary placement and retrieval of nodes on the seabed may cause minor physical disturbance and elevated turbidity in and adjacent to the Cliff Head Development pipelines. However, given the small size and weight of the nodes and the widely spaced grid over which they will be placed, no significant impacts to either the shipwreck site or pipelines are predicted to occur.		
Inherent impact	Consequence	Likelihood	Risk ranking
	Minor	Unlikely	Low

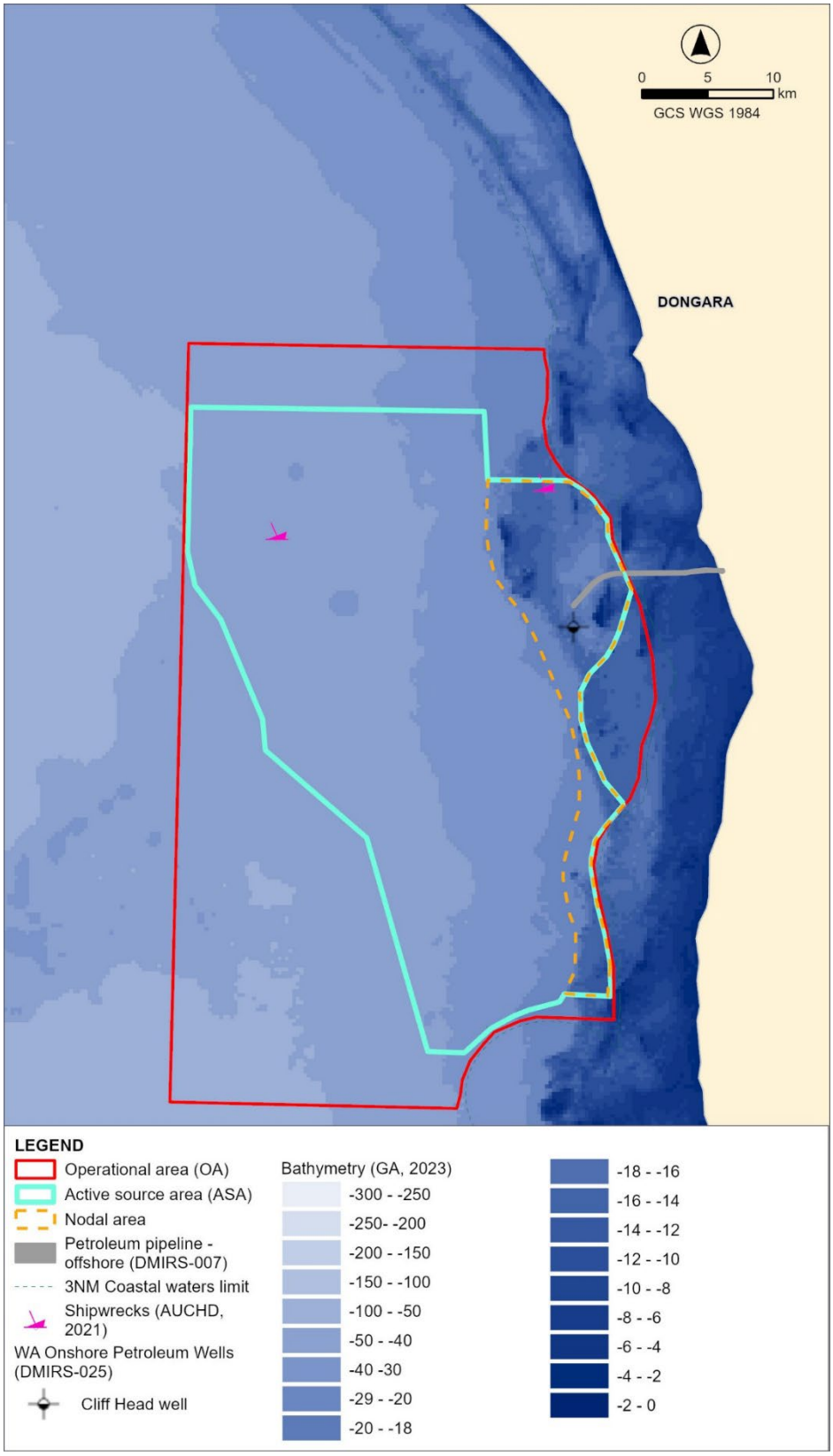


Figure 7-9: Submerged features within the OA

7.7.4 Impact treatment

7.7.4.1 Demonstration of ALARP

Pilot considers the adopted controls to be appropriate in reducing the environmental impacts associated with seabed disturbance from placement of OBNs to ALARP. Additional controls have been considered and adopted where they can further reduce risks to ALARP. Where the cost of implementing the additional control measures is disproportionate to the benefit gained, they have not been adopted (Table 7-31).

Table 7-31: Demonstration of ALARP – seabed disturbance – placement of ocean bottom nodes

Control measures	Cost benefit analysis	Impact reduction	Control adopted
ALARP assessment technique – good practice, legislative requirements			
No placement of nodes within the 500 m radius petroleum safety zone (PSZ) around the Cliff Head Development wellhead platform	Legislative requirement. Benefit outweighs cost.	Yes	Yes
Environmental monitoring of the seabed prior to and following the Eureka 3D MSS to assess any impacts to the seabed.	Monitoring will not reduce the consequence of any impacts to the seabed, and the costs associated with the level of monitoring required to accurately assess any impacts greatly outweighs the benefits gained.	No	No
Eliminate use of OBNs during the survey	Although the control would reduce the consequence of any impacts to the seabed, it would result in the inability to acquire seismic data in the shallower waters of the ASA and therefore compromise the geophysical objectives of the survey.	Yes	No
No placement of nodes within proximity to exposed areas of any identified shipwreck	Legislative requirement. Benefit outweighs cost.	Yes	Yes
Vessels will be fitted with sonar and depth sounders to assess depth of water when in the nodal area or areas <12m deep	Industry standard	Yes	Yes
Vessels will contain geospatial information on exclusion zone areas, ASA, OA and relevant significant features (shipwrecks, BIA's etc)	Industry standard	Yes	Yes
Support vessels will always maintain a 2m depth under keel (except when scouting water depths).	This control ensures awareness of grounding risks and reduces risks to benthic habitats.	Yes	Yes
The seismic vessel will always maintain a 5m depth under keel.	This control ensures awareness of grounding risks and reduces risks to benthic habitats.	Yes	Yes
ALARP assessment technique – EIA			
Nodes will not be placed within 300 m of the 12 m contour of Leander Reef, Big Horseshoe Reef or other unnamed reef areas in the Node Survey Area	Although the control would reduce the consequence of any impacts to the seabed, it would result in the inability to acquire seismic data in the shallower waters of the ASA and therefore compromise the geophysical objectives of the survey.	Yes	No

Nodes will not be placed within the 12m contour of Leander Reef, Big Horseshoe Reef or other unnamed reef areas in the Node Survey Area	Although the control would reduce the impacts to the seabed, this would result in the inability to acquire seismic data underneath these reefs which are the prospective areas of the survey and would compromise the geophysical objectives of the survey.	Yes	No
Nodes will not be placed shallower than 6m water depth from LAT.	This control measure is the optimum balance of proximity from reefs and geophysical objectives that can be achieved to minimise benthic disturbance and protect the shallow reef areas.	Yes	Yes
Nodal placement and retrieval procedures to ensure location of nodes avoids sensitive benthic habitat.	Although the reef areas are expected to be hard limestone outcrops, there is a possibility of corals, seagrasses, or epifauna in the region making clear procedural measures for placement and retrieval protective of the environment at little additional cost.	Yes	Yes

Residual impact evaluation				
Residual impact	Consequence	Likelihood	Risk ranking	Decision type
	Low	Unlikely	Low	A

7.7.4.2 Demonstration of acceptability

The impact assessment has determined that given the adopted controls seabed disturbance from the placement of nodes are unlikely to result in a potential impact greater than localised and temporary disruption. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls are considered good industry practice, meet legislative requirements and are aligned with the principles of ESD. An additional control was added, in response to relevant person feedback, to demonstrate that standard industry equipment (ECDIS, depth sounder, sonar) will be utilised to ensure awareness of water depth in shallow areas. Marine order 27 was also referenced in the performance standards. Pilot considers that the adopted standard and additional controls appropriate to manage the impacts and risks of seabed disturbance to a level that is broadly acceptable.

The impact assessment has concluded that, with the implemented control measures, seabed disturbance from the placement of nodes is expected to result in no more than localised and temporary disruption. These impacts are anticipated to be limited in both extent and duration.

Pilot has thoroughly explored additional opportunities to further mitigate impacts and risks associated with seabed disturbance, as discussed in previous sections. The adopted control measures are in line with good industry practice, fully comply with relevant legislative requirements, and align with the principles of ESD.

In response to feedback from relevant stakeholders, Pilot has implemented an additional control measure. This measure demonstrates that standard industry equipment, including Electronic Chart Display and Information System (ECDIS), depth sounders, and sonar, will be utilised to ensure awareness of water depth in shallow areas. Furthermore, Marine Order 27 has been explicitly referenced in the performance standards to enhance regulatory compliance.

Given these factors, Pilot believes the adopted standard and additional control measures are appropriate and sufficient to manage the impacts and risks of seabed disturbance to a level that is broadly acceptable.

7.7.4.3 Environmental performance outcomes, standards and measurement criteria

The environmental performance outcomes, standards and measurement criteria appropriate to measure performance of the adopted control measures for seabed disturbance from placement of OBN are presented below in Table 7-32. Environmental performance standards and relevant measurement criteria have been developed for each control measure adopted in Section 7.4.4.1.

Table 7-32: Environmental performance outcomes, standards and measurement criteria for seabed disturbance – placement of ocean bottom nodes

Environmental performance outcomes	Environmental performance standards	Measurement criteria
EPO 15 Seabed disturbance to be limited to planned activities and impacts described as part of the Seismic Activity and will not occur outside the Operational Area. EPO15A No significant damage to sensitive benthic habitats (corals, seagrass or reef communities) because of node deployment and retrieval.	PS 64 Operational procedures will be in place for deployment and retrieval of OBNs that ensures minimal seabed disturbance where nodes will be lowered in a controlled manner (not freely dropped) to avoid impact damage, positioned only on bare substrate (avoiding live corals or significant epifauna), and retrieved vertically to prevent dragging across the seabed. Nodes must not be placed shallower than 6m water depth (from LAT).	MC 82 Vessel inspections show evidence of implementing geophysical contractor procedures for node deployment and recovery
	PS 65 Nodes will be retrieved at the end of the survey to prevent long-term loss or disturbance of benthic habitats and communities	MC 83 Records demonstrate that nodes are retrieved at the end of the survey
	PS 66 Nodes will not be placed within the 500 m PSZ around the Cliff Head Development wellhead platform	MC 84 Data from survey show that nodes were not placed within the wellhead platform PSZ
	PS 67 The Cliff head Development offshore pipelines and the approximate Leander wreck site will be marked on vessel navigation systems and actively avoided during placement of nodes	MC 85 Vessel logs show a 500 m exclusion zone around pipelines avoided during placement of nodes. Vessel logs will note if any artefacts of the shipwreck are identified and that these sites were then avoided.
	PS 107 Compliance of Marine Order 27 (Safety of navigation and radio equipment) 2023	MC 105 Records demonstrate that the survey and support/chase vessels are compliant with Marine Orders 27.
	PS 108 Vessels will be fitted with sonar and depth sounders to assess depth of water when in the nodal area or areas <12m deep	MC 117 Vessel inspection shows inclusion of sonar and depth sounder equipment in working order.
	PS 116 Vessels will contain geospatial information on exclusion zones	MC 130 Vessel logs will show areas traversed